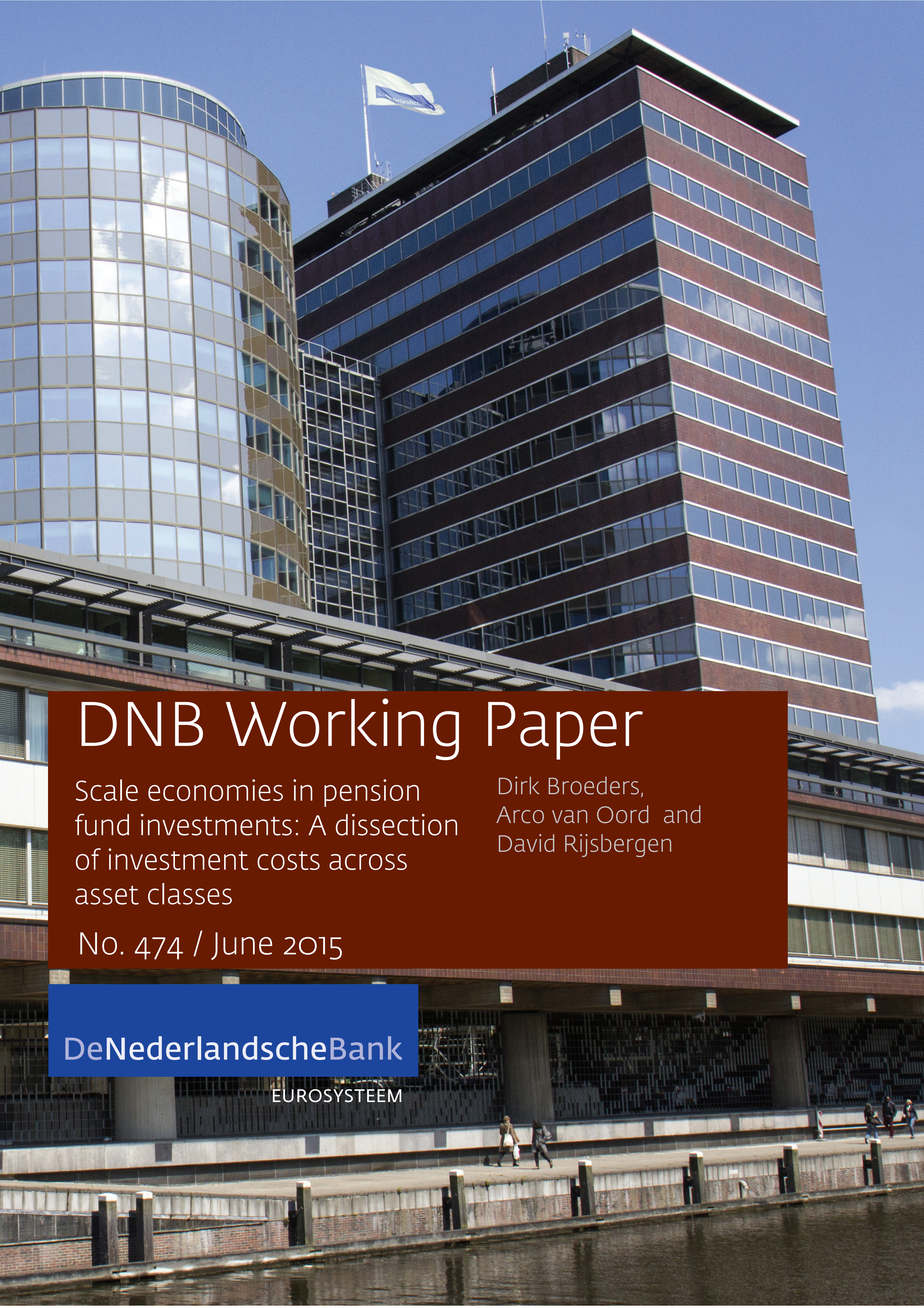


DNB Working Paper

Scale economies in pension fund investments: A dissection of investment costs across asset classes

Dirk Broeders,
Arco van Oord and
David Rijsbergen

No. 474 / June 2015

DeNederlandscheBank
EUROSYSTEEM

Scale economies in pension fund investments: A dissection of investment costs across asset classes

Dirk Broeders, Arco van Oord and David Rijsbergen *

* Views expressed are those of the authors and do not necessarily reflect official positions of De Nederlandsche Bank.

Working Paper No. 474

June 2015

De Nederlandsche Bank NV
P.O. Box 98
1000 AB AMSTERDAM
The Netherlands

Scale economies in pension fund investments
A dissection of investment costs across asset classes*

Dirk Broeders [a,b], Arco van Oord [a] and David Rijsbergen [a]

[a] *De Nederlandsche Bank, the Netherlands*
[b] *Maastricht University, the Netherlands*

1 June 2015

Abstract

Using a unique dataset of 225 Dutch occupational pension funds with a total of 928 billion euro of assets under management, we provide a comprehensive analysis of the relation between investment costs and pension fund size. Our dataset is free from self-reporting biases and decomposes investment costs for 6 asset classes in management costs and performance fees. A pension fund that has 10 times more assets under management, has on average 7.67 basis points lower annual investment costs. These economies of scale are solely driven by management costs. Robustness checks show that this key finding does not vary over different pension fund sizes. Economies of scale do, however, differ per asset class. We find significant economies of scale in fixed income, equity and commodity portfolios, but not in real estate investments, private equity and hedge funds. We also find that large pension funds pay significantly higher performance fees for equity, private equity and hedge fund investments.

Keywords: pension funds, asset management, management costs, performance fees.
JEL classifications: G11, G12, G23.

* The authors would like to thank Jack Bekooij for research assistance and Andre Lucas, Paul Hilbers, Janko Gorter and participants at the DNB seminar series for valuable comments and suggestions. The views expressed in this article are our own and do not necessarily reflect those of DNB.

1. Introduction

Investment costs are an important determinant of pension fund performance. High investment costs can significantly impact beneficiaries' wealth and consumption, as they reduce the net rate of return on investments and subsequently raise the costs of providing pensions.[1] This is even more relevant in recent years, as many pension funds around the world face significant challenges following the financial crisis and the ageing of society. As a result, pension funds face public and political pressure to operate more efficiently and show greater transparency to beneficiaries and the general public regarding their cost structure.[2] Investment costs are also interesting from a broader financial markets perspective, as pension funds are among the largest institutional investors in the world. During 2013, pension fund assets in the seven countries with the largest (occupational) pension fund sectors – the U.S., Japan, the U.K., Australia, Canada, the Netherlands and Switzerland – amounted to $30.5 trillion, representing on average 105.6 percent of their GDP. By comparison, mutual fund assets in these countries aggregated to approximately $20 trillion during 2013.[3]

Despite the importance of investment costs in pension fund performance, little empirical evidence is available on pension funds' cost structures.[4] This can largely be attributed to the absence of sufficiently detailed, unbiased and comparable data on investment costs. Several academic papers investigate pension fund costs and document a significantly negative relation with the size of a pension fund. These papers, however, concentrate on investment costs for U.S. pension funds (e.g., Bauer et al.,

[1] Bikker and de Dreu (2009), for example, report that an increase in annual operating costs of 1 percentage point over the entire accrual period results in a reduction of the eventual pension benefits by about 27 percent.

[2] In the U.S. for example, the Pension Protection Act of 2006, strengthens plan reporting and information disclosure requirements (An, Huang and Zhang, 2013).

[3] See Global Pension Asset Study 2014 from Towers Watson for pension fund statistics, and http://www.ici.org/research for mutual fund statistics.

[4] Pension funds may incur higher investment costs in pursuit of higher returns. Academic evidence on the relation between higher costs and superior performance is mixed. The majority of studies find that pension funds, on average, are unable to outperform external benchmarks (e.g., Lakonishok, Shleifer and Vishny, 1992; Busse, Goyal and Wahal, 2010; Blake, Rossi, Timmermann and Tonks, 2013). Some studies, on the other hand, find evidence for outperformance by pension funds, but predominantly in the U.S. context (e.g., Bauer, Cremers and Frehen, 2010; Andonov, Bauer and Cremers, 2011).

2010) and the aggregate investment cost level (e.g., Bikker and De Dreu, 2009). As a result, little is known about investment costs for European pension funds – that typically deviate from their American counterparts in terms of asset allocation – or what drives the observed economies of scale. Are they primarily driven by management costs or performance fees? Do economies of scale differ between asset classes that pension funds invest in? And to what extent are they stable over different pension fund sizes, types, and plans?

This paper aims to fill this gap by providing a detailed analysis of the relation between investment costs and pension fund size. For that, we have a unique and cross-sectional dataset containing information on fund-specific investment costs for 225 Dutch pension funds during the year 2013. The dataset is free from self-reporting biases, and is to our knowledge the first to distinguish between two components of investment costs, namely management costs and performance fees. Furthermore, we have detailed information on the asset allocation of pension funds for six asset classes, namely fixed income, equities, real estate, private equity, hedge funds, and commodities. We can further decompose this into thirteen sub-asset classes (e.g., for equities between mature markets and emerging markets) and different credit ratings for fixed income securities. This allows us to correct the investment cost analysis for differences in asset allocations and other pension fund investments' characteristics.

As a case study, we examine pension fund investment costs in the Netherlands. The Dutch occupational pension system provides an interesting case study for several reasons.[5] For one, the Dutch system is well-developed and relatively large in terms of size. This results from an important feature of the Dutch pension system, namely its mandatory nature. Due to this, large collective pools are created and participants of occupational pension funds benefit from economies of scale (Bikker and De Dreu, 2009). Another key characteristic of the Dutch pension system is that pension funds

[5] Like many pension systems, the Dutch pension system consists of three pillars, see, e.g., Broeders and Ponds (2012). Public pension schemes form the first pillar which is financed on a pay-as-you-go-basis. The second pillar consists of funded occupational pension plans and is the focus of this study. Finally, the third pillar is made up of private retirement savings accounts, which individuals undertake on their own initiative.

face no quantitative investment restrictions.[6] They are free to invest in any asset class in any currency denomination. As such, the Dutch pension system offers an interesting case study, as the pension funds allocate money to a wide variety of asset classes.

After correcting for differences in asset allocation, we find evidence that large pension funds profit from economies of scale in investment costs. A pension fund that is ten times larger in terms of assets under management has, on average, 7.67 basis points lower annual investment costs. These economies of scale are solely driven by management costs and appear stable over different pension fund sizes. We find no evidence for diminishing economies of scale for very large pension funds. However, the scale effect disappears when we do not control for differences in asset allocation, indicating that large pension funds invest relatively more in asset classes with higher investment costs. In addition, we find that the presence of economies of scale differs per asset class. Size is an important driver for economies of scale in fixed income, equity and commodity portfolios, but not for real estate, private equity and hedge funds.

Several studies document economies of scale in pension funds' cost structures. Bikker and De Dreu (2009) examine administrative and investments costs for Dutch pension funds and find strong economies of scale at the pension fund level. Using the well-known CEM pension fund dataset, Bauer, Cremers and Frehen (2010) study domestic equity investments of U.S. pension funds and also find evidence for the existence of economies of scale in investment costs. Andonov, Bauer and Cremers (2011) extend the focus beyond equity investments and find that the impact of investment costs on performance varies between asset classes. Possible explanations for these economies of scale include more bargaining power for large pension funds (e.g., Andonov *et al*., 2011) and a comparative advantage of internalization (Dyck and Pomorski, 2011). Moreover, the presence of economies of scale in the pension fund industry is in line with empirical

---

[6] Dutch pension funds are obliged to follow the so-called prudent person rule. In the Netherlands, the prudent person rule, however, contains no quantitative investment limits regarding securities, asset classes or currencies. It does mean however that pension funds must invest in the interest of the pension fund's participants, taking into account sufficient liquidity, diversification and quality.

evidence for the mutual fund industry (e.g., Indro, Jiang, Hu and Lee, 1999; Collins and Mack, 1997).

The key goal of this paper is to examine the relationship between investment costs and pension fund size on a more detailed level using an unbiased dataset. Following the academic literature, we hypothesize that investment costs are negatively related to the size of a pension fund. We expect that these economies of scale are primarily driven by management costs as pension funds can spread these costs more efficiently over a larger asset base. Examples include the costs of trading facilities, financial research, risk management and compliance with regulatory standards and reporting requirements (Bikker and De Dreu, 2009). This is less so for performance-based fees as these are typically a fixed percentage of the outperformance (which is independent of size). We hypothesize that the observed economies of scale differ between asset classes, with large pension funds realizing more economies of scale in traditional asset classes (e.g., fixed income, equity). These asset classes have a higher level of liquidity and standardization and are therefore easily scalable. Alternative asset classes (e.g., hedge funds, private equity and real estate) are less scalable as they involve specific investment strategies, projects or objects. In addition, we perform several robustness checks. First, we divide our sample into different subsamples based on pension fund size. Second, we perform piecewise linear regressions. This enables us to further examine whether the economies of scale are stable across different pension fund sizes.

Given the substantial cross-sectional cost differences between pension funds, we also investigate whether key pension fund characteristics influence investment costs. These include pension fund type, pension plan type and different interest rate hedging strategies. Corporate pension funds, for instance, are related to corporations that feel greater pressure to compete for employees by offering attractive pension arrangements that include lower costs (Clark and Bennett, 2001). In addition, pension funds may be willing to pay relatively more for investing in long-term bonds and interest rate derivatives to lengthen the duration of their assets. This decreases the duration mismatch between their assets and liabilities and subsequently makes the financial position of the pension fund less vulnerable to (nominal) interest rate changes (Broeders, Hilbers, Rijsbergen, Shen, 2014).

The remainder of this paper is structured as follows. Section 2 describes the data and methodology used in our analysis. Section 3 presents the results of our analysis of the overall investment costs at the pension fund level. Section 4 subsequently explores the investment costs at the asset class level. In Section 5 we perform additional analyses to test the robustness of the economies of scale for differences in pension fund size. The conclusions are set out in the final section.

2. Data and methodology

We use a cross-sectional, unbiased dataset with investment-related data on 225 Dutch pension funds for the year 2013. The dataset contains pension fund-specific information on investment costs and is more detailed than the information used in earlier academic studies. We are able to decompose annual investment costs in management costs and performance fees.[7] In addition to data at the pension fund level, we are also able to differentiate between the costs of the following six asset classes: fixed income, equities, real estate, private equity, hedge funds and commodities. We also have data on the allocation to these asset classes and are able to further decompose these asset classes into thirteen sub-classes with regard to fixed income (i.e. government bonds, inflation linked bonds, mortgages, corporate bonds and cash), equities (i.e. mature markets and emerging markets) and real estate (i.e. direct real estate, listed real estate and indirect real estate). Moreover, we are able to differentiate between credit rating classes for fixed income securities (i.e. AAA-rated bonds, AA-rated bonds, A-rated bonds, BBB-rated bonds, non-investment grade and non-rated bonds). In addition, we use other pension fund-specific variables in the analysis, including pension fund size (assets

[7] Some pension funds voluntary also report transactions costs separately. Transaction costs are also important. Thapa and Poshakwale (2010), for instance, provide evidence that equity markets where transactions costs are low attract greater investments. However, the number of pension funds reporting transaction costs in our sample is too few for including them in the analysis. In the applicable cases transaction costs are incorporated in management fees.

under management), asset class size, pension fund type, pension contract type, the duration contribution of fixed income assets and the duration contribution of the interest rate overlay.

The pension funds in the sample represent a wide variety of pension fund sizes and types. During 2013, the pension funds in the dataset had nearly 928 billion euro of assets under management which amounted to approximately 98 percent of the total assets under management for all Dutch pension funds in that year.[8] The data is collected by De Nederlandsche Bank (DNB), responsible for prudential supervision of all Dutch pension funds. The dataset does not suffer from self-reporting biases as pension funds in our sample are obliged to submit their investment costs and asset allocation to DNB. In addition, all submitted investment costs by the pension funds in the sample are validated by their independent auditor as well as by DNB.

2.1 Definition of variables

The key dependent variable in our analysis is the investment cost level. We measure investment costs at the pension fund level as well as for each asset class separately, and examine whether certain pension fund-specific characteristics significantly influence the cost level.

Investment costs: management costs and performance fees

Investment costs include all costs incurred in the investment management process, from strategy, implementation to monitoring the portfolio.[9] Within *investment costs* we differentiate between two key components, namely *management costs* and *performance fees* (see, e.g., Drago, Lazzari and Navone 2010). We measure both cost types on an annual basis. We define management costs as the cost of having assets professionally managed. These costs include the fees paid for security selection, execution and

[8] This represents approximately 157 percent of Dutch GDP.
[9] We exclude general administrative costs such as personnel costs, rent and depreciation. Bikker and De Dreu (2009) find that, on average, these administrative costs (15 basis points) are higher than investment costs (10 basis points) for Dutch pension funds.

disclosure.[10] Management costs structures are typically based on a percentage of assets under management. A pension fund's external asset manager could, for instance, charge 50 basis points of assets under management for managing the portfolio. Performance fees, on the other hand, are contingent on a specific performance objective such as the realization of positive or excess returns against a pre-determined benchmark (Davanzo and Nesbitt, 1987). A performance fee is commonly calculated as a percentage of investment profits, either over realized or unrealized excess returns (or both). The rationale for performance fees is that they provide an incentive for professional fund managers to generate positive excess returns. Performance fees therefore typically create a skewed – call option like – incentive structure. As the professional manager typically only profits from positive excess returns but does not suffer from losses, it may incentivize to take excessive risks to generate high returns, see Goetzmann, Ingersoll and Ross (2003).[11]

We measure investment costs C for pension fund j in basis points as the investment costs in a year over the average assets under management in that year in the following manner:

$$C_{j,k}^{z} = \frac{\text{Investment cost}_{j,k}^{z}}{\frac{1}{4}\sum_{i=1}^{4} \text{Investments}_{j,k,i}^{z}}$$

We use index k to distinguish between total costs, management costs and performance fees. We use indicator z to identify the asset classes, which include fixed income, equity, real estate, private equity, hedge funds and commodities. At the asset class level, we define investment costs as the investment costs (either total, management of performance) of the particular asset class divided by the average of the investments in that asset class. If z is suppressed it refers to the overall pension fund's portfolio. The overview below summarizes the relevant indicators.

[10] Pension funds can manage their investments in different ways. They can choose to actively or passively manage their investments, as well as to do this on an internal or external basis. We do not further elaborate on these differences as the dataset is not able to distinguish between these different investment styles or processes.
[11] In recent years, several policy initiatives are introduced to limit these incentives, such as so-called 'claw backs'. Testing for the impact of these initiatives, however, is beyond the scope of our analysis.

Index	*Variable*	*Indicator for*
j	Pension fund	Pension fund 1 to 225
k	Investment cost	Total investment costs, management costs or performance fees
z	Asset class	Fixed income, equity, real estate, private equity, hedge funds or commodities

Pension fund size

We hypothesize that investment costs are negatively related to a pension funds' *size* and that this relation is primarily driven by management costs. Pension fund size might influence investment costs in several manners. *First*, certain investment-related costs tend to increase less than proportionally with size, such as the costs of financial research and cost of risk management (Bikker and De Dreu, 2009). Large pension funds are thus able to spread these costs over a larger asset base and profit from economies of scale. *Second*, large pension funds tend to have more bargaining power and are therefore more likely to negotiate lower fees for investment mandates (Andonov *et al*., 2011). *Third*, large pension funds may have a better ability to replace expensive external asset management with more cost-effective internal management (Dyck and Pomorski, 2011). Not surprisingly, several studies document economies of scale with regard to pension funds' investment costs (e.g., Andonov *et al.,* 2011; Bauer *et al.,* 2010). Furthermore, Bikker and De Dreu (2009) find evidence for the existence of an optimal pension fund size, as economies of scale appear to vary with the pension fund size. We measure the size of pension funds in two manners. At the pension fund level, we use the logarithmic value of total assets under management. At the asset class level, we define size as the log of the assets under management in a specific asset class.

In addition, we hypothesize that the relationship between pension fund size and investment costs is not uniform across different asset classes. Andonov *et al*. (2011) analyze pension fund returns and observe that large pension funds realize economies of scale in alternative asset classes (e.g., in real estate and private equity), but experience diseconomies of scale with regard to investments in equity and fixed income due to liquidity constraints and the lower returns for larger funds due to their larger market impact.

Pension fund type

The *type* of pension fund might also influence the cost structure. In the Netherlands, there are three types of pension funds. The first are industry-wide pension funds, organized for a specific sector of industry (e.g., the government or the health care sector). Participation in an industry-wide pension fund is usually mandatory for all firms operating in the sector.[12] The second type of pension funds are the professional group pension funds, organized for a specific profession such as doctors and pharmacists. And finally, there are corporate pension funds that execute the pension plan for a specific company. Clark and Bennett (2001) argue that corporate pension funds feel greater pressure to compete for employees and therefore have a stronger incentive to offer an attractive pension plan, e.g., by pushing down costs. Dyck and Pomorski (2011) find that U.S. corporate pension funds tend to have stronger overall performance than U.S. public pension plans. The authors hypothesize that the corporate status is likely associated with fewer politically-driven resource constraints and better performance because returns on pension plans impact corporate 'bottom line figures'. Translating this to the Dutch context, we hypothesize that corporate pension funds, on average, have lower investment costs.

Pension plan type

We also examine the influence of pension plan types on investment costs and distinguish between defined benefit and defined contribution plans. We hypothesize that defined benefit pension plans have lower investment costs and therefore realize higher returns than defined contribution plans. Bauer *et al.* (2010) find that defined contribution plans in the U.S. have higher investment costs than defined benefit plans. Bikker and De Dreu (2009) also find that defined contribution plans tend to have higher investment costs. As a possible explanation, Bauer *et al.* (2010) argue that defined benefit plans are typically more efficient in using their bargaining power to lower costs

[12] An industry-wide pension fund loses its mandatory status if a pension fund fails a performance test based on the so-called Z-score. Participating companies can then opt out and either establish their own pension fund or join another.

than defined contribution plans. Furthermore, the authors hypothesize that the monitoring of external managers is generally more efficient at defined benefit plans.

Pension fund asset duration

Finally, we also examine the relation between investment costs and the duration of a pension fund's assets. A pension fund can opt to hedge the interest rate risk of its participants' (guaranteed) pension income using long-term bonds or derivatives. By lengthening the duration of the assets, the assets better match with the duration of the pension fund's liabilities. This form of interest rate hedging mainly applies to nominal liabilities as it is difficult for pension funds to hedge inflation risks via financial markets as a market for Dutch inflation is close to non-existent. We hypothesize that defined benefit pension plans are willing to pay additionally for investing in long-term bonds and derivatives such as interest rate swaps to lengthen the duration of their assets so that they are better matched with the duration of their liabilities (Broeders, Hilbers, Rijsbergen and Shen, 2014).[13] We employ two variables to measure duration. For one, we define *duration contribution fixed income* as the part of a pension funds' total duration ascribable to its bond portfolio. In addition, we define *duration contribution overlay* as the incremental duration due to the interest rate overlay exposure of interest rate derivatives. Both measures add up to the overall duration of the total assets in a pension fund's portfolio.

2.2 Investment costs and descriptive statistics

Table I presents an overview of the total annual investment costs which are the key variables in this paper. The table reports the average total investment costs for the year 2013, as well as the average management costs and performance fees at the pension fund level and the asset class level. All costs are expressed as annual basis points of respectively pension fund size (total assets under management) or asset class size. In addition, Table I also presents the average asset allocation for the pension funds in our sample. Fixed income and equities are the most important asset classes with an average

[13] Instruments such as inflation-linked bonds, inflation swaps and inflation-linked structured products exist, but in practice their availability is limited and they typically have low liquidity.

weight of 61.8 percent and 30.2 percent respectively. This is different from U.S. pension funds that, on average, invest about 35 percent of their assets in fixed income and 55 percent in equity (Andonov *et al*., 2011).

On average, the 225 pension funds in our sample report total investment costs of approximately 42 basis points. This is somewhat higher than the 35 basis points that Andonov *et al*. (2011) document for U.S. pension funds during the period 1990 - 2008, although they argue that investment costs are increasing after 1999 due to a higher allocation in alternative assets.[14] Ten percent of the pension funds in the sample report investment costs lower than 19 basis points, whereas ten percent report more than 65 basis points. These outcomes imply a wide range in observed investment costs. Table I also indicates that the investment costs of pension funds primarily consist of management costs. At the overall portfolio level, pension funds on average pay 39 basis points on management costs versus 3 basis points in performance fees.

Table I also reports the investment costs decomposed for six asset classes: fixed income, equity, real estate, private equity, hedge funds and commodities. The costs for fixed income investments average 21 basis points. As such, fixed income is the asset class with the lowest average investment costs in our dataset. For equities, we find an average total cost of 34 basis points. This is higher than the 27 basis points that Bauer *et al.* (2010) report for U.S. pension funds investing in domestic equities.[15] Our equity sample, however, also includes emerging market equities that are typically characterized by lower liquidity and higher costs than the mature and liquid U.S. market. As such, it is not surprising that we find a somewhat higher cost level for equities compared to Bauer *et al*. (2010). Furthermore, investments in private equity appear to have the highest cost level. The mean investment costs for private equity are 274 basis points, ranging from 88 to 526 basis points across the pension funds in our

---

[14] For 2008, the authors report an average total investment cost of 49.7 basis points for U.S. pension funds.

[15] Note that Bauer *et al*. (2010) find that U.S. pension fund costs levels for equity investments are lower than in the mutual fund industry. At the pension fund level, they find a median cost level of 27 basis points for defined benefit pension plans and 51 basis points for defined contribution pension plans. This is substantially lower than the 150 basis points that Swensen (2005) documents for average mutual fund fees.

sample[16]. Hedge fund investments, on the other hand, report the highest performance fees with an average level of 86 basis points, amounting up to more than 204 basis points for the top decile of pension funds in our sample.

We also illustrate the descriptive statistics of our dataset graphically. Figure I displays the cumulative distribution of management costs and performance costs for the six asset classes in our sample. The first graph concentrates on management costs and clearly displays that fixed income securities have the lowest average management costs. Nearly 80 percent of the pension funds in our sample, for instance, pay less than 25 basis points in annual management costs for their fixed income portfolio. For equities, the similar outcome is about 40 basis points.

Table II provides an overview of the key explanatory variables. Log Size is the logarithm of the total assets under management (pension fund size). The average log size in our sample is 5.7 with translates to an average pension fund size of approximately 4.1 billion euro. Moreover, the sample dispersion in size is considerable skewed. The largest pension fund in the sample, for instance, is 75 times the mean sample size in terms of assets under management. Table II also presents two duration variables, namely the duration contribution of fixed income securities ('*Duration Contribution Fixed Income*') and the duration contribution of derivatives ('*Duration Contribution Overlay*') to the total duration. Both variables are measured in years. The average duration contribution of fixed income securities is 4.4 years, while the incremental duration contribution of the interest rate overlay equals 6.0 years for the pension funds in our sample. Therefore, the average duration of total assets corresponds to 10.4 years. This compares to an average duration of the liabilities of 18.2 years for the pension funds in our sample.

---

[16] Note that Andonov *et al.* (2011) find a higher average cost level of 284 basis points for private equity investments by U.S. pension funds. For Canadian pension funds they find a more comparable cost level of 273 basis points.

In addition, Table II also reports the characteristics of the pension funds in the dataset. Our sample, for instance, consists of 160 corporate pension funds, 55 industry wide pension funds and 10 professional group pension funds. Finally, most pension contracts in our sample, namely 212, are of the defined benefit type, whereas only 13 defined contribution contracts are observed.

2.3 Methodology

At the pension fund level, we use the following cross-sectional regression model to explain the investment costs C for pension fund j:

$$C_{j,k} = \beta_{1,k} \log(Size_j) + \beta_{2,k}\text{Corp}_j + \beta_{3,k}\text{Prof}_j + \beta_{4,k}\text{DC}_j + \beta_{5,k}\text{DUR}_{FI,j} + \beta_{6,k}\text{DUR}_{O,j} + X_j\beta_{7,k} + R_j\beta_{8,k} + u_{j,k} \qquad (1)$$

Index k indicates either the total costs, the management costs or the performance fees. In this model we use the following independent variables. $Size$ is the pension funds' average total assets under management in euro during 2013. $Corp$ is a dummy variable equal to one if it concerns a corporate pension fund and 0 otherwise. $Prof$ is a dummy variable equal to one if it concerns a profession group pension fund and 0 otherwise. This way the results are relative to the third pension fund type, the group of industry-wide pension funds. DC is a dummy variable equal to one if it concerns a defined contribution plan (and 0 otherwise), making the reported results relative to defined benefit plans. DUR_{FI} is the duration contribution of the fixed income portfolio, while DUR_{O} represents the duration contribution of fixed income derivatives. Both variables are measured in years. X is a vector of control variables that represent the pension fund's asset allocation. The weights in the asset allocation add up to one. Finally, R is a vector of control variables that represent the allocation within the fixed income portfolio to different credit rating classes. In this vector, we leave the allocation to AAA-rated bonds out to avoid singularity since the allocation to fixed income in X also adds up to the sum of the allocation to the difference credit rating classes. Results for different credit rating classes are thus relative to AAA-rated bonds. Finally, the error term is indicated by u. All standard errors in the regression model are White standard errors corrected for heteroskedasticity.

Moreover, we run the following regression to examine the investment costs C at the asset class level z for pension fund j:

$$C_{j,k}^{z} = \beta_{1,k}^{z} \log\left(Size_{j}^{z}\right) + \beta_{2,k}^{z}\mathrm{Corp}_{j} + \beta_{3,k}^{z}\mathrm{Prof}_{j} + \beta_{4,k}^{z}\mathrm{DC}_{j} + \beta_{5,k}^{z}\mathrm{DUR}_{FI,j} + \beta_{6,k}^{z}\mathrm{DUR}_{O,j} + X_{j}^{z}\beta_{7,k}^{z} + R_{j}^{z}\beta_{8,k}^{z} + u_{j,k}^{z} \qquad (2)$$

Index k indicates either the total costs, the management costs or the performance fees, whereas z represents the six different asset classes we distinguish: fixed income, equity, real estate, private equity, hedge funds and commodities. The independent variables are defined in a similar manner as the variables at the pension fund level in (1), with the exception of size and the constituents of vectors X and R. The size variable at the asset class level (2) is defined as the amount that pension fund j invests in the specific asset category z. In addition, X differs for the vector in our main regression model in the sense that it only represents the sub-asset classes relevant for asset category z. In the case that z represents equities, for instance, the vector X only contains the sub-asset classes equities mature markets and equities emerging markets relative to the total equity investments. Note that the weights in X thus again add up to one. Finally, the vector R is only maintained for fixed income securities. The overview below displays the relevant sub-classes for each asset class in our dataset.

Asset class z	***Subcategories included in asset allocation R***
Equity	Emerging markets, mature markets
Fixed Income	Government bonds, index-linked bonds, credits, mortgages, cash
Real Estate	Direct investments, Indirect unlisted investments, indirect listed investments
Private Equity, Hedge Funds, Commodities	No subclasses available

3. Investment costs at the pension fund level

We now turn to the results of our empirical analysis. In this section, we describe the main findings at the pension fund level. We also explore the impact of asset allocation on investment cost structures in greater detail.

3.1 Main findings

Table III presents our main findings. Panel A of this table shows the impact of different pension fund characteristics on the total investment costs of 225 pension funds in 2013. The column '*Total Costs*' reports the annual total investment costs at the pension level, after correcting for differences in asset allocation. The key result is a significant negative relation between investment costs and pension fund size. A pension fund that is 10 times larger in terms of assets under management has, on average, 7.67 basis points lower annual investment costs. The finding is statistically significant at the 1 percent level and provides evidence for our first hypothesis that large pension funds profit from economies of scale. These economies of scale are fully driven by management costs, where the applicable coefficient is 7.81 basis points. At the pension fund level, the coefficient for performance fees is not statistically different from zero.

Table III also shows that corporate pension funds, after correcting for size and differences in asset allocation, report 7.33 basis points higher investment costs on an annual basis. This finding is statistically significant at the 1 percent level and completely driven by higher management costs. This contradicts our hypothesis. A possible explanation is that corporate pension funds are potentially more exposed to a misalignment of interests as they rely on commercial pension service providers and asset managers. Industry wide pension funds in the Netherlands on the other hand, typically are the single shareholder of their own pension service provider and therefore – in theory – have less agency costs.[17] In addition, we find that professional group pension funds also appear to face higher investment costs than industry-wide pension funds. This finding, however, is only significant at the 10 percent level.

[17] Dyck and Pomorski (2011) find that internal asset management results in cost savings as it can reduce potential agency conflicts from multiple layers.

Furthermore, we find no statistical difference in investment costs between defined contribution plans and defined benefit pension plans.[18] Therefore we do not find support for the hypothesis that defined benefit plans can more efficiently use their bargaining power to lower costs (Bauer *et al*., 2010), although it should be noted that the number of defined contribution plans in our sample is low.

Panel A of Table III also presents the relation between investments costs and duration. We find that pension funds with a one year higher duration via fixed income securities report lower total investment costs of approximately 2.99 basis points. This contradicts our hypothesis that pension funds are incurring higher costs for hedging their interest rate risk exposure. Apparently lowering the duration gap between fixed income assets and liabilities not only reduces the exposure to interest rate risk, but also has cost advantages. A possible explanation is that a portfolio with a relatively high duration needs to annually reinvest a lower amount of its fixed income investments than a similar portfolio with a low duration. Hence, the lower turnover for higher durations could be associated with lower costs.

Moreover, it is noteworthy that the costs of the incremental duration due to the interest rate overlay exposure via interest rate derivatives is not statistically different from zero. This appears to contradict general concerns in the pension fund industry that interest rate derivative overlays are accompanied by high costs. However, increasing the duration with derivatives does appear significantly more expensive compared to using bonds. This difference is significant at the 1 percent level using a Wald test (t-statistic of -3.30). We therefore observe that duration extension using bonds results in lower investment costs, whereas the use of interest rate derivatives does not appear to increase or decrease investment costs. However, it is doubtful whether liquidity in (very) long term fixed income securities is sufficient to fully cover pension funds' hedging demand.

[18] Note that the economic coefficient suggests that defined contribution plans incur higher investment costs than defined benefit plans. This is in line with earlier studies (e.g., Bikker and De Dreu, 2009). Our finding, however, is not statistically significant.

3.2 Asset allocation results

Panel B of Table III presents the coefficients of the vector X_j in our main regression model (1). The vector represents the pension fund's asset allocation. That way, we control for the effect that differences in the asset allocation have on the total investment costs. The coefficients of the control variables also provide detailed information on the relation between total investment costs and the average asset allocation. It is important to note that the coefficients in Panel B are representative for the average pension fund in our sample.

The coefficients in Panel B report the marginal effects that changes in asset allocation have on the investment costs. For instance, increasing the allocation to government bonds with 1 percent raises the average total investment costs by 0.96 basis points (at the pension fund level). However, to examine the net cost effect of this transaction, it is also necessary to include the asset class that is sold to finance the purchase of government bonds. A pension fund, for example, can opt to reduce the allocation towards cash by 1 percent. In that case, the net increase in investment costs is 0.96 – 0.10 = 0.86 basis points.

Panel B also displays interesting costs differences within asset classes. In general, investments in government bonds and inflation linked bonds are associated with higher costs than other sub-classes within the fixed income domain. From Panel B, we can read that this is primarily driven by management costs. The differences between the fixed income sub-classes, however, are not statistically significant.[19]

Based on the results reported in Panel B it is also possible to analyze the cost differences between sub-classes of equities. For that, we break down the equity portfolio in equities mature markets and equities emerging markets.[20] Increasing the

---

[19] To examine the statistical significance of these differences we run a Wald test. The results are not reported in the interest of brevity.

[20] The pension funds in our sample make this distinction themselves, but they are encouraged to follow the OECD classification. Therefore, the distinction by the pension funds in our sample is generally made on a similar basis.

allocation towards emerging market equities with 1 percent raises the total investment costs by 2.38 basis points. This is only 0.75 basis points for mature market equities. Reallocating 1 percent within the equity portfolio from mature markets into emerging markets therefore increases overall investment costs by 1.63 basis points. This difference is statistically significant at the 5 percent level using a Wald test (t-statistic of -2.48) and appears again to be primarily driven by differences in management costs.

Within real estate, we are able to distinguish between three sub-classes: namely direct real estate, listed real estate and indirect real estate (non-listed). Direct real estate involves investments in real estate objects under the management of the pension fund. Listed real estate relates to investments in shares and units of exchange-traded real estate funds. Similarly, indirect real estate primarily relates to investments in shares and units of real estate funds that are not traded on a regulated market. Following Panel B, indirect non-listed real estate appears to be the most expensive investment sub-class in the real estate business. Reallocating 1 percent of total assets from indirect real estate into direct real estate would lower total investment cost by approximately 1 basis point. The difference between the cost levels within the real estate domain are statistically significant using a Wald test (t-statistic of 4.91). A possible explanation for the lower listed real estate costs are the reporting requirements. Pension funds typically invest through so-called 'fund of funds' in the shares of the listed real estate investment trust. As a consequence, pension funds only report the costs charged by the 'fund of fund' and neglect the additional underlying costs of the listed investment trust. For indirect (non-listed) real estate on the other hand, the costs of the real estate investment trust are reported on top of the costs charged by the 'fund of fund'. This may lead to a higher cost level.

In addition, Panel B reveals that performance fees have a significant effect on total investment costs for private equity and hedge funds. For both asset classes the effect is positive and statistically significant at the 1 percent level. This is not surprising as investments in private equity and hedge funds are generally characterized by forms of performance-based fees, sometimes combined with a hurdle rate or high-water mark.

Phalippou and Gottschalg (2009), e.g., find that a third of the costs for private equity investments comes from performance fees.

3.3 Fixed income allocation to credit ratings

Panel C of Table III reports the coefficients of the vector R_j in our main regression model (1). The vector contains control variables that represent the allocation of fixed income securities to different credit ratings. The results in Panel C provide in even more detail the relation between total investment costs and the average asset allocation, by including the effect that differences in credit ratings have on the total investment costs. Like Panel B, these outcomes are representative for the average pension fund in our sample and can therefore be interpreted as marginal effects when reallocating from AAA-rated bonds to bonds with a lower credit rating. The AAA-rated bonds are left out of the regression to avoid singularity.

Panel C reports that non-rated bonds appear to have higher investment costs than AAA-rated bonds. Reallocating 1 percent of the total portfolio from AAA-rated bonds to non-rated bonds would increase the total investment costs by 0.87 basis points. This effect is statistically significant at the 5 percent level and primarily driven by management costs. Non-investment grade bonds ('*<BBB-Rated Bonds*') also appear to be associated with higher costs than AAA-rated bonds. This difference, however, is only statistically significant at the 10 percent level.

3.4 Basic regression without controlling for asset allocation

In our main regression models it appears essential to control for the differences in asset allocation across the pension funds in our sample. To underline the effect of the asset allocation on investment costs, we also perform our main regression without controlling for asset allocation. In this model, we replace the asset allocation vector X, the rating allocation vector R and the two duration variables in (1) by a constant (Y_j).

This leads to the following regression equation:

$$C_{j,k} = Y_j + \beta_{1,k} \log(Size_j) + \beta_{2,k}\text{Corp}_j + \beta_{3,k}\text{Prof}_j + \beta_{4,k}\text{DC}_j + u_{j,k} \tag{3}$$

Table IV presents these results. Several findings stand out. First, we observe a substantial drop in the R^2 when we exclude the asset allocation variables. The R^2 decreases from 0.541 (in Table III) to 0.021 in this regression model. Table IV also displays that the constant Y_j equals 45.18 basis points and is statistically different from zero. As such, the constant is comparable to the mean total investment costs of 42 basis points (reported in Table I). Strikingly we no longer find a significant relation in (3) between size and investment costs. Increasing the size by a factor ten only lowers the investment costs economically by 0.99 basis points. Moreover, this effect is not statistically significant.

Since we only find significant economies of scale when we control for differences in asset allocation (in 1), we conclude that large pension funds apparently invest more in asset classes with higher investment costs (like private equity and hedge funds) than smaller pension funds. We observe a similar finding for corporate pension funds. Without controlling for differences in asset allocation, we no longer document a significant difference in investment costs between corporate pension funds and other types of pension funds. We thus conclude that corporate pension funds also invest more in asset classes with higher investment costs compared to other types of pension funds.

4. Investment costs at the asset class level

After examining investment costs at the pension fund level in the previous section, we now turn to the analysis at the asset class level. For that, we investigate the separately reported costs for the following six asset classes: fixed income, equities, real estate, private equity, hedge funds and commodities. This enables us to examine whether the main results described in Section 3 differ per asset class.

Table V, panel A, reveals the main findings at the asset class level using (2). The columns in Panel A report the total investment costs for the six asset classes, after controlling for differences in the allocation within these asset classes. For ease of reference the results at the total portfolio level (Table III) are presented in the left most column.

We find a significant negative relation between total investment costs and size for fixed income, equities and commodities.[21] These findings are statistically significant at the 1 percent level and in line with our finding at the pension fund level. The effect is strongest for commodities, where a tenfold increase in size results in a decrease of total investment costs by 21.57 basis points. On the other hand, we find no evidence for economies of scale in real estate, private equity and hedge funds. A possible explanation for the difference in economies of scale is that more traditional asset classes (e.g., fixed income, equity) are more easily scalable to a larger size. Costs for financial research, risk management and monitoring increase less with size for fixed income and equity investments than for alternative asset classes such as real estate, private equity or hedge funds. The latter classes typically require new projects, new objects or investment strategies when the total investment size increases.

For real estate, we find evidence for diseconomies of scale. A tenfold increase in real estate investments raises total investment costs with 14.55 basis points. The economic explanation for this finding is likely due to the different reporting requirements for

[21] Note that asset class size is measured as the assets under management in that particular asset class.

listed and unlisted real estate investments. Several pension funds have a small exposure to listed real estate via the equity funds they invest in. The investment costs of these real estate exposures are not directly observable for the pension fund as they are included in the investment costs of the equity fund. Although this effect is largely captured by the differentiation to direct, listed and unlisted real estate investments, a remainder could be estimated via size.

Panel A also reports the effects at the asset class level for the other pension fund-specific characteristics. Compared to industry-wide pension funds, corporate pension funds appear to have relatively high cost structures in fixed income (5.12 basis points), real estate investments (24.31 basis points) and commodities (15.39 basis points). For professional group pension funds, we find no significant effects at the asset class level. The relation between the duration of the fixed income portfolio and the total investment costs of fixed income is statistically different from zero. A one year higher duration implies a reduction in total fixed income costs of 1.47 basis points. This is in line with our earlier finding at the portfolio level.[22]

Panel B and Panel C of Table V examine the management costs and performance fees at the asset class level. In both cases, we also display the results at the portfolio level (Table III) in the left column for ease of comparability. Panel B reports that the relation between investment costs and size is primarily driven by management costs. We find lower management costs for larger pension funds in the case of fixed income, equity, private equity and commodities. A tenfold increase in fixed income investments, for example, leads to a decline in annual management costs of 4.83 basis points. On the other hand, we document diseconomies of scale in management costs for real estate. This is likely explained by underreporting of these costs by small funds as mentioned earlier. In addition, Panel B reports that the relatively higher costs for corporate

[22] On average, the pension funds in our sample invest 61.8 percent of their portfolio in fixed income securities. At the portfolio level we document a reduction in investment costs of 2.99 basis points for a one year higher duration, which roughly translates to the finding for fixed income securities (2.99 * 0.618 = 1.84). We deem the remaining difference as noise.

pension funds appear to be driven by fixed income, real estate and commodities investments.

Table IV, panel C, reports the results for performance fees. We find that larger pension funds pay higher performance fees for equities, private equity and hedge funds. We find that a tenfold increase in equity investments leads to a raise in performance fees by 0.74 basis points. This effect is statistically significant at the 5 percent level. A tenfold increase in private equity investments would raise the annual performance fees by 41.49 basis points on average. For hedge funds, the result is an increase of 33.36 basis points. Both findings are statistically significant at the 1 percent level.[23]

A possible explanation for the positive relation between pension fund size and performance fees for these asset classes could be that larger funds are better able to select the best-performing equity, private equity of hedge funds. Large pension funds may have more bargaining power in private deals and can devote more resources to closely monitor their external counterparties (Andonov *et al*., 2011), which is especially valuable for alternative asset classes. The ability of large pension funds to select the best-performing asset managers with the higher returns would subsequently lead to paying higher performance fees. Although we have no direct way of validating our hypothesis, there is academic evidence suggesting that private equity funds with higher compensation earn higher returns. Robinson and Sensoy (2013) examine buyout and venture capital private equity funds and find no evidence that high fee funds earn lower net-of-fee performance. This implies that private equity funds with higher compensation earn their pay by generating higher gross performance.[24] This is important, as Kaplan and Schoar (2005) observe large differences in the returns of individual private equity funds – as well as strong persistence in returns – indicating the importance of selecting the top-performing asset managers.

[23] Note that we only have 71 observations for private equity and 57 observations for hedge fund investments.
[24] Robinson and Sensoy (2013) also investigate whether private equity funds with higher compensation earn their fees by taking more systematic risk, but they find no evidence fort his.

5. Robustness checks

In the previous sections, we document strong economies of scale in pension fund investment costs that are primarily driven by management costs, but appear to differ between asset classes. In this section, we perform additional analyses to test the robustness of our findings. In particular, we perform two robustness checks. First, we divide our sample into different subsamples based on pension fund size. Second, we perform piecewise linear regressions. This enables us to further examine whether the economies of scale are stable across different pension fund sizes.

There is academic literature indicating that economies of scale are dependent on pension fund size. Bikker (2013) argues that pension funds typically exhibit a U-shaped average cost function. The downward sloping left leg of the U shape is caused by economies of scale due to fixed-cost components in pension activities, such as research and development, compliance with accounting and regulatory requirements and size-related bargaining power with respect to investments. At the same time, larger pension funds may face inefficiencies such as additional management layers, over-hiring and additional costs related to overconfidence (see also Griffin and Tversky, 1992; Chatterton *et al*., 2010; Bauer *et al*., 2010). These inefficiencies can cause diseconomies of scale and may therefore suggest an optimal pension fund size. Bikker (2013) reports a minimal optimal scale with respect to investment costs of 690 million euro. However, he finds no support for diseconomies of scale for investment costs as larger pension funds remain equally cost efficient. Following Bikker (2013) we also analyze whether economies of scale are stable across different pension fund sizes.

5.1 Subsamples

As a first robustness test we divide the full sample of 225 pension funds into two equal subsamples in terms of the number of pension funds. At the pension fund level, the first subsample contains the 112 smallest pension funds with a maximum fund size of 430 million euro of assets under management. The second subsample consists of 113 pension funds that have more than 430 million euro assets under management. In addition, we also divide the full samples into two equal subsamples for the six asset classes.

Table VI, panel A, presents the results for both subsamples at the pension fund level. For ease of comparison, the table also reports our main findings for the full sample. Several findings stand out. First, we observe a negative relation between investment costs and pension fund size for both subsamples. In both cases the relation is statistically significant at the 1 percent level, although the economies of scale appear to be somewhat higher for small pension funds (-10.03 basis points) than for large pension funds (-7.72 basis points). Second, small corporate and professional group pension funds appear to report significantly higher costs than small industry-wide pension funds. In the first subsample, corporate pension funds on average report 14.02 basis points higher investment costs than industry-wide pension funds. For large pension funds, on the other hand, we find no statistically significant difference between different types of pension funds. In the subsample with the large pension funds, both corporate and professional group pension funds no longer have higher costs compared to industry-wide pension plans. This indicates that small corporate and professional group pension funds have relatively large cost advantages when increasing their size. Finally, we document that the relation between investment cost and the duration contribution via fixed income securities is stable across both subsamples, although the negative relation is more significant for large pension funds.

The results at the asset class level are displayed in Panel B of Table VI. For fixed income, the economies of scale appear relatively stable over the subsamples, although we only find a statistically significant result (at the 1 percent level) for pension funds with large mandates. For equities, we find that the economies of scale are stronger for pension funds with a small mandate (-21.52 basis points) than for [pension funds with a large mandate (-4.80 basis points). In addition, we observe that the diseconomies of scale in real estate appear to be driven by pension funds with small mandates. We also find diseconomies of scale for larger investments in private equity, but we note that the subsamples for private equity only contains 35 observations.

5.2 Piecewise linear regressions at the pension fund level

To further test the relation between investment costs and pension fund size over different pension fund sizes, we also perform a two- and three-piecewise linear regression models by allowing the linear relation between (log) size and costs to vary with size. In the two-piecewise linear regression we adjust the main regression model (1) as follows:

$$C_{j,k} = \beta_{1,k} \log(Size_j) + \beta_{2,k}\text{Corp}_j + \beta_{3,k}\text{Prof}_j + \beta_{4,k}\text{DC}_j + \beta_{5,k}\text{DUR}_{FI,j} + \beta_{6,k}\text{DUR}_{O,j} + X_j\beta_{7,k} + R_j\beta_{8,k} + \beta_{9,k}\left(\log(Size_j) - \log(\beta_{10,k}) \,\middle|\, Size_j > \beta_{10,k}\right) + u_{j,k} \quad (4)$$

where $\beta_{9,k}$ measures the incremental increase (or decrease) in the economies of scale for pension funds with investments larger than the cutoff point $\beta_{10,k}$. This two-piecewise linear model (4) is non-linear and we estimate the coefficients by varying $\beta_{10,k}$ over a grid between the minimum and maximum pension fund size to find the maximum likelihood estimators of $\beta_{\mathrm{i},k}$.[25]

In addition, we also run a three-piecewise regression model where we allow for an extra variation in the economies of scale in model (4) as follows:

$$C_{j,k} = \beta_{1,k} \log(Size_j) + \beta_{2,k}\text{Corp}_j + \beta_{3,k}\text{Prof}_j + \beta_{4,k}\text{DC}_j + \beta_{5,k}\text{DUR}_{FI,j} + \beta_{6,k}\text{DUR}_{O,j} + X_j\beta_{7,k} + R_j\beta_{8,k} + \beta_{9,k}\left(\log(Size_j) - \log(\beta_{10,k}) \,\middle|\, Size_j > \beta_{10,k}\right) + \beta_{11,k}\left(\log(Size_j) - \log(\beta_{12,k}) \,\middle|\, Size_j > \beta_{12,k}\right) + u_{j,k} \quad (5)$$

where we require $\beta_{10,k} < \beta_{12,k}$ to identify a unique model as the model with $\beta_{10,k} = a$ and $\beta_{12,k} = b$ is the same as the model with $\beta_{10,k} = b$ and $\beta_{12,k} = a$. This three-

[25] In more detail the algorithm is as follows:

1. Set $R^2 = 0$;
2. Set $\beta_{10,k} = c$, if c larger than the minimum pension fund size and smaller than the maximum pension fund size, else move to step 5;
3. Estimate model (4) for $\beta_{10,k} = c$ that has become a linear model when $\beta_{10,k}$ is set;
4. If the R-squared of the regression in step 3 is larger than the previous maximum R^2, then set $R^2 = R_c^2$ and store $\hat{c} = c$;
5. Run steps 2 to 4 multiple times for different c, $c = j \times 10^i \quad i = 6, \dots, 11 \quad j = 1, \dots 9$;
6. Rerun model 4 for $\beta_{10,k} = \hat{c}$ to find the maximum likelihood estimators of the other $\beta_{i,k}$.

piecewise linear model (5) is also non-linear and we estimate the coefficients by varying both $\beta_{10,k}$ and $\beta_{12,k}$ over a grid between the minimum and maximum pension fund size to find the maximum likelihood.[26]

Table VII shows the results of both piecewise linear regressions, whereas Figure II graphically presents the outcome of the regression estimates at the pension fund level. In addition, Figure II contains a scatter plot where the observed total investment costs (y-axis) are plotted against pension fund size (x-axis).[27]

Table VII, Panel A, presents the results for the two-piecewise linear model (4). In this case, the single cutoff point is located at a pension fund size of 5 million euro, which is relatively small. Panel A reports an insignificant positive relation between costs and size for pension funds with less than 5 million euro of assets under management. However, for pension funds larger than 5 million, we find a negative relation between investment costs and pension fund size indicating economies of scale. A tenfold increase in size for these pension funds leads to a reduction in investment costs with 10.12 basis points. This coefficient is statistically significant at the 1 percent level and roughly in line with the outcome of our main regression where we find a negative coefficient of 7.67 basis points.

[26] In more detail the algorithm becomes:

1. Set $R^2 = 0$;
2. Set $\beta_{10,k} = c$, if c larger than the minimum pension fund size and smaller than the maximum pension fund size, else move to step 7;
3. Set $\beta_{12,k} = d$, if d smaller than the maximum pension fund size, else move to step 6;
4. Estimate model (4) for $\beta_{10,k} = c$ and $\beta_{12,k} = d$ that has become a linear model when $\beta_{10,k}$ and $\beta_{12,k}$ are set;
5. If the R-squared of the regression in step 4 is larger than the previous maximum R^2, then set $R^2 = R^2_{c,d}$ and store $\hat{c} = c$ and $\hat{d} = d$;
6. Run steps 3 to 5 multiple times for different $d, d = m \times 10^n \quad n = i, \ldots, 11 \quad m = j + 1, \ldots 9$;
7. Run steps 2 to 6 multiple times for different $c, c = j \times 10^i \quad i = 6, \ldots, 11 \quad j = 1, \ldots 9$;
8. Rerun model 4 for $\beta_{10,k} = \hat{c}$ and $\beta_{12,k} = \hat{d}$ to find the maximum likelihood estimators of the other $\beta_{i,k}$.

[27] Due to confidentiality restrictions, we are unable to report individual observations and therefore present the average investment costs for 50 groups of pension funds – each containing either 4 or 5 individual pension funds – versus their average size.

Panel B of Table VII reports the results for the three-piecewise linear model (5). In this case, we find two cutoff points that are located at a pension fund size of respectively 10 million euro and 20 million euro. The main finding is that we document significant economies of scale for pension funds with more than 20 million euro of assets under management (which is the vast majority of pension funds in our sample). For these pension funds, a tenfold increase in size lowers total investment costs by 6.41 basis points. Again, the outcome is statistically significant at the 1 percent level and in line with the result of our main regression.

Following the additional analyses in this section, we conclude that the documented economies of scale are robust. The findings appear not to be driven by outliers, since we find statistically significant economies of scale for pension funds with more than 20 million euro of asset under management (which are the vast majority of pension funds in our sample). Although we appear to find diseconomies of scale for very small pension funds (with less than 5 million euro assets under management), we note that we only have a very limited number of observations and that this finding could be driven by the costs of the smallest funds being outliers (see Figure II). In addition, we find no significant evidence for diminishing economies of scale (or diseconomies of scale) for very large pension funds. This confirms the findings of Bikker (2013).

5.3 Piecewise linear regressions at the asset class level

Table VII, Panels C and D show the piecewise linear regressions at the asset class level, for respectively the two-piecewise and three-piecewise models. Figure III graphically displays these results. For fixed income, we document a strong negative relation between size and total costs for investments larger than 40 million euro (see Panel D). In this case, a tenfold increase in size lowers investment costs by 2.43 basis points. This is somewhat smaller than the finding for the full sample (-4.76 basis points), but still statistically significant at the 1 percent level. Furthermore, we observe significant diseconomies of scale for very small fixed income mandates (below 4 million euro), but attribute this finding to a few pension funds with small exposures to fixed income funds that charge very high costs (also see Figure III).

For equities, we find significant economies of scale that appear strongest for small mandates (below 20 million euro). This is in line with the outcome for the subsamples (see Table VI). Panel C and Panel D, however, report that economies of scale remain significant for equity investments larger than 20 million euro. A tenfold increase in size for these mandates lowers total costs with 3.75 basis points. Again, this finding is somewhat smaller than observed for the full sample (-7.75 basis points), but still statistically significant at the 1 percent level.

The diseconomies of scale observed for real estate appear primarily driven by pension funds with a small mandate. Panel C and Panel D show that pension funds with real estate investments smaller than 20 million euro face significant diseconomies of scale (at the 1 percent level). This supports our finding with respect to the subsamples (see Table VI).

In line with our main findings, we observe no economies of scale for investments in private equity and hedge funds. Following the subsample analysis, we again observe significant diseconomies of scale for pension funds with large investments in private equity (larger than 400 million euro). These diseconomies of scale are primarily driven by performance fees. As mentioned earlier, a possible explanation for this finding could be that larger funds are better able to select the best-performing private equity funds and therefore pay significantly higher performance fees.

For commodities, we document significant economies of scale for pension funds that invest less than 300 million euro. A tenfold increase in size for these pension funds reduces total costs with 21.59 basis points (see Table VII, Panel D). However, these economies of scale appear to disappear for mandates larger than 300 million euro.

6. Conclusions

This paper provides a comprehensive analysis of pension funds' cost structures. For that, we focus on the Dutch pension system, which is well-developed, relatively large in terms of size and characterized by pension funds that allocate money to a wide variety of asset classes. Our cross-sectional dataset is unique as it is free from self-reporting biases, and contains detailed information on pension fund-specific investment costs. We decompose investment costs into management costs and performance fees for six separate asset classes: equity, fixed income, real estate, commodities, private equity and hedge funds. We specifically investigate the impact of pension funds size to test for the presence of economies of scale. Our key findings are as follows.

First, after correcting for differences in asset allocation, we find significant evidence of economies of scale in investment costs. A pension funds that is ten times larger, in terms of assets under management, has on average 7.67 basis points lower annual investment costs. These economies of scale are solely driven by management costs. Moreover, the effect disappears when we do not control for asset allocation, indicating that larger pension funds invest relatively more in asset classes with higher investment costs.

Second, the observed economies of scale in investment cost appear to be constant over pension fund size. Using a piecewise linear regression model we find significant economies of scale for all pension funds with more than 20 million euro in asset under management (which is the vast majority of pension funds in our sample). We find no evidence for diminishing economies of scale for very large pension funds.

Third, we conclude that the presence of economies of scale differs per asset class. Size appears to be an important driver for economies of scale in fixed income and equity. Ten folding the size of these asset classes lowers annual investment costs by 4.76 and 7.75 basis points respectively on an annual basis, although economies of scale appear even stronger for small equity mandates (below 20 million euro). We also document significant economies of scale for commodities, but these disappear for investments exceeding 300 million euro. For real estate investments, on the other hand, we document diseconomies of scale, which appear primarily driven by small mandates.

Fourth, although most of the findings are primarily driven by differences in management costs, we find that performance fees significantly impact investment costs for equities, private equity and hedge funds. For these asset classes, we find that a tenfold increase in size raises performance fees by 0.74, 41.49 and 33.36 basis points respectively. All findings are statistically significant at the 1 percent level.

Fifth, compared to industry-wide pension funds, corporate pension plans pay 7.33 basis points higher investment costs. This contradicts our hypothesis that corporate pension plans operate in a more competitive environment. A possible explanation is that corporate pension funds are potentially more exposed to a misalignment of interests as they rely on commercial asset managers. Industry-wide pension funds on the other hand, typically are the shareholder of their own pension service provider and therefore in theory might have less agency costs. Moreover, we observe no significant difference in investment costs between defined benefit and defined contribution plans.

Sixth, a one year higher duration contribution of the fixed income portfolio implies a decline of total investment cost by 2.99 basis points. Apparently, increasing the hedge of the interest rate risk of the liabilities has cost advantages. It is also noteworthy that the costs of the incremental duration due to the interest rate overlay exposure of interest rate derivatives is not statistically different from zero. We therefore find that it is more attractive to hedge interest rate risk with bonds rather than with interest rate derivatives. Although it is doubtful whether liquidity in (very) long term bonds is sufficient to cover pension funds' hedging demand. The finding contradicts our hypothesis that pension funds pay a premium for hedging liabilities with long term bonds and derivatives.

References

An, H., Z. Huang and T. Zhang, 2013, What determines corporate pension fund risk-taking strategy, *Journal of Banking & Finance*, 37(2): 597-613.

Andonov, A., R.M.M.J. Bauer and K.J.M. Cremers, 2011, Can large pension funds beat the market? Asset allocation, market timing, security selection and the limits of liquidity, *Maastricht University Working paper*.

Bauer, R.M.M.J., K.J.M. Cremers and R.G.P. Frehen, 2010, Pension fund performance and costs: small is beautiful, *Maastricht University Working paper*.

Bikker, J.A. and J. De Dreu, 2009, Operating costs of pension funds: the impact of scale, governance and plan design, *Journal of Pensions, Economics and Finance*, 8(1): 863-889.

Bikker, J.A., 2013, Is there an optimal pension fund size? A scale economy analysis of administrative and investments costs, *DNB Working paper series,* no. 376.

Blake, D., A.G. Rossi, A. Timmermann, I. Tonks and R. Wermers, 2013, Decentralized investment management: evidence from the pension fund industry, *Journal of Finance*, 68(3): 1133-1178.

Broeders, D.W.G.A. and E.H.M. Ponds, 2012, Dutch Pension System reform a step closer to the ideal system design?, *CESifo DICE Report*, 3/2012.

Broeders, D.W.G.A., P.L.C. Hilbers, D.R. Rijsbergen and N. Shen, 2014, What drives pension indexation in turbulent times? An empirical examination of Dutch pension funds, *De Economist*, 162(1): 41-70.

Busse, J., A. Goyal and S. Wahal, 2010, Performance persistence in institutional investment management, *Journal of Finance*, 65(2): 765-790.

Chatterton, M., E. Smyth, K Darby, 2010, Pension scheme administrative costs, Department for Work and Pensions, Working Paper no 91, London.

Clark, G.L. and P. Bennett, 2001, Dutch sector-wide supplementary pensions: fund governance, European competition policy, and the geography of finance, *Environment and Planning,* 33(1): 27-48.

Collins, S. and Ph. Mack, 1997, The optimal amount of assets under management in the mutual fund industry, *Financial Analysts Journal*, 53(5): 67-73.

Davanzo, L.E. and S.L. Nesbitt, 1987, Performance fees for Investment Management, *Financial Analysts Journal*, 43 (1): 14-20.

Drago, D., V. Lazzari and M. Navone, 2010, Mutual fund incentive fees: Determinants and effects, *Financial Management*, 39(1): 365-392.

Dyck, A. and L. Pomorski, 2011, Is bigger better? Size and performance in pension plan management, *Working paper.*

Goetzmann, W.N., J.E. Ingersoll Jr and S.A. Ross, 2003, High water marks, *Journal of Finance,* 58(4): 1685-717.

Griffin, D. and A. Tversky, 1992, The weighing of evidence and the determinants of confidence, *Cognitive Psychology,* 24(3): 411–435.

Kaplan, S.N. and A. Schoar, 2005, Private equity performance: Returns, persistence and capital flows, *Journal of Finance*, 60 (4): 1791-1823.

Lakonishok, J., A. Shleifer and R. Vishny, 1992, The structure and performance of the money management industry, *Brookings Papers on Economic Activity: Microeconomics*, 1992: 339-391.

Indro, D.C., C.X. Jiang, M.Y. Hu and W.Y. Lee, 1999, Mutual fund performance: does fund size matter? *Financial Analysts Journal*, 55(3): 74-87.

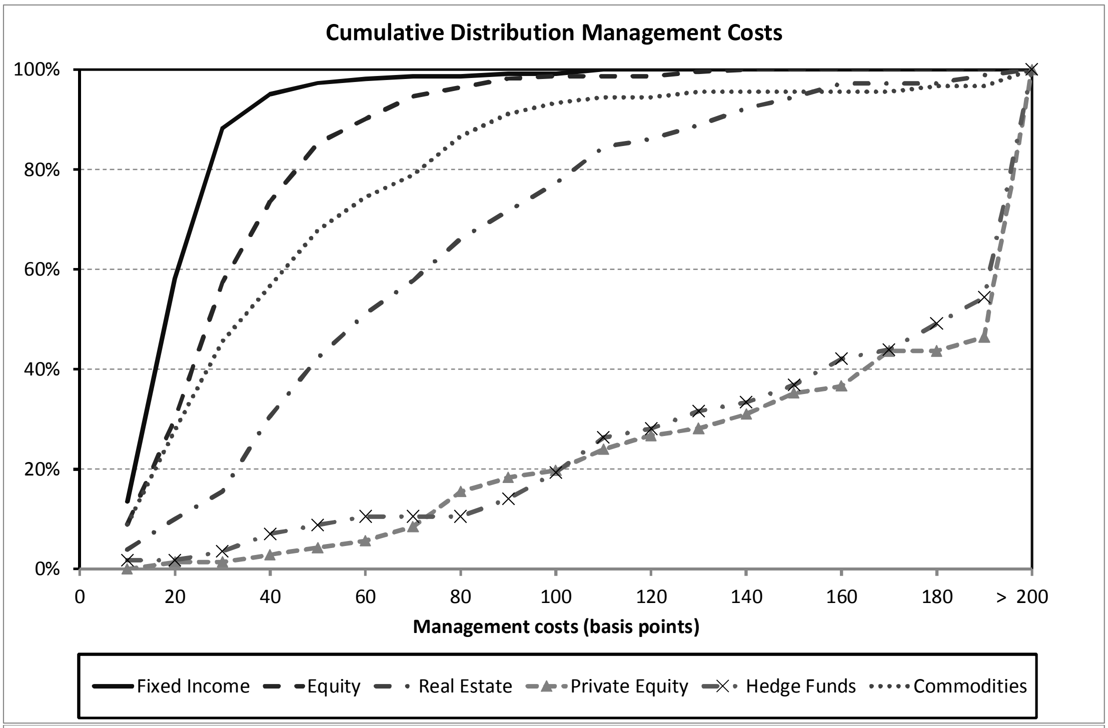
Phalippou, L. and O. Gottschalg, 2009, The performance of private equity funds, *The Review of Financial Studies*, 22(4): 1747-1776.

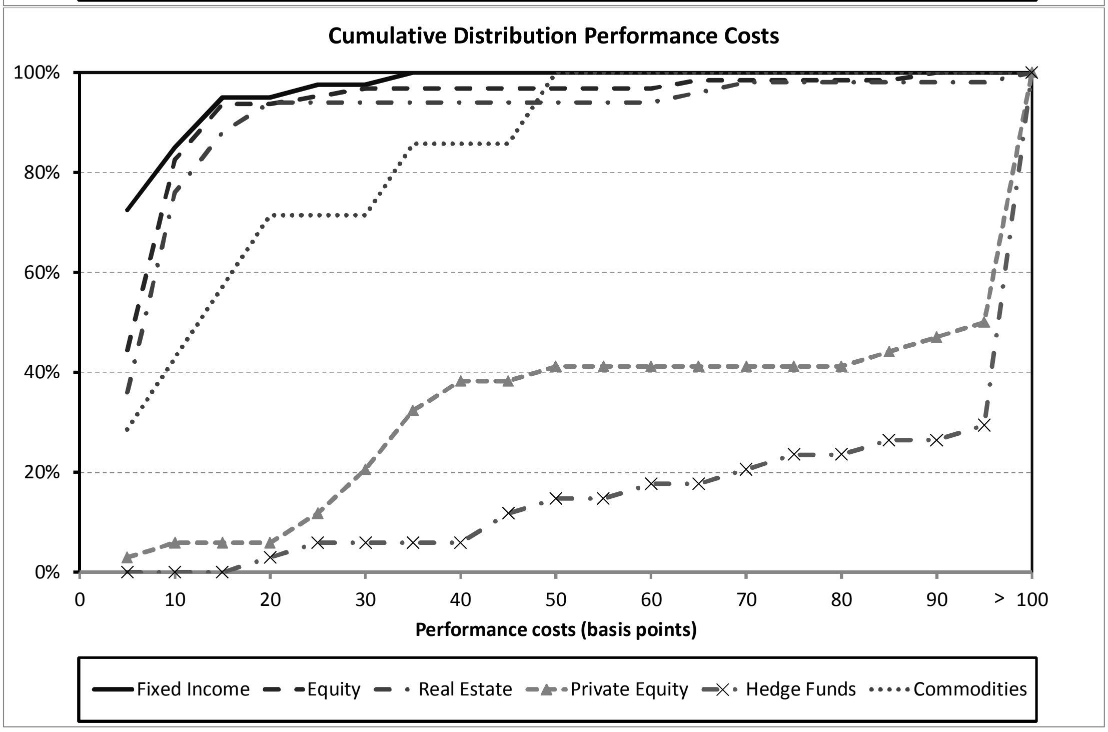
Robinson, D.T. and B.A. Sensoy, 2013, Do private equity fund managers earn their fees? Compensation, ownership, and cash flow performance, *Review of Financial Studies*, 26 (11): 2760-2797.

Swensen, D., 2005, *Unconventional Success: A Fundamental Approach to Personal Investment, Free Press, New York.*

Thapa, C. and S.S. Poshakwale, 2010, International equity portfolio allocations and transaction costs, *Journal of Banking & Finance*, 34(11): 2627-2638.

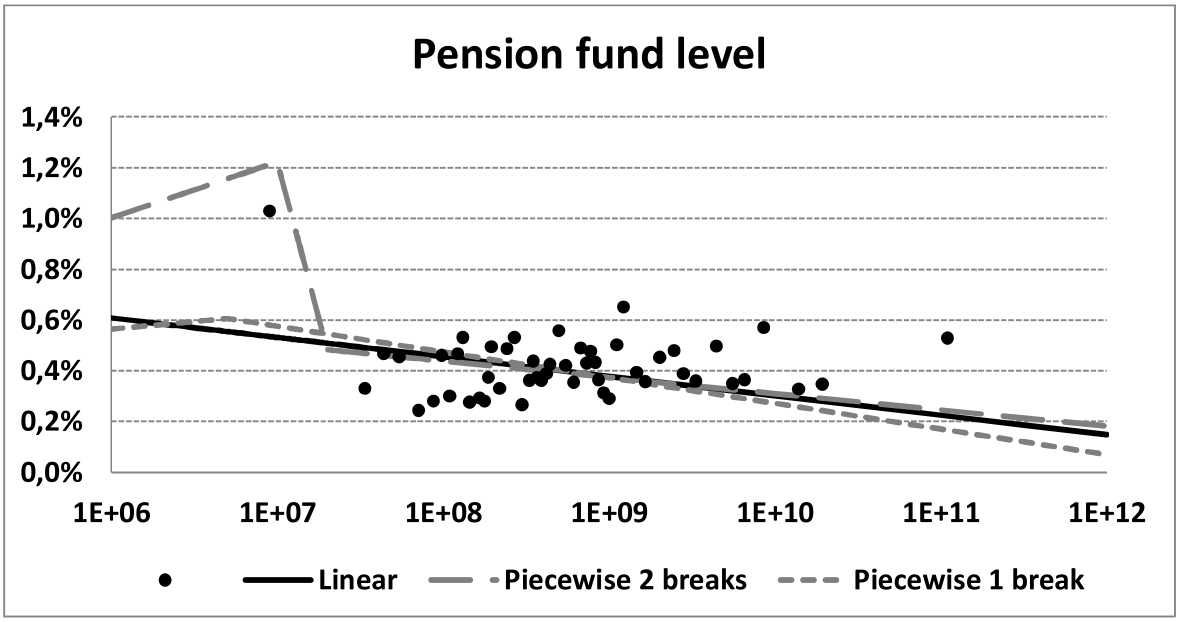
Figure I: Cumulative Distribution of Management Costs and Performance Costs





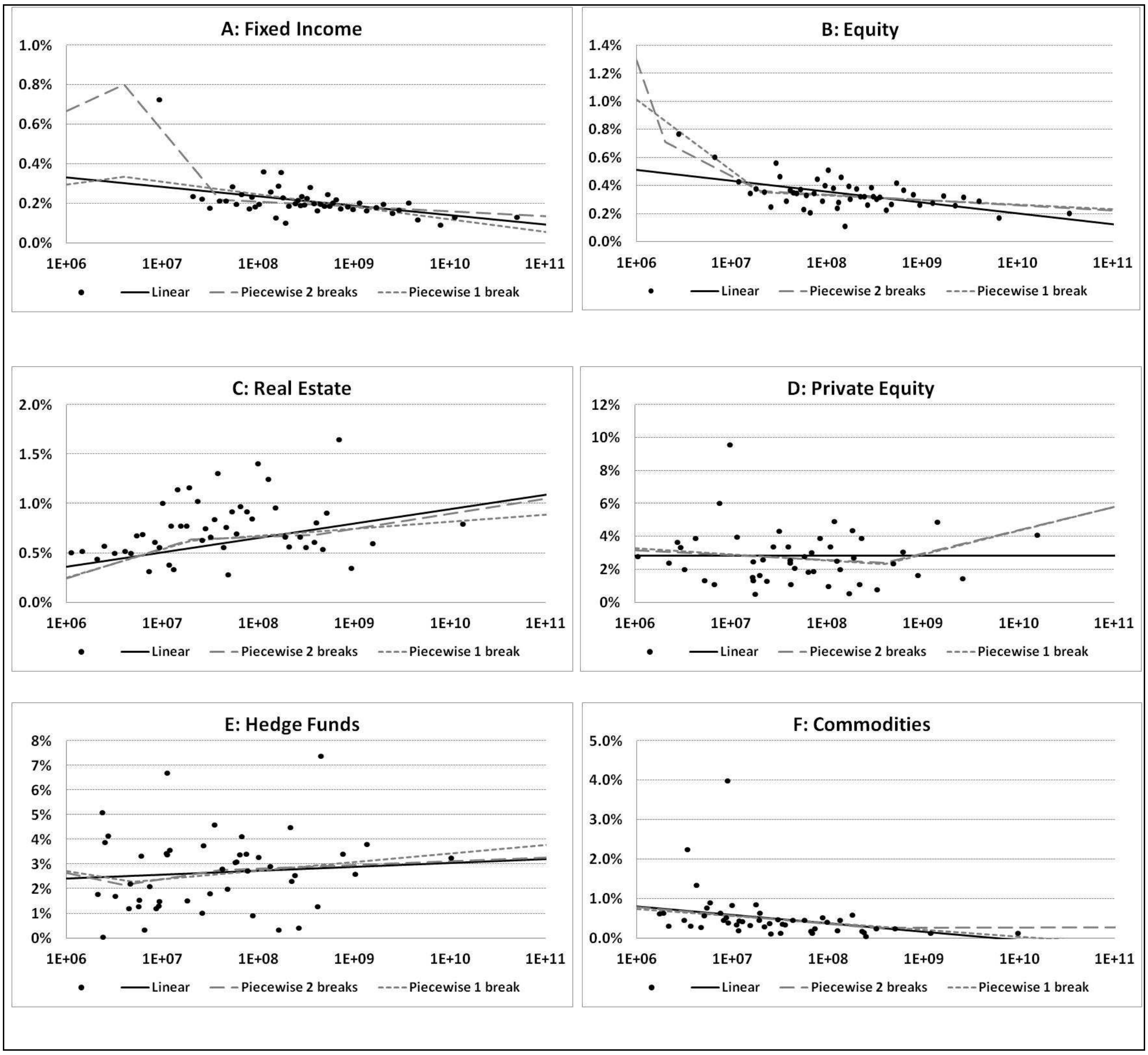
Note: Figure I shows the cumulative distribution of management costs and performance costs in our dataset for the year 2013. The figure displays this distribution for six asset classes: fixed income, equity, real estate, private equity, hedge funds and commodities.

Figure II: Economies of scale for total investment costs at the pension fund level



Note: Figure II displays the estimated linear relation (based on regression model (1)) and the piecewise linear relations (based on regression models (4) and (5)) between size and total investment cost at the pension fund level for the average pension fund in the sample. Table VII, panel A contains the exact coefficients of these estimations. Figure II also presents a scatter plot with the observations in our sample. Due to confidentiality restrictions, we are unable to report individual observations and therefore present the average investment costs for 50 groups of pension funds based on their average size. The y-axis represents the total annual investment costs. The x-axis displays the size of a pension fund (on a logarithmic scale) and ranges from 1 million euro to 100 billion euro.

Figure III: Economies of scale for total investment costs at the asset class level



Note: Figure III displays the estimated linear relation (based on regression model (1)) and the piecewise linear relations (based on regression models (4) and (5)) between size and total investment cost for six different asset classes in the dataset. Table VII, panel B contains the exact coefficients of these estimations. Figure III also presents scatter plots with the observations in our sample. Due to confidentiality restrictions, we are unable to report individual observations and therefore present the average investment costs for 50 groups of pension funds based on their average size. The y-axis represents the total annual investment costs. The x-axis displays the size of the investments in a particular asset category (on a logarithmic scale) and ranges from 1 million euro to 100 billion euro.

Table I
Statistics on Pension Fund Investment Costs

Table I presents an overview of the main statistics on the pension fund investments costs during 2013. The minimum and maximum observations are represented by the 10^{th} percentile and the 90^{th} percentile. All costs are expressed as annual basis points. The row "*Total Portfolio*" represents the total investment costs at the portfolio level, while the table also reports the total investment costs for six separate asset classes. All investment costs are also decomposed into managements costs and performance fees. Finally, the column '*Asset allocation*' reports the average allocation to a specific asset class for the pension funds in the sample. The asset allocation is measured as a percentage of total assets under management.

	Mean	Standard deviation	Minimum (10^{th} percentile)	Maximum (90^{th} percentile)	Asset allocation
Total Portfolio	**42**	**21**	**19**	**65**	
Management costs	39	19	18	60	
Performance fees	3	7	0	11	
Fixed Income	**21**	**14**	**10**	**31**	**61.8%**
Management costs	20	13	9	31	
Performance fees	1	3	0	2	
Equity	**34**	**22**	**11**	**62**	**30.2%**
Management costs	32	21	10	59	
Performance fees	2	6	0	7	
Real Estate	**73**	**52**	**21**	**134**	**5.0%**
Management costs	70	47	21	132	
Performance fees	3	15	0	7	
Private Equity	**274**	**178**	**88**	**526**	**0.9%**
Management costs	217	143	72	337	
Performance fees	57	91	16	220	
Hedge Funds	**268**	**156**	**76**	**443**	**0.9%**
Management costs	181	93	76	273	
Performance fees	86	102	0	204	
Commodities	**49**	**54**	**13**	**90**	**1.2%**
Management costs	48	51	13	89	
Performance fees	1	6	0	0	

Table II
Descriptive Statistics

Table II contains an overview of the explanatory variables in this paper. Panel A reports the descriptive statistics of the variables. The coefficients under the “Mean” column represent the mean of the variable for 2013, while the numbers in square brackets present the standard deviation of each variable in 2013. The minimum and maximum observations are represented by the 10th percentile and the 90th percentile. ‘Log Size’ is expressed as the logarithm of the total assets under management, while the duration variables are both measured in years. Panel B presents the average number of pension fund types – corporate pension funds, industry wide pension funds and professional group pension funds – as well as the contract types – DB and DC – for the year 2013.

Panel A: Descriptive statistics for the explanatory variables

	Mean	Minimum (10th percentile)	Maximum (90th percentile)
Log Size	5.7	4.9	6.8
	[0.8]		
Duration Contribution Fixed Income	4.4	2.4	7.0
	[2.2]		
Duration Contribution Overlay	6.0	0.0	12.1
	[4.9]		

Panel B: Means for pension fund type and contract type

	Corporate pension funds	Industry wide pension funds	Professional group pension funds
Mean	160	55	10

	DB	DC
Mean	212	13

Table III

Pension Fund Overall Investment Costs and Size controlling for Asset Allocation

Table III presents a cross section of the impact of pension fund characteristics on investment costs of 225 pension funds during 2013. Panel A reports the main results. For that, we run the following regression: $C_{j,k} = \beta_{1,k} \log(Size_j) + \beta_{2,k}\text{Corp}_j + \beta_{3,k}\text{Prof}_j + \beta_{4,k}\text{DC}_j + \beta_{5,k}\text{DUR}_{FI,j} + \beta_{6,k}\text{DUR}_{O,j} + X_j\beta_{7,k} + R_j\beta_{8,k} + u_{j,k}$ where X_j is a vector containing control variables for the asset allocation of a pension fund *j*, and R_j is a vector controlling for the allocation to rating classes. Index *k* either represents the annual total investment costs (reported in column '*Total Costs*'), the management costs or the performance fees for a pension fund (reported in the columns '*Management Costs*' and '*Performance Fees*'). The economic coefficients are measured as annual basis points, whereas the numbers in squared brackets report the t-statistics. *,**,*** represent the statistical significance at the 10 percent. 5 percent and 1 percent level, while the table also reports the number of pension funds in the sample (N) and the R^2. All standard errors are corrected for heteroskedasticity using White's test. Finally, Panel B and Panel C display the results for the asset allocation of the pension funds in our sample. Panel B reports the results on the asset class level (vector X_j in our regression model), while Panel C presents the results for the decomposition into different credit ratings for fixed income securities (vector R_j in our regression model). The results in Panel C are relative to AAA-rated bonds to avoid singularity.

Panel A: Main Regression Results

	Total Costs	Management Costs	Performance Fees
Log Size	-7.67***	-7.81***	0.14
	[-3.92]	[-3.95]	[0.29]
Type of Fund: Corporate	7.33***	8.04***	-0.71
	[3.16]	[3.47]	[-0.71]
Type of Fund: Professional	9.83*	6.32	3.51
	[1.74]	[1.26]	[1.06]
DC	1.44	4.15	-2.71
	[0.34]	[0.95]	[-1.53]
Duration Fixed Income	-2.99***	-2.88***	-0.11
	[-2.78]	[-2.67]	[-0.68]
Duration Overlay	0.00	0.11	-0.11
	[0.01]	[0.36]	[-1.29]
N	225	225	225
R^2	0.541	0.449	0.407

Table III (*continued*)

Panel B: Asset Allocation

	Total Costs	Management Costs	Performance Fees
Government Bonds	0.96***	0.94***	0.02
	[3.96]	[3.76]	[0.49]
Inflation Linked Bonds	0.96***	0.91***	0.05
	[2.88]	[2.71]	[0.62]
Mortgages	0.69**	0.57*	0.12
	[1.99]	[1.66]	[0.95]
Corporate Bonds	0.59**	0.53**	0.06
	[2.13]	[1.99]	[0.57]
Cash and Cash Equivalents	0.10	0.13	-0.03
	[0.26]	[0.37]	[-0.21]
Direct Real Estate	0.43	0.66**	-0.22*
	[1.39]	[2.04]	[-1.91]
Listed Real Estate	0.22	0.36	-0.14
	[0.46]	[0.75]	[-0.77]
Indirect Real Estate	1.45***	1.59***	-0.14
	[4.15]	[4.61]	[-1.04]
Equities – Mature Markets	0.75***	0.70***	0.05
	[4.92]	[4.70]	[0.99]
Equities – Emerging Markets	2.38***	2.14***	0.25*
	[3.57]	[3.19]	[1.69]
Private Equity	4.86***	3.56***	1.30***
	[7.72]	[4.76]	[2.86]
Hedge Funds	4.69***	3.33***	1.37***
	[6.51]	[4.15]	[2.88]
Commodities	0.19	-0.13	0.32
	[0.43]	[-0.32]	[1.45]
N	225	225	225
R^2	0.541	0.449	0.407

Table III (*continued*)

Panel C: Fixed Income Allocation in Credit Ratings

	Total Costs	Management Costs	Performance Fees
AA-Rated Bonds	-0.37*	-0.34*	-0.03
	[-1.90]	[-1.78]	[-0.52]
A-Rated Bonds	-0.25	0.03	-0.28
	[-0.55]	[0.07]	[-1.56]
BBB-Rated Bonds	0.12	0.14	-0.02
	[0.50]	[0.58]	[-0.15]
< BBB-Rated Bonds	0.76*	0.85**	-0.09
	[1.84]	[2.12]	[-0.57]
Non-Rated Bonds	0.87**	0.83**	0.04
	[2.44]	[2.54]	[0.32]
N	225	225	225
R^2	0.541	0.449	0.407

Table IV

Pension Fund Overall Investment Costs and Size without Controlling for Asset Allocation

Table IV presents a cross section of the impact of pension fund characteristics on investment costs of 226 pension funds during 2013. The column '*Total Costs*' reports the annual total investment costs at the portfolio level. For that, we run the following regression: $C_{j,k} = Y_j + \beta_{1,k} \log(Size_j) + \beta_{2,k} \mathrm{Corp}_j + \beta_{3,k} \mathrm{Prof}_j + \beta_{4,k} \mathrm{DC}_j + u_{j,k}$, where Y_j is a constant. Index *k* either represents the annual total investment costs (reported in column '*Total Costs*'), the management costs or the performance fees for a pension fund (reported in the columns '*Management Costs*' and '*Performance Fees*'). The economic coefficients are measured as annual basis points, whereas the numbers in squared brackets report the t-statistics. *,**,*** represent the statistical significance at the 10 percent. 5 percent and 1 percent level. All standard errors are corrected for heteroskedasticity using White's test. The table also reports the number of pension funds in the sample (N) and the R^2.

	Total Costs	Management Costs	Performance Fees
Y_j	45.18**	57.27***	-12.09**
	[2.52]	[3.64]	[-2.11]
Log Size	-0.99	-3.60	3.61***
	[-0.34]	[-1.44]	[2.73]
Type of Fund: Corporate	2.46	2.00	0.46
	[0.88]	[0.82]	[0.44]
Type of Fund: Professional	14.95*	8.38	6.56*
	[1.92]	[1.51]	[1.84]
DC	0.35	3.18	-2.82*
	[0.05]	[0.47]	[-1.69]
N	225	225	225
R^2	0.021	0.036	0.126

Table V

Pension Fund Investment Costs at the Asset Class Level

Table V presents a cross section of the impact of pension fund characteristics on investment costs of 225 pension funds during 2013 at the asset class level. For that, we run the following regression: $C_{j,k}^{z} = \beta_{1,k}^{z}\log\left(Size_{j}^{z}\right) + \beta_{2,k}^{z}\mathrm{Corp}_{j} + \beta_{3,k}^{z}\mathrm{Prof}_{j} + \beta_{4,k}^{z}\mathrm{DC}_{j} + \beta_{5,k}^{z}\mathrm{DUR}_{FI,j} + \beta_{6,k}^{z}\mathrm{DUR}_{O,j} + X_{j}^{z}\beta_{7,k}^{z} + R_{j}^{z}\beta_{8,k}^{z} + u_{j,k}$, where X_j is a vector controlling for the asset allocation of a pension fund j and R_j a vector controlling for the allocation to rating classes. The results for these control variables are not reported in the interest of brevity. Index k either represents the annual total investment costs (see column '*Total Costs*'), the management costs or the performance fees for a pension fund (see the columns '*Management Costs*' and '*Performance Fees*'). We further distinguish between six asset classes through index z: fixed income, equities, real estate, private equity, hedge funds and commodities. The economic coefficients are measured as annual basis points, whereas the numbers in squared brackets report the t-statistics. *,**,*** represent the statistical significance at the 10 percent, 5 percent and 1 percent level. All standard errors are corrected for heteroskedasticity using White's test. The table also reports the number of pension funds in the sample (N) and the R^2. Panel A reports the results for total investment costs. Panel B reports the outcomes for management costs, while Panel C displays the results for performance fees. All numbers in Panel B and Panel C are obtained in a similar manner as the numbers in Panel A. As a reference, column '*Total Portfolio*' repeats the annual investment costs at the portfolio level from Table III.

Panel A: Total Investment Costs

	Total Portfolio	Fixed Income	Equities	Real Estate	Private Equity	Hedge Funds	Commodities
Log Size	-7.67***	-4.76***	-7.75***	14.55***	-0.18	15.86	-21.57***
	[-3.92]	[-2.72]	[-3.32]	[3.00]	[-0.01]	[0.81]	[-3.86]
Type of Fund: Corporate	7.33***	5.12***	4.75	24.31***	46.85	-10.90	15.39*
	[3.16]	[2.51]	[1.54]	[2.59]	[1.01]	[-0.26]	[1.67]
Type of Fund: Professional	9.83*	3.98	4.83	1.49	39.97	53.83	8.06
	[1.74]	[1.01]	[0.58]	[0.10]	[0.36]	[0.46]	[1.18]
DC	1.44	3.64	3.77	27.04**	-72.35	-51.04	-9.61
	[0.34]	[0.71]	[0.51]	[2.06]	[-1.04]	[-0.70]	[-0.88]
Duration Fixed Income	-2.99***	-1.47***					
	[-2.78]	[-2.65]					
Duration Overlay	0.00	-0.05					
	[0.01]	[-0.34]					
N	225	222	223	180	71	57	90
R^2	0.541	0.340	0.108	0.234	0.021	0.029	0.159

Table V (*continued*)

Panel B: Management Costs

	Total Portfolio	Fixed Income	Equities	Real Estate	Private Equity	Hedge Funds	Commodities
Log Size	-7.81***	-4.83***	-8.49***	11.30***	-41.68**	-17.50	-20.79***
	[-3.95]	[-2.75]	[-3.65]	[3.10]	[-2.45]	[-1.17]	[-3.74]
Type of Fund: Corporate	8.04***	5.21***	3.65	19.81**	45.82	-20.76	15.37*
	[3.47]	[2.59]	[1.19]	[2.50]	[1.38]	[-0.68]	[1.82]
Type of Fund: Professional	6.32	-0.70	3.97	-1.32	9.16	12.99	5.87
	[1.26]	[-0.18]	[0.50]	[-0.10]	[0.12]	[0.24]	[0.84]
DC	4.15	5.58	4.57	27.96**	-16.68	8.77	-10.16
	[0.95]	[1.12]	[0.61]	[2.21]	[-0.27]	[0.24]	[-1.02]
Duration Fixed Income	-2.88***	-1.41***					
	[-2.67]	[-2.58]					
Duration Overlay	0.11	-0.05					
	[0.36]	[-0.37]					
N	225	222	223	180	71	57	90
R^2	0.449	0.360	0.123	0.214	0.124	0.038	0.173

Table V (*continued*)

Panel C: Performance Fees

	Total Portfolio	Fixed Income	Equities	Real Estate	Private Equity	Hedge Funds	Commodities
Log Size	-0.14	0.07	0.74**	3.24	41.49***	33.36***	-0.78
	[-0.29]	[0.43]	[2.02]	[1.33]	[3.12]	[3.31]	[-1.24]
Type of Fund: Corporate	-0.28	-0.09	1.10*	4.50	1.03	9.86	0.02
	[-1.56]	[-0.16]	[1.76]	[1.16]	[0.04]	[0.42]	[0.02]
Type of Fund: Professional	-0.02	4.69**	0.86	2.80	30.81	40.84	2.19
	[-0.15]	[1.98]	[0.83]	[0.92]	[0.68]	[0.56]	[0.92]
DC	-0.09	-1.94*	-0.81	-0.92	-55.67*	-59.81	0.55
	[-0.57]	[-1.79]	[-0.96]	[-0.27]	[-1.92]	[-1.45]	[0.25]
Duration Fixed Income	-0.11	-0.06					
	[-0.68]	[-0.78]					
Duration Overlay	-0.03	0.01					
	[-0.52]	[0.13]					
N	225	222	223	180	71	57	90
R^2	0.407	0.155	0.014	0.064	0.194	0.123	0.019

Table VI
Total Investment Costs controlling for Different Pension Fund Sizes

Table VI presents the results of the robustness test where we divide the full sample into two equal subsamples based on pension fund size. For that, we run this regression for total investment costs: $C_{i,j,k}^{z} = \beta_{1,i,k}^{z}\log\left(Size_j^z\right) + \beta_{2,i,k}^{z}\text{Corp}_j + \beta_{3,i,k}^{z}\text{Prof}_j + \beta_{4,i,k}^{z}\text{DC}_j + \beta_{5,i,k}^{z}\text{DUR}_{FI,j} + \beta_{6,i,k}^{z}\text{DUR}_{O,j} + X_j^z\beta_{7,i,k}^{z} + R_j^z\beta_{8,i,k}^{z} + u_{i,j,k}$, estimated for two equal subsamples ($i = 1,2$). Panel A reports the results at the pension fund level where we divide the full sample of 225 pension funds into two equal subsamples, whereas Panel B presents the results at the asset class level. In Panel A, the results for the vectors containing control variables for the asset allocation (X_j) and the allocation to credit rating classes (R_j) are omitted in the interest of brevity. In Panel B, only the coefficient for the log (size) variable are presented in the interest of clarity. In both panels, the column *'Full Sample'* reports the full sample results for ease of comparison. All economic coefficients are measured as annual basis points, whereas the numbers in squared brackets report the t-statistics. *,**,*** represent the statistical significance at the 10 percent. 5 percent and 1 percent level, while the table also reports the number of pension funds in the sample (N) and the R^2. All standard errors are corrected for heteroskedasticity using White's test.

Panel A: Pension Fund Level

	Full Sample	First Half *(small)*	Second Half *(big)*
Log Size	-7.67***	-10.03***	-7.72***
	[-3.92]	[-2.32]	[-3.24]
Type of Fund: Corporate	7.33***	14.02***	4.33
	[3.16]	[2.89]	[1.39]
Type of Fund: Professional	9.83*	17.54***	8.41
	[1.74]	[2.10]	[1.06]
DC	1.44	6.94	-1.96
	[0.34]	[1.24]	[0.91]
Duration Fixed Income	-2.99***	-2.98*	-2.48***
	[-2.78]	[-1.95]	[-2.33]
Duration Overlay	0.00	0.23	0.15
	[0.01]	[0.51]	[0.42]
N	225	112	113
R^2	0.541	0.489	0.664

Table VI (*continued*)

Panel B: Asset Class Level

	Full Sample	First Half *(small)*	Second Half *(big)*
Fixed Income	-4.76***	-5.87	-5.56***
	[-2.72]	[-1.36]	[-4.51]
Equities	-7.75***	-21.52***	-4.80*
	[-3.32]	[-2.79]	[-1.80]
Real Estate	14.55***	27.14***	9.16
	[3.00]	[3.22]	[1.03]
Private Equity	-0.18	-37.76	72.85**
	[-0.01]	[-0.85]	[2.15]
Hedge Funds	15.86	-21.17	2.40
	[0.81]	[-0.33]	[0.07]
Commodities	-21.57***	-26.86	-5.95
	[-3.86]	[-1.25]	[-1.45]

Table VII
Piecewise Linear Regressions for Total Investment Costs

Table VII presents the results of the robustness test where we vary the coefficient for the (log) size of the investments over the size of the funds. For that, we run the following piecewise linear regressions for total investment costs: $C_{j,k} = \beta_{1,k}\log(Size_j) + \beta_{2,k}\text{Corp}_j + \beta_{3,k}\text{Prof}_j + \beta_{4,k}\text{DC}_j + \beta_{5,k}\text{DUR}_{FI,j} + \beta_{6,k}\text{DUR}_{O,j} + X_j\beta_{7,k} + R_j\beta_{8,k} + \beta_{9,k}(\log(Size_j) - \log(\beta_{10,k})\,|Size_j > \beta_{10,k}) + u_j$ (Panel A) and: $C_{j,k} = \beta_{1,k}\log(Size_j) + \beta_{2,k}\text{Corp}_j + \beta_{3,k}\text{Prof}_j + \beta_{4,k}\text{DC}_j + \beta_{5,k}\text{DUR}_{FI,j} + \beta_{6,k}\text{DUR}_{O,j} + X_j\beta_{7,k} + R_j\beta_{8,k} + \beta_{9,k}(\log(Size_j) - \log(\beta_{10,k})\,|Size_j > \beta_{10,k}) + \beta_{11,k}(\log(Size_j) - \log(\beta_{12,k})\,|Size_j > \beta_{12,k}) + u_j$ (Panel B) at the pension fund level. The table only reports the coefficients for (log) size. The coefficients of the other independent variables in the regression are omitted in the interest of clarity. The rows '*Cutoff Point(s)*' show the estimated cutoff points $\beta_{10,k}$ and $\beta_{12,k}$ in terms of pension fund size. The second column '*Slope*' shows the actual slope coefficients for the size, whereas the numbers between brackets in this column represent the t-statistics of the Wald test on the actual slope being different from zero. The third column '*Incremental Slope*' is the estimated coefficients for the incremental slope $\beta_{9,k}$ and $\beta_{11,k}$ measured in annual basis points. The numbers in squared brackets report the t-statistics. *,**,*** represent the statistical significance at the 10 percent. 5 percent and 1 percent level. All standard errors are White standard errors corrected for heteroskedasticity. The table also reports the R^2. Panel C and Panel D present the results at the asset class level. All numbers in these panels are obtained in a similar manner to Panels A and B.

Panel A: Piecewise Linear with One Cutoff Point at Pension Fund Level

	Slope	Incremental Slope
β_1	5.97	
	[1.54]	
Cutoff Point β_{10}	5 mln	
$\beta_1 + \beta_9$	-10.12***	-16.10***
	[-4.45]	[-3.18]
R^2	0.561	

Panel B: Piecewise Linear with Two Cutoff Points at Pension Fund Level

	Slope	Incremental Slope
β_1	21.99***	
	[4.36]	
Cutoff Point β_{10}	10 mln	
$\beta_1 + \beta_9$	-245.82***	-267.80***
	[-5.27]	[-5.30]
Cutoff Point β_{12}	20 mln	
$\beta_1 + \beta_9 + \beta_{11}$	-6.41***	239.40***
	[-3.84]	[5.11]
R^2	0.651	

Table VII (*continued*)

Panel C: Piecewise Linear with One Cutoff Point at Asset Class Level

	Fixed Income		Equities		Real Estate		Private Equity		Hedge Funds		Commodities	
	Slope	Incremental Slope	Slope	Incremental Slope	Slope	Incremental Slope	Slope	Incremental Slope	Slope	Incremental Slope	Slope	Incremental Slope
β_1	6.59***		-50.74***		28.81***		-37.22		-62.93		-86.09***	
	[2.94]		[-3.32]		[3.69]		[-1.31]		[-0.96]		[-7.70]	
Cutoff Point β_{10}	4 mln		20 mln		20 mln		400 mln		5 mln		1 mln	
$\beta_1 + \beta_9$	-6.34***	-12.93***	-3.29**	47.45***	7.12	-21.69*	145.02***	182.25***	34.96	97.89	-17.63***	68.47***
	[-3.89]	[-3.99]	[1.98]	[3.02]	[0.98]	[-1.81]	[3.35]	[3.07]	[1.45]	[1.25]	[-3.61]	[4.48]
R^2	0.369		0.194		0.244		0.073		0.049		0.185	

Panel D: Piecewise Linear with Two Cutoff Points at Asset Class Level

	Fixed Income		Equities		Real Estate		Private Equity		Hedge Funds		Commodities	
	Slope	Incremental Slope	Slope	Incremental Slope	Slope	Incremental Slope	Slope	Incremental Slope	Slope	Incremental Slope	Slope	Incremental Slope
β_1	22.32***		-194.16*		30.32***		-268.84*		-82.41		-82.19***	
	[6.23]		[-1.85]		[3.60]		[-1.86]		[-1.18]		[-6.32]	
Cutoff Point β_{10}	4 mln		2 mln		20 mln		1 mln		4 mln		1 mln	
$\beta_1 + \beta_9$	-58.16***	-80.48***	-35.06	159.10	3.64	-26.68*	-29.44	239.40	60.82	143.24	-21.59***	60.60***
	[-5.38]	[-5.67]	[-1.42]	[1.23]	[0.34]	[-1.67]	[-0.88]	[1.37]	[1.05]	[1.36]	[-3.11]	[3.16]
Cutoff Point β_{12}	40 mln		20 mln		400 mln		400 mln		40 mln		300 mln	
$\beta_1 + \beta_9 + \beta_{11}$	-2.43***	55.73***	-3.75***	31.30	15.27*	11.63	141.59***	171.03***	15.08	-45.75	0.51	22.10
	[-2.50]	[5.08]	[-2.22]	[1.24]	[1.74]	[0.76]	[-3.26]	[2.68]	[0.45]	[-0.59]	[0.07]	[1.67]
R^2	0.542		0.205		0.245		0.078		0.053		0.191	

Previous DNB Working Papers in 2015

No. 454 **Mauro Mastrogiacomo and Rob Alessie**, Where are the retirement savings of self-employed? An analysis of 'unconventional' retirement accounts
No. 455 **Clemens Bonner and Paul Hilbers**, Global liquidity regulation - Why did it take so long?
No. 456 **Leo de Haan, Jan Willem van den End and Philip Vermeulen**, Lenders on the storm of wholesale funding shocks: Saved by the central bank?
No. 457 **Wilko Bolt and David Humphrey**, Assessing bank competition for consumer loans
No. 458 **Robert Beyer and Michael Stemmer**, From progress to nightmare - European regional unemployment over time
No. 459 **Stijn Claessens and Neeltje van Horen**, The impact of the global financial crisis on banking globalization
No. 460 **Francisco Blasques, Falk Bräuning and Iman van Lelyveld**, A dynamic network model of the unsecured interbank lending market
No. 461 **Carin van der Cruijsen, Lola Hernandez and Nicole Jonker**, In love with the debit card but still married to cash
No. 462 **Koen van der Veer**, Loss shocks and the quantity and price of private export credit insurance: Evidence from a global insurer
No. 463 **Cenkhan Sahin and Jakob de Haan**, Market reactions to the ECB's Comprehensive Assessment
No. 464 **Melanie de Waal, Floor Rink and Janka Stoker**, How internal and external supervisors influence employees' self-serving decisions
No. 465 **Andrea Colciago and Lorenza Rossi**, Firms entry, oligopolistic competition and labor market dynamics
No. 466 **Peter Heemeijer and Ronald Heijmans**, Central bank intervention in large value payment systems: An experimental approach
No. 467 **Natalya Martynova**, Effect of bank capital requirements on economic growth: a survey
No. 468 **Melle Bijlsma and Robert Vermeulen**, Insurance companies' trading behaviour during the European sovereign debt crisis: Flight home or flight to quality?
No. 469 **Robert Vermeulen, Marco Hoeberichts, Bořek Vašíček, Diana Žigraiová, Kateřina Šmídková and Jakob de Haan**, Financial stress indices and financial crises
No. 470 **Nicole Jonker , Mirjam Plooij and Johan Verburg,** Does a public campaign influence debit card usage? Evidence from the Netherlands
No. 471 **Carin van der Cruijsen en Mirjam Plooij,** Changing payment patterns at point-of-sale: their drivers
No. 472 **Christina Strobach and Carin van der Cruijsen**, The formation of European inflation expectations: One learning rule does not fit all
No. 473 **Jan Willem van den End and Christiaan Pattipeilohy**, Central bank balance sheet policies and inflation expectations