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

Gosse A.G. Alserda[†1,2], Jaap A. Bikker[‡2,3] and Fieke (S.G.) van der Lecq[§4]

[1]Erasmus School of Economics, Erasmus University Rotterdam

[2]De Nederlandsche Bank

[3]Utrecht School of Economics, University of Utrecht

[4]Faculty of Economics and Business Administration, Vrije Universiteit Amsterdam

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Abstract

Pension funds' operating costs come at the cost of 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 size classes. This paper discusses scale inefficiency and X-inefficiency using various approaches and models, based on a unique supervisory data set, which distinguishes between administrative and investment costs. 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.

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†alserda@ese.eur.nl

‡j.a.bikker@uu.nl

§s.g.vander.lecq@vu.nl

1. 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 and investment costs. Administrative costs include file keeping 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 development and implementation 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 et al. (2012) find that administrative costs 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) find 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 et al., 2012).

At the same time, larger pension providers may also suffer from costs that increase more than proportionally with their scale: they can have more severe price impacts with their trades (Bikker et al., 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 et al., 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.

The issue of pension fund efficiency is especially relevant as pension capital represents a large proportion of household capital in the Netherlands. In that country, pension capital amounted to over EUR 1,159 billion in 2013, which equals 71% of total household wealth and 252% of GDP (DNB, 2015a). Even small cost inefficiencies would therefore have large effects in absolute terms. This paper measures X-inefficiency and scale inefficiency in the Dutch pensions sector and, in a next step, indicates to what extent X-inefficiency and scale inefficiency is affected by pension fund characteristics such as size and pension plan type.

The measurement approach of these types of efficiency is discussed in Section 4, but we will first give a brief description of the Dutch pension system in Section 2 in order to explain the context of our research Section 3 presents the data. We separate the activities of pension funds into administration (Section 5) and investment management (Section 6). 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. We also analyse developments over time to see the effects of changes in the institutional setting of pensions and analyse two clearly defined components of administrative costs: auditing costs and management costs, which may have distinct distributions of X-efficiency and economies of scale. Section 7 combines administrative and investment costs to total costs and analyses how the combination of the two interact with pension fund size. Section 8 presents our conclusions.

2. Brief description of the Dutch pensions system

The Dutch pensions system is based on the three-pillar structure. The first pillar comprises 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 1,060 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).

3. Data

This paper 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 labor 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 1: Pension fund characteristics over time (1992-2013)

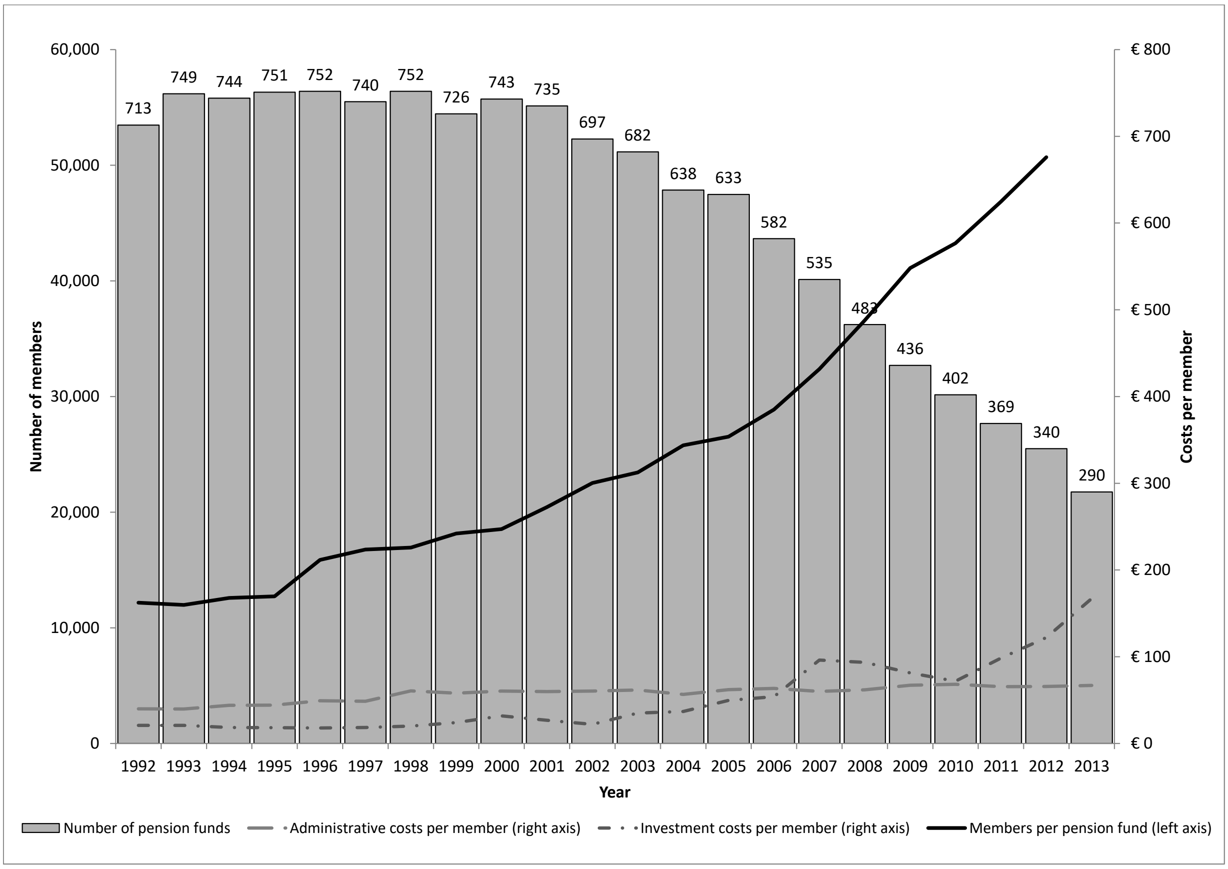


Figure 2 shows the 10th, 25th, 50th, 75th and 90th percentile of administrative costs per member for 10 size classes expressed in the number of members. The figure shows that there are strong economies of scale in administrative costs per member. The 10% largest pension funds have administrative costs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

Figure 2: Administrative costs per member in size classes 2002-2013 (2013 prices)

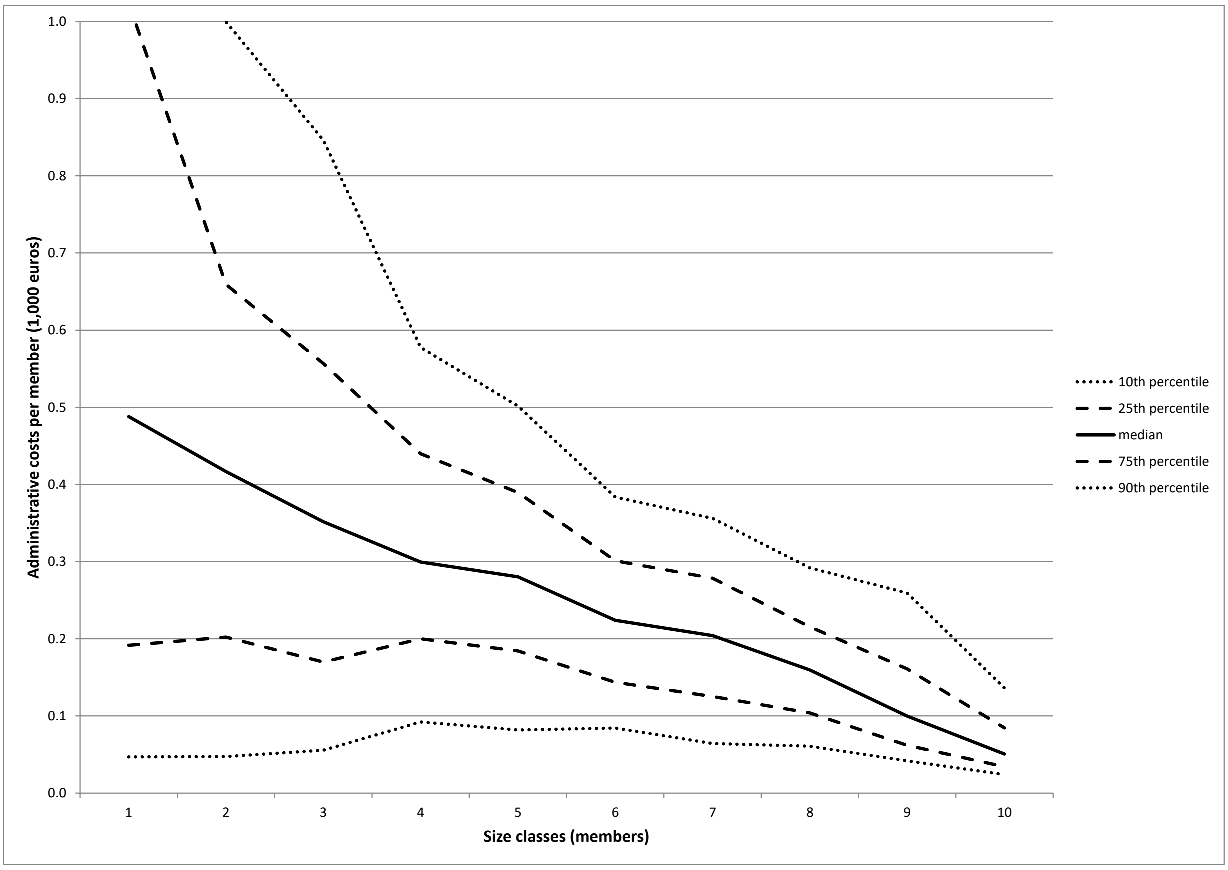
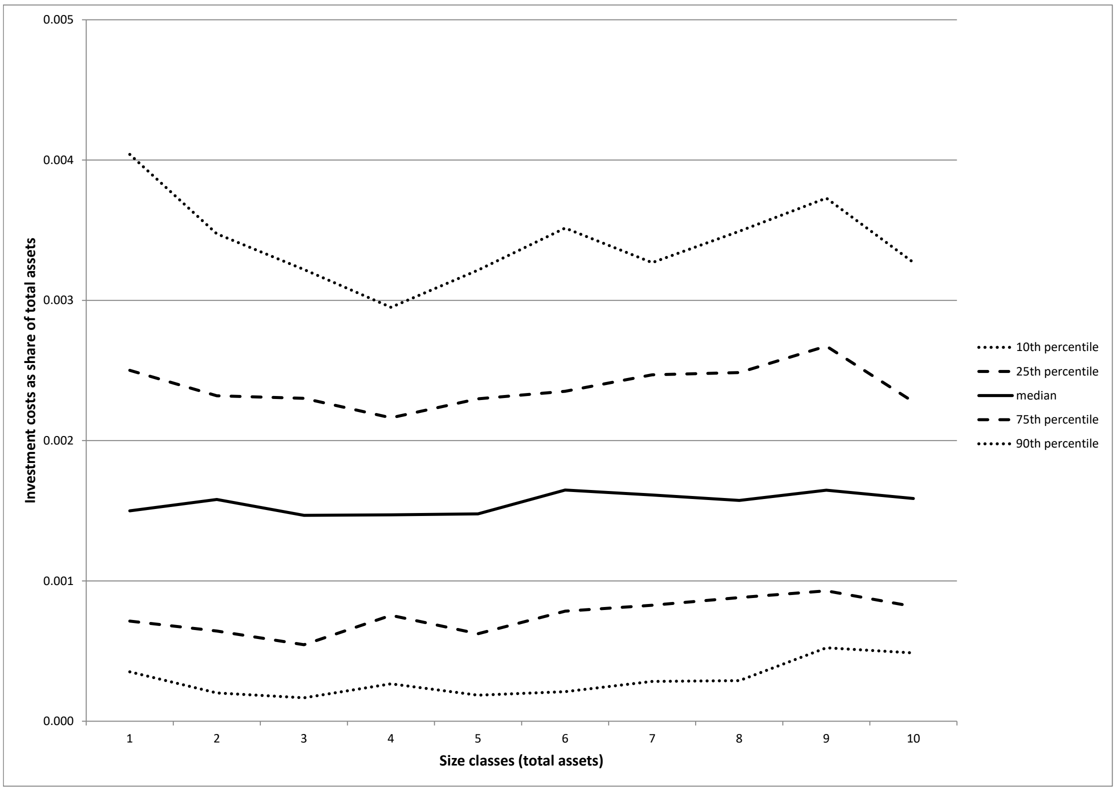


Figure 3 shows the same information for investment costs with size expressed as total assets of the pension fund. Contrary to administrative costs, there are no clear economies of scale visible for investment costs. According to Bikker (2017) this may be because larger pension funds tend to invest a higher relative proportion of assets in complex assets classes. These 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 presence of fixed costs it is likely that in principle 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 show the consolidation of pension funds and the increase in both administrative and investment costs per member, as explained above. The proportion of inactive members increases over time, due to increased labour mobility across sectors, while the proportion of retirees remains 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

Figure 3: Investment costs as proportion of total assets 2002-2013 (2013 prices)



because of the splitting of pension funds and pension delivery organizations. Investment data shows 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 administrative costs 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 paper. 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 is more reliable.

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

Time period	1992-1996	1997-2001	2002-2007	2008-2013
Administrative costs per member	44	58	61	57
Investment costs per member	19	25	52	103
Number of pension funds	742	739	628	387
Members per fund	13,081	18,163	26,297	43,319
Active members (%)	49	46	41	35
Retirees (%)	19	19	19	23
Inactive members (%)	32	35	40	42
Total contributions (€billion)	32.8	65.3	154.2	185.0
Total assets per fund *(discounted, €million)*	331	750	1,090	2,093
Total liabilities per fund *(discounted, €million)*	286	579	863	1,997
Assets per member *(€)*	25,276	41,319	41,461	66,955
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	24	35	60
Reinsurance premiums/total premiums (%)	10	4	2	3
Investments (%):				
Fixed income	57	47	45	50
Equity	24	40	41	34
Real estate	12	10	10	10
Other assets	7	3	4	6

Note: Values are expressed in 2013 prices.

4. 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 minimised 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, (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 et al., 1978). Plotting the number of members and administrative costs 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 pre-defined 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)[1]. 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 Sections 4.2 and 4.3. 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.

4.1. 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 minimise costs, thereby optimising their inputs.

Outputs for pension administration and investment are factors such as processed changes, messages sent and processed investment returns, etc. As these outputs, and their prices, are not reported, we took the number of members and total assets as indicators for output respecively 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 .

[1]Contrary to non-parametric methods, parametric methods use a pre-defined functional form of costs to model efficiency.

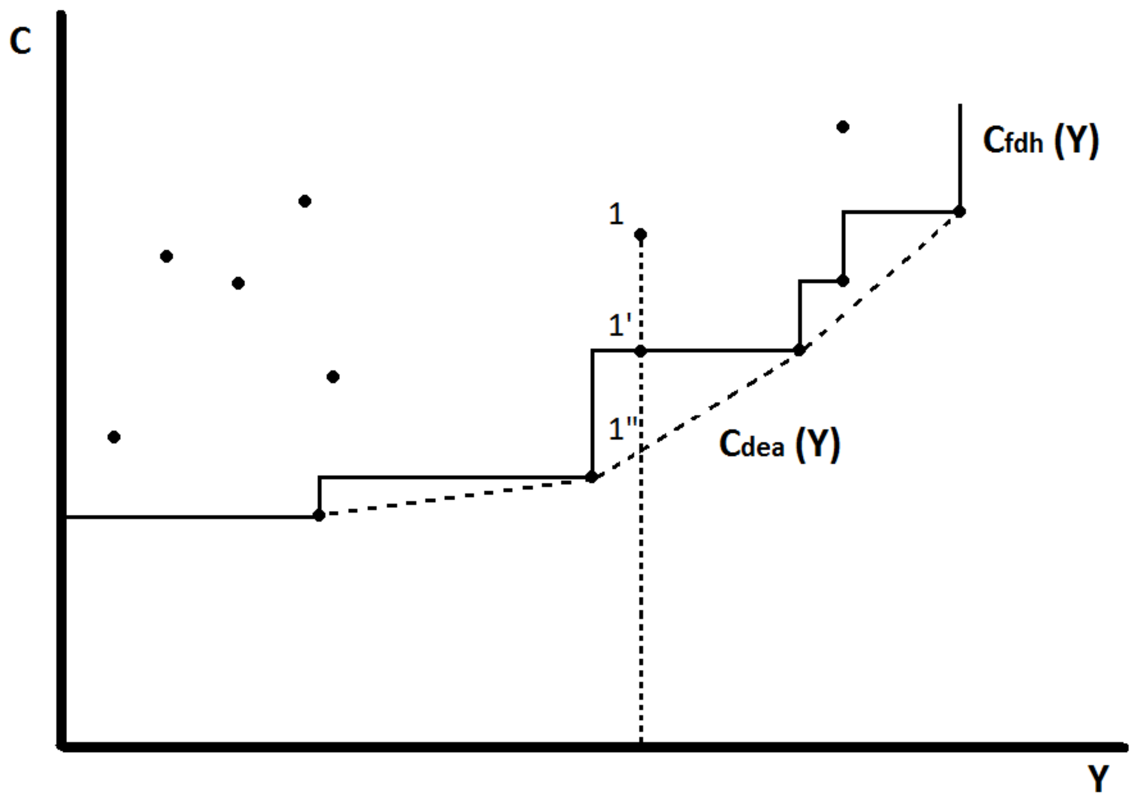
Pension fund members in the Netherlands are not free to choose their own pension fund, so Dutch pension funds are unable to use retail marketing to influence the number of members or the value of total assets they manage. This means that pension funds are input-oriented: they will try to minimise inputs (*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.

4.2. 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 a 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 a 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 et al., 1978; Färe et al., 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 (Lee and Ji, 2009), which makes the method unfeasible for large datasets. Free Disposal Hull (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 step-wise cost frontier between the best practice pension funds, which requires less computational power (De Borger and Kerstens, 1996). Due to this 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 dataset, we chose to use FDH rather than DEA, in order to keep our computations manageable.

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



Notes: 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 DMU. FDH effiency for this dot is value of C for 1' divided by that of 1, while DEA eficfiency is value of C for 1" divided by that of 1. Source: De Borger and Kerstens 1996, p. 150

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).

[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)

As noted, a major disadvantage of the non-parametric 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 et al., 2005) and Order$-m$ (Cazals et al., 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 x^{th} 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 $\alpha\%$ most efficient observation, given size. Order$-\alpha$ is equal to FDH if $\alpha = 100$ (Tauchmann, 2012). Order$-m$ compares pension funds to the best 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 paper 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.

4.3. 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 linear regression model (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 stochastic cost frontier analysis (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.

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 shows the structure of, respectively the ULD and HACD model:

$$ULF : lnAC(o) = \alpha + \beta_1(ln\,o) + \beta_2(ln\,o - \overline{ln\,o})^2 + \beta_3/(ln\,o) + \beta_4/(ln\,o)^2 + \beta_5(pension\,fund\,characteristics) \tag{2}$$

$$HACD : lnAC(o) = \alpha + \beta_1(ln\,o) + \beta_2/o + \beta_3(pension\,fund\,characteristics) \tag{3}$$

Note that the TCF follows from equation 2 if $\beta_3 = \beta_4 = 0$[6]. This paper 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 breakpoints 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 minimising Akaike's information criterion (AIC)[7] of the model over a grid of possible values of x_1. Appendix 1 shows the model specifications for the double and triple quadratic spline models, and provides first derivatives of these quadratic spline cost functions, *i.e.*, cost elasticities as functions of size.

$$QSF : lnAC(o) = \alpha + \beta_1(ln\,o) + \beta_2[(ln\,o - ln\,x_1)^2|_{o \leq x_1}] + \beta_3[(ln\,o - ln\,x_1)^2|_{o > x_1}] + \beta_4(pension\,fund\,characteristics) \tag{4}$$

[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.

[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).

where β_2 is conditional ($| |$) on the output being 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, proportion of reinsured liabilities, and the outsourcing of administration (as proportion of administrative costs paid to third parties).

Below, we will apply the two variations of the parametric method, and the two variations of the non-parametric method, on administrative costs. The estimation results will show which method is most suitable for describing pension fund efficiency.

5. Empirical results for administrative costs

This section presents the estimation results of the various approaches and functional forms for administrative costs, while Section 6 presents the empirical results for investment costs. We start by selecting the best approach, parametric or non–parametric, and next investigate what the best functional form is. We will then discuss the corresponding effects of separate pension fund characteristics on costs, and possible changes in these effects across different periods. Finally, we will examine the available separate components of administrative costs.

5.1. Parametric estimation results

Table 2 presents the results of a first exploration of 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 most often applied in the literature and resembles a number of alternative cost functions. The most general specification with annual values for inefficiency had difficulty to converge, and the error term tends to be fully attributed to 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). A side effect is that the impact of possible under-reporting of costs on efficiency estimation is reduced, as non-persistent under-reporting will be attributed to the random shocks term v. 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 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 of variable, and other variables that are constant over time, cannot be included in the SCFA model, because they cannot be distinguished from the (also constant) X-inefficiencies[8]. The results for LRM show that mandatory industry-wide funds face the lowest costs (-29%), while professional

[8]Similar as in the case of a fixed effects model

group funds face the highest cost (+75%).[9] We will discuss the parameter estimates in the section on functional forms. On average, pension fund X-efficiency is low (0.212), with 75% of funds having an X-efficiency score of lower than 0.271. Note that this inefficiency may be overestimated due to the under-reporting errors and the omission of pension fund type dummies. Overall, the parameter estimates of both methods are similar, but as SCFA allows for the estimation of X-inefficiency, it is preferred over LRM.

Table 2: Results of parametric models for administrative costs (2002 - 2013)

Variables	(1) **LRM** Cost elasticity		(2) **SCFA** Cost elasticity	
Members (*in logarithms*)	0.736***	(0.008)	0.807***	(0.019)
Members^2 (*ln, mean dev.*)	0.005**	(0.002)	0.034***	(0.006)
Industry fund (mandatory)	-0.341***	(0.079)		
Industry fund (non-mandatory)	-0.029	(0.098)		
Company fund	0.134**	(0.065)		
Professional group fund	0.559***	(0.111)		
Pension plan: defined contribution	-0.131***	(0.036)		
Outsourcing	0.670***	(0.047)	0.270***	(0.037)
Reinsured	-0.112***	(0.021)	-0.034***	(0.012)
Assets per member (€million)	0.534***	(0.049)	0.082**	(0.038)
% Pensioners	0.408***	(0.075)	1.665***	(0.129)
% Inactive members	-0.554***	(0.079)	0.440***	(0.076)
Constant	-0.140	(0.088)	-4.362***	(0.148)
σ_u^2 (*inefficiency*)			10.501	(0.625)
σ_v^2 (*random shocks*)			0.234	(0.005)
R^2	0.702		0.660	
Akaike's IC	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	
X-efficiency:				
Average			0.212	
25th percentile			0.103	
Median			0.166	
75th percentile			0.271	

Notes: p = number of members, number of observations = 6,087, number of pension funds = 799, $\overline{lnp}$ = ln(2,316). Standard errors in parentheses, $P > |t|$ = * <0.10, ** <0.05, *** <0.01.

5.2. Non-parametric results

This section explores two variations of the non-parametric method: FDH, and an Order$-\alpha$ model with $\alpha = 95\%$. Table 3 presents summary data of the efficiency estimates for both models and the results of a regression analysis explaining these efficiency estimates. We will see how efficiency can be explained

[9]In all regression analyses the pension fund types are compared to a group of none defined pension funds

from pension fund characteristics. The robustness of these results may help to assess the validity of the X-efficiency estimates

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 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 shows the frontiers resulting from FDH and order$-\alpha$. As Order$-\alpha$ is less sensitive to outliers (see Section 4.2), 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. Also in explaining the inefficiency estimates from both non-parametric models we observed similar parameter estimates, also suggesting that the inefficiencies from both approaches resemble each other. Also the comparison of these non-parametric X-inefficiencies with the SCFA X-efficiencies show high values of Spearman rank correlation (between 0.652 and .750), indicating that the rank in X-efficiency is relatively robust for the choice of method.

Explaining the inefficiency estimates from pension fund characteristics reveal that mandatory industry-wide pension funds on average have the highest X-efficiencies, while, professional group funds are least X-efficient. Defined contribution plans are more X-efficient and pension funds that have less outsourcing,[10] more reinsurance, and more pensioners also tend to be more X-efficient. These results are in line with Table 2 in the sense that pension fund characteristics which go with the lowest cost levels now show the highest efficiencies. The economic impact of population effects is relatively small, as administrative costs change by up to 0.3% with a standard deviation change in the ratio of pensioners and up to 4.5% for a standard deviation change in the ratio of inactive members.

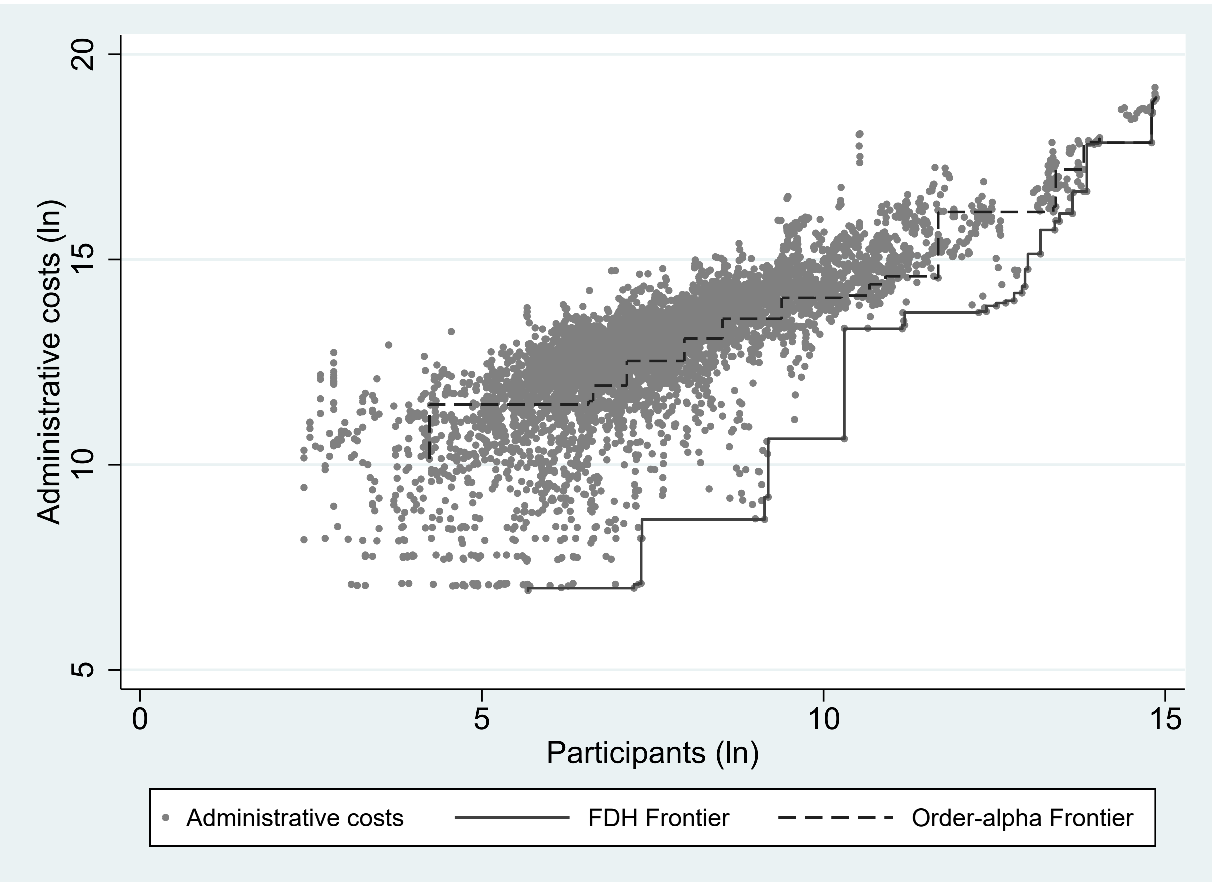
[10] Outsourcing costs are included in administrative costs. As they are easily observable they are less likely to be under-reported. Outsourcing can therefore in this sense act as a negative proxy for under-reporting

Table 3: Explaining non-parametric estimates of X-efficiency for administrative costs (2002-2013)

Variables	(1) FDH		(2) Order-α, $\alpha = 95$	
X-efficiency:				
Average	0.058		0.546	
25th percentile	0.005		0.311	
Median	0.010		0.471	
75th percentile	0.029		0.797	
Members *(in logarithms)*	0.014***	(0.001)	-0.015***	(0.002)
Members^2 (*ln, mean dev.*	0.011***	(0.000)	-0.001	(0.001)
Industry fund (mandatory)	0.001	(0.009)	0.154***	(0.023)
Industry fund (non-mandatory)	-0.012	(0.011)	-0.025	(0.028)
Company fund	-0.002	(0.008)	-0.072***	(0.019)
Professional group funds	-0.034***	(0.013)	-0.181***	(0.032)
Pension plan: defined contribution	0.011**	(0.004)	0.051***	(0.010)
Outsourcing	-0.047***	(0.006)	-0.185***	(0.013)
Reinsured	0.006**	(0.003)	0.033***	(0.006)
Assets per member *(€million)*	-0.030***	(0.004)	-0.091***	(0.011)
% Pensioners	-0.039***	(0.009)	-0.067***	(0.021)
% Inactive members	0.018*	(0.009)	0.210***	(0.022)
Constant	-0.072***	(0.011)	0.703***	(0.025)
Adjusted R^2	0.389		0.127	

Notes: Number of observations = 6,087, pension funds = 799, $\overline{lnp}$ = ln(2,316). Standard errors in parentheses, $P > |t|$ = * <0.10, ** <0.05, *** <0.01.

Figure 5: Non-parametric estimates of administrative cost frontiers



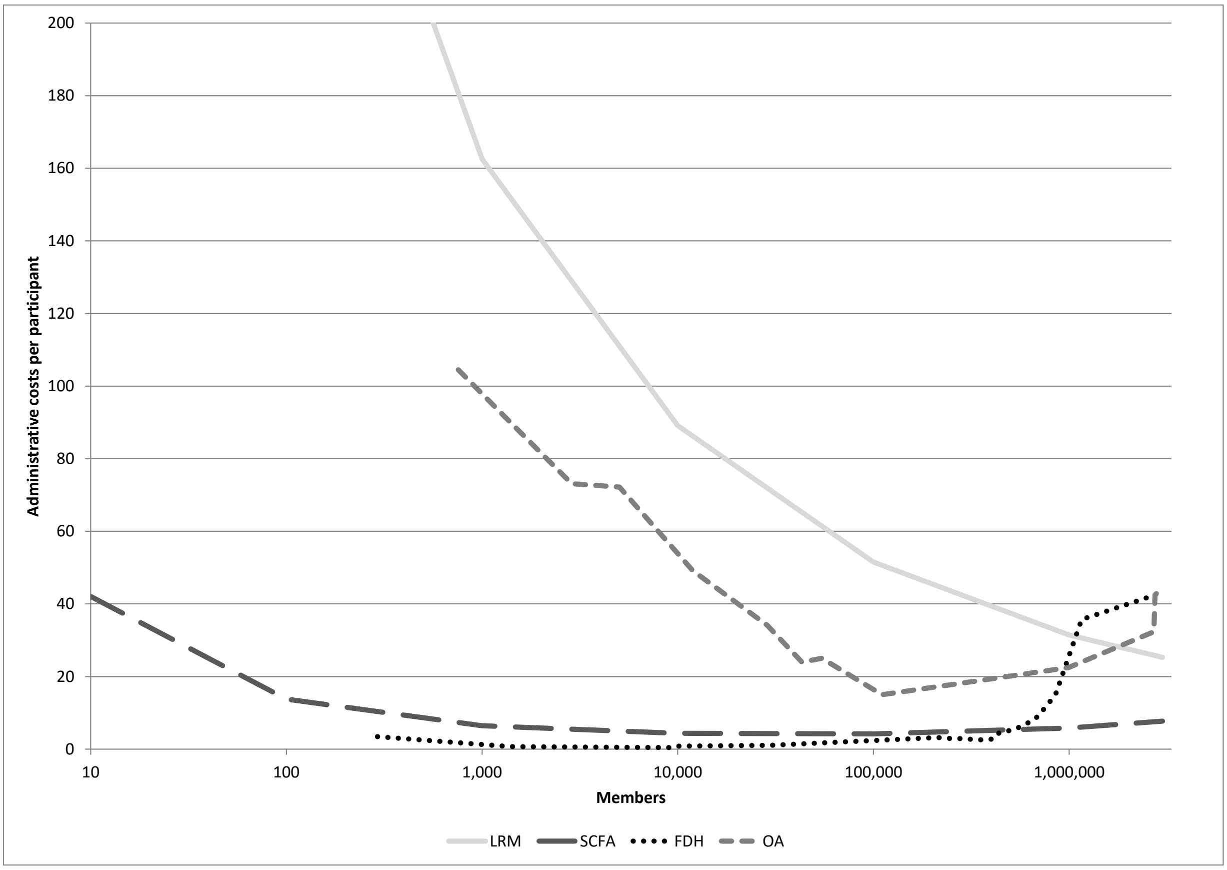
5.3. Method

The parametric and non-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 95^{th} percentile of the efficiency distribution. The remaining frontiers (SCFA and FDH) represent fully efficient or best-practice pension funds: pension fund costs can therefore theoretically be on or above 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 (that is, number of members) variables from Table 2 on administrative costs 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.

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

Figure 6: Cost frontier estimates from four model approaches (2002 - 2013)



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 paper 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.

5.4. Functional form specification

Table 4 investigates several cost functions for the preferred SCF approach: TCF, ULF, SULF, HACD and QSF (see Section 4.3). We use AIC to find the functional forms that best fits the data . QSF with a single break point at ln(members)= 5.5 or 245 members is the preferred model[12]. The results show

[12]In Appendix 1 we show model specifications for QSF with up to three break points. The results in that section show that the QSF with one break point at ln(members)= 5.5 has the lowest AIC value.

that there are vast unused economies of scale for small pension funds which decrease with pension fund size. Beyond the breakpoint of ln(members)= 5.5 small, constant economies of scale remain. 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 below.

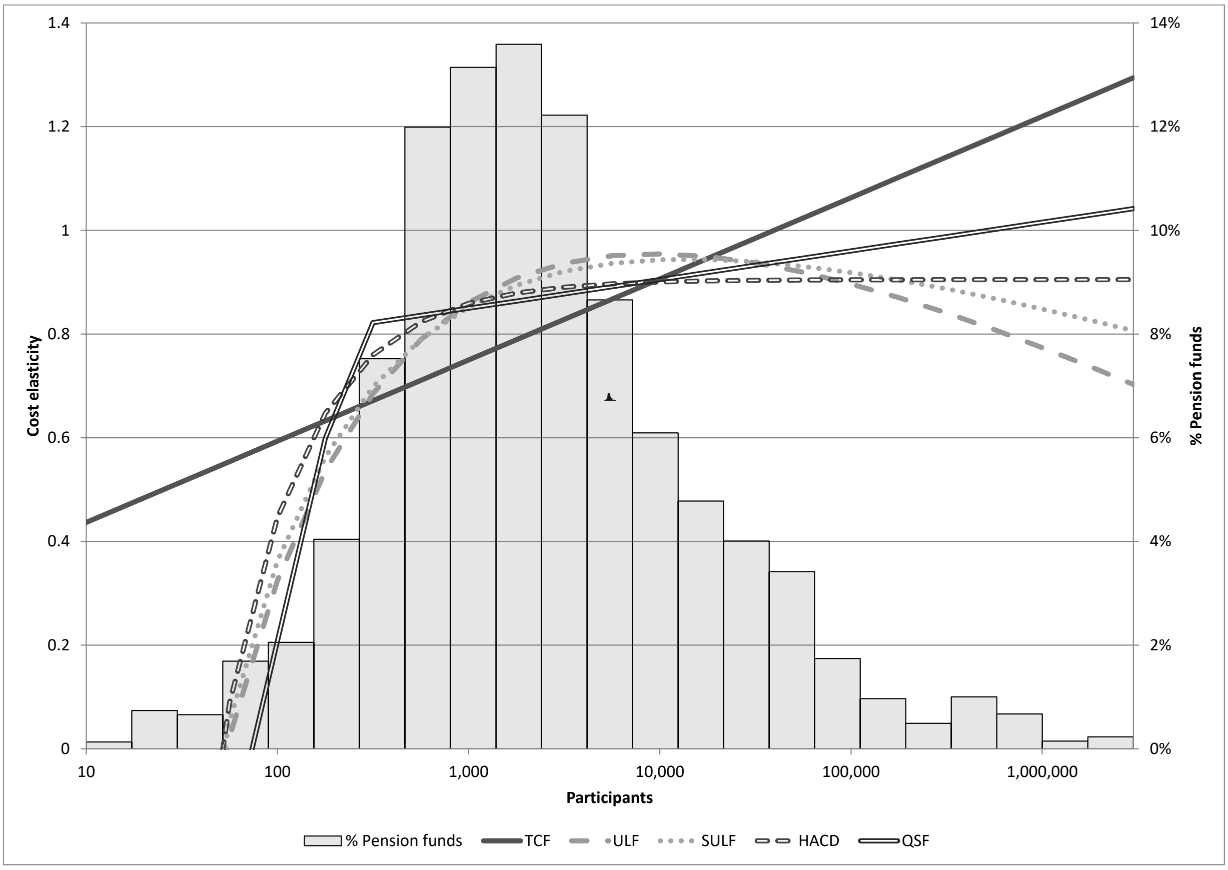
Figure 7 shows the cost elasticity (CE) over pension fund sizes for different functional forms (see left axis). The cost elasticity of four functional forms, ULF, SULF, HACD, and QSF, are relatively similar. These functional forms show large unused economies of scale for small pension funds (particularly below $< 1,000$ members) and small economies of scale for larger pension funds. The most important result is that these functions have cost elasticities below 1, so that no optimal scale exists: scale economies remain limited to exits without upper 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 dis-economies 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.

Table 4: **Estimates of five functional forms of administrative costs (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)	(0.019)	(0.314)	(0.078)	(0.022)	(0.042)
Members^2	0.034***	-0.045*	-0.027**		
(ln, mean dev.)	(0.006)	(0.026)	(0.011)		
1/(ln members)		42.992	23.469***		
		(26.442)	(3.569)		
1/(ln members)^2		-26.557			
		(35.765)			
1/ members				45.853***	
				(4.346)	
Members^2					0.340***
(ln, x_1 dev. $\|p < x_1$)					(0.041)
Members^2					0.012*
(ln, x_1 dev. $\|p \geq x_1$)					(0.007)
Outsourcing	0.270***	0.270***	0.270***	0.273***	0.270***
	(0.037)	(0.037)	(0.037)	(0.037)	(0.037)
Reinsured	-0.034***	-0.035***	-0.035***	-0.034***	-0.035***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Assets per member	0.082**	0.064*	0.065*	0.066*	0.064*
(€million)	(0.038)	(0.038)	(0.038)	(0.038)	(0.038)
% Pensioners	1.665***	1.718***	1.716***	1.714***	1.727***
	(0.129)	(0.128)	(0.128)	(0.128)	(0.127)
% Inactive members	0.440***	0.453***	0.450***	0.453***	0.441***
	(0.076)	(0.076)	(0.076)	(0.076)	(0.076)
Constant	-4.362	-14.951	-11.116	-5.017	-4.387
	(0.148)	(5.247)	(1.049)	(0.174)	(0.269)
σ_u^2 (inefficiency)	10.501	10.053	10.055	9.981	10.056
	(0.625)	(0.602)	(0.602)	(0.593)	(0.600)
σ_v^2 (random shocks)	0.234	0.234	0.234	0.234	0.234
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
R^2	0.672	0.674	0.673	0.673	0.654
Akaike's IC	11,921	11,889	11,887	11,889	11,881
Wald test[a]	119***	195***	199***	227***	240***
First derivatives	$0.807 + 2 * 0.034 * (lnp - \overline{lnp})$	$1.525 - 2 * 0.045 * (lnp - \overline{lnp}) - 42.992/(lnp)^2 + 2 * 26.557/(lnp)^3$	$1.299 - 2 * 0.027 * (lnp - \text{-} \overline{lnp} - 23.469 /(lnp)^2$	$0.905 - 45.853/p$	$0.816 + (0.340\|p < x1) *(lnp - lnx_1) - (0.012\|p \geq x_1) *(lnp - lnx_1)$
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

Notes: p = number members. Number of observations = 6,087, number of pension funds = 797, $\overline{lnp}$ = ln(2,316). Break point $ln\, x_{1,p} = 5.5$ is equal to 235 members. [a]Wald test for Constant Returns to Scale Hypothesis: coefficient 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. Standard errors in parentheses, $P > |t|$ = * <0.10, ** <0.05, *** <0.01.

Figure 7: Cost elasticity across pension fund size classes for five administrative cost functions (2002 - 2013)



Notes: Cost elasticities below 1 indicate economies of scale. Grey bars give frequency distribution of observed pension fund sizes.

5.4.1. The impact of pension fund characteristics on costs

The SCFA model with a single quadratic spline functional costs form has the lowest AIC. This section discusses the corresponding estimation results in Table 4, Column 5, to explain the effect of pension fund characteristics on administrative costs. Although SCFA was selected as the preferred method, most outcomes deviate hardly or not at all from those of the other functional forms, indicating that the results are robust for the selected functional form of costs.

For the (geometric) average number of members, administrative costs increase on average by 0.87% if the number of members increase by 1%, resulting in lower average costs per member. Beyond the breakpoint of 245 members the quadratic effect of the number of members is no longer significant at the 5% level ($p = 0.072$), indicating that no evidence exists that the cost elasticity changes with size beyond this point.

Pension funds that outsource more of their activities have higher reported costs. As oursourcing costs will be 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 (especially wages and rents of premises, which are sometimes allocated to the sponsoring company), true economies of scale may be even larger. In addition, pension funds that re-insure larger parts of their liabilities have lower average costs. According to the regression results costs in the cost frontier are higher for inactive and retired members. Although higher proportions of inactive or retired members may represent inactive funds (which can be relatively more expensive to operate), the effect-sign is not intuitive and the results are inconsistent. Analysing the variation of these variables shows that the variation between pension funds is far larger than for a given pension fund over time. It is likely that part of this age distribution effect is captured by the time constant X-inefficiency estimates. We will therefore also analyse the correlation of X-efficiency with the type of pension fund member (*e.g.*, active, passive or retired) below.

5.4.2. X-efficiency of administrative costs

The average X-efficiency of pension funds for the QSF specification is 0.221. Hence, most X-inefficiency estimates are very large. In interpreting this high level we should realise 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.

X-efficiency estimates presented in Table 4 are substantially lower than those found for most other financial institutes such as banks (Mester, 1996) and mutual funds (Annaert et al., 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. X-efficiency is higher on average for pension funds with defined contribution schemes (0.218) than for those with defined benefit schemes (0.222). 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).

Figure 8 shows the average X-efficiency for different size categories. Interestingly, both the smallest and largest pension funds in terms of members have the highest X-efficiency. Pension funds that are in between (the majority of pension funds) are least X-efficient. 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.

Figure 8: Average X-efficiency for different size categories

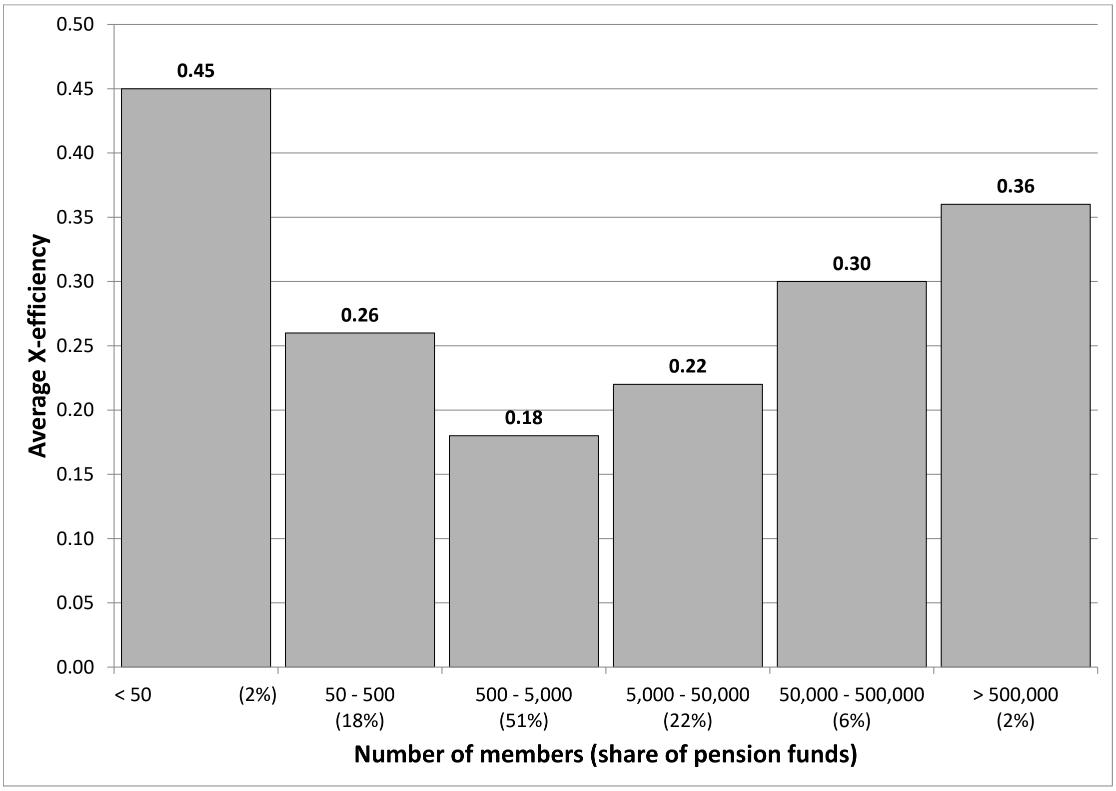


Table 5 shows regression results of various pension fund characteristics on X-efficiency estimates. As said before, characteristics that are (mostly) constant over time cannot be adequately distinguished from X-inefficiency in our model. The type of pension fund, and type of pension fund member, only change very little over time for a given pension fund, and are consequently included in the X-inefficiency estimates. Industry funds on average have higher X-efficiency estimates than professional group funds and company funds, and are therefore less expensive to operate, which may reflect the complexity of operating different types of pension funds (Bikker et al., 2012). Pension funds with higher ratios of pensioners and inactive members are on average more X-efficient. Combining these results with those in Table 4 gives mixed results, meaning that we are unable to make any strong statements about pension fund members. The number of members has both substantial within variation and between variation. So in addition to the effect of economies of scale, larger pension funds tend to be more X-efficient. These pension funds are likely to be more closely supervised, and therefore are, on average, closer to best practice performance.

5.5. Developments in inefficiency over time

Over the past two decades, pension funds faced a number of changes. The number of pension funds has decreased rapidly, and given the growing population of pension beneficiaries, the average number of members per pension fund has increased even faster as a result. Pension funds also faced changes

Table 5: Administrative costs X-efficiency explained (2002-2013)

Members (*in logarithms*)	-0.011***	(0.001)
Members^2 (*ln, mean dev.*)	0.007***	(0.000)
Industry fund (mandatory)	0.088***	(0.014)
Industry fund (non-mandatory)	0.061***	(0.017)
Company fund	0.039***	(0.011)
Professional group fund	0.043**	(0.019)
Pension plan: defined contribution	0.014**	(0.006)
Outsourcing	-0.098***	(0.008)
Reinsured	0.013***	(0.004)
Assets per member (*€million*)	-0.053***	(0.006)
% Pensioners	0.225***	(0.013)
% Inactive members	0.230***	(0.013)
Constant	0.134***	(0.015)
R^2	0.194	

Notes: Number of observations = 6,087, $\overline{lnp}$ = ln(2,316). Standard errors in parentheses, $P > |t|$ = * <0.10, ** <0.05, *** <0.01.

in regulations and new production technologies, particularly IT developments, and mass communication through the internet. This may have lowered marginal costs, and raised fixed costs, thereby pushing the optimal size to a higher level. Applying the preferred approach (SCFA) and functional form (QSF), Table 6 presents regression results for four sub-periods over the past two decades to illustrate possible changes in inefficiency over time, while Figure 9 shows the cost elasticities that follow from the regression results for a range of pension fund sizes.

The optimal break point (that corresponds with the lowest value of AIC) varies across the different sub-periods, which confirms that the shape of the cost function has changed over time. Average X-efficiency is lower (σ_u^2 higher) in the two most recent periods, which may indicate that either inefficiency or heterogeneity has increased. For the three most recent periods, the cost elasticities are somewhat similar, while the first period differs strongly, with large economies of scale for small pension funds and large diseconomies of scale for larger pension funds. We see that most coefficients of pension fund characteristics fluctuate over time, without showing a clear trend. The coefficient for outsourcing has become insignificant in the most recent period, this coincides with the introduction of the FTK in 2006, which went hand in hand with stricter data reporting requirements.

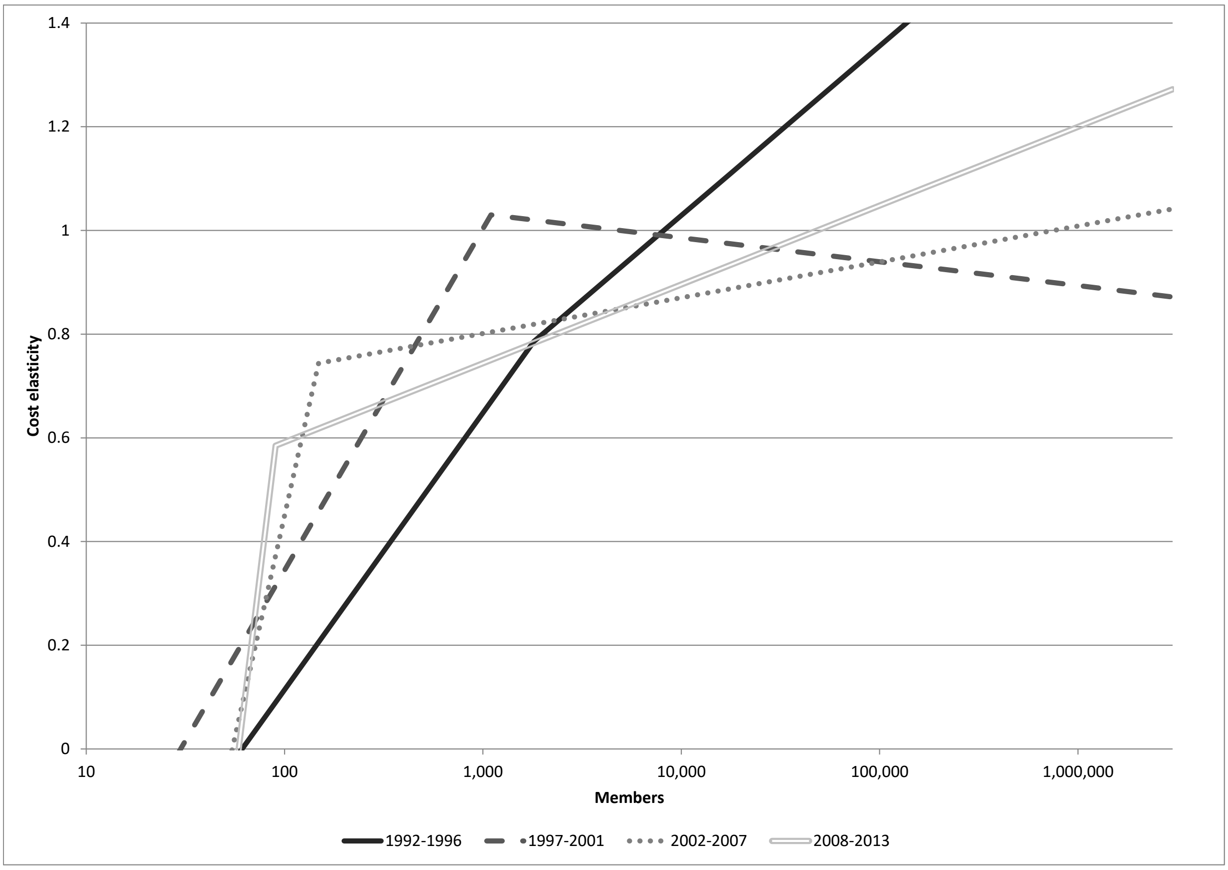
In the regressions of Table 6, X-efficiency is assumed to be constant for the sub-periods of between five and six years, instead of the 12 years for the main analysis. This less restrictive assumption results in lower X-inefficiency estimates. The correlation results in Table 6 show that X-efficiency of pension funds more or less correlates over two subsequent periods (10-12 year). However, these correlations become smaller or even negative when periods are more apart, indicating that the X-efficiency levels are on average not maintained for longer periods than 10 to 12 years.

Table 6: Administrative costs estimation for four sub-periods

Variables	(1) **1992-1996**[#]	(2) **1997-2001**	(3) **2002-2007**	(4) **2008-2013**
Break point	$lnx_1 = 7.5$	$lnx_1 = 7.0$	$lnx_1 = 5.0$	$lnx_1 = 4.5$
Members	0.786***	1.030***	0.744***	0.585***
(in logarithms)	(0.047)	(0.048)	(0.054)	(0.081)
members^2	0.116	0.143***	0.371***	0.684
(ln, x_1 dev. $\vert < x_1$)	(0.013)	(0.016)	(0.071)	(0.511)
Members^2	0.071***	-0.010	0.015*	0.033***
(ln, x_1 dev. $\vert \geq x_1$)	(0.012)	(0.013)	(0.008)	(0.010)
Outsourcing	0.493***	0.987***	0.377***	0.048
	(0.077)	(0.084)	(0.058)	(0.045)
Reinsured	0.048	-0.434***	-0.153***	-0.009
	(0.060)	(0.061)	(0.029)	(0.008)
Assets per member	1.315***	1.229***	1.178***	-0.066***
(€million)	(0.125)	(0.155)	(0.152)	(0.025)
% Pensioners	0.508***	1.275***	1.250***	1.157***
	(0.133)	(0.191)	(0.186)	(0.227)
% Inactive members	-0.075	0.372***	0.158	0.101
	(0.119)	(0.139)	(0.103)	(0.135)
Constant	-4.488***	-5.950***	-3.781***	-2.637***
	(0.334)	(0.345)	(0.333)	(0.513)
Number of observations	3,549	3,696	3,767	2,320
Number of pension funds	852	900	785	495
σ_u^2 (*inefficiency*)	8.182	6.855	9.698	11.642
	(0.459)	(0.430)	(0.620)	(0.895)
σ_v^2 (*random shocks*)	0.226	0.355	0.214	0.088
	(0.006)	(0.010)	(0.006)	(0.003)
R^2	0.753	0.634	0.650	0.695
Wald test[a]	676***	193***	121***	45***
First derivatives	0.786	1.030	0.744	0.585
$p \leq x_1$	$+2 * 0.116*$	$+2 * 0.143*$	$+2 * 0.371*$	$+2 * 0.684*$
	$(lnp - lnx_1)$	$(lnp - lnx_1)$	$(lnp - lnx_1)$	$(lnp - lnx_1)$
$p > x_1$	$+2 * 0.071*$	$-2 * 0.010*$	$+2 * 0.015*$	$+2 * 0.033*$
	$(lnp - lnx_1)$	$(lnp - lnx_1)$	$(lnp - lnx_1)$	$(lnp - lnx_1)$
Cost elasticity at $\overline{lnp}$	0.786	1.020	0.819	0.783
X-efficiency:				
Average	0.439	0.483	0.378	0.388
25th percentile	0.259	0.340	0.260	0.291
Median	0.412	0.466	0.370	0.388
75th percentile	0.604	0.617	0.483	0.478
Correlation X-efficiency:				
1992-1996	-	0.412	-0.248	-0.303
1997-2001	0.412	-	0.188	-0.315
2002-2007	-0.248	0.188	-	0.400
2008-2013	-0.303	-0.0315	0.400	-
2002-2013	-0.307	-0.015	0.883	0.732

Notes: p = number of members, $\overline{lnp} = \ln(2{,}316)$. Break points $ln\,x_1 = 4.5$, $ln\,x_1 = 5.0$, $ln\,x_1 = 7.0$ and $ln\,x_1 = 7.5$ are equal to 90, 148, 1,097 and 1,808 members respectively. [a]Wald test for Constant Returns to Scale Hypothesis: coefficient of ln(partipants) = 1 and coefficient(s) of non-linear term(s) of ln(members) = 0. Standard errors in parentheses, $P > |t|$ = * <0.10, ** <0.05, *** <0.01.

Figure 9: Cost elasticity for four sub-periods



5.6. Auditing and management costs

Administrative costs are related to activities, such as administration of members' entitlements and received premiums, communication with members, and the board of the pension fund. Pension funds in our data set were asked to report to the external supervisors a number of separate administrative cost components, among which their auditing and management costs, internal and external administration costs and wage and other staff costs.

Separate cost components may have their own X-efficiency and economies of scale levels. Table 7 presents the estimation results for two clearly defined cost components[13] Not all pension funds reported costs for these two separate components, meaning that the number of observations for these components is lower than for total administrative costs. Both auditing and management costs show unused scale economies of about four times larger at the mean size than those for total administrative costs. Both types of costs are associated with substantial fixed costs, such as the minimum size of a pension fund board and the minimum activities of external accountants, which explains the existence of substantial economies of scale. The effects on costs of other pension fund characteristics are very similar to the

[13]Other cost components, such as wage and other costs, vary widely between pension funds, which probably indicates that these cost categories do not encompass the same activities for each pension fund.

effect on total administrative costs, with outsourcing acting as a negative proxy for under-reporting and without consistent trends for the other characteristics.

Median X-efficiency estimates for these costs components are substantially higher than they are for total administrative costs. Possibly, these subcategory activities are more homogeneous. We also expect that these cost components are less affected by under-reporting, as pension funds were included in the sample only if they report these costs. Note that under-reporting concerns particularly wages and rents of premises.

Table 7: Auditing and management costs estimation (2002-2013)

	(1)		(2)	
Variables	**Auditing costs**		**Management costs**	
Break point	$lnx_1 = 5.5$		$lnx_1 = 6.0$	
Members *(in logarithms)*	0.750***	(0.042)	0.365***	(0.072)
Members^2 *(ln, x_1 dev. $\vert < x_1$)*	0.454***	(0.093)	-0.063	(0.099)
Members^2 *(ln, x_1 dev. $\vert x_1 - x_2$)*	-0.032***	(0.005)	0.020*	(0.011)
Outsourcing	-0.367***	(0.005)	0.509***	(0.093)
Reinsured	0.000	(0.014)	0.015	(0.023)
Assets per member (€million)	0.058*	(0.032)	2.917***	(0.242)
% Pensioners	1.788***	(0.119)	2.081***	(0.252)
% Inactive members	0.679***	(0.084)	0.947***	(0.1956
Constant	-2.748	(0.262)	-2.938	(0.531)
Number of observations	5,445		3,003	
Number of pension funds	739		473	
σ_u^2 *(inefficiency)*	3.685	(0.261)	4.351	(0.399)
σ_v^2 *(random shocks)*	0.300	(0.006)	0.781	(0.022)
R^2	0.637		0.708	
Wald test[a]	1,259***		375***	
First derivatives	0.750		0.365	
$p \leq x_1$	$+2 * 0.454 * (lnp - lnx_1)$		$-2 * 0.063 * (lnp - lnx_1)$	
$p > x_1$	$-2 * 0.032 * (lnp - lnx_1)$		$+2 * 0.020 * (lnp - lnx_1)$	
Cost elasticity at $\overline{lnp}$	0.542		0.435	
X-efficiency:				
Average	0.451		0.593	
25th percentile	0.277		0.379	
Median	0.410		0.657	
75th percentile	0.614		0.812	

Notes: p = number of members, $\overline{lnp}$ = ln(2,316). Break points $ln\, x_1 = 5.5$ and $ln\, x_1 = 6.0$ are equal to 235 and 403 members respectively. [a]Wald test for Constant Returns to Scale Hypothesis: coefficient of ln(partipants) = 1 and coefficient(s) of non-linear term(s) of ln(members) = 0. Standard errors in parentheses, $P > |t|$ = * <0.10, ** <0.05, *** <0.01.

6. 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 requires a different model: 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 bad, 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. Most other 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 summarised in Table 1. We followed the strategy from Section 5, first investigating parametric and non-parametric approaches, and then examining functional forms. Table 8 presents for investment costs the SCFA and LRM estimation results, similar to Table 2 for administrative costs. Table 9 presents the non-parametric estimation of investment costs: FDH and Order$-\alpha$, similar to Table 3 for administrative costs.

The estimation results for LRM and SCFA are again quite similar, with an approximately equal cost elasticity at the mean (0.988 and 0.952 respectively), and fairly equal optimal sizes (€223 and €220 million respectively). LRM can include variables that are constant over time, such as pension fund type.

For the non-parametric results, FDH X-efficiency is strongly affected by size, but is not significantly correlated with most other pension fund characteristics. Also FDH X-efficiency is again very low on average, so comparable to the administrative costs results. The results for investment costs are presumably affected by the presence of under-reporting for some pension funds, *e.g.*, for some pension funds the external asset managers have netted investment costs with investment returns. Order$-\alpha$ (with $\alpha = 95$) results in higher X-efficiency scores and more significant variables.

X-efficiency estimates are relatively robust for the selected method, with Spearman rank correlations ranging between 54% and 67%. As we did for administrative costs, we again selected 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.

6.1. Functional form of investment costs

As in the administrative costs analysis in Section 5.4, we applied TCF, (S)ULF, HACD and QSF to investment costs. The results are presented in Table 10, where the number of break points and their locations are selected by minimising AIC. Figure 10 shows the cost elasticities that follow from the five cost functions. Both the average X-efficiency that follows from the five functional forms of investment

Table 8: Results of parametric models for investment costs (2002-2013)

Variables	(1) **LRM**		(2) **SCFA**	
Total assets *(€1,000, in logarithms)*	0.988***	(0.012)	0.952***	(0.022)
Total assets^2 *(in ln, mean dev.)*	0.011***	(0.003)	0.045***	(0.005)
Industry fund (mandatory)	-0.438***	(0.107)		
Industry fund (non-mandatory)	-0.322**	(0.132)		
Company fund	-0.341***	(0.132)		
Professional group fund	0.298**	(0.146)		
Pension plan: defined contribution	0.111**	(0.051)		
Assets per member *(€million)*	-0.066	(0.099)	-0.202	(0.143)
% Pensioners	0.163	(0.111)	0.178	(0.184)
% Inactive members	0.606***	(0.114)	0.565***	(0.143)
Investments:				
Equity	0.421***	(0.135)	-0.147	(0.139)
Real estate	1.577***	(0.326)	0.730*	(0.408)
Fixed income	0.209*	(0.112)	0.264**	(0.110)
Constant	-6.916***	(0.184)	-8.361***	(0.261)
σ_u^2 *(inefficiency)*			3.042	(0.259)
σ_v^2 *(random shocks)*			0.661	(0.016)
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	
X-efficiency:				
Average			0.372	
25th percentile			0.213	
Median			0.337	
75th percentile			0.484	

Notes: ta = value of total assets. Number of observations = 4,498, number of pension funds = 646, $\overline{ln\,ta}$ = ln(€1,291 million). Standard errors in parentheses, $P > |t|$ = * <0.10, ** <0.05, *** <0.01.

and the implied cost elasticities 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 total assets, best describes investment costs. This functional form suggests that the cost elasticity of investment costs increases up to the break point, and decreases after this point (the coefficient after the breakpoint is not significantly different from zero). The majority of pension funds (55.7%) investment activities operate under implied decreasing returns to scale (cost elasticity > 1), which is markedly different from administrative activities. The coefficients of type of member and investment allocation give non-intuitive results. These variables vary between pension funds, but relatively little over time for a given pension fund. The effect of these variables is therefore difficult to distinguish from inefficiency, which is also assumed to be constant over short periods. As the combined results (of u and v) give ambiguous results, no strong conclusions can be made from them. These characteristics are analysed in the next section (X-efficiency of investment costs). The value of average assets per member does not appear to be relevant for pension fund investment costs.

Table 9: **Results of non-parametric models for investment costs (2002-2013)**

Variables	(1) **FDH**		(2) **Order**$-\alpha$, $\alpha = 95$	
X-efficiency:				
Average	0.057		0.446	
25th percentile	0.004		0.188	
Median	0.010		0.314	
75th percentile	0.034		0.689	
Total assets *(€1,000, in logarithms)*	-0.021***	(0.001)	-0.009***	(0.003)
Total assets ^{2} *(in ln, mean dev.)*	0.015***	(0.000)	0.012***	(0.001)
Industry fund (mandatory)	0.025***	(0.012)	0.171***	(0.030)
Industry fund (non-mandatory)	-0.018	(0.015)	0.102***	(0.037)
Company fund	0.022**	(0.011)	0.125***	(0.027)
Professional group fund	-0.019	(0.017)	-0.049	(0.041)
Pension plan: defined contribution	0.009	(0.006)	-0.008	(0.041)
Assets per member *(€million)*	0.009	(0.011)	0.050	(0.028)
% Pensioners	-0.003	(0.013)	0.003	(0.031)
% Inactive members	0.013	(0.013)	-0.216***	(0.032)
Investments:				
Equity	-0.005	(0.015)	-0.101***	(0.038)
Real estate	-0.056	(0.037)	-0.329***	(0.092)
Fixed income	-0.015	(0.013)	-0.119***	(0.032)
Constant	0.257***	(0.021)	0.595***	(0.052)
Adjusted R^2	0.270		0.063	

Notes: Number of observations = 4,498, number of pension funds = 646, $\overline{ln\,ta}$ = €1,291 million. Standard errors in parentheses, $P > |t|$ = * <0.10, ** <0.05, *** <0.01

The cost elasticity 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.

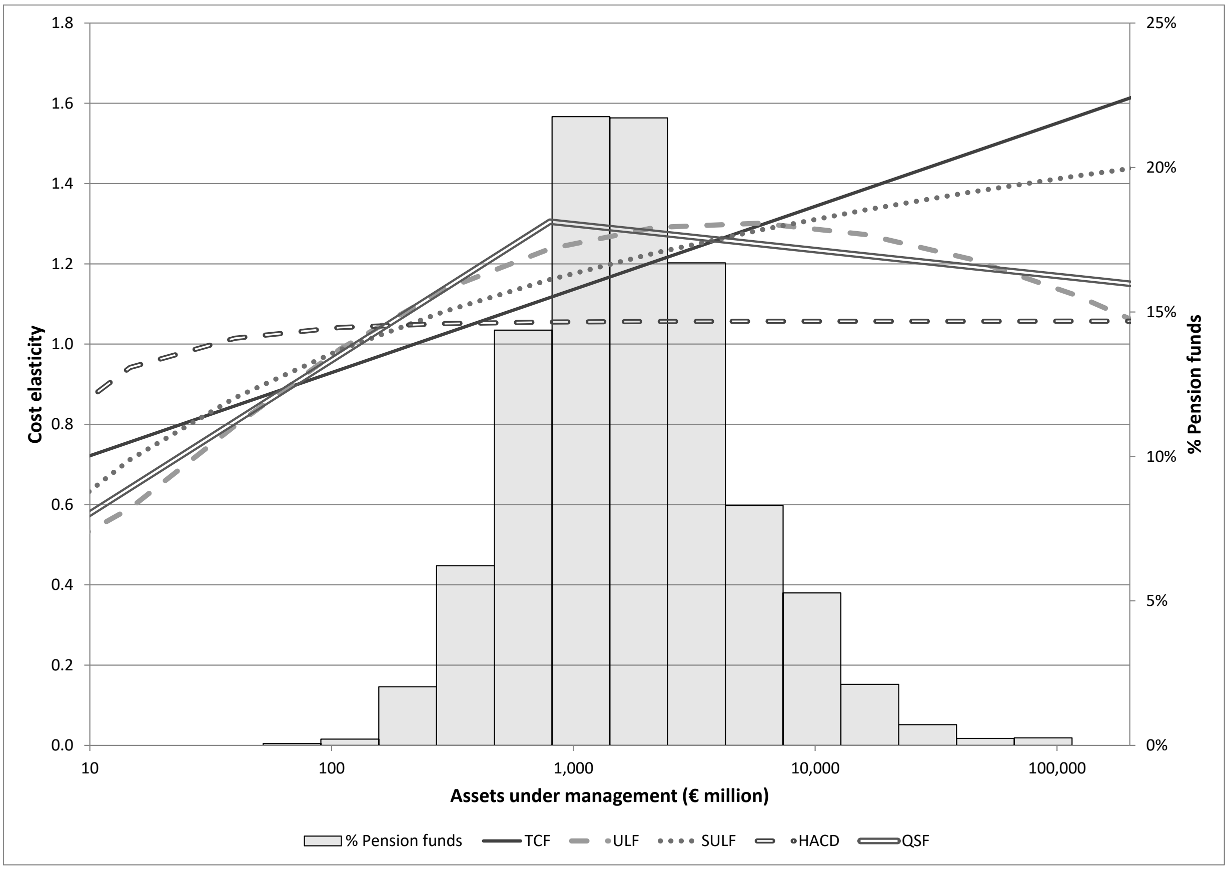
As the cost elasticity for investment costs is markedly different from that of administrative costs, pension funds may have economies of scale in administrative costs, while facing diseconomies of scale in investment costs. Section 7 analyses total costs, using both the number of members and total assets as output indicators to obtain an overall view on the optimal scale.

Table 10: Estimates of five functional forms of investment costs (2002 - 2013)

Variables	(1) TCF	(2) ULF	(3) SULF	(4) HACD	(5) QSF
Break point					$ln\, x_1 = 20.5$
Total assets	0.952***	5.466***	1.513***	1.057***	1.305***
(€1,000, in logarithms)	(0.022)	(1.433)	(0.212)	(0.025)	(0.048)
Total assets^2	0.045***	-0.151**	0.008		
(in ln, mean dev.)	(0.005)	(0.060)	(0.015)		
Total assets^2					0.083***
(ln, x_1 dev. $\| < x_1$)					(0.010)
Total assets^2					-0.014
(ln, x_1 dev. $\|x_1 - x_2$)					(0.019)
1 / (ln total assets)		1,088.582***	70.768***		
		(366.860)	(26.497)		
1 / (ln total assets)^2		-2,779.579***			
		(1,005.218)			
1 / total assets				1,688.651***	
				(310.788)	
Assets per member	-0.202	-0.200	-0.181	-0.205	-0.193
(€million)	(0.143)	(0.143)	(0.143)	(0.144)	(0.142)
% Pensioners	0.178	0.158	0.165	0.098	0.167
	(0.184)	(0.182)	(0.182)	(0.184)	(0.182)
% Inactive members	0.565***	0.559***	0.560***	0.485***	0.557***
	(0.143)	(0.142)	(0.142)	(0.142)	(0.142)
Investments:					
Equity	-0.147	-0.105	-0.135	-0.178	-0.111
	(0.139)	(0.138)	(0.139)	(0.141)	(0.138)
Real estate	0.730*	0.601	0.643	0.817**	0.583
	(0.408)	(0.412)	(0.410)	(0.407)	(0.412)
Fixed income	0.264**	0.270**	0.261**	0.233**	0.267**
	(0.110)	(0.110)	(0.110)	(0.112)	(0.110)
Constant	-8.361	-133.982	-20.975	-9.417	-12.849
	(0.261)	(40.815)	(4.739)	(0.309)	(0.623)
σ_u^2 (*inefficiency*)	3.042	2.995	2.996	2.981	2.966
	(0.259)	(0.252)	(0.255)	(0.256)	(0.251)
σ_v^2 (*random shocks*)	0.661	0.661	0.661	0.670	0.660
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
R^2	0.733	0.731	0.733	0.734	0.730
Akaike's IC	12,340	12,328	12,336	12,380	12,325
Wald test[a]	106***	97***	105***	30***	96***
First derivatives	$0.952 + 2* 0.045 (ln\, ta - \overline{ln\, ta})$	$5.466 - 2* 0.151 (ln\, ta - \overline{ln\, ta}) -1,088.582/(ln\, ta)^2 + 2* 2,779.579/(ln\, ta)^3$	$1.513 + 2* 0.008 (ln\, ta - \overline{ln\, ta}) -70.768/(ln\, ta)^2$	$1.057 - 1,688.651/ta$	$1.305 + [2* 0.083 (ln\, ta - x_1)\| ta \leq x_1] - [2* 0.014 (ln\, ta - x_1)\| ta > x_1]$
Cost elasticity at mean	0.952	1.017	1.004	1.057	1.002
X-efficiency:					
Average	0.372	0.381	0.378	0.377	0.382
25th percentile	0.213	0.214	0.211	0.216	0.217
Median	0.337	0.339	0.341	0.343	0.341
75th percentile	0.484	0.504	0.496	0.494	0.509

Notes: ta = value of total assets. Number of observations = 4,498, number of pension funds = 646, $\overline{ln\, ta}$ = ln(€1,291 million). Break point $lnx_1 = 20.5$ 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. Standard errors in parentheses. $P > |t|$ = * <0.10, ** <0.05, *** <0.01

Figure 10: Cost elasticity for five investment cost functions (2002-2013)



6.1.1. X-efficiency of investment costs

Table 11 below shows a regression analysis explaining X-inefficiency output from the QSF estimation. The type of pension fund, which could not be included in the cost function, shows that industry funds are more X-efficient while professional group funds are least efficient. Average X-efficiency is 0.341, which is higher than that for administrative costs (0.221). This indicates that investment costs are more level between pension funds than administrative costs.

7. 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 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; $ln\, x_{1,p}$) and total assets (€800 million; $ln\, x_{1,ta}$) obtained in the previous sections. In order to allow for possible output interaction

Table 11: Investments X-efficiency explained (2002-2013)

Total assets *(€1,000, in logarithms)*	-0.008***	(0.002)
Total assets^2 *(in ln, mean dev.)*	0.009***	(0.001)
Industry fund (mandatory)	0.164***	(0.019)
Industry fund (non-mandatory)	0.114***	(0.024)
Company fund	0.134***	(0.017)
Professional group fund	0.034	(0.027)
Pension plan: defined contribution	-0.026***	(0.009)
Assets per member *(€million)*	-0.055***	(0.018)
% Pensioners	0.097***	(0.020)
% Inactive members	0.055***	(0.021)
Investments:		
Equities	-0.058**	(0.025)
Real estate	-0.022	(0.059)
Fixed income	0.008	(0.020)
Constant	0.293***	(0.033)
R^2	0.091	

Notes: Number of observations = 4,498, $\overline{ln\, ta}$ = ln(€1,291 million). Standard errors in parentheses, $P > |t|$ = * <0.10, ** <0.05, *** <0.01.

effects we included an additional variable:

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

Table 12 shows the resulting coefficients for the quadratic spline function 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 cost elasticity at the average number of members (2.136) and for average total assets (€129 million) is 0.990, which indicates approximate constant returns to scale (not significantly different from 1). Average X-efficiency is 0.475 which indicates that the deviation in performance is smaller for total costs than for its two components (0.221 for administrative costs and 0.382 for investment costs).

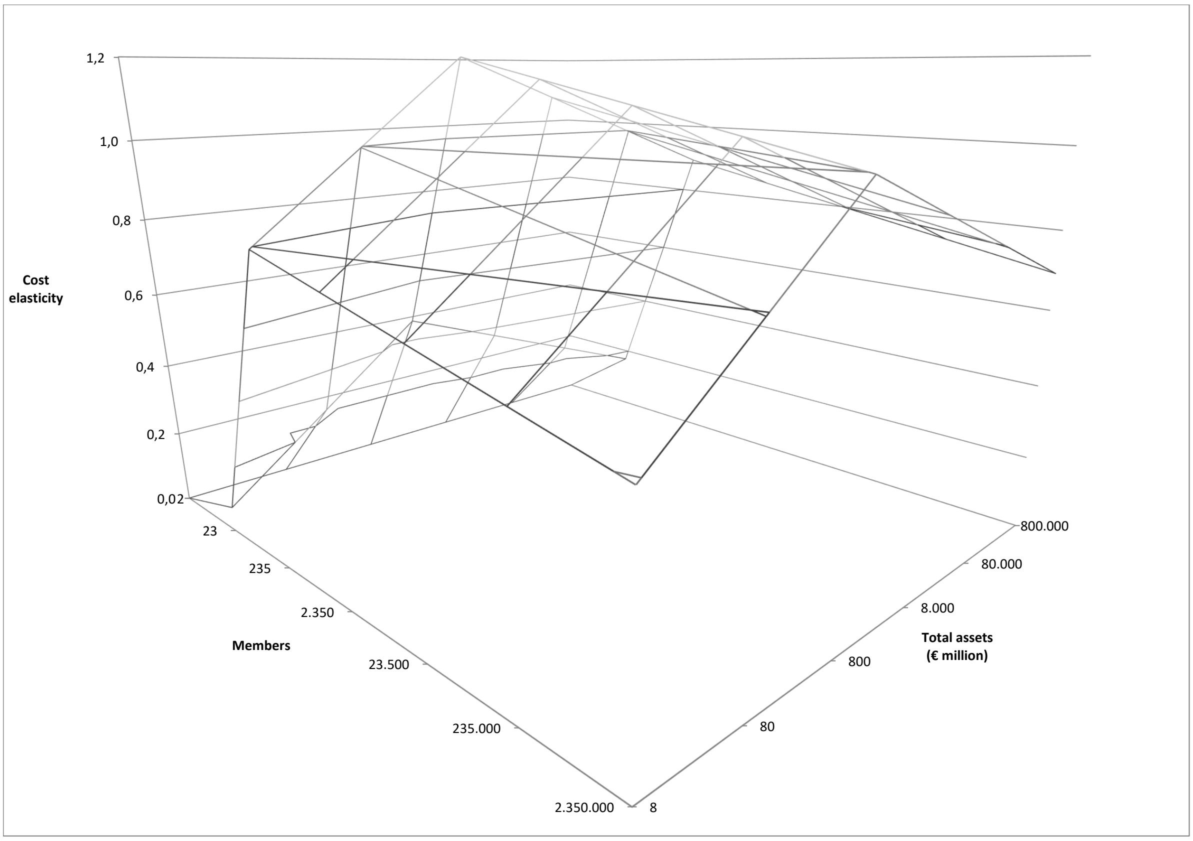
Figure 11 shows a 3D graph of cost elasticity dependent on the number of members (Z axis) and total assets (X axis). Cost elasticity depends most strongly on the number of members and shows strong economies of scale for pension funds with a number of members or total assets up to the breaking points. After the breaking points cost elasticity is close to 1, indicating that there are few benefits to further increases in size.

Table 12: **Total costs quadratic spline estimation (2002-2013)**

Variables	**SCFA**	
	$ln\, x_{1,p} = 5.5$	$ln\, x_{1,ta} = 20.5$
Members *(in logarithms)*	0.134*	(0.073)
Members^2 *(ln, $x_{1,p}$ dev. $\mid \leq x_{1,p}$)*	0.189***	(0.042)
Members^2 *(ln, $x_{1,p}$ dev. $\mid > x_{1,p}$)*	0.020**	(0.009)
Total assets *(€1,000, in logarithms)*	1.066***	(0.063)
Total assets^2 *(ln, $x_{1,ta}$ dev. $\mid \leq x_{1,ta}$)*	0.075***	(0.009)
Total assets^2 *(ln, $x_{1,ta}$ dev. $\mid > x_{1,ta}$)*	0.009	(0.017)
Interaction members x total assets *(ln, x_1 dev.)*	-0.062***	(0.012)
Outsourcing	0.307***	(0.034)
Reinsured	-0.014	(0.010)
% Pensioners	0.690***	(0.121)
% Inactive members	0.180**	(0.072)
Investments:		
Equities	-0.385***	(0.069)
Real estate	0.264	(0.182)
Fixed income	0.180***	(0.055)
Constant	-9.382***	(0.590)
σ_u^2 (*inefficiency*)	1.955***	(0.164)
σ_v^2 (*random shocks*)	0.132***	(0.003)
R^2	0.769	
Wald test[a]	5,007***	
First derivative	$1.200 + 2*0.189*(ln\, p - ln\, x_{1,p} \mid p \leq x_{1,p})+$ $2*0.020*(ln\, p - ln\, x_{1,p} \mid p > x_{1,p})+$ $2*0.075*(ln\, ta - ln\, x_{1,ta} \mid ta \leq x_{1,p})+$ $2*0.009*(ln\, ta - ln\, x_{1,ta} \mid ta > x_{1,p})-$ $0.062*(ln\, p - ln\, x_{1,p}) - 0.062*$ $(ln\, ta - ln\, x_{1,ta})$	
Cost elasticity at $\overline{ln\, p}$ and $\overline{ln\, ta}$	0.990	
X-efficiency:		
Average	0.475	
25th percentile	0.334	
Median	0.465	
75th percentile	0.612	

Notes: p = number of members, ta = value of total assets. Number of observations = 4,498, number of pension funds = 646, $\overline{lnp}$ = ln(2,316), $\overline{ln\, ta}$ = ln(€1,291 million). Break points $ln\, x_{1,p} = 5.5$ and $ln\, x_{1,ta} = 20.5$ 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. Standard errors in parentheses, $P > |t|$ = * <0.10, ** <0.05, *** <0.01.

Figure 11: 3D graph of cost elasticity for total costs



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

7.1. Total costs X-efficiency

Table 13 explains total costs X-efficiency by pension fund characteristics, which allows us to include pension fund type dummies and pension scheme dummies, which could not be estimated in the prior analysis. Mandatory industry pension funds and company pension funds are relatively X-efficient in terms of total costs, while professional group pension funds are again least efficient. Defined contribution plans are significantly less efficient (more costly) than defined benefit plans. The effect of size (in terms of number of members and value of total assets) follows a very flat inverse U-shaped relation. Initially, larger pension funds are more X-efficient, but later on (dependent on the interplay between the number of members and total assets) size decreases average X-efficiency again. For the other characteristics we found similar coefficients as for the administrative and investment costs models.

Table 13: Total costs X-efficiency explained (2002-2013)

Members (in logarithms)	0.061***	(0.012)
Members^2 (ln, x_1 dev. $\mid < x_1$)	0.020***	(0.005)
Members^2 (ln, x_1 dev. $\mid x_1 - x_2$)	-0.001	(0.001)
Total assets (€1,000, in logarithms)	0.015	(0.013)
Total assets^2 (ln, x_1 dev. $\mid < x_1$)	0.007***	(0.002)
Total assets^2 (ln, x_1 dev. $\mid x_1 - x_2$)	-0.023***	(0.002)
Interaction members x total assets *(ln, x_1 dev.)*	0.007***	(0.002)
Industry fund (mandatory)	0.081***	(0.017)
Industry fund (non-mandatory)	0.046**	(0.020)
Company fund	0.088***	(0.014)
Professional group fund	0.042*	(0.022)
Pension plan: defined contribution	-0.036***	(0.008)
Outsourcing	-0.026***	(0.010)
Reinsured	0.012***	(0.004)
% Pensioners	0.347***	(0.017)
% Inactive members	0.105***	(0.018)
Investments		
Equities	0.014	(0.020)
Real estate	0.244***	(0.049)
Fixed income	0.039**	(0.017)
Constant	-0.430***	(0.101)
R^2	0.323	

Notes: Number of observations = 4,494, $\overline{lnp}$ = ln(2,316), $\overline{ln\,ta}$ = ln(€1,291 million). Standard errors in parentheses, $P > |t|$ = * <0.10, ** <0.05, *** <0.01.

8. 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 reinsurance of pension rights. 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 administrative costs we found a cost elasticity of below 1 for the vast majority of pension fund sizes, indicating economies of scale on administrative costs. Only 11 pension funds (118 observations) are above the implied optimal size of 52,650 members. We found that industry funds are the most efficiency and professional group funds are the least efficient. Higher levels of outsourcing and reinsurance correlate with higher and lower costs, respectively. 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.

Auditing and governance costs, two components of administrative costs, have larger unused scale efficiencies, and lower average X-inefficiencies. They have large fixed costs components and therefore benefit more strongly from scale increases. From the perspective of administrative costs, pension funds would benefit from consolidation.

For investments costs we found substantially higher cost elasticities. This implies that the majority of pension funds (pension funds with total assets below €127 million) have disecononomies 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 be a bad situation. The same as for administrative costs industry funds have the lowest investment costs, and professional group funds the highest.

As administrative and investment costs have different economies of scale estimates we also analysed their sum: total costs. We found a cost elasticity 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 efficiency remain, however.

References

Akaike, H. (1974). A new look at the statistical model identification. *IEEE transactions on automatic control 19*(6), 716–723.

Annaert, J., J. Van Den Broeck, and R. Vander Vennet (2003). Determinants of mutual fund underperformance: a bayesian stochastic frontier approach. *European Journal of Operational Research 151*(3), 617–632.

Aragon, Y., A. Daouia, and C. Thomas-Agnan (2005). Nonparametric frontier estimation: a conditional quantile-based approach. *Econometric Theory 21*(02), 358–389.

Benartzi, S. and R. H. Thaler (1995). Myopic loss aversion and the equity premium puzzle. *The Quarterly Journal of Economics 110*(1), 73–92.

Benartzi, S. and R. H. Thaler (2013). Behavioral economics and the retirement savings crisis. *Science 339*, 1152–1153.

Beshears, J., J. J. Choi, D. Laibson, and B. C. Madrian (2008). How are preferences revealed? *Journal of Public Economics 92*(8), 1787–1794.

Bikker, J. A. (2017). Is there an optimal pension fund size? a scale-economy analysis of administrative costs. *Journal of Risk and Insurance Forthcoming.*

Bikker, J. A. and J. De Dreu (2009). Operating costs of pension funds: the impact of scale, governance, and plan design. *Journal of Pension Economics & Finance 8*(1), 63.

Bikker, J. A., L. Spierdijk, and P. J. Van Der Sluis (2007). Market impact costs of institutional equity trades. *Journal of International Money and Finance 26*(6), 974–1000.

Bikker, J. A., O. W. Steenbeek, and F. Torracchi (2012). The impact of scale, complexity, and service quality on the administrative costs of pension funds: A cross-country comparison. *Journal of Risk and Insurance 79*(2), 477–514.

Bishop, P. and S. Brand (2003). The efficiency of museums: a stochastic frontier production function approach. *Applied Economics 35*(17), 1853–1858.

Bovenberg, L. and R. Mehlkopf (2014). Optimal design of funded pension schemes. *Annual Review of Economics 6*, 445–474.

Bruil, A., C. Schmitz, J. Gebraad, and R. Bhageloe-Datadin (2015). Totale pensioenaanspraken van nederland in beeld. Technical report, Centraal Bureau voor de Statistiek.

Cazals, C., J.-P. Florens, and L. Simar (2002). Nonparametric frontier estimation: a robust approach. *Journal of econometrics 106*(1), 1–25.

Charnes, A., W. W. Cooper, and E. Rhodes (1978). Measuring the efficiency of decision making units. *European journal of operational research 2*(6), 429–444.

Chen, J., H. Hong, M. Huang, and J. D. Kubik (2004). Does fund size erode mutual fund performance? the role of liquidity and organization. *The American Economic Review 94*(5), 1276–1302.

Coelli, T. (1996). A guide to deap version 2.1: A data envelopment analysis (computer) program. *Center for Efficiency and Productivity Analysis. University of New England 96*(08), 1–50.

Cummins, J. D. and M. A. Weiss (2013). Analyzing firm performance in the insurance industry using frontier efficiency and productivity methods. In *Handbook of insurance*, pp. 795–861. Springer.

De Borger, B. and K. Kerstens (1996). Cost efficiency of belgian local governments: A comparative analysis of fdh, dea, and econometric approaches. *Regional Science and Urban Economics 26*(2), 145–170.

Diewert, W. E. and T. J. Wales (1992). Quadratic spline models for producer's supply and demand functions. *International Economic Review 33*(3), 705–722.

DNB (2015a). Tabel 11.1 vermogenscomponenten van nederlandse huishoudens. accessed July 22, 2015, http://www.dnb.nl/statistiek/statistieken-dnb/huishoudens/index.jsp.

DNB (2015b). Tabel 8.17 onder toezicht staande pensioenfondsen. accessed July 22, 2015, http://www.statistics.dnb.nl/financieele-instellingen/pensioenfondsen/register/index.jsp.

Dyck, A. and L. Pomorski (2011). Is bigger better? size and performance in pension plan management. *Rotman School of Management Working Paper*, 1–36.

Färe, R., S. Grosskopf, and C. K. Lovell (1985). *The Measurement of Efficiency of Production*, Volume 6. Springer Science & Business Media.

Favero, C. A. and L. Papi (1995). Technical efficiency and scale efficiency in the italian banking sector: a non-parametric approach. *Applied economics 27*(4), 385–395.

Fenn, P., D. Vencappa, S. Diacon, P. Klumpes, and C. OBrien (2008). Market structure and the efficiency of european insurance companies: A stochastic frontier analysis. *Journal of Banking & Finance 32*(1), 86–100.

Gollier, C. (2008). Intergenerational risk-sharing and risk-taking of a pension fund. *Journal of Public Economics 92*(5), 1463–1485.

Greene, W. H. (2008). *The econometric approach to efficiency analysis.* Oxford University Press New York, NY.

Hardwick, P. (1997). Measuring cost inefficiency in the uk life insurance industry. *Applied Financial Economics 7*(1), 37–44.

Iyengar, S. S. and E. Kamenica (2006). Choice overload and simplicity seeking. *University of Chicago Graduate School of Business Working Paper 87.*

Latruffe, L., K. Balcombe, S. Davidova, and K. Zawalinska (2004). Determinants of technical efficiency of crop and livestock farms in poland. *Applied economics 36*(12), 1255–1263.

Lee, C. and Y.-b. Ji (2009). Data envelopment analysis in stata.

Leibenstein, H. (1966). Allocative efficiency vs." x-efficiency". *The American Economic Review 56*(3), 392–415.

Mester, L. J. (1996). A study of bank efficiency taking into account risk-preferences. *Journal of Banking & Finance 20*(6), 1025–1045.

Niskanen, W. A. (1974). *Bureaucracy and representative government.* Transaction Publishers.

Pitt, M. M. and L.-F. Lee (1981). The measurement and sources of technical inefficiency in the indonesian weaving industry. *Journal of development economics 9*(1), 43–64.

Seiford, L. M. and R. M. Thrall (1990). Recent developments in dea: the mathematical programming approach to frontier analysis. *Journal of econometrics 46*(1), 7–38.

Shaffer, S. (1998). Functional forms and declining average costs. *Journal of Financial Services Research 14*(2), 91–115.

Tauchmann, H. (2012). Partial frontier efficiency analysis. *Stata Journal 12*(3), 461–478.

Tirole, J. (1988). *The theory of industrial organization*. MIT press.

Van Rooij, M. C., A. Lusardi, and R. J. Alessie (2011). Financial literacy and retirement planning in the Netherlands. *Journal of Economic Psychology 32*(4), 593–608.

1. Appendix, quadratic spline cost functions

This appendix briefly discusses the functional forms and empirical results of the quadratic spline functions (QSF) with one, two and three break-poins.

1.1. Functional forms

1.1.1. Single spline

The single quadratic spline cost function has a spline at x_1. This gives the following cost function:

$$lnAC(o) = \alpha + \beta_1(ln\,o) + \beta_2[(ln\,o - ln\,x_1)^2|_{o\leq x_1}] + \beta_3[(ln\,o - ln\,x_1)^2|_{o>x_1}] \\ + \beta_4(plan\,characteristics) \quad (6)$$

The first derivative (cost elasticity) with respect to o gives:

$$= \beta_1 + [2\beta_2(ln\,o - ln\,x_1)|_{o\leq x_1}] + [2 * \beta_3[((ln\,o - ln\,x_1)|_{o>x_1}] \quad (7)$$

1.1.2. Double spline

For the double quadratic spline cost function a constraint is necessary to prevent the cost elasticity from being discontinuous in x_2.

$$\triangleright With \quad \beta_2 = (\beta_4 - \beta_5) * (ln\,x_2 - ln\,x_1) * 2 \\ lnAC(o) = \alpha + \beta_1(ln\,o) + \beta_2(ln\,o|_{o>x_2}) + \beta_3[(ln\,o - ln\,x_1)^2|_{o<x_1}] + \\ \beta_4[(ln\,o - ln\,x_1)^2|_{x_1<o<x_2}] + \beta_5[(ln\,o - ln\,x_1)^2|_{x_2>o}] + \beta_6(plan\,characteristics) \quad (8)$$

This equals:

$$lnAC(o) = \alpha + \beta_1(ln\,o) + \beta_2[(ln\,o - ln\,x_1)^2|_{o\leq x_1}] + \beta_3[(ln\,o - ln\,x_1)^2|_{x_1<o\leq x_2}] + \\ [2(\beta_3 - \beta_4)(ln\,x_2 - ln\,x_1)](ln\,o|_{o>x_2}) + \beta_4[(ln\,o - ln\,x_1)^2|_{x_2>o}] + \beta_5(plan\,characteristics) \quad (9)$$

And gives the first derivative:

$$= \beta_1 + 2\beta_2[(ln\,o - ln\,x_1)|_{o\leq x_1}] + 2\beta_3[(ln\,o - ln\,x_1)|_{x_1<o\leq x_2}] + \\ [2(\beta_3 - \beta_4)(ln\,x_2 - ln\,x_1)|_{o>x_2}] + 2\beta_4[(ln\,o - ln\,x_1)|_{x_2>o}]) \quad (10)$$

1.1.3. Triple spline

Finally, two constraints are necessary to prevent points of discontinuity in the triple quadratic spline function in x_2 and x_3 respectively.

$$
\begin{aligned}
&\triangleright With \quad \beta_2 = (\beta_5 - \beta_6) * (ln\, x_2 - ln\, x_1) * 2, \quad and \\
&\triangleright With \quad \beta_3 = \beta_2 + (\beta_6 - \beta_7) * (ln\, x_3 - ln\, x_1) * 2 \\
&lnAC(o) = \alpha + \beta_1(ln\, o) + \beta_2(ln\, o|_{x_2<o<x_3}) + \beta_3(ln\, o|_{o>x_3}) + \beta_4[(ln\, o - ln\, x_1)^2|_{o<x_1}] + \\
&\quad \beta_5[(ln\, o - ln\, x_1)^2|_{x_1<o<x_2}] + \beta_6[(ln\, o - ln\, x_1)^2|_{x_2<o<x_3}] + \beta_7[(ln\, o - ln\, x_1)^2|_{x_3>o}] + \\
&\quad \beta_8(plan\, characteristics)
\end{aligned}
\tag{11}
$$

Rearranging this gives:

$$
\begin{aligned}
&lnAC(o) = \alpha + \beta_1(ln\, o) + \beta_2[(ln\, o - ln\, x_1)^2|_{o\leq x_1}] + \beta_3[(ln\, o - ln\, x_1)^2|_{x_1<o\leq x_2}] + \\
&\quad [2(\beta_3 - \beta_4)(ln\, x_2 - ln\, x_1)](ln\, o|_{x_2<o\leq x_3}) + \beta_4[(ln\, o - ln\, x_1)^2|_{x_2<o\leq x_3}] + \\
.\ &\quad [2(\beta_3 - \beta_4)(ln\, x_2 - ln\, x_1) + 2(\beta_4 - \beta_5)(ln\, x_3 - ln\, x_1)](ln\, o|_{o>x_3}) + \beta_5[(ln\, o - ln\, x_1)^2|_{x_3>o}] + \\
&\quad \beta_6(plan\, characteristics)
\end{aligned}
\tag{12}
$$

And the first derivative is:

$$
\begin{aligned}
&= \beta_1 + 2\beta_2[(ln\, o - ln\, x_1)|_{o\leq x_1}] + 2\beta_3[(ln\, o - ln\, x_1)|_{x_1<o\leq x_2}] + \\
&\quad [2(\beta_3 - \beta_4)(ln\, x_2 - ln\, x_1)|_{x_2<o\leq x_3}] + 2\beta_4[(ln\, o - ln\, x_1)|_{x_2<o\leq x_3}] + \\
&\quad [2(\beta_3 - \beta_4)(ln\, x_2 - ln\, x_1) + 2(\beta_4 - \beta_5)(ln\, x_3 - ln\, x_1)|_{o>x_3}] + 2\beta_5[(ln\, o - ln\, x_1)|_{x_3>o}]
\end{aligned}
\tag{13}
$$

1.2. Empirical results

1.2.1. Administrative costs QSF results

Table 14 shows the regression results for administrative costs of the TCF and three QSF with 1, 2 and 3 break points respectively. The QSF with a single break point at $lnx_1 = 5.5$ (235 members) has the best model fit (lowest AIC).

1.2.2. Investment costs QSF results

Table 15 shows the regression results for administrative costs of the TCF and three QSF with 1, 2 and 3 break points respectively. The QSF with a single break point at $lnx_1 = 5.5$ (€800 million total assets) has the best model fit (lowest AIC).

Table 14: Quadratic spline administrative cost functions (2002 - 2013)

	(1)	(2)	(3)	(4)
Variables	**TCF**	**Single spline**	**Double spline**	**Triple spline**
Break point(s)	no spline	$lnx_1 = 5.5$	$lnx_1 = 5.5$	$lnx_1 = 5.5$
			$lnx_2 = 8.0$	$lnx_2 = 8.0$
				$lnx_3 = 9.5$
Members	0.657***	0.816***	0.852***	0.843***
(in logarithms)	(0.034)	(0.042)	(0.043)	(0.043)
Members ($\| x_2 - x_3$)			-0.023***	-0.023***
			(0.007)	(0.007)
Members ($\| > x_3$)				-0.006
				(0.011)
Members^2	0.034***	0.340***	0.360***	0.355***
(ln, x_1 dev. $\| < x_1$)	(0.006)	(0.041)	(0.041)	(0.042)
Members^2		0.012*	0.009	0.008**
(ln, x_1 dev. $\|x_1 - x_2$)		(0.007)	(0.007)	(0.007)
Members^2			0.013**	0.012***
(ln, x_1 dev. $\|x_2 - x_3$)			(0.006)	(0.007)
Members^2				0.010**
(ln, x_1 dev. $\| > x_3$)				(0.007)
Outsourcing	0.270***	0.270***	0.269***	0.269***
	(0.037)	(0.037)	(0.037)	(0.037)
Reinsured	-0.034***	-0.035***	-0.035***	-0.035***
	(0.012)	(0.012)	(0.012)	(0.012)
Assets per member	0.062**	0.048*	0.049*	0.048*
(€million)	(0.029)	(0.029)	(0.029)	(0.029)
% Pensioners	1.665***	1.727***	1.715***	1.717***
	(0.129)	(0.127)	(0.127)	(0.127)
% Inactive members	0.440***	0.441***	0.430***	0.437***
	(0.076)	(0.076)	(0.076)	(0.076)
Constant	-3.093***	-4.116***	-4.329***	-4.277***
	(0.222)	(0.269)	(0.276)	(0.278)
σ_u^2 (*inefficiency*)	10.501	10.056	10.104	10.142
	(0.624)	(0.599)	(0.600)	(0.604)
σ_v^2 (*random shocks*)	0.234	0.234	0.233	0.233
	(0.005)	(0.005)	(0.005)	(0.005)
R^2	0.660	0.654	0.654	0.653
Akaike's IC	11,921	11,881	11,873	11,871
First derivatives:	0.657..	0.816..	0.852..	0.834..
$p \leq x_1$	$+2 * 0.034$	$+2 * 0.340$	$+2 * 0.360$	$+2 * 0.355$
	$*(lnp - lnx_1)$	$*(lnp - lnx_1)$	$*(lnp - lnx_1)$	$*(lnp - lnx_1)$
$x_1 < p \leq x_2)$	id.	$+2 * 0.012$	$+2 * 0.009$	$+2 * 0.008$
		$*(lnp - lnx_1)$	$*(lnp - lnx_1)$	$*(lnp - lnx_1)$
$x_2 < p \leq x_3)$	id.	id.	$-0.023 + 2 * 0.013$	$-0.023 + 2 * 0.012$
			$*(lnp - lnx_1)$	$*(lnp - lnx_1)$
			-0.023	-0.023
$p > x_3$	id.	id.	id.	$-0.006 + 2 * 0.010$
				$*(lnp - lnx_1)$
				-0.006
Cost elasticity at mean	0.810	0.870	0.892	0.879

Notes: p = members. Number of observations = 6,087, number of pension funds = 799, $\overline{lnp} = \ln(2{,}316)$. Break points $ln\, x_1 = 5.5$, $ln\, x_2 = 8.0$, and $ln\, x_3 = 9.5$, are equal to 235, 2,981 and 13,360 members respectively. Standard errors in parentheses, $P > |t|$ = * <0.10, ** <0.05, *** <0.01.

Table 15: Quadratic spline investment cost functions (2002 - 2013)

Variables	(1) **No spline** =TCF	(2) **Single spline** $lnx_1 = 20.5$	(3) **Double spline** $lnx_1 = 20.5$ $lnx_2 = 21.5$	(4) **Triple spline** $lnx_1 = 20.5$ $lnx_2 = 21.5$ $lnx_3 = 22.5$
Total assets	1.117***	1.305***	1.324***	1.312***
($1,000, in logarithms)	(0.018)	(0.048)	(0.053)	(0.055)
Total assets ($\|x_2 - x_3$)			-0.007	-0.007
			(0.009)	(0.009)
Total assets ($\| > x_3$)				0.031***
				(0.011)
Total assets^2	0.045***	0.083***	0.086***	0.084***
(ln, x_1 dev. $\| < x_1$)	(0.005)	(0.010)	(0.011)	(0.011)
Total assets^2		-0.014	-0.008	-0.035
(ln, x_1 dev. $\|x_1 - x_2$)		(0.019)	(0.009)	(0.023)
Total assets^2			-0.004	-0.031
(ln, x_1 dev. $\|x_2 - x_3$)			(0.009)	(0.024)
Total assets^2				-0.041*
(ln, x_1 dev. $\| > x_3$)				(0.024)
Assets per member	-0.202	-0.193	-0.193	-0.207
(€million)	(0.143)	(0.142)	(0.142)	(0.141)
% Pensioners	0.178	0.167	0.162	0.146
	(0.184)	(0.182)	(0.182)	(0.182)
% Inactive members	0.565***	0.557***	0.556***	0.550***
	(0.143)	(0.142)	(0.142)	(0.141)
Investments				
Equities (%)	-0.147	-0.111	-0.111	-0.107
	(0.139)	(0.138)	(0.138)	(0.138)
Real estate (%)	0.730*	0.583	0.584	0.594
	(0.408)	(0.412)	(0.411)	(0.411)
Fixed income (%)	0.264**	0.267**	0.266**	0.262**
	(0.110)	(0.110)	(0.110)	(0.110)
Constant	-10.459***	-12.849***	-13.084***	-12.927***
	(0.264)	(0.623)	(0.685)	(0.700)
Sigma u^2	3.042	2.966	2.948	2.952
	(0.259)	(0.251)	(0.250)	(0.250)
Sigma v^2	0.661	0.660	0.661	0.660
	(0.016)	(0.016)	(0.016)	(0.016)
R-squared	0.733	0.730	0.730	0.729
Akaike's IC	12,340	12,325	12,326	12,321
First derivatives:	1.117..	1.305..	1.324..	1.312..
$ta \leq x_1$	$+2 * 0.045$ $*(lnta - lnx_1)$	$+2 * 0.083$ $*(lnta - lnx_1)$	$+2 * 0.086$ $*(lnta - lnx_1)$	$+2 * 0.084$ $*(lnta - lnx_1)$
$x_1 < ta \leq x_2)$	id.	$-2 * 0.0014$ $*(lnta - lnx_1)$	$-2 * 0.008$ $*(lnta - lnx_1)$	$-2 * 0.035$ $*(lnta - lnx_1)$
$x_2 < ta \leq x_3)$	id.	id.	$-2 * 0.004$ $*(lnta - lnx_1)$ -0.007	$-2 * 0.031$ $*(lnta - lnx_1)$ -0.007
$ta > x_3$	id.	id.	id.	$-2 * 0.041$ $*(lnta - lnx_1)$ $+0.031$
Cost elasticity at mean	0.953	1.002	1.010	1.006

Notes: ta = total assets. Number of observations = 4,498, number of pension funds = 646, $\overline{ln\,ta}$ = €1,291 million. Break point $lnx_1 = 20.5$, $lnx_1 = 21.5$ and $lnx_1 = 22.5$ are at €800, €2,217 and €5,911 million total assets respectively. Standard errors in parentheses, $P > |t|$ = * <0.10, ** <0.05, *** <0.01