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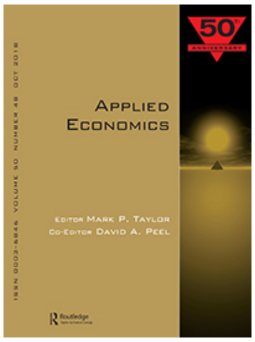

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X-efficiency and economies of scale in pension fund administration and investment

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ABSTRACT
Pension funds' operating costs impair pension benefits, so it is crucial for pension funds to operate at the lowest cost possible. In practice, we observe substantial differences in costs per member for Dutch pension funds, both across and within pension fund size classes. This article presents new estimates of scale economies of pension funds and is the first that also measures pension fund X-inefficiency. We use a unique supervisory data set which distinguishes between administrative and investment costs and apply various approaches and models. Our estimates show large economies of scale for pension fund administrations, but modest diseconomies of scale for investment activities. We also found that many pension funds have substantial X-inefficiencies for both administrative and investment activities. The two kinds of inefficiency differ across types of pension funds. Therefore, most pension funds should be able to improve their cost performance, and hence increase pension benefits.

KEYWORDS
Efficiency; pension funds; operating costs; cost elasticity; stochastic cost frontier analysis; optimal scale

JEL CLASSIFICATION
G23; L10

I. Introduction

Pension funds have an important role in economies worldwide in consumption smoothing and preventing old-age poverty. More precisely, they prevent their members from under-saving for retirement and can mitigate the problem of myopic loss aversion (Benartzi and Thaler 1995, 2013). Pension fund members can benefit from economies of scale in investment (Bikker and De Dreu 2009) and (intergenerational) risk sharing (Gollier 2008; Bovenberg and Mehlkopf 2014). However, operating a pension fund is not without costs, and excess costs reduce pension capital and thus members' final benefits. Pension fund cost levels appear to vary widely. A simple calculation shows that a 1% variance can reduce pension capital, i.e. benefits, by 27% (Bikker and De Dreu 2009).

Pension funds' operating expenses can be broken down into administrative costs (AC) and investment costs. AC include keeping files of members' entitlements, managing the cash flows of contributions and benefits, performing actuarial calculations, submitting regular reports to external supervisors, and providing customer services for plan members. Investment costs include developing and implementing of the strategic asset allocation, selecting and monitoring internal and external fund managers, providing regular performance evaluations, assessing the risk and return profiles of asset classes, and supporting the fund's investment committee. Bikker, Steenbeek, and Torracchi (2012) find that AC vary widely across countries, pension fund types, pension fund sizes and the ratio of active fund members to total members. Bikker and De Dreu (2009) observe that both administrative and investment costs differ widely between pension funds, mainly due to unused economies of scale, while type of pension fund and type of pension plan also influence execution costs.

Larger pension funds may benefit from economies of scale; they can spread their fixed costs (e.g. following from IT, reporting, policy development, risk management) across a larger number of members and have more negotiating power in investments. They can also benefit to a larger extent from more internal investment management (which is three times less expensive than external management) and receive more invitations to co-investments (Bikker, Steenbeek, and Torracchi 2012).

At the same time, larger pension providers may also suffer from costs that increase more than

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proportionally with their scale: they can have more severe price impacts with their trades (Bikker, Spierdijk, and Van Der Sluis 2007), they may have on average poorer investment ideas (as the better ideas are chosen first) and may encounter hierarchy costs as well as budget-maximizing bureaucracies (Chen et al. 2004; Dyck and Pomorski 2011; Niskanen 1974). The relationship between size and costs can be different across specific ranges of size. For example, bargaining power may require a minimum size, while bureaucracy will only be relevant for larger size pension funds (Chen et al. 2004). Most authors find that economies of scale dominate diseconomies of scale for pension funds of all current sizes (Bikker and De Dreu 2009; Dyck and Pomorski 2011). This would imply that there is value to be gained by increasing the size of pension funds, by merging for example.

In addition to scale inefficiency, average pension fund costs can also be higher due to X-inefficiency. X-inefficiency represents the managerial ability to choose the input set, given input prices, and the output mix, which minimizes costs, for all given scales. Where competitive pressure is insufficient or even absent, there is insufficient incentive to keep inefficiency down. The Netherlands, as well as many other countries, has mandatory participation in employer pension funds (Van Rooij, Lusardi, and Alessie 2011). This means that pension fund members cannot leave the pension fund (unless they change employer), and pension funds face little competitive pressure. Competitive pressure in the pension domain may therefore fall short as a result of the institutional setting. In addition, the complexity of the choices involved (such as asset allocation), makes most members unable to compare pension fund performance (Iyengar and Kamenica 2006; Beshears et al. 2008). Note, however, that employers are allowed to choose a pension fund, if they are active in one of the (few) sectors where industry funds are not mandatory. This article is the first that measures X-inefficiency in the pensions sector. Further, it indicates to what extent X-inefficiency and scale inefficiency is affected by pension fund characteristics such as size and pension plan type.

The issue of pension fund efficiency is especially relevant as pension capital represents a large proportion of household capital. In the Netherlands, pension capital amounted to over EUR 1159 billion in 2013, which equals 71% of total household wealth and 252% of GDP DNB (2015b). Even small cost inefficiencies would therefore have large effects in absolute terms. Our results for the Netherlands have value for other countries too, as administrative and investment operations of pension funds are roughly similar across countries. This has been confirmed by a cross-country study of Bikker, Steenbeek, and Torracchi (2012). This statement holds broadly irrespective of the institutional structure of other countries' pension systems, except where the degree of competition across pension funds deviates, as in, e.g. Chile. Competitive pressure may lower operational costs but cost of acquisition of clients may raise costs. However, markets with competition among pension funds are rare.

In this article, we execute a thorough search for the optimal functional form of the cost function underlying our scale economies and X-efficiency estimates, following Shaffer (1998). The optimal result is a so-called Quadratic Spline Function (QSF), which, so far, has not been applied in the pension funds efficiency literature.

The plan of the article is as follows. Section II gives a brief description of the Dutch pension system in order to explain the context of our research and Section III presents the data. Section IV discusses the measurement approach of X-inefficiency and scale inefficiency. We separate the activities of pension funds into administration (Section V) and investment management (Section VI). For both activities, we use two different methods that are often applied in the literature to calculate efficiency. Each method has advantages and disadvantages that depend on the nature of the data. On the basis of the empirical results, we select the method that is most suited for the specific activity. Next, we investigate for the parametric approach five different cost functions to find the one that best describes the data. Using the preferred method, we determine pension fund X-efficiency and assess economies of scale. Section VII combines administrative and investment costs to total costs and analyses how the combination of the two interact with pension fund size. Section VIII presents our conclusions.

II. Brief description of the Dutch pensions system

The Dutch pensions system is based on the three-pillar structure. The first pillar comprises of a pay-as-you-go state pension, which is not means tested (Bruil et al. 2015). Average retirement income from the first pillar represents about 54% of total retirement benefits (Bruil et al. 2015). The second pillar consists of occupational pension plans, collectively managed by pension funds, insurance companies, and other types of plan managers. Second-pillar pensions account for 40% of retirement benefits. The third pillar consists of tax-deferred savings that can be accrued on an individual basis, representing the remaining 6% of retirement benefits. These individual accounts are managed by banks, life insurance companies and retail asset managers.

Three types of pension funds are distinguished: industry-wide; company and professional group funds. Industry-wide pension funds cater to employees from several companies operating within the same industry. Some industries have mandatory membership of their industry pension fund, while others have voluntarily membership (non-mandatory). Company pension funds have members deriving from a single employer, or from several entities in case of a multinational firm. Professional group pension funds cater to members with specific professions, such as doctors and dentists. Industry-wide pension funds have the best opportunities to benefit from economies of scale, as they can facilitate members from many employers. They cover 85% of the market. However, these pension funds are more distantly connected to the companies than company pension funds, meaning that they can benefit less from direct support by the sponsoring companies. In addition, a more fragmented employer base will increase costs. Professional group pension funds lack both the large number of members creating economies of scale and the advantage of a single employer. Actually, their members are often self-employed and have varying incomes. These pension funds are expected to operate at relatively high costs.

In recent years, the Dutch pensions sector saw a consolidation trend. The number of pension funds fell to 365 in 2014 from 1060 in 1997 (DNB 2015b), while the total of life insurers decreased to 40 in 2013 from 90 in 1995. This raises the question as to what extent consolidation has affected the costs, and more specifically the efficiency, of pension funds.

For a full overview of the Dutch pensions sector, we refer to Bikker (2017). Bikker, Steenbeek, and Torracchi (2012) compare the institutional structure of the Dutch pension system with that of the US, Canada and Australia.

III. Data

This article is based on a unique (non-public) supervisory data set of all Dutch pension funds between 1992 and 2013. These pension funds all operate in the second pillar (occupational pension). We ignored pension funds that report zero or negative costs, which is probably due to their termination. Pension funds that have 10 or fewer members were also omitted from further analysis, as many of them do not represent collective pension arrangements, but rather provide a tax vehicle for senior management.

Figure 1 shows the number of pension funds, their average number of members and their average costs over time. The increasing average number of members per pension fund is due to both the decline in the number of pension funds and the growth in the labour force. Given the growing size of pension funds, we may expect lower costs per member. However, we observed increasing (inflation-adjusted) administrative and investment costs over time. This may indicate increased demands on pension funds in terms of reporting and regulatory requirements and the use of more complex asset categories.

Figure 2 shows the 10th, 25th, 50th, 75th and 90th percentile of AC per member for 10 size classes expressed in the number of members. The figure shows that there are strong economies of scale in AC per member. The 10% largest pension funds have AC per member that are about 10 times lower at the median than they are for the 10% smallest pension funds in terms of the number of members.

Figure 3 shows the same information for investment costs with size expressed as total assets of the pension fund. Contrary to AC, there are no clear economies of scale visible for investment costs. According to Bikker (2017), this may be because larger pension funds tend to invest a higher relative proportion of assets in complex assets classes. These

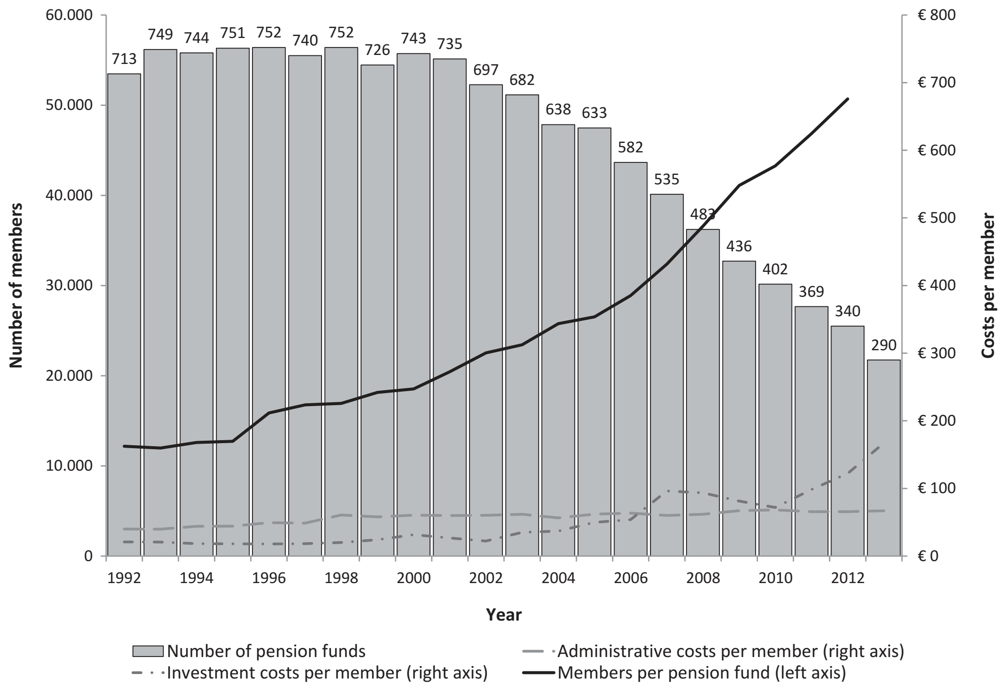

Figure 1. Pension fund characteristics over time (1992–2013).

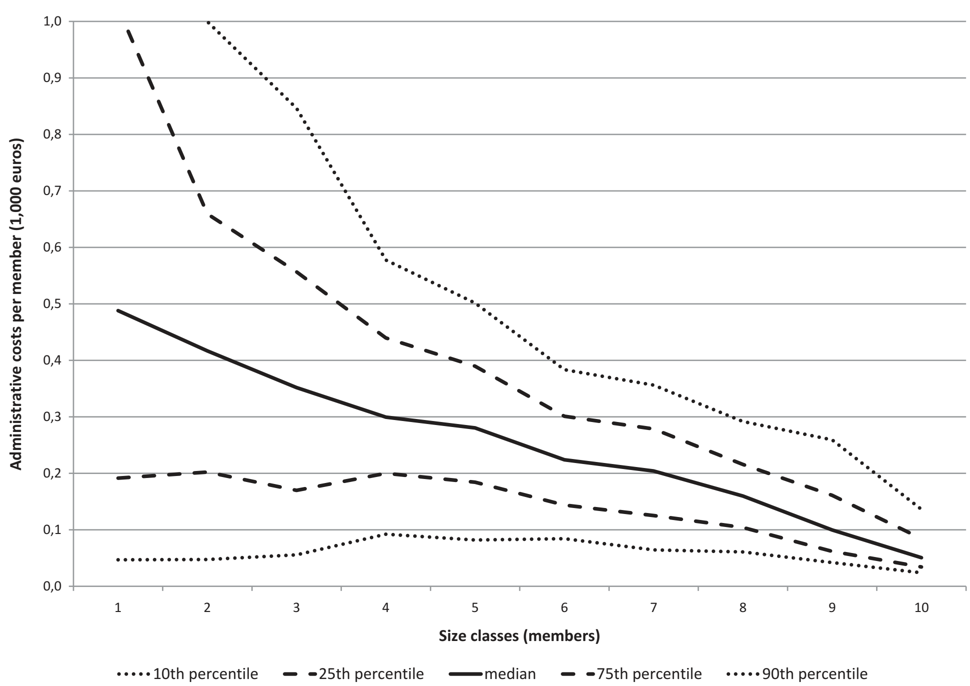

Figure 2. Administrative costs per member in size classes 2002–2013 (2013 prices).

more complex assets tend to have higher costs, and therefore increase median costs for larger pension funds, but they also give higher expected returns (Bikker 2017). Due to the presence of fixed costs, it is likely that scale economies are present for investment costs.

Table 1 presents the summary of the relevant variables for four time periods. These variables are relevant for the models that we will estimate. The table clearly shows the consolidation of pension funds and the increase in both administrative and investment costs per member, as explained above.

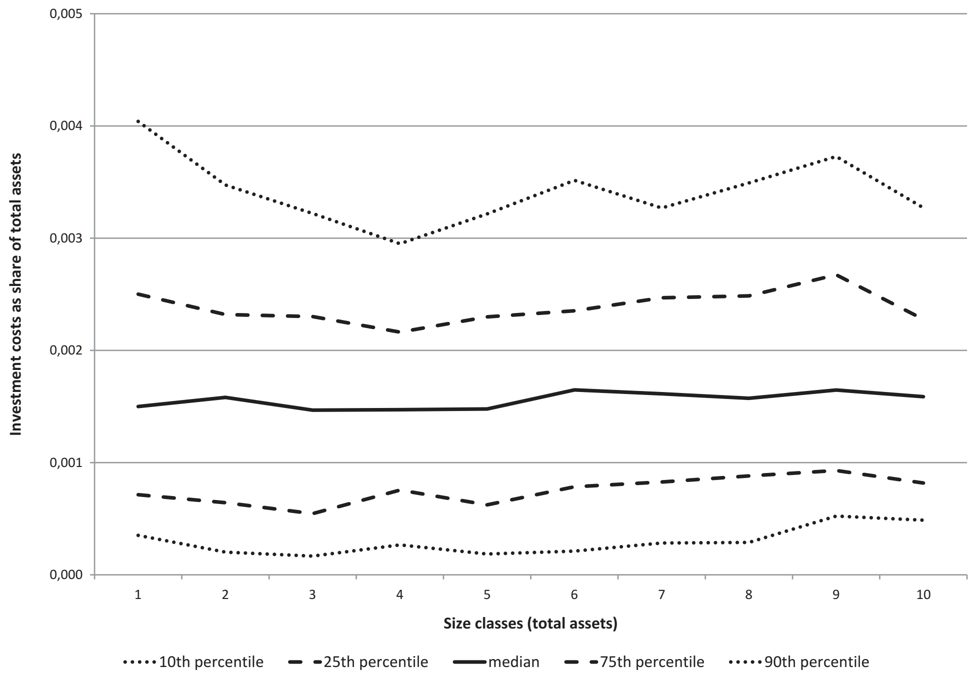

Figure 3. Investment costs as proportion of total assets 2002–2013 (2013 prices).

The proportion of inactive members increased over time, due to increased labour mobility across sectors, while the proportion of retirees remained fairly stable. Total assets per member increase over time, reflecting pension fund wealth growth. On top of that, total assets per fund increased even more, reflecting consolidation. The number of members with defined contribution plans increased substantially. This shows that pension risks are increasingly shifting towards members. From 2002 onwards, the share of administration that is outsourced has increased substantially, partly due to new regulations and partly because of the splitting of pension funds and pension delivery organizations. Investment data show that over the past two decades, the proportion of fixed-income investments has decreased, mostly in favour of equity. The proportion of real estate investments has remained fairly constant and the share of alternative investments fell between the first and the second period and has increased since then. We expect that investment costs increase with the proportions of equity and real estate, as investment analyses and risk management in these areas are more complicated.

Some pension funds report AC that are substantially lower than those of others. Examples are zero wage or accommodation costs, which are especially observed for smaller, company-specific, pension funds. These pension funds are often administered by the sponsoring company, so that specific costs in some cases are not or not fully accounted for. This kind of under-reporting is specifically taken into account in the remainder of this article. As long as under-reporting typically has an inverse relation to size, scale economies and the potential cost benefits of consolidation are underestimated. Due to stricter data provision requirements prompted by regulatory reporting duties since the introduction of the financial assessment framework for pension funds (Financieel toetsingkader FTK) in the Netherlands in 2006, data from 2007 onwards are more reliable.

IV. Measuring efficiency

Efficiency has many different definitions: productive, technical, allocation, scale and X-efficiency. Productive efficiency represents efficiency gained by combining different inputs in the optimal mix (minimizing average costs). Technical efficiency is achieved when average costs are minimized given the mix of inputs, and allocative efficiency is achieved when prices of output are equal to the marginal costs of producing this output. X-efficiency is the difference between theoretical minimum costs and actual costs incurred

Table 1. Summary of key pension fund data for four periods: averages.

Time period	1992–1996		1997–2001		2002–2007		2008–2013	
	μ	σ	μ	σ	μ	σ	μ	σ
Administrative costs per member (€)	44	1291	58	467	61	685	66	678
Investment costs per member (€)	19	358	25	501	52	340	103	469
Number of pension funds	742		739		628		387	
Members per fund (thousand)	13	100	18	111	26	141	43	197
Active members (%)	49	25	46	24	41	21	35	19
Retirees (%)	19	20	19	18	19	17	23	18
Inactive members (%)	32	20	35	19	40	17	42	18
Total contributions (€ million)	9	100	18	144	41	278	80	468
Total assets per fund (€ million)	331	4980	750	6625	1090	8631	2093	12,766
Total liabilities per fund (€ million)	286	4454	579	5342	864	7153	1997	12,765
Assets per member (€ thousand)	72	170	90	193	91	171	116	534
Defined contribution (% members)	2.8		2.2		7.8		9.2	
Mandatory industry fund (% members)	81		82		84		84	
Non-mandatory industry fund (% members)	1.8		2.3		1.5		1.4	
Company fund (% members)	12		13		14		13	
Professional fund (% members)	0.6		0.5		0.4		0.5	
Outsourcing/administration costs (%)	24	20	24	21	35	21	60	29
Reinsurance premiums/total premiums (%)	10	36	4	47	2	10	3	15
Investments (% total assets):								
Fixed income	57	26	47	25	45	22	50	19
Equity	24	19	40	19	41	17	34	14
Real estate	12	9	10	5	10	5	10	7
Other assets	7	18	3	21	4	17	6	17

Average value (μ) and cross-sectional SD (σ). Values are expressed in 2013 prices.

(Leibenstein 1966). X-inefficiency may exist due to a lack of competitive pressure, allowing pension funds to survive while operating at higher costs. Finally, a pension fund is scale efficient if any change in size will make it less efficient, as measured by average costs. These different types of efficiency can overlap. Firms that have X-inefficiency or scale inefficiency will also be technically inefficient and technical efficiency is required for allocative efficiency, as otherwise price cannot equal marginal costs (Tirole 1988; Charnes, Cooper, and Rhodes 1978). Plotting the number of members and AC for the X-efficient funds (or total assets and investment costs) gives the cost frontier. Deviations of observed costs from the cost frontier represent X-inefficiency, as the other categories of efficiency are included in the cost frontier. The frontier itself illustrates the relation between size and costs and can therefore be used to assess economies of scale.

Pension funds are not obliged to report all their activities, but only the costs of these activities, such as pension administration and investment outlays. This means that there is no information about the exact activities undertaken (such as the amount of hours spent on membership administration) and the price of that activity (such as wages of pension fund employees). Consequently, productive efficiency cannot be estimated, and pension fund efficiency is only differentiated between X-efficiency and economies of scale, which overlap with technical efficiency.

We investigate and compare two different measurement approaches to efficiency, a parametric method and a non-parametric method. Non-parametric methods use mathematical programming techniques to calculate the frontier representing the optimal ratio of inputs to costs. We apply two different variations of non-parametric efficiency measurement, the Full Disposal Hull (FDH) reference technology, and Order $-\ \alpha$. Parametric methods start with a predefined cost function which is fitted to the data. Again we apply two variations, the linear regression model (LRM), which measures economies of scale and not X-inefficiency, and stochastic cost frontier analysis (SCFA). In the non-parametric method, efficiency is calculated by comparing the input-to-output ratio of the pension funds to the best practice pension funds (determined by selecting the most efficient one for each possible pair of pension funds). The parametric and non-parametric methods are discussed in detail in 'Inputs and output' and 'Non-parametric method' sections. However, before efficiency can be estimated, we must specify the fund's production process. This means that we have to know the relevant inputs and outputs of pension funds.

Inputs and outputs

Inputs for pension administration and investment are factors such as labour, premises and equipment, IT, energy, etc. As these inputs, and their prices, are not reported, we took administrative and investment costs as indicators for inputs in the administration and investment processes, in line with Bikker (2017). Given the amount of outputs, pension funds should minimize costs, thereby optimizing their inputs.

Outputs for pension administration and investment are factors such as processed changes, messages sent and processed investment returns. As these outputs, and their prices, are not reported, we took the number of members and total assets as indicators for output respectively in the administration and investment processes, in line with Bikker and De Dreu (2009). Administration offers services to members, and most services are proportional to the number of members. The number of members was therefore selected as the relevant measure of output. Investments are usually managed on an aggregate level, irrespective of the number of members: the number of investment activities (such as transactions) depends on the total size of these investments. Therefore, total assets, discounted for inflation, is taken as the output measure for investment activities.

Pension fund members in the Netherlands are not free to choose their own pension fund, so Dutch pension funds are unable to use retail marketing to influence the number of members or the value of total assets they manage. This means that pension funds are input-oriented: they will try to minimize inputs (i.e. costs), given their output levels. We follow this input orientation for the efficiency analysis instead of the output orientation, as this only marginally influences efficiency estimates, but makes the interpretation of the results more intuitive, i.e. allows us to express efficiency in terms of costs.

Berk and Green (2004) suggest that larger funds could be run by managers with higher skill, that is those being more cost efficient. Cost efficiency could then be correlated with both output (measured by number of members or total assets) and costs, as a better management team could supposedly be able to reduce costs. An omission bias issue may arise as the 'pure' or 'initial' size effect is expanded with the cost efficiency effect, correlated with size. Both fixed effects estimation and our stochastic cost approach (which identifies efficiency) help in reducing this omission bias.

Another estimation issue may be potential endogeneity of the number of members or total assets, as lower costs may, in principle, attract more members or raises total assets. Pástor, Stambaugh, and Taylor (2015) provide a detailed discussion of a related endogeneity issue in their study of the returns to scale in active mutual fund management. In the pension sector, this endogeneity problem is unlikely as most pension funds are company funds where the number of members is determined by the labour needs of the company. Most industry-wide funds have compulsory participation, also excluding any impact of cost on the number of members.

This may be different for possible endogeneity of 'total assets' in the investment cost equation: total assets increase slightly (in relative terms) where investment costs are lowest, though than we should correct for higher investment costs for investments where expected returns are higher. In an additional instrumental least squares regression,[1] we controlled for endogeneity of total assets using the instrument 'number of participants'. The coefficient estimates were hardly affected.

Non-parametric method

Non-parametric methods use mathematical programming techniques to calculate the cost frontier representing best-practice pension funds. Given scale, the pension funds with the lowest costs-to-output ratios constitute the cost frontier (De Borger and Kerstens 1996). This means that pension funds are only X-efficient if neither a smaller nor a larger pension fund have lower costs-to-output ratios (dependent on the exact non-parametric method used). Plotting the X-efficient pension funds, and drawing connecting lines between these best practice pension funds, gives the cost frontier. The deviation with the cost frontier is X-inefficiency, while the difference between the cost frontier and the lowest costs-to-output ratio (irrespective of size) represents scale inefficiency. An important advantage of non-parametric methods is that they do not need assumptions about the functional form of a cost model, like parametric approaches do (De Borger and Kerstens 1996). A drawback of non-parametric methods is that they are extremely sensitive to outliers (e.g. errors in measured inputs), as these may influence the cost frontier and thereby the efficiency estimates (Cummins and Weiss 2013; Tauchmann 2012). Large negative errors in input costs (e.g. under-reporting of costs) would for example shift the cost frontier upwards, hugely increasing X-inefficiency (difference between actual performance and cost frontier) estimates.

Several non-parametric methods have been suggested in the literature. Data Envelopment Analysis (DEA) is most commonly used, and calculates the cost frontier by comparing all observations with all other observations, the pension fund in each size category that has best practices (Charnes, Cooper, and Rhodes 1978; Färe, Grosskopf, and Lovell 1985; Seiford and Thrall 1990; Favero and Papi 1995; Coelli 1996; De Borger and Kerstens 1996). Although DEA is often used, the necessary computational power of the model increases exponentially with the number of observations (Ji and Lee et al. 2010), which makes the method unfeasible for large datasets. FDH reference technology is very similar to DEA. Where DEA uses linear interpolation between the best-practice pension funds to constitute a minimum cost frontier, FDH builds a stepwise cost frontier between the best practice pension funds, which requires less computational power (De Borger and Kerstens 1996). Due to this

[1]These estimates are not shown here, but are available from the authors upon request.

stepwise function, X-efficiency estimates can be slightly higher, as the stepwise cost frontier will always be lower or equal to the DEA cost frontier (De Borger and Kerstens 1996). This is illustrated in Figure 4, where the difference between 1′ and 1″ represents the difference between DEA and FDH X-inefficiency. Given the large data set, we choose to use FDH rather than DEA, in order to keep our computations manageable.

So far, pension funds have been designated as best-practice pension funds if neither a smaller nor a larger pension fund has lower costs-to-output ratios, in order to allow for variable returns to scale. However, by repeating the analysis, but only designating the pension fund with the single lowest costs-to-output ratio as best practice (not controlling for size), gives efficiency values with constant returns to scale.[2] Efficiency in this case is lower than (or equal to) the efficiency estimates in the case of variable returns to scale, as the cost function will be lower in the case of constant returns to scale. The difference between efficiency under variable returns to scale and constant returns to scale represents economies of scale, while the remainder represents X-efficiency. The implicit assumption is that by incorporating best practices, all pension funds should be able to achieve an X-efficiency score of 1.[3] For a detailed description of FDH, including an illustration of separating X-inefficiency and scale inefficiency, we refer to De Borger and Kerstens (1996).

As noted, a major disadvantage of the nonparametric methods discussed so far is their sensitivity to outliers. To deal with this problem, partial frontier approaches have been developed. Partial frontier approaches, such as Order $-\alpha$ (Aragon, Daouia, and Thomas-Agnan 2005) and Order$-m$ (Cazals, Florens, and Simar 2002) efficiency, allow for superefficient observations, which are below the cost frontier. Superefficient observations can represent random shocks (luck) or measurement noise, but do not necessarily represent sustainable best practices. The cost frontier is formed by the selecting the xth percentile most efficient pension funds, where x depends on the level of α or m used. The cost frontier is therefore not formed by the most extreme efficiency values, which makes it less sensitive to outliers (Tauchmann 2012). In the case of Order $-\alpha$, the lowest cost frontier is defined as the α% most efficient observation, given size. Order $-\alpha$ is equal to FDH if $\alpha = 100$ (Tauchmann 2012). Order $-m$ compares pension funds to the best

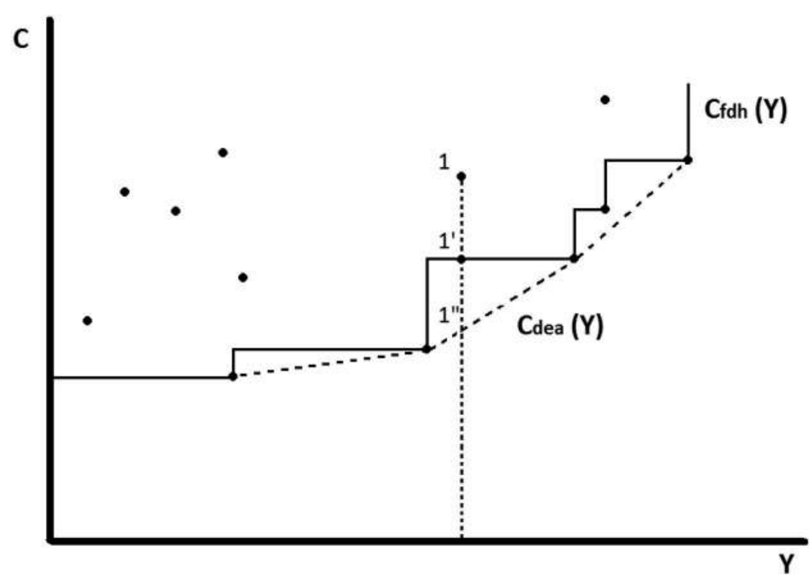

Figure 4. Example of a cost frontier resulting from the FDH or DEA method.

This figure presents cost frontiers resulting from FDH (solid line) and DEA (dashed line). The *X*-axis gives output *Y* and the *Y*-axis gives costs *C*. The dots represent pension funds. Dot 1 gives an inefficient pension fund. FDH efficiency for this dot is value of C for 1′ divided by that of 1, while DEA efficiency is value of C for 1″ divided by that of 1. Source: De Borger and Kerstens (1996, p. 150).

[2]In this case, the frontier will be a linear line from the origin to the observation with lowest costs-to-output ratio and further.
[3]Efficiency is by definition between (or equal to) 0 and 1, where 0 represents total inefficiency (no output) and 1 total efficiency (lowest possible costs-to-output ratio).

performance in a random sample of m peers, based on the sample at hand. As this sample does not necessarily include all the pension funds in the sample at hand, including the pension fund being analysed, X-efficiency can be higher than 1. This article uses Order $-\ \alpha$ and set $\alpha = 95\%$ in order to reduce the problems caused by the most extreme outliers. Lower values of α would cause large proportions of superefficient pension funds.

Parametric method

Parametric methods define a cost function, which explains costs by explanatory variables, such as output, input prices and – in our case – other pension fund characteristics. The model parameters can be estimated, constituting a median cost frontier, which is comparable to Order $-\ \alpha$ with $\alpha = 50\%$ in the sense that about half of the observations is more efficient and the other half less efficient than the 'median' observations. The error terms of the cost function describe measurement errors of the variables, specification errors (relating to the functional form among other things) and omitted variables. Inefficiency may be one of the omitted variables. We refer to this model as the LRM.

An alternative approach is to assume that the error term consists of two components, measurement errors or random shocks (as in the LRM) and inefficiency. In the SCFA, these two components are distinguished by attributing a non-negative statistical distribution for inefficiency besides a normal distribution for the random shock. This method is also frequently applied, although not for pension funds (Hardwick 1997; Bishop and Brand 2003; Latruffe et al. 2004; Fenn et al. 2008). Pitt and Lee (1981) define the cost function's error term ε as

$$\varepsilon_{i,t} = u_i + v_{i,t} \tag{1}$$

The first disturbance, inefficiency u_i, is one-sidedly distributed ($u \geq 0$), for instance half-normal, with mean zero. The second disturbance, uncontrolled random shocks $v_{i,t}$, is normally distributed, also with mean zero. Sub-indices i and t refer to pension fund i and time period t. In explaining X-efficiency $(1 - Exp(u_i))$, we transform its estimates using logistic transformation (Amihud and Goyenko 2013) to control for the non-normality of X-efficiency. The transformation reads as follows: X-efficiency$^{transformed} = ln([1 - Exp(u_i)]/Exp(u_i))$.

Parametric methods are based on a cost function. Shaffer (1998) explains how sensitive scale economy estimates are on the specification of the relationship between costs and output or size. A log-linear relationship between cost and pension fund size would imply a constant cost elasticity and hence a scale economy estimate that is constant over sizes. The quadratic Translog cost function (TCF), frequently applied in economic literature, assumes a U-shaped unit cost, i.e. costs per member, function. This allows for large but declining scale economies for pension funds to below the optimal size, but forces equally strong diseconomies of scale for pension funds above that optimal scale. To allow for permanently decreasing costs per member, or for asymmetry around the optimal scale, more flexible functional forms are needed. Shaffer (1998) proposes the unrestricted Laurent function (ULF)[4] and the hyperbolically adjusted Cobb–Douglas (HACD) function[5] also applied to pension funds by Bikker (2017). Equations 2 and 3 of AC shows the structure of, respectively the ULF and HACD model:

$$\begin{aligned} ULF: lnAC(o) = {} & \alpha + \beta_1(lno) + \beta_2(lno - \overline{lno})^2 \\ & + \beta_3/(lno) + \beta_4/(ln\,o)^2 \\ & + \gamma(pension\,fund\,characteristics) \end{aligned} \tag{2}$$

$$\begin{aligned} HACD: lnAC(o) = {} & \alpha + \beta_1(lno) + \beta_2/o \\ & + \gamma(pension\,fund\,characteristics) \end{aligned} \tag{3}$$

where 'o' refers to output, or size. The various βs represent the coefficients of the (log-) linear and non-linear functions of output, and γ is a vector of coefficients of the pension fund-specific characteristics. The latter include pension fund type, pension scheme, wealth, type of participants (working, retired or inactive) and outsourcing. We expect that industry-wide pension fund has lower costs on average, as

[4]ULF (Equation 2) adds two inverse (log) terms to the TCF, making parabolic costs per member more flexible.
[5]HACD (Equation 3) is the most simple model, it describes constant economies (or diseconomies) of scale with only one single inverse term of members to allow for fixed costs.

they have more standard pension schemes with less complexity, while the professional funds are expected to have the highest costs as their participants are independent entrepreneurs with variable income. Pension funds with relatively much assets are expected to have additional cost. We hypothesize that inactive participants cause less costs while retired require more costs, e.g. paying benefits. Finally, outsourcing should lower costs. Note that the TCF follows from equation 2 if $\beta_3 = \beta_4 = 0$.[6] This article applies another, even more flexible method, the quadratic spline cost function (QSF), which may also incorporate possible breaks in the output cost relationship (Diewert and Wales 1992). QSF add one or more break points to the quadratic output term of the TCF. Equation 4 shows a quadratic spline model of pension fund efficiency with a single quadratic spline. The location of the breaking point (where output is x_1) is chosen by minimizing AIC[7] of the model over a grid of possible values of x_1.

$$\begin{aligned} QSF: lnAC(o) = \alpha &+ \beta_1(lno) \\ &+ \beta_2[(lno - lnx_1)^2|_{o \geq x_1}] \\ &+ \beta_3[(lno - lnx_1)^2|_{o < x_1}] \\ &+ \gamma(pension\ fund\ characteristics) \end{aligned} \tag{4}$$

where β_2 is conditional (||) on the output being before the break point x_1, and β_3 conditional on the output being after the break point x_1. In addition to the variables to capture the relationship with size, we included as explanatory variable of costs: type of pension fund, type of pension scheme, ratio of active, inactive, and retired members to total members, assets per member and the outsourcing of administration (as proportion of AC paid to third parties). For all panel data linear regression we apply double-clustered SEs, by pension fund and by year (Thompson 2011). Bootstrapping is used to estimate the SEs from the SCFA (Efron and Tibshirani 1986). Below, we will apply the two variations of the non-parametric method, and the two variations of the parametric method, on AC. The estimation results will show which method is most suitable for describing pension fund efficiency.

V. Empirical results for AC

This section presents the estimation results of the various approaches and functional forms for AC, while Section VI presents the empirical results for investment costs. We start by selecting the best approach, either non-parametric or parametric, and next, for the preferred parametric approach, investigate what the best functional form is for the cost model.

Non-parametric results

This section explores the non-parametric methods: FDH, and an Order $-\ \alpha$ model with $\alpha = 95\%$. The top of columns (1) and (2) of Table 2 presents summary data of the X-efficiency estimates for both non-parametric models and the bottom the results of a regression analysis explaining these X-efficiency estimates. The degree of robustness of these results may help to assess the validity of the X-efficiency estimates. The regression model explaining efficiency contains as explanatory variables linear and non-linear pension fund size measures as well as pension fund-specific characteristics, similar as in the cost model. With respect to the pension fund characteristics, we expect their coefficient signs to be opposite to those in the cost models, as high X-efficiency goes with low costs.

The median X-efficiency following from the FDH model at 0.010 is extremely low. Applying Order $-\ \alpha$ yields considerably higher X-efficiency estimates (with a median value of 0.471). The same is true for the 25th and 75th percentile, with X-efficiency estimates of 0.005 and 0.029 for FDH, respectively, and 0.311 and 0.797 for Order $-\ \alpha$, respectively. These results suggest that the data has severe measurement errors, among other things due to under-reporting of costs, which particularly for the FDH strongly influences the X-efficiency estimates. The sensitivity to outliers can be clearly observed in Figure 5, which

[6]To avoid multicollinearity, we also applied a simplified ULF (SULF) model with $\beta_4 = 0$.

[7]AIC gives information about the goodness of fit of a function, given the sample. Lower values of AIC represent better model fits. For more information, we refer to Akaike (1974).

Table 2. Estimates of X-efficiency for administrative costs and their explanation (2002–2013).

	(1)		(2)		(3)	
	FDH		Order-a, $a = 95$		SCFA	
			Estimates of X-efficiency			
Average	0.058		0.546		0.221	
25th percentile	0.005		0.311		0.110	
Median	0.010		0.471		0.176	
75th percentile	0.029		0.797		0.283	
			Estimates of a regression model which explains X-efficiency			
Variables						
Members (in logarithms)	0.156***	(0.034)	0.009	(0.024)	−0.022	(0.038)
Members^2 (ln, mean dev.)	0.125***	(0.09)	−0.021***	(0.007)	0.039***	(0.008)
Industry fund (mandatory)	0.453**	(0.213)	0.750***	(0.227)	0.994***	0.(323)
Industry fund (non-mandatory)	0.155	(0.276)	−0.176	(0.223)	0.850***	(0.311)
Company fund	−0.254	(0.177)	−0.273	(0.178)	0.642**	(0.294)
Professional group funds	−0.847***	(0.224)	−0.605**	(0.257)	0.882***	(0.304)
Pension plan: defined contribution	0.132	(0.114)	0.127	(0.108)	0.024	(0.157)
Outsourcing	−0.667***	(0.165)	−0.390***	(0.131)	−0.739***	(0.160)
Assets per member (€ million)	−0.400	(0.274)	−0.226	(0.201)	−0.334*	(0.194)
% Pensioners	−0.059	(0.232)	0.125	(0.189)	2.084***	(0.271)
% Inactive members	0.552**	(0.252)	0.968***	(0.210)	1.927***	(0.355)
Constant	−5.713***	(0.331)	0.310	(0.249)	−3.125***	(0.528)
R^2	0.447		0.122		0.229	
Observations	6053[a]		4961[a]		6087	

A logistic transformation has been applied to X-efficiency. Double-clustered SE are presented in parentheses, number of observations is 6087, number of pension funds is 799, $\overline{lnp}$ = ln(2316).
[a]The number of observations is lower due to the logistic transformation of X-efficiency. $P>|t| =$ *<0.10, **<0.05, and ***<0.01.

shows the frontiers resulting from FDH and order $-\alpha$. As Order $-\alpha$ is less sensitive to outliers (see 'Inputs and output' section), this approach is much more suitable to this situation. The levels of X-inefficiency for FDH and Order $-\alpha$ deviate hugely, but remarkably, the Spearman rank correlation (0.652) shows that both methods yield similar rankings of pension fund-time observations. In explaining the inefficiency estimates from both non-parametric models, we observed similar parameter estimates, suggesting that the inefficiencies from both approaches resemble each other.

We explain the X-efficiency estimates from pension fund sizes and characteristics. Focusing on the significant coefficients, Table 2 reveals that mandatory industry-wide pension funds on average have the highest X-efficiencies, while, professional group funds are least X-efficient, both in line with expectations. Inactive participants increase efficiency, also in line with expectations. Pension funds that outsource more of their activities have higher reported costs. As outsourcing costs is administered more accurately than internal costs, it is likely that this effect indicates that outsourcing goes hand in hand with less under-reporting, rather than showing a true cost effect. As under-reporting will mostly affect small, company, pension funds (where wages and rents of premises are sometimes paid directly by the sponsoring company), true economies of scale may be even larger than we estimate (Bikker and De Dreu 2009).

Parametric estimation results

The third column of Table 2 presents pension fund X-efficiency estimated with SCFA. The efficiency is low, on average, at 0.221, with 75% of funds having an X-efficiency score of lower than 0.283. A comparison of these SCFA estimates with the X-inefficiencies following from the nonparametric methods show high values of Spearman rank correlation (between 0.652 and 0.750), indicating that the rank in X-efficiency is rather robust for the choice of method. The results of the parametric models are in line with those of the non-parametric models in the sense that pension fund characteristics with the lowest cost levels now show the highest efficiencies.

Table 3 presents the results of a first exploration of the parametric models SCFA and LRM over the 2002–2013 period. Our main interest is in SCFA which allows for estimation of inefficiency, but we will also show LRM for comparison. For both variations we specify a TCF, as this is simple, most often applied in the literature and resembles a

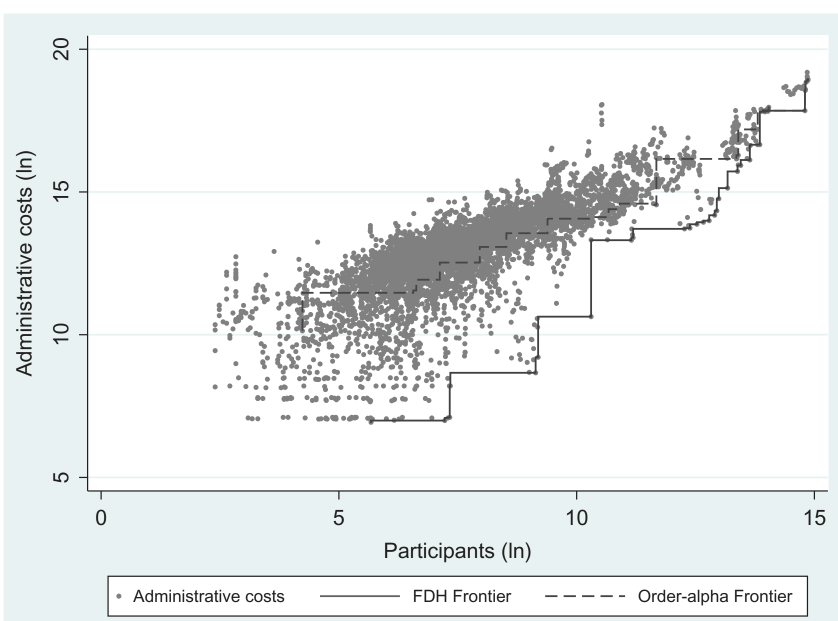

Figure 5. Non-parametric estimates of administrative cost frontiers.

Table 3. Results of parametric models for administrative costs (2002–2013).

	(1)		(2)	
	LRM		SCFA	
Variables	Cost elasticity		Cost elasticity	
Members (in logarithms)	0.736***	(0.024)	0.807***	(0.050)
Members^2 (ln, mean dev.)	0.005	(0.005)	0.034***	(0.012)
Industry fund (mandatory)	−0.341**	(0.0145)		
Industry fund (non-mandatory)	−0.029	(0.160)		
Company fund	0.134	(0.134)		
Professional group fund	0.559***	(0.559)		
Pension plan: defined contribution	−0.131	(0.109)		
Outsourcing	0.670***	(0.147)	0.270***	(0.95)
Assets per member (€ million)	0.407	(0.270)	0.062	(0.645)
% Pensioners	0.408***	(0.193)	1.665**	(0.296)
% Inactive members	−0.554**	(0.240)	0.440**	(0.182)
Constant	−0.132	(0.231)	−4.091***	(0.396)
σ_u^2 (inefficiency)			10.501	(0.977)
σ_v^2 (random shocks)			0.234	(0.016)
R^2	0.702		0.660	
AIC	16,609		11,921	
First derivatives	$(0.736 + 2 * 0.005 * (lnp - \overline{lnp})$		$(0.807 + 2 * 0.034 * (lnp - \overline{lnp})$	
Cost elasticity at $\overline{lnp}$	0.736		0.807	

LRM: Double-clustered SEs, SCFA: SEs estimated using Bootstrap, presented in parentheses. p = number of members, number of observations is 6087, number of pension funds is 799, $\overline{lnp}$ = ln(2316). $P>|t| =$ *<0.10, **<0.05 and ***<0.01.

number of alternative cost functions. The most general SCFA specification with annual estimates for inefficiency did not converge. The inefficiency estimates went to zero so that the error term was almost fully attributed to the random shocks v. Therefore, we assume for the SFCA that X-efficiency is fixed over time, opposed to the random shocks that vary each year (Greene 2008). For both methods, substantial economies of scale exist for the pension fund with (geometric) mean size (in terms of the number of members): cost elasticities (CEs) are 0.74 and 0.81, respectively, indicating that costs increase substantially less than proportionally to size. As pension funds never or almost never change in terms of type, this type variable, and another variable that is constant over time (Defined Benefit versus Defined Contribution), cannot be included in the SCFA model, because they cannot be distinguished from the (also constant) X-inefficiencies.[8] Their coefficients only appear in the LRM estimates (first column of Table 3). That is the first reason why we (only) discuss the significant effects of pension fund-specific characteristics for the LRM. The second reason is that the constant inefficiency estimates distort the estimations of the population coefficients, because the distribution of active, inactive and retired hardly changes over time.

The mandatory industry-wide funds face the lowest costs (−29%),[9] while professional group funds face the highest costs (+75%), both in line with expectations.[10] As explained above, outsourcing acts as an indicator of under-reporting: outsourced costs are included in costs precisely whereas loans and office cost are sometimes not included, because staff and offices were provided directly by the company, as particularly occurs at smaller pension funds. Pensioners go with higher cost, while inactive members cost less than active ones.

Method

The non-parametric and parametric approaches of the previous two sections result in distinctively different cost frontiers, as shown in Figure 6. This figure shows the cost frontier for each pension fund size, expressed as the (lowest) costs per member. Please note that the frontier following from LRM is the average (and not absolute) cost frontier, whereas the frontier following from Order $-\alpha$ represents the 95th percentile of the efficiency distribution. The remaining frontiers (SCFA and

[8]Similar as in the case of a fixed effects model.
[9]Note that -29% follows from the coefficient -0.341 according to: $-0.29 = 1 - exp(-0.341)$.
[10]In all regression analyses, the pension fund types are compared to a rest group of non-defined types of pension funds.

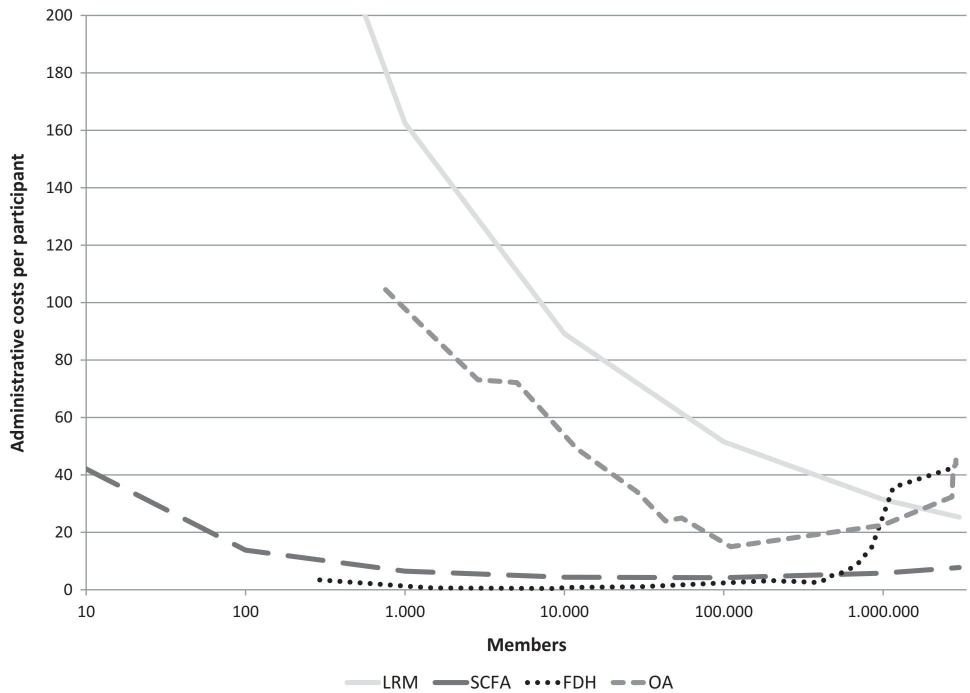

Figure 6. Cost frontier estimates from four model approaches (2002–2013).

FDH) represent fully efficient or best-practice pension funds: pension fund costs can therefore theoretically be on or above, but not below, the cost frontier. SCFA allows for model errors and hence lies above the FDH curve. The plotted frontiers of LRM and SCFA are the estimated effect of the output (i.e. number of members) variables from Table 3 on AC per member. For example, the SCFA cost frontier equals $(0.807 * \ln particants + 0.034 (\ln particants - \overline{\ln particants})^2)/members$. The plotted frontiers of FDH and Order-α are costs per member and number of members of X-efficient pension funds (X-efficiency $= 1$) for pension funds sorted by their number of members, where the dots or observations are connected by interpolation.

As the number of observations drops sharply for very large pension funds, the non-parametric methods have different properties at this point. This results in increasing estimated costs per members.[11] In our sample, the LRM frontier shows continuously decreasing costs per member while the other three approaches reveal increases for the largest pension funds, but not necessary statistically significant one.

Contrary to the other three methods, LRM does not allow for the calculation of X-efficiency, and serves only for comparison. As said, the X-efficiency calculated for the remaining three methods show high values of Spearman rank correlation (between 0.652 and 0.750), indicating that the rank in X-efficiency is relatively robust for the choice of method, though the median estimated value of X-inefficiency varies hugely. As FDH and Order $- \alpha$ are more sensitive to the presence of outliers (including under-reporting), due to ignoring of the possibility of measurement and specification errors, we choose the SCFA approach for the remainder of this article to measure X-efficiency in the pension sector. An additional argument for selecting SCFA is that it can incorporate a number of pension fund characteristics in explaining costs, so that the X-inefficiency measurement is not disturbed by these other costs determinants.

Functional form specification

Scale economy estimates are very sensitive to the applied functional form of pension size in the cost model. Therefore, we investigate five different cost

[11] As the number of observations drops, so does the expected value of the minimum cost frontier.

Table 4. SCFA estimates of five functional forms of administrative costs and of X-efficiency (2002–2013).

Variables	(1) TCF	(2) ULF	(3) SULF	(4) HACD	(5) QSF
Break point					$lnx_1 = 5.5$
Members	0.807***	1.525**	1.299***	0.905***	0.816***
(in logarithms)	(0.053)	(0.616)	(0.218)	(0.064)	(0.119)
Members^2	0.034***	−0.045	−0.027		
(ln, mean dev.)	(0.013)	(0.059)	(0.032)		
1/(ln members)		42.992	23.469***		
		(46.456)	(8.595)		
1/(ln members)^2		−26.557			
		(56.429)			
1/members				45.853***	
				(7.595)	
Members^2					0.340***
(ln, x_1 dev. $\|p<x_1$)					(0.079)
Members^2					0.012
(ln, x_1 dev. $\|p \geq x_1$)					(0.017)
σ_u^2 (inefficiency)	10.501	10.053	10.055	9.981	10.056
	(1.190)	(1.601)	(1.412)	(1.014)	(1.495)
σ_v^2 (random shocks)	0.234	0.234	0.234	0.234	0.234
	(0.023)	(0.020)	(0.018)	(0.019)	(0.019)
R^2	0.672	0.674	0.673	0.673	0.654
AIC	11,921	11,889	11,887	11,889	11,881
Wald test^a	14***	65***	46***	68***	57***
First derivatives	$0.807 + 2 * 0.034 * (lnp - \overline{lnp})$	$1.525 - 2 * 0.045 * (lnp - \overline{lnp}) - 42.992/(lnp)^2 + 2 * 26.557/(lnp)^3$	$1.299 - 2 * 0.027 * (lnp - \overline{lnp} - 23.469/(lnp)^2$	$0.905 - 45.853/p$	$0.816 + (0.340\|p<x_1) * (lnp - lnx_1) - (0.012\|p \geq x_1) * (lnp - lnx_1)$
Cost elasticity at $\overline{lnp}$	0.807	0.866	0.908	0.885	0.870
X-efficiency:					
Average	0.213	0.222	0.221	0.221	0.221
25th percentile	0.103	0.110	0.110	0.111	0.110
Median	0.166	0.177	0.176	0.178	0.176
75th percentile	0.271	0.287	0.285	0.284	0.283

SEs estimated using bootstrap, presented in parentheses. p = number of members. Number of observations is 6087, number of pension funds is 797, $\overline{lnp}$ = ln(2316). Break point $lnx_{1,p} = 5.5$ is equal to 235 members. [a]Wald test for Constant Returns to Scale Hypothesis: coefficient of ln(participants) and ln(total assets) = 1 and coefficient(s) of non-linear term(s) of ln(members) and ln(total assets) and the interaction term = 0. $P>|t|$ = *<0.10, **<0.05, and ***<0.01.

functions for the preferred SCFA approach: TCF, ULF, SULF, HACD and QSF, as discussed in 'Non-parametric method' section. Table 4 presents the estimation results.[12] We use AIC to select the functional form that best fits the data. QSF with one single break point at ln(members) = 5.5, or 245 members, is the optimal model.[13] The key results for the QSF estimation show that vast unused economies of scale exist for small pension funds which decrease with pension fund size. Beyond the break point of ln(members) = 5.5, small, constant economies of scale remain for larger pension funds. Three other specifications, (S)ULF and HACD, confirm that large cost disadvantages exist for small pension funds, likely because of the presence of substantial fixed costs. These models have roughly the same AIC value and do not differ statistically significantly from the QSF. The model coefficients and the other statistics hardly differ across these four functional forms. The popular TCF, however, is rejected firmly in favour of the alternative specifications. This has a great impact on the conclusions drawn from the model, as is illustrated by Figure 7.

Figure 7 shows the CE over pension fund sizes for different functional forms (see left axis). The CE of four functional forms, ULF, SULF, HACD and QSF, are relatively similar. These functional forms show large unused economies of scale for small pension funds (particularly below 1000 members) and small economies of scale for larger pension funds. The most important result is that these functions have CEs below 1, so that no optimal scale exists: scale economies remain limited to exist without upper

[12]The models of Table 4 include pension fund-specific variables, but we do not present them here, as the coefficient estimates are almost identical to the SCFA estimates presented in Table 3 for each of the five models.
[13]QSFs with more break points give lower values of AIC.

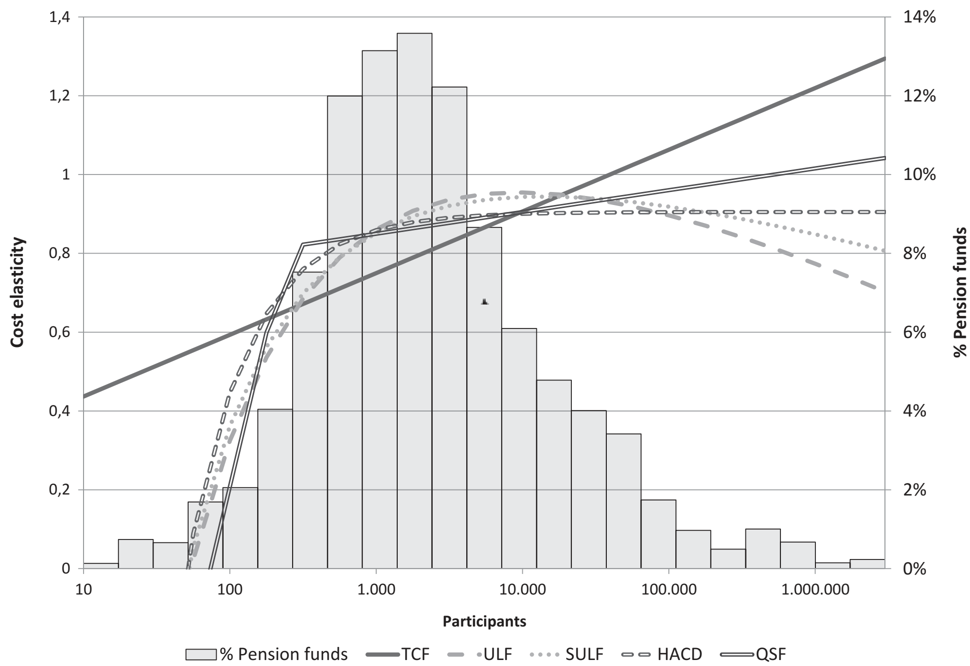

Figure 7. Cost elasticity across pension fund size classes for five administrative cost functions (2002–2013). Cost elasticities below 1 indicate economies of scale. Grey bars give frequency distribution of observed pension fund sizes.

size limit. The only exception is the QSF, which touches the CE = 1 line, but only at the outer range of the sample and within the confidence interval (not shown in Figure 7), so that no conclusions can be drawn. TCF, however, gives deviating results, and is the only functional form that crosses the CE = 1 line firmly and results in substantial diseconomies of scale within the sample size range. This outcome illustrates how the restrictive parabolic TCF forms may wrongly dictate the existence of an optimal scale, and hence diseconomies of scale beyond that size, which is our key reason for using more flexible alternative cost functions.

X-efficiency of AC

The average X-efficiency of pension funds for the QSF specification is 0.221, see bottom panel of Table 4. Hence, most X-inefficiency estimates are very large. In interpreting this high level, we should realize that these estimates incorporate all pension fund characteristics which differ across pension funds, but are (mostly) constant over time. We will therefore take a closer look at X-efficiency and the effect of these constant characteristics on X-efficiency.

X-inefficiency in this case not only covers managerial inabilities (reflecting less optimal input and output choices, as in the classic interpretation) but also heterogeneity across pension funds in terms of complexity of pension plans, defined benefits versus defined contribution, service level for members, etc. Inefficiencies also include institutional obstacles to achieving the lowest possible cost levels, such as pension fund types mandated by collective labour agreements. Finally, any under-reporting of costs may also affect X-inefficiency estimates.

Our X-efficiency estimates are substantially lower than those found for most other financial institutes such as banks (Mester 1996) and mutual funds (Annaert, Van Den Broeck, and Vander Vennet 2003), where under-reporting is most probably more limited. And strong links with other institutes, like company pension funds have with their sponsors are absent. Mandatory industry-wide funds are on average most X-efficient (0.291), followed by non-mandatory industry funds (0.217), company funds (0.215) and professional group funds (0.169). X-efficiency is higher, on average, for pension funds with defined contribution schemes (0.218) than for those with defined benefit schemes (0.222).

When we analyse X-efficiency for different size categories, we find that both the smallest and largest pension funds in terms of members have the highest

X-efficiency (0.45 and 0.36 respectively). Pension funds that are in between (the majority of pension funds) are least X-efficient (0.18). We do not have clear explanations for these phenomena. A general argument may be that medium-sized pension funds are more heterogeneous. These pension funds more often vary in the type of fund and the type of pension plan they offer, which may also lead to larger discrepancies in terms of performance.

VI. Investment costs

Management of investments is a core task of pension funds, besides administration. These activities are often outsourced to specialist investment managers, but we will analyse investment costs irrespectively of whether investments are managed internally or externally. Explaining investment costs require a different model compared to administration costs: scale in investments is best described by total assets under management, as investment activities are related to the asset portfolio rather than the number of members. In addition, investment allocation to different asset classes is expected to influence costs and may therefore be an important determinant. More complex asset classes, such as equity, hedge funds, commodities and real estate, will have higher expected returns, but they also have higher fund selection and risk management costs compared to fixed income investment (Bikker 2017). This means that higher costs are not necessarily waste, but this makes it more difficult to estimate an optimal size with respect to investment costs, as higher costs may go accompanied by higher returns. Pension fund-specific characteristics included in our previous analysis may remain relevant for investment costs analysis. As some pension funds do not report investment costs, the number of observations for investment costs is lower. Key statistics of the relevant variables are summarized in Table 1. We followed the strategy from Section V, first investigating parametric and non-parametric approaches, and then examining functional forms.

The top of Table 5 presents summary data of X-efficiency estimates for investments and the bottom results of a regression analysis explaining these efficiency estimates. FDH X-efficiency estimates are at 0.057 very low on average, comparable to the AC results. Order $-\alpha$ (with $\alpha = 95$) results in higher X-efficiency scores (0.446) and that also holds for SCFA (0.523). Note that average X-efficiency particularly for SCFA is substantially higher than that for AC (0.221). X-efficiency estimates are relatively robust for the selected method, with Spearman rank correlations ranging between 54% and 67%.

Explaining X-efficiency with a regression model, using the logistic transformation (lower panel of Table 5) reveals that efficiency tends to decline with size. Efficiency is much higher for industry-wide and company pension funds, compared to professional group funds, in line with expectations (lower costs, more efficiency). For SCFA efficiency estimates, we find that efficiency is higher for retired and inactive participants, as expected. X-efficiency is lower for investments in equity and real estates, which is plausible as costs of investment analyses are higher for those investment categories.

As for AC, we select SCFA as our preferred method for estimating investment costs. It is least sensitive to outliers (e.g. due to under-reporting) and can incorporate pension fund characteristics, in particular the asset allocation variables into the cost function, which are therefore not included in the inefficiency term.

Table 6 presents results for the parametric models of investment costs. We include LRM for comparison and because that is the only model which allows the estimation of pension fund types and pension plans effects.[14] The estimation results for LRM and SCFA are quite similar, with an approximately equal CE at the mean (0.988 and 0.952, respectively), and fairly equal optimal sizes (€223 and €220 million, respectively). The LRM dummy coefficient of pension fund types indicate that industry-wide and company pension funds have much lower costs than professional group pension funds, similarly to administration costs and also in line with the X-efficiency estimates explanations in Table 5. We conclude that industry-wide and company pension funds appear to be more efficient. Equity and real estate go with higher

[14]Note that dummies cannot be identified in SCFA with constant X-efficiency terms. Furthermore, these constant terms distort the estimations of the population coefficients, because the distribution of active, inactive an retired hardly change over time. That is why we present the LRM estimates.

Table 5. Estimates of X-efficiency for investment costs and their explanation (2002–2013).

	(1)		(2)		(3)	
	FDH		Order − a, $a = 95$		SCFA	
			Estimates of X-efficiency			
Average	0.057		0.446		0.523	
25th percentile	0.004		0.188		0.322	
Median	0.010		0.314		0.511	
75th percentile	0.034		0.689		0.738	
			Estimates of a regression model which explains X-efficiency			
Variables						
Total assets (€1000, in logarithms)	−0.459***	(0.025)	0.043	(0.027)	−0.120***	(0.21)
Total assets ^{2} (in ln, mean dev.)	0.221***	(0.016)	0.047***	(0.013)	0.049***	(0.005)
Industry fund (mandatory)	0.323*	(0.196)	0.398**	(0.163)	0.630***	(0.258)
Industry fund (non-mandatory)	0.179	(0.232)	0.321*	(0.190)	0.536*	(0.293)
Company fund	0.270***	(0.161)	0.309**	(0.126)	0.798***	(0.238)
Professional group fund	0.077	(0.302)	−0.119	(0.212)	0.434	(0.265)
Pension plan: defined contribution	−0.106	(0.114)	−0.133	(0.082)	−0.236**	(0.118)
Assets per member (€ million)	0.307	(0.265)	0.048	(0.305)	−0.247	(0.177)
% Pensioners	−0.407	(0.282)	−0.088	(0.188)	0.654**	(0.259)
% Inactive members	−0.680**	(0.263)	−0.693***	(0.207)	0.591***	(0.225)
Investments:						
Equity	−0.48*	(0.329)	−0.660**	(0.282)	−0.711***	(0.242)
Real estate	−0.761	(0.914)	−0.399	(0.665)	−1.254*	(0.640)
Fixed income	−0.325	(0.286)	−0.234	(0.248)	−0.419**	(0.162)
Constant	0.944**	(0.416)	−1.131***	(0.382)	0.740**	(0.328)
R^2	0.396		0.094		0.131	
Observations	4476[a]		3705[a]		4498	

A logistic transformation has been applied to X-efficiency. Double-clustered SEs are presented in parentheses, number of observations is 4498, number of pension funds is 646, $\overline{\ln ta}$ = (ln 1291 million:)
[a]The number of observations is lower due to logistic transformation of X-efficiency. $P>|t| =$ *<0.10, **<0.05 and ***<0.01.

Table 6. Results of parametric models for investment costs (2002–2013).

	(1)		(2)	
Variables	LRM		SCFA	
Total assets (€1000, in logarithms)	0.988***	(0.021)	0.952***	(0.038)
Total assets^2 (in ln, mean dev.)	0.011**	(0.004)	0.045***	(0.010)
Industry fund (mandatory)	−0.438***	(0.159)		
Industry fund (non-mandatory)	−0.322*	(0.168)		
Company fund	−0.341**	(0.132)		
Professional group fund	0.298*	(0.170)		
Pension plan: defined contribution	0.111	(0.089)		
Assets per member (€ million)	−0.066	(0.153)	−0.202	(0.151)
% Pensioners	0.163	(0.230)	0.178	(0.404)
% Inactive members	0.606***	(0.193)	0.565**	(0.262)
Investments:				
Equity	0.421*	(0.250)	−0.147	(0.213)
Real estate	1.577**	(0.612)	0.730	(0.539)
Fixed income	0.209	(0.191)	0.264**	(0.166)
Constant	−6.916***	(0.331)	−8.361***	(0.341)
σ_u^2 (inefficiency)			3.042	(0.494)
σ_v^2 (random shocks)			0.661	(0.043)
R^2	0.746		0.738	
First derivatives	$0.988 + 2 * 0.011 * (lnta - \overline{lnta})$		$0.952 + 2 * 0.045 * (lnta - \overline{lnta})$	
Cost elasticity at $\overline{lnta}$	0.988		0.952	

LRM: Double-clustered SEs, SCFA: SEs estimated using Bootstrap, presented in parentheses. *ta* = value of total assets. Number of observations is 4498, number of pension funds is 646, $\overline{lnta}$ = ln(1291 million).
$P>|t| =$ *<0.10, **<0.05 and ***<0.01.

investment cost, as said due to more elaborate investment analyses for these types of investments.

Functional form of investment costs

As in the AC analysis in 'Functional form specification', we applied TCF, (S)ULF, HACD and QSF to investment costs. The results are presented in Table 7, where the number of break points and their locations are selected by minimizing AIC.[15] Figure 8 shows the CEs over time that follow from the five cost functions. Both the average X-efficiency that follows from the five functional forms of investment and the implied CEs differ only slightly across the specifications. The results are therefore relatively robust for the choice of functional form of investment costs.

Using AIC we found that QSF, with a single break point at total assets of €800 million, best describes investment costs. Column 5 in Table 7 presents the QSF estimation results. This functional form suggests that the CE of investment costs increases up to the break point, and decreases after this point (the coefficient after the break point is not significantly different from zero). The majority of pension funds (55.7%) have investment activities which operate under implied decreasing returns to scale (CE > 1), which is markedly different from administrative activities.

The CE at the mean level of total assets is 1.002, and higher for larger portfolio's due to the quadratic effect. This means that increases in total assets will give, although not statistically significant, a more than proportional increase in investment costs. However, larger pension funds may invest in more complex assets, and may invest more actively. This has higher costs, but also yields higher (expected) returns. Higher costs due to more complex investments by larger pension funds therefore does not necessarily imply that larger funds have lower efficiency.

As the CE for investment costs is markedly different from that of AC, pension funds may have economies of scale in AC, while facing diseconomies of scale in investment costs. Section VII analyses total costs, using both the number of members and total assets as output indicators to obtain an overall view on the optimal scale.

[15]The models also include pension fund-specific characteristics, not shown in Table 7, as the respective coefficient estimates are almost identical to those in Table 5 for SCFA.

Table 7. Estimates of five functional forms of investment costs and of X-efficiency (2002–2013).

	(1)	(2)	(3)	(4)	(5)
Variables	TCF	ULF	SULF	HACD	QSF
Break point					$ln x_1 = 20.5$
Total assets	0.952***	5.466***	1.513***	1.057***	1.305***
(€1000, in logarithms)	(0.038)	(1.809)	(0.393)	(0.054)	(0.078)
Total assets^2	0.045***	−0.151*	0.008		
(in ln, mean dev.)	(0.010)	(0.078)	(0.032)		
Total assets^2					0.083***
(ln, x_1 dev. $\vert < x_1$)					(0.015)
Total assets^2					−0.014
(ln, x_1 dev. $\vert > x_1$)					(0.026)
1/(ln total assets)		1088.582**	70.768		
		(451.384)	(47.391)		
1/(ln total assets)^2		−2779.579**			
		(1219.563)			
1/total assets				1688.651	
				(1.355.087)	
σ_u^2 (inefficiency)	3.042	2.995	2.996	2.981	2.966
	(0.494)	(0.454)	(0.448)	(0.464)	(0.534)
σ_v^2 (random shocks)	0.661	0.661	0.661	0.670	0.660
	(0.043)	(0.051)	(0.042)	(0.040)	(0.044)
R^2	0.733	0.731	0.733	0.734	0.730
AIC	12,340	12,328	12,336	12,380	12,325
Wald test[a]	22***	62***	52***	1.63	34***
First derivatives	$0.952 + 2 * 0.045 (\ln ta - \overline{\ln ta})$	$5.466 - 2 * 0.151 (\ln ta - \overline{\ln ta}) - 1,088.582/(\ln ta)^2 + 2 * 2,779.579/(\ln ta)^3$	$1.513 + 2 * 0.008 (\ln ta - \overline{\ln ta}) - 70.768/(\ln ta)^2$	$1.057 - 1688.651/ta$	$1.305 + [2 * 0.083 (\ln ta - x_1)\vert ta \leq x_1] - [2 * 0.014 (\ln ta - x_1)\vert ta > x_1]$
Cost elasticity at mean	0.952	1.017	1.004	1.057	1.002
X-efficiency:					
Average	0.516	0.522	0.520	0.520	0.523
25th percentile	0.318	0.320	0.320	0.329	0.322
Median	0.495	0.510	0.498	0.491	0.511
75th percentile	0.739	0.741	0.742	0.737	0.738

SEs estimated using Bootstrap, presented in parentheses, ta = value of total assets. Number of observations is 4498, number of pension funds is 646, $\overline{\ln ta}$ = ln(€1291 million). Break point $ln x_1 = 20.5$ is at €800 million total assets. [a]Wald test for Constant Returns to Scale Hypothesis: coefficient of ln(total assets) = 1 and coefficient(s) of non-linear term(s) of ln(total assets) = 0.
$P>|t|$ = *<0.10, **<0.05 and ***<0.01.

VII. Total costs

The previous two sections show that administrative and investment costs have different optimal sizes. To find the overall results, we combined both cost categories and analysed total operational costs. As both output measures, the number of members and total assets, are relevant in explaining total costs, we included them in the total cost function. In line with the previous findings, we applied a QSF SCFA for total costs, using the optimal break points for the number of members (245 members; $lnx_{1,p}$) and total assets (€800 million; $lnx_{1,ta}$) obtained in the previous sections. In order to allow for possible output interaction effects, we included an additional variable:

$$\text{Interaction members x total assets} = (lnp - lnx_{1,p}) * (ln\,ta - lnx_{1,ta}) \quad (5)$$

Table 8 shows the resulting coefficients for the QSF of total costs. The coefficients for total costs are all of similar sign and magnitude as found before. Average total costs initially rise substantially with increases in the number of members and/or total assets and smooth out with increases beyond both breaking points. The negative coefficient of the interaction effect shows that costs increase relatively stronger if one of the two output measures, number of members or total assets, outpaces the other. The CE at the average number of members (2.136) and for the average total assets (€129 million) is 0.990, which indicates approximate constant returns to scale (CE not significantly different from 1).

Figure 9 shows a 3D graph of CE dependent on the number of members (Z-axis) and total assets (X-axis). CE depends most strongly on

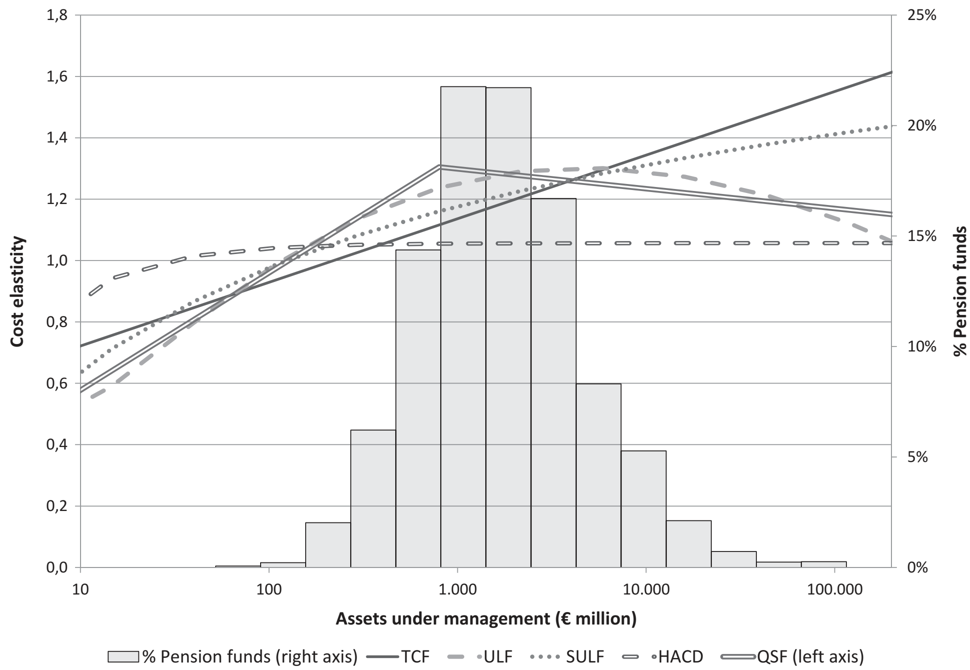

Figure 8. Cost elasticity for five investment cost functions (2002–2013).

Table 8. SCFA estimates of the QSF model of total operational costs (2002–2013).

Variables		
Members (in logarithms)	0.134	(0.167)
Members^2 *(ln, $x_{1,p}$ dev.* $\| \leq x_{1,p}$)	0.189*	(0.097)
Members^2 *(ln, $x_{1,p}$ dev.* $\| > x_{1,p}$)	0.020	(0.019)
Total assets (€1000, ln)	1.066***	(0.145)
Total assets^2 *(ln, $x_{1,ta}$ dev.* $\| \leq x_{1,ta}$)	0.075***	(0.020)
Total assets^2 *(ln, $x_{1,ta}$ dev.* $\| > x_{1,ta}$)	0.009	(0.028)
Interaction members × total assets (ln, x_1 dev.)	−0.062**	(0.026)
σ_u^2 (inefficiency)	1.955***	(0.700)
σ_v^2 (random shocks)	0.132***	(0.013)
R^2	0.769	
Wald test[a]	1055***	
First derivative	$1.200 + 2 * 0.189 * (lnp - lnx_{1,p} \| p \leq x_{1,p}) + 2 * 0.020 * (lnp - lnx_{1,p} \| p > x_{1,p}) + 2 * 0.075 * (lnta - lnx_{1,ta} \| ta \leq x_{1,ta}) + 2 * 0.009 * (lnta - lnx_{1,ta} \| ta > x_{1,ta}) - 0.062 * (lnp - lnx_{1,p}) - 0.062 * (lnta - lnx_{1,ta})$	
Cost elasticity at $\overline{lnp}$ and $\overline{lnta}$	0.990	

SEs estimated using Bootstrap presented in parentheses, p = number of members, ta = value of total assets. Number of observations is 4498, number of pension funds is 646, $\overline{lnp}$ = ln(2316), $\overline{lnta}$ = ln(€1291 million). Break points $lnx_{1,p} = 5.5$ and $lnx_{1,ta} = 20.5$ are equal to 235 members and €800 million total assets respectively.

[a]Wald test for Constant Returns to Scale Hypothesis: sum of coefficients of ln(partipants) and ln(total assets) = 1 and coefficient(s) of non-linear term(s) of ln (members) and ln(total assets) and the interaction term = 0.

$P>|t| =$ *<0.10, **<0.05 and ***<0.01.

the number of members and shows strong economies of scale for pension funds with a number of members or total assets up to the breaking points. After the breaking points, CE is close to 1, indicating that there are few benefits to further increases in size.

The analysis of total costs shows that small pension funds (below the breaking points) can benefit from reduced average costs by increasing the number of members and/or total assets, preferably both. Although the economies of scale smooth out after the breaking points, we found no (global) substantial

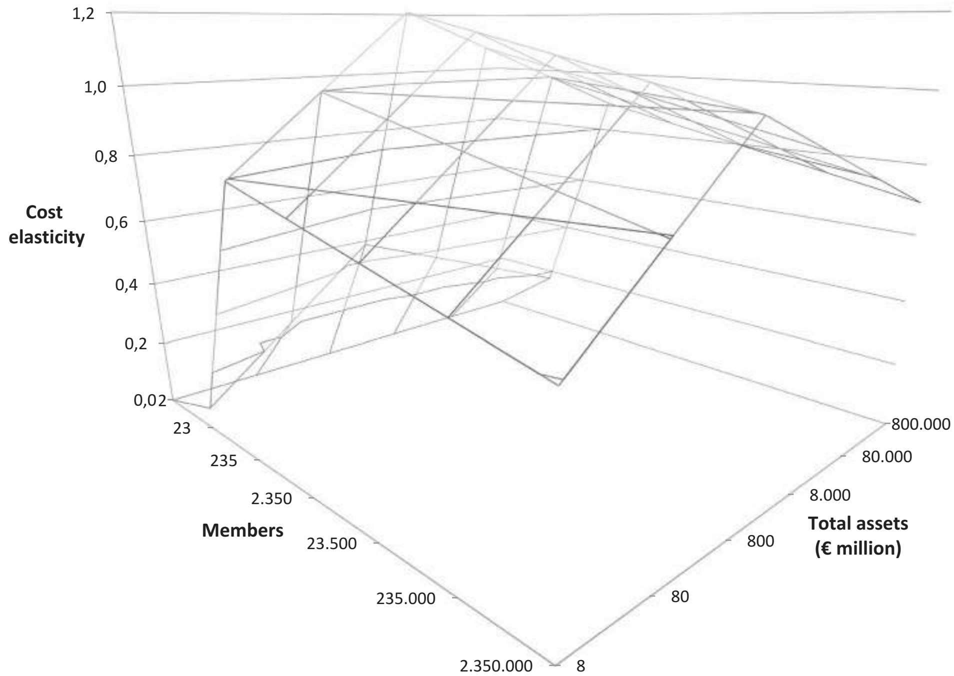

Figure 9. 3D graph of cost elasticity for total costs.

Table 9. Estimates of X-efficiency for total operational costs (2002–2013).

Average	0.785
25th percentile	0.334
Median	0.465
75th percentile	0.612

diseconomies of scale for any size observed in our sample. Although there is no optimal size, benefits of increasing pension fund size, either in the number of members or in the value of total assets, are absent beyond the breaking points (235 members and €800 million total assets).

Table 9 presents X-efficiency estimates for total operational costs. Average X-efficiency is at 0.785 much higher than for total operational costs than for its two components (0.221 for AC and 0.523 for investment costs).

VIII. Summary and conclusion

Pension benefits not only depend on pension fund investment returns, but also on the costs incurred during the accumulation of pension capital. Higher costs reduce pension capital, and therefore depress final benefits. Substantial differences are found in per capita pension fund costs. We expect that these cannot be fully attributed to differences in quality of the services and thus may represent differences in efficiency of running the pension funds. We analysed the efficiency of the administrative and investment activities of Dutch pension funds by comparing the cost-output ratio of pension funds with best practice pension funds. The number of members and value of total assets were chosen as proxies for the output of the administration and investment activities, respectively.

We measured X-efficiency by means of both a parametric method and a non-parametric method. SCFA was selected as preferred research method for both administrative and investment activities as it can explicitly incorporate random noise, such as measurement error, and allows for incorporation of pension fund characteristics, such as type of member and outsourcing. Five functional cost models were applied to investigate the complex relation between size and output. For both activities the estimation results are relatively robust across functional forms; a QSF with a single break point best describes administrative and investment costs.

For AC, we found a CE of below 1 for the vast majority of pension fund sizes, indicating economies of scale on AC. Only 11 pension funds (118 observations) are above the implied optimal size of 52,650 members. We found that industry funds are the most efficient and professional group funds are the least efficient. Higher levels of outsourcing correlate with higher costs. Outsourcing may indicate under-reporting, so that the coefficient of outsourcing partly acts as a negative proxy to under-reporting. Note that under-reporting means that economies of scale are even larger than observed, leaving the recommendation of consolidation unchanged.

For investments costs, we found substantially higher CEs. This implies that the majority of pension funds (pension funds with total assets below €127 million) have diseconomies of scale for investment activities. However, as larger pension funds may invest in more complex asset classes (which have higher costs, but also higher expected returns), this may not necessarily point to waste. Industry-wide funds have the lowest investment costs, and professional group funds the highest, similarly as for AC.

As administrative and investment costs have different economies of scale estimates we also analysed their sum: total operational costs. We found a CE close to 1 for average sized pension funds (in terms of members and total assets). Smaller funds have unused economies of scale, pension funds beyond the breaking points (235 members and €800 million total assets) fluctuate around constant returns to scale.

From the perspective of efficiency, it seems desirable for smaller pension funds to consolidate, but for medium-sized and larger pension funds, no scale-economy benefits can be achieved. Within each size class, large differences in X-efficiency remain, however.

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