Longevity assumptions and defined benefit pension plans*

Michael Kisser[†], John Kiff[‡], Erik Oppers[‡], Mauricio Soto[†]

December 31, 2013

Abstract

This paper investigates the relation between life expectancy assumptions and pension liabilities for a large sample of U.S. corporate defined benefit pension plans. We show that longevity assumptions are systematically related to the lagged funding status of a pension plan: underfunded plans make lower life expectancy assumptions. Cross-sectional analysis further reveals that each year of life expectancy increases pension liabilities by around 4-5 percent. The economic magnitude is substantial: a one-year shock to longevity would more than double the degree of aggregate pension underfunding. Forecasts of future life expectancy typically underestimate realized improvements, thereby increasing chances of lumpy adjustments to pension liabilities.

JEL Classification: G23; G39; J1; J32

*The views expressed herein are those of the authors and should not be attributed to the IMF, its Executive Board, or its management. We thank Laura Kodres, Benedict Clements, Frank Eich and Gregorio Impavido for valuable feedback. Also, we are grateful to David Gustafson and Steven Boyce of the Pension Benefit Guarantee Corporation. Finally, we are grateful to seminar participants at the European Finance Association, Southern Finance Association, the Swiss Finance Institute, the Vienna Graduate School of Finance, Norwegian School of Economics and the 8th Longevity Risk Conference. A previous version of the paper has been circulated under the title: The impact of longevity improvements on U.S. Corporate Defined Benefit Pension Plans. Please address all correspondence to michael.kisser@nhh.no.

[†]Norwegian School of Economics

[‡]International Monetary Fund

1 Introduction

Longevity risk is the risk that, on average, people live longer than expected. From a human point of view, lower realized mortality rates constitute positive news. However, for pension systems and defined benefit (DB) pension plans this is not necessarily the case: higher life expectancy increases future pension costs as benefits have to be provided over a longer period. At the same time, pension plans have a certain leeway with respect to the mortality assumptions underlying their pension cost computation. From a policy perspective, it is an important question whether the variation in life expectancy assumptions across plans also reflects financial risk characteristics of the pension plan or the plan sponsor.

The objective of this paper is to investigate the relation between life expectancy assumptions and pension liabilities. We focus on a large sample of pension plans provided by the U.S. Department of Labor (DOL), specifically on the Form 5500 data, which contain detailed information on various actuarial assumptions, including the mortality table used in the computation of a plan's pension liabilities. First, we investigate whether life expectancy assumptions are related to characteristics of the pension plan. Second, we estimate the impact of life expectancy assumptions on pension liabilities.

Life expectancy assumptions are systematically related to financial risk measures of the pension plan. Specifically, we find a positive relation between the (lagged) funding status of the pension plan and life expectancy assumptions. Put differently, better funded plans on average make more conservative (i.e. higher) life expectancy assumptions. When further allowing life expectancy assumptions to respond differently to overfunded (underfunded) plans, we find that this effect is mostly driven by plans with a funding deficit: underfunded plans make substantially *lower* life expectancy assumptions.

Life expectancy assumptions are also related to risk measures of the plan sponsor. Merging our sample of Form 5500 pension plans with firm-level data obtained from Compustat, our findings show that longevity assumptions are negatively related to measures of financial risk and growth opportunities whereas size and the sponsor's dividend yield have a positive effect. Put differently, plan sponsors with higher leverage ratios or more growth opportunities are more likely to bias life expectancy assumptions downward. Taken together, the results suggest that sponsors of not so well funded plans may be making inadequate life expectancy assumptions to artificially reduce their actuarial liabilities, clearly not in the best interests of pensioners and the Pension Benefit Guaranty Corporation (PBGC). [1]

These findings are new and contribute to a literature on earnings management and agency conflicts. More specifically, our results are closest to Bergstresser, Desai, and Rauh (2006), who show that firms offering pension plans manipulate earnings by opportunistically changing future return assumptions of the underlying pension plans. Specifically, they find that firms with large pension assets relative to their operating income are more likely to assume a higher return on their investments, thereby decreasing pension costs and increasing earnings. The paper provides additional evidence that the opportunistic behaviour is stronger for firms engaging in takeovers or seasoned equity offerings.

Life expectancy assumptions are equally important, as they directly affect the value of pension liabilities and thereby also the level of pension contributions. Using cross-sectional analysis, our results show that each year of life expectancy raises pension liabilities by around 4-5 percent. The economic magnitude of this effect is substantial. As of 2007, U.S. private DB pension plans were underfunded by $81 billion and had total aggregate pension liabilities of approximately $2.2 trillion. A one-year shock to longevity would thus increase U.S. private DB pension liabilities by as much as $110 billion, more than doubling the degree of underfunding. Corporate pension plan sponsors would in turn have to make many multiples of typical annual pension contributions to match these extra liabilities. Put into a different perspective, the impact of an additional year of life expectancy on the liabilities of both U.S. private and public pension funds corresponds to an amount equivalent to 1.9 percent of U.S. 2007 Gross Domestic Product (GDP).[2] On a global basis, the aggregate value

[1] The PBGC is a federal government agency that enjoys implicit government support.

[2] The estimate for the total amount of U.S. public DB pension liabilities in 2009 is $3.19 trillion and corresponds

of corporate DB pension liabilities amounts to \$23 trillion, implying that a similar longevity shock could raise global private pension liabilities by as much as \$1.1 trillion.[3]

Unexpected increases in future life expectancy–the realization of longevity risk–constitute a likely event. Past forecasts, independent of the technique they used, have consistently underestimated improvements in future life expectancy. A study by the U.K. Office for National Statistics has evaluated the forecast errors made in the United Kingdom over the past decades and has shown that forecasts were consistently too low.[4] Bongaarts and Bulatao (2000) show that 20-year forecasts of future life expectancy in Australia, Canada, Japan, New Zealand and the United States have underestimated longevity improvements by three years on average.[5] Underfunded pension plans further bias life expectancy assumptions downward, thereby increasing the chance of significant adjustments to life expectancy assumptions and pension liabilities.

Mortality tables are typically based on official mortality forecasts and their accuracy thus depends on the quality of the forecasting technique and the frequency with which they are updated. While the Pension Protection Act of 2006 has partly constrained the freedom pension plan sponsors had in using (outdated) mortality tables, it is not able to completely mitigate the problem of underestimating improvements in life expectancy. Specifically, it only requires that mortality tables are updated (at least) every ten years, thereby leaving room for a lumpy and significant increase in pension liabilities due to the realization of longevity risk. In addition, sponsors can still apply to use their own tables and thus have some leeway to adjust life expectancy assumptions.

Our estimates regarding the impact of life expectancy assumptions on pension liabilities are

to the most conservative estimate in Novy-Marx and Rauh (2011). Note that the impact of life expectancy shocks on both private and public pension liabilities should only be viewed as a rough approximation as (i) the data for private pension liabilities stems from 2007 whereas the estimate in Novy-Marx and Rauh (2011) refers to 2009 and (ii) it is assumed that an additional year of life expectancy has the same effect on public pension liabilities as it has on private DB pension liabilities.

[3] The aggregate value of the projected benefit obligation (PBO) for 2010, reported for all of the listed companies in the 139 research lists from Datastream includes more than 90 countries and equals \$22.6 trillion: \$14.4 trillion in Europe, \$5 trillion in the Americas, and about \$2 trillion in the rest of the world.

[4] For more details, see Shaw (2007).

[5] In addition, a sudden break-through in the treatment of a severe illness has the potential to substantially increase life expectancy. Although clearly beneficial for individuals and society as a whole, this would lead to a lumpy and significant increase in pension liabilities. For details, see International Monetary Fund (2012).

novel and complement existing literature, which generally relies on hypothetical or what-if-type analyses to derive the effect of life expectancy assumptions on pension liabilities. Antolin (2007) computes the effect of deterministic improvements in life expectancy on the liabilities of a hypothetical pension fund and finds that an unexpected improvement in life expectancy of one-year per decade could increase pension liabilities by 8-10 percent, depending on the age-structure of the hypothetical pension fund. Dushi, Friedberg, and Webb (2010) compute the degree to which mortality tables understate true pension liabilities for hypothetical pension funds.[6] They find that updating mortality tables according to the Lee-Carter model – a stochastic model to forecast future mortality - would increase life expectancy at age 60 by about 3 years and pension liabilities by 12 percent.[7]

Why does it all matter? In a frictionless world financing decisions are irrelevant and only cash flows relating to investment projects matter for firm value (Modigliani and Miller, 1958). Also, wages would be set such that workers only care about total compensation and are thus indifferent between DB and defined contribution (DC) plans (Rauh, Stefanescu, and Zeldes, 2013). Pension liability adjustments due to increased life expectancy would therefore not create or destroy value, but they would merely reshuffle wealth between the firm's equity holders, creditors and employees. In reality, various frictions including taxes, bankruptcy costs and external financing fees exist and they affect investment, capital structure choice and ultimately firm value (Jensen and Meckling, 1976; Myers and Majluf, 1984; Fazzari, Hubbard, and Petersen, 1988; Fischer, Heinkel, and Zechner,

[6]Dushi, Friedberg, and Webb (2010) report that in 2006, the majority of U.S. pension plans used the GAM-1983 Table and more recently more plans have started to switch to the RP-2000. The use of outdated tables has also been reported in the United Kingdom, where pension plans assume a life expectancy at age 60 of 85, two years lower than suggested by more recent estimates. See fore example LCP (2006).

[7]A common benchmark approach for modeling future mortality rates is based on the model proposed by Lee and Carter (1992) which employs time-series analysis to forecast mortality rates. Their methodology first estimates an underlying mortality index using variation in mortality data across different age groups over time, and then employs this index to forecast future longevity rates. The Lee-Carter model explains 93 percent of the past variation in U.S. mortality rates. Follow-up studies have successfully applied the model to other countries such as Canada, France, Japan and Sweden. Nevertheless, the Lee-Carter model might be unable to detect any structural changes in the underlying mortality index. It might also have trouble explaining mortality experience in countries with strong cohort effects such as the United Kingdom (Lee and Miller, 2001; CMI, 2004, 2011; Girosi and King, 2007). For a detailed literature review on mortality projections in general, see Waldron (2005).

1989; Erickson and Whited, 2000; Hennessy and Whited, 2005).

In particular, several studies focus on the interaction between capital structure, investment and optimal pension policy. Jin, Merton, and Bodie (2006) show that the risk of firm's pension plan affects its cost of equity and therefore suggest to consider a plan's assets and liabilities when computing the unlevered cost of equity. Shivdasani and Stefanescu (2010) investigate how pension liabilities affect capital structure decisions and find that their inclusion substantially increases average leverage ratios.[8] Given that pension contributions create a similar tax shield as interest payments and missing payments also trigger bankruptcy proceedings, their results suggest that firm's capital structure choices appear less conservative than previously assumed. Rauh (2006) investigates the impact of mandatory pension contributions to DB pension funds and finds that they substantially reduce investment. The effect is particularly strong among financially constrained firms. Bakke and Whited (2012) show that the reduction in investment is driven by severely underfunded firms, thereby suggesting that changes in a firm's investment opportunity set drive the strong sensitivity to mandatory pension contributions.

The findings in this paper thus matter for corporate financing and investment decisions. Unexpected increases in life expectancy occur frequently and raise pension liabilities. While this has also happened in the past, the current financial situation of pension funds is more problematic. Funding gaps have increased due to mediocre performance of assets and a low interest rate environment, which mechanically increases pension liabilities (International Monetary Fund, 2012). Additional liabilities thus need to be financed, which may be costly depending on the source of capital (Myers and Majluf, 1984). In addition, we show that underfunded plans tend to make lower life expectancy assumptions and are less likely to increase them in the future. Realized longevity risk is likely to be more severe for these plans, as external financing costs are presumably higher.

A pragmatic way for pension plan sponsors to mitigate longevity risk is to offer DC plans instead.[9] In that case, the plan sponsor is only required to make regular contributions to the plan

[8] To be precise, leverage ratios of firms sponsoring pension plans increase by roughly 35 percent.

[9] Note that DB pension plan providers can hedge longevity risk using market based solutions such as pension

but the risk regarding future benefits is shifted to the employee.[10] While companies have moved towards organizing new pension plans as DC plans, the aggregate plan coverage of DB plans is still substantial. As of 2011, DB (DC) pension plans covered 42 (76) million plan participants. In addition, various rules and regulations exist which make it difficult for companies to terminate DB pension plans and thus reduce the number of plan participants.[11]

The paper proceeds as follows. Section (2) presents the underlying dataset, Section (4) estimates the impact of life expectancy assumptions on the pension liabilities corporate DB pension plans and Section (3) analyzes the determinants of life expectancy assumptions. Section (5) finally concludes.

2 Pension Data

This study uses the filings of the Form 5500 pension plan data from the Department of Labor (DOL).[12] The information submitted to the DOL is partitioned into separate schedules and includes general information on the plan (Form 5500), actuarial information (Schedule B), financial information (Schedule H) and others.[13] Any administrator or sponsor of a plan must file this information once a year.

The analysis focuses on plans with at least 100 plan participants for the period from 1999 to 2007. The starting point is motivated by the fact that as of 1999 information regarding retirement age,

buy-ins, buy-outs, securitization, longevity swaps or longevity bonds. Bifis and Blake (2009) provide a detailed comparison of the various trade-offs involved across the different methodologies and products. However, as also shown by International Monetary Fund (2012), while the use of capital market based solutions to manage longevity risk has been growing, the overall global activity remains rather small.

[10] In that case, also the longevity risk is transferred to the employee who can hedge it by purchasing annuities from the insurance sector. However, Mitchell, Poterba, Warshawsky, and Brown (1999) demonstrate that for the average retiree the cost of purchasing annuities is significant. Dushi and Webb (2006) show that few households actually purchase annuities, partly also because annuities are not priced at actuarially fair levels for the general population. The high cost of purchasing annuities can to some degree be explained by adverse selection, that is those who expect to live longer opt to buy annuities which forces private insurers to raise prices for the average retiree. In fact, when providing evidence on manadatory annuitization in Singapore Fong, Mitchell, and Koh (2011) show that annuities are cheaper when provided by the public sector.

[11] Note that freezing of existing DB plans does not eliminate the accrued longevity risk, see Rauh et al. (2013). Furthermore, our empirical analysis is based on the concept of accumulated benefit obligations (for reasons outlined in Section 2), such that our estimates of the potential impact of longevity risk are unaffected.

[12] We use data provided by the Center of Retirement Research at Boston College.

[13] For more information on other type of information, please see IRS (2007) page 8.

number of plan participants and the underlying mortality tables used in actuarial computations are jointly available. The study ends in 2007 as this is the last year for which this information is provided – starting in 2008 schedule B was replaced by schedules MB and SB, which do not explicitly identify the mortality tables used. This results in a total of 96,049 observations (18,028 pension plans) for which information on pension liabilities, pension assets and mortality tables are available.

As of 2007, private DB pension plans covered approximately 42 million plan participants and the total value of existing pension promises equaled \$2.2 trillion.[14] In this paper, pension liabilities correspond to the current liability measure as stated in Schedule B (actuarial section) of Form 5500 and are similar to accumulated benefit obligations. That is, they correspond to the nominal value of payments that have been already promised and accrued. It is important to note that this definition is very conservative as future years of service and potential wage increases are not taken into account. At the same time, this also implies that our results are robust with respect to potential future plan freezes as acquired pension benefits can not be terminated.

While the Form 5500 also includes an actuarial liability measure which in principle is similar to the concept of a projected benefit obligation, it turns out that this actuarial liability is often lower than the current liability measure. The reason for the difference is that the current liability measure uses state-imposed discount rates and mortality assumptions whereas for the actuarial liability measure companies are more flexible in their assumptions, allowing typically higher discount rates.[15]

Computing the present value of future pension obligations requires corporations to make and

[14]Dropping the requirement that information on pension liabilities, assets and mortality tables are available, makes it possible to compare total coverage under DB and DC pension plans. In that case, 42 (67) million plan participants are covered under DB (DC) plans respectively.

[15]U.S. pension law uses two different definitions of pension liabilities. For pension contributions to the funding standard account, the relevant measure is the Actuarial Liability (AL). The AL is an estimate of the benefits that workers earned from their past service, calculated under assumptions set by the sponsor. For additional charges, on the other hand, the relevant measure is the Current Liability (CL). The CL is a measure of the benefits accrued to date using discount rates and mortality tables prescribed by law. Since the discount rate mandated by law is likely to be lower than the rate used by the sponsor, the AL is generally lower than the CL. Both measures are used in the calculation of the full funding limitations. For a clear and concise presentation of the different liability concept and their relationship to liability concepts used for accounting, see Pension Committee of the American Academy of Actuaries (2004).

report several actuarial assumptions. These range from the interest rate they employ to the mortality tables underlying the computations of the expected length of future payout streams. Table (1) shows which mortality tables have been used for male active workers between 1995 and 2007. Over the sample period, pension plans have based their calculations on the (1) 1951 Group Annuity Mortality Table, (2) 1971 Group Annuity Mortality Table, (3) 1971 Individual Annuity Mortality Table, (4) the 1984 Unisex Pension Table, (5) the 1983 Individual Annuity Mortality Table, (6) the 1983 Group Annuity Mortality Table, (7) the 1994 Uninsured Pensioner Table and (8) the 2007 Mortality Table.[16] The category "Other" includes undefined mortality tables, "None" means that no mortality table has been used and "Hybrid" means that the standard mortality tables have been modified by the pension fund.

Several issues are worthwhile commenting on. First, there is a substantial amount of variation in the use of different mortality tables over time and across pension funds. Specifically, Table (1) shows that the fraction of firms employing the 1983 GAM Table varies between 75 percent and 18 percent over the sample period. Also, 13 percent of all the funds switched to the most recent mortality table in 2007. Finally, we can also observe that the fraction of funds which employ an unspecified table (i.e. "Other") increased from 7 percent in 1999 to 57 percent in 2007.

Table (2) displays additional summary statistics of funds using the different mortality tables. Panel A displays the average pension liabilities and shows that plans using the most current mortality table or unspecified tables are on average larger than funds employing the 1983 GAM mortality table. This finding is consistent with anecdotal evidence highlighted in Dushi, Friedberg, and Webb (2010) suggesting that larger plans are more likely to use more up to date mortality tables. Robustness checks below will make sure that results are neither driven by the size of pension funds nor by the fact for some funds information regarding their mortality assumptions is unavailable. Finally, the column "All" shows that there has been a steady increase in the average pension liabilities

[16] To be precise, the Form 5500 distinguishes between (i) the 1983 Group Annuity Mortality and (ii) the 1983 Group Annuity Mortality (solely per Rev. Rul. 95-28). Because both (i) and (ii) are based on the same mortality table, we do not distinguish between the two. For more information, see Service (1995).

per plan.[17] Panel B includes the number of plans employing the respective mortality tables and implicitly shows that part of the variation in the average size of plans – using for example the 1951 and 1971 GAM tables – is driven by the small overall number of plans in that category.

Mortality tables provide information on future age specific death rates. Table (3) displays a snapshot of expected death rates of males and females at different ages as implied by the various mortality tables. Focusing on males aged 60, it can be seen that the 1951 Group Annuity Mortality Table and the 1984 Unisex Pension Table specify the highest death rates whereas the 1983 Individual Annuity Mortality Table and the 2007 Table incorporate the most conservative longevity assumptions. The table suggests that the year in the title of the mortality table can not be used to judge whether a table is more *up-to-date* than another. This is because the title does not refer to the year in which the table was constructed but instead to the year for which the forecast was undertaken. In addition, the tables also differ with respect to the underlying sample.[18]

Most importantly, death rates only display a static snapshot and do not provide information regarding mortality at higher ages. To optimally employ the information implicit in the mortality tables, we compute the implied life expectancy at retirement age. This is possible, because the Form 5500 contains yearly information on the average retirement age per plan, which in turn enables us to compute time-varying plan specific life expectancies.[19] Following standard literature (Coughlan et al., 2007), life expectancy can be derived from mortality rates by first computing survival rates and then summing up all successive multi-period survival rates. Conditional on any given retirement age, the concept of life expectancy is superior to observing age specific death rates as it incorporates all future expected death rates beyond that age. Definition (1) summarizes the

[17]Note that the average plan-specific pension liabilities are similar to figures imputed when using data from the Pension Benefit Guarantee Corporation (PBGC).

[18]The 1971 Group Annuity Mortality is based on data from 1964-1968 and summarizes expected mortality rates of persons at all ages in the year 1971. The Unisex Pension (UP) 1984 Table uses mortality experience of uninsured pension plans over the period from 1965 to 1970. The 1983 Group Annuity Mortality is based on data from 1966 to 1975 and summarizes expected mortality rates for the year 1983. The 1994 Uninsured Pensioners Table serves as an update to the 1984 UP Table whereas the the mortality table 2007 subject to Section 1.412(I)(7)-1 of the income tax regulations provides an update to the 1983 GAM table.

[19]Note that the computation is done the reported mortality tables for men.

computation.

Proposition 1 *Life expectancy is computed as follows. First, survival rates are imputed from reported death rates. Second, using information on the yearly plan-specific retirement age we compute individual time-varying life expectancy assumptions by summing up all successive multi-period survival rates. Mathematically, this amounts to*

$$e_x = \sum_{t=1}^{\infty} {}_t p_x \tag{1}$$

where e_x denotes life expectancy at age x and ${}_t p_x$ is a t-period survival rate which can be derived from reported death rates q_i as follows

$${}_t p_x = \Pi_{i=0}^{t-1}(1 - q_{x+i}) \tag{2}$$

To compute a time-varying life expectancy variable for each pension plan, we proceed as follows. Because we do not have information on the sex composition of a plan's workforce, the life expectancy computation is based on mortality tables for males. The choice is purely driven by general evidence of higher historical labor force participation of men. To guarantee a consistent estimation, we drop observations in case plans employ different mortality tables for active and retired workers (minus 4,362 obs.). Furthermore, we drop observations in case plans report tables as "Other" (minus 21,581 obs.), "None" (minus 9 obs.) and "Hybrid" (minus 9,761 obs.) Finally, we also need to drop observations in case information on retirement age is not available (minus 252 obs.) and–to reduce obvious data errors–we also exclude observations for which the retirement age is below (above) the 1 (99) percent level (minus 1061 obs.), pension liabilities to retirees exceed total pension liabilities (minus 113 obs.) or are negative (minus 1 obs.). The final sample consists of 58,909 plan-year observations for 13,908 pension plans and captures both cross-sectional as well as plan-specific variability in the underlying mortality tables.

Figure (1) shows a frequency distribution of actual life expectancy assumptions and reveals strong underlying dispersion. This is reassuring as the subsequent regression analysis will exploit cross-sectional and time-series variation in life expectancy assumptions in order to estimate its effect on pension liabilities.[20] The graph further shows that most observations assume that the conditional life expectancy at retirement is equal to 16 years. The average (median) longevity assumption in our sample equals 17.52 (17.51) years and minimum and maximum life expectancy assumptions range between 13.71 and 25.21 years.

The subsequent analysis focuses on two following questions. First, do life expectancy assumptions relate to risk characteristics of the pension plan and / or the plan sponsor. Second, what is the impact of an additional year of life expectancy on the liability of pension funds. Section 3 and Section 4 separately address these issues.

3 Do longevity assumptions reflect financial risk?

In a frictionless world without wars and natural disasters, life expectancy assumptions would mainly reflect the characteristics of a firm's workforce, the state of medical research and treatment and the quality of the underlying mortality forecasting technology. The objective of this section is to investigate whether the observed life expectancy assumptions also reflect measures of financial risk of the pension plan and/or the plan sponsor. We therefore use the full sample of Form 5500 data and investigate whether life expectancy assumptions depend on the funding status of pension plans. In a second step, we then merge our Form 5500 sample with Compustat and also analyze the impact of firm characteristics on life expectancy assumptions.

[20] Note that the Pension Protection Act of 2006 specifies that as of 2008, pension plans have to base computation of pension liabilities on mortality tables prescribed by the Secretary of the Treasury. The regulation requires that these tables shall be updated at least every ten years. Companies can apply to use their own mortality tables if certain conditions are met. For further information, see H.R. (2006).

3.1 Life expectancy assumptions and a plan's funding status

Mortality forecasting models do not assign a role to financial risk measures of pension plans when forecasting future longevity. Instead, they are either based on historical mortality data (Lee and Carter, 1992), expert opinion or a combination of the two. Mortality tables are typically based on official mortality forecasts and they form the basis of corporate life expectancy assumptions. However, as shown in Table (1), plan sponsors could choose between a wide range of different mortality tables with severe implications for implied life expectancy assumptions. While the Pension Protection Act (PPA) of 2006 has partly mitigated this freedom, companies can still apply to the Internal Revenue Service (IRS) for permission to use their own table.

The funding status of a pension plan, measured as the difference between pension assets and pension liabilities expressed relative to pension liabilities, should have no systematic impact on life expectancy assumptions. Figure (**??**) is based on a kernel regression and displays the non-parametric relation between the lagged funding status of a pension plan and the expected age of the workforce. While the univariate evidence is insufficient to conclude that underfunded plans bias life expectancy assumptions downward, it suggests that there is a positive relation between the funding status and life expectancy assumptions and that most of the statistical relationship is driven by underfunded plans.

To more formally investigate the cross-sectional determinants of life expectancy assumptions, we employ the following regression model

$$n_{i,t} = \alpha_k + \eta_t + \beta \text{retirement}_{i,t} + \gamma \text{funding}_{i,t-1} + \delta X_{i,t-1} + \epsilon_{i,t} \tag{3}$$

where $n_{i,t}$ is the life expectancy assumption of plan i at time t, α_k is either an industry-fixed or a plan-fixed effect (in which case $k = i$), η_t are time-fixed effects, $\text{retirement}_{i,t}$ is the average retirement age of plan i at time t, $\text{funding}_{i,t-1}$ are one-period lagged control variables for the funding status of the pension plan and $X_{i,t-1}$ is a vector of lagged control variables to be explained below.

It is important to emphasize that our setup is inherently different from Rauh (2006), who uses the existence of nonlinear funding rules for underfunded pension plans to analyze the impact of mandatory pension contributions on corporate investment. The main idea is that mandatory pension contributions are a non-linear function of the plan's funding status and are therefore uncorrelated with unobserved investment opportunities, which are typically controlled for with the mis-measured variable Tobin's Q in standard investment/cash-flow regressions (Fazzari, Hubbard, and Petersen, 1988; Erickson and Whited, 2000).[21]

In this paper, we do not use the plan's funding status as an identification mechanism because our research design is not driven by the necessity to deal with changes in the unobserved investment opportunity set. Put differently, there is no counterpart of the q-theory of investment which stipulates that the investment opportunity set affects life expectancy assumptions. Instead, we simply ask whether financial risk, as measured by the plan's lagged funding status, affects life expectancy assumptions.

To estimate the impact of the lagged funding status on life expectancy assumptions, we control for the plan's retirement age, its lagged size, time dummies and the industry in which the plan sponsor operates. To be precise, the Form 5500 contains a six-digit industry classification (North American Industry Classification, NAICS) and we classify plans into 19 different industries, based on the broad classification suggested by the Form 5500. In addition, we control for the ratio of liabilities to retirees relative to total pension liabilities. The intuition is that this measure serves as a proxy for the (inverse) duration of pension liabilities and should be negatively related to life expectancy assumptions. Given the evidence in Bergstresser, Desai, and Rauh (2006), we also control for the (lagged) return on assets assumption of the pension plan.

Table (4) summarises results when equation (3) is estimated for our sample. Column 1 displays results under OLS estimation and shows that retirement age has the strongest effect on life expectancy assumptions. Increasing the average retirement age by one year, decreases life ex-

[21] Bakke and Whited (2012) show that the results in Rauh (2006) are driven by severely underfunded pension plans, thereby raising the possibility that unobserved changes in investment opportunities drive investment decisions.

pectancy by approximately 0.8 years. The strong impact of retirement assumptions is expected as a higher retirement age mechanically reduces remaining life expectancy. We can also see that the impact of the lagged funding status is positive and statistically significant. This suggests that more well funded pension plans make higher life expectancy assumptions or – put differently – the lower the funding status of the pension plan, the lower are also its life expectancy assumptions. These results hold true when controlling for industry effects, year dummies and plan specific factors such as the (inverse) duration of the pension liabilities, plan size and return on asset assumptions.

Results under plan-fixed effects estimation are presented in column 2. With the exception of retirement, all coefficients are smaller in absolute magnitude and some lose their economic significance. Nevertheless, the funding status continues to have a positive and statistically significant impact on life expectancy assumptions. While controlling for fixed effects has the advantage of eliminating unobservable constant firm characteristics, corresponding estimates only emphasize within-firm variation of the respective variables, which (by construction) is limited for pension data (Bergstresser, Desai, and Rauh, 2006).

To further understand the impact of financial risk on life expectancy assumptions, we split the funding status variable into a positive and a negative component. This allows us to estimate the sensitivity of life expectancy assumptions to the degree of over- and underfunding. Column 3 is based on OLS estimation and shows that the overall positive relation between the plan's funding status and its life expectancy assumption is to a large degree driven by underfunded plans which make substantially lower life expectancy assumptions.

When accounting for plan-specific effects, the coefficient is smaller and the negative funding status is only significant at the 10 percent level. However, further analysis of this result suggests that it is driven by correlation of the negative funding status with the size of the pension plan. When choosing (the logarithm of) pension liabilities instead of (the logarithm of) pension assets to proxy for size, then the negative funding status continues to be significant at the traditional 5 percent level.

Taken together, the results suggest that sponsors of not so well funded plans may be making inadequate life expectancy assumptions to artificially reduce their actuarial liabilities. This would clearly not be in the best interests of pensioners and the Pension Benefit Guaranty Corporation.

3.2 Life Expectancy Assumptions and Risk Measures of Plan Sponsors

We now merge our sample of pension funds with firm-level data from Compustat and investigate whether characteristics of the plan sponsor also impact life expectancy assumptions.[22] We are specifically interested how measures of financial risk (leverage, dividend yield), firm size and operational risk (profitability, and growth options) affect life expectancy assumptions.

In a given year, firms can sponsor multiple pension funds and we need to adjust our previously introduced plan specific factors. We therefore compute aggregate values of pension assets, liabilities and liabilities to retirees for each firm per year in order to obtain an aggregate funding status, aggregate size and an aggregate duration measure. In addition, we calculate average firm-year values of life expectancy, return on asset and retirement assumptions.

Above steps result in the following modified regression setup

$$n_{j,t} = \alpha_k + \eta_t + \beta \text{retirement}_{j,t} + \gamma \text{funding}_{j,t-1} + \delta X_{j,t-1} + \theta Y_{j,t-1} + \epsilon_{j,t} \tag{4}$$

where $n_{j,t}$ is the average life expectancy assumption of firm j at time t, α_k is either an industry-fixed or a firm fixed effect (in which case $k = j$), η_t are time-fixed effects, $\text{retirement}_{j,t}$ is the average retirement age of firm j at time t, $\text{funding}_{j,t-1}$ is the one period lagged control variable for the aggregate funding status of firm j and $X_{j,t-1}$ is a vector of lagged plan specific control variables for each firm.[23] The newly introduced vector $Y_{j,t-1}$ includes lagged values of leverage, cash holdings, profitability (the ratio of income before extraordinary items to the book value of

[22] The match is performed using information on a firm's employment number (EIN) and the fiscal year and results in a total of 6,906 matched observations. For general information regarding matching Form 5500 data to firms in Compustat, see Gron and Madrian (2004).

[23] Note that because the estimation requires an industry classification at the firm level, we define industry dummies using the SIC codes provided in Compustat.

assets), growth options (market-to-book ratio), firm size (the logarithm of the market value of the firm's assets), and the firm's dividend yield (the ratio of dividend payments to the market value of the firm's equity). A formal definition of all variables is provided in the Appendix.[24]

Table (8) presents regression estimates for different definitions of corporate leverage. Panel A is based on unconsolidated market leverage ratios and shows results under OLS estimation (columns 1 and 2) or firm-fixed effect estimation (columns 3 and 4). Focusing on column 1, the regression reveals several statistically significant coefficients. First, the previously identified plan specific factors continue to be relevant: plan sponsors with better funded plans or higher duration of pension liabilities on average make higher life expectancy assumptions. Second, several firm characteristics systematically affect longevity assumptions. Specifically, results reveal a negative relation between leverage and longevity assumptions, which is statistically significant at the 10 percent level. Adding cash holdings as an additional regressor (column 2) further shows that large cash holdings are associated with higher life expectancy assumptions. Measures of profitability and growth options are negatively related to longevity assumptions, while size has a positive effect.[25] Finally, a firm's dividend yield has a strong positive effect on life expectancy assumptions.

Shivdasani and Stefanescu (2010) show that consolidation of pension assets and liabilities substantially increases market leverage ratios of firms sponsoring defined benefit pension plans. Panel B therefore displays results using consolidated leverage ratios and reveals a strong negative relation (columns 1 and 2) between leverage and longevity assumptions. The increase in the statistical significance of the leverage coefficients (i.e. comparing Panel A to Panel B) is interesting as it suggests that firms seem to trade off its overall financial risk profile when making life expectancy assumptions.

Focusing on the coefficients under firm-fixed effect estimation, it can be seen that only the

[24] The use of consolidated leverage ratios follows Shivdasani and Stefanescu (2010) who show that consolidation of pension assets and liabilities substantially increases market leverage ratios of firms sponsoring defined benefit pension plans.

[25] Larger firms, on average, make higher life expectancy assumptions. This might be driven by regulation or by the fact that large firms have more resources and are therefore able to adequately monitor recent trends in life expectancy.

aggregate funding statues continues to be statistically significant, though only at a 10 percent significance level. This might be driven by the substantially smaller sample size (previous regressions relied on a large sample of Form 5500 data) or the fact that the firm fixed-effect estimator focuses only on the within-firm variation of the individual variables. In fact, Bergstresser, Desai, and Rauh (2006) report similar inconsistencies between OLS and firm-fixed effect estimates when investigating whether pension plans opportunistically change future return assumptions.

4 Do longevity assumptions matter?

The results in the preceding section have shown that life expectancy assumptions reflect financial risk characteristics of the pension plan and the plan sponsor. In this section, we further investigate the significance of longevity assumptions by estimating its impact on pension liabilities. We start by introducing a simple valuation model which serves as a guideline for the subsequent empirical tests and then apply the implied regression setup to our dataset. The section concludes with a discussion of the economic significance of our results.

4.1 A Simple Valuation Model

The subsequent analysis focuses on the idea that DB pensions can be modeled as an annuity, i.e. that they guarantee a specified regular payment to retirees for the remainder of their lives. Going back to as early as De Witt (1671), it is known that the present value of a pension liability L is given by

$$L = pb \sum_{i=1}^{T} \frac{(1 - q_i)}{(1 + r)^i} \tag{5}$$

where p is the number of plan participants, b is the promised amount of periodical payouts, T is the assumed maximum life span, q_i denotes the death rate over i periods, and r is the discount rate.[26] To capture the impact of longevity assumptions, we will proxy for equation (5) by using

$$L \approx pb\left[\frac{1-(1+r)^{-n}}{r}\right] \tag{6}$$

where n is the expected length of future payouts.[27] Rearranging terms and taking the logarithm, it follows that

$$\log(L) = \log(p) + \log(b) - \log(r) + \log\left[(1+r)^{n} - 1\right] - n\log(1+r) \tag{7}$$

Equation (7) leaves different possibilities for assessing the impact of an additional year of life expectancy on pension liabilities. Under the assumption that the liabilities of each fund can be exactly modeled as an annuity with a length of n periods, the effect can be derived by computing the partial derivative of $\log(L)$ with respect to the longevity variable n. Alternatively, one can view equation (7) as a proxy for the true and unknown liability process and use regression analysis to infer the marginal impact of an additional year of life. Proceeding with the latter option, we employ the following specification

$$\log(L) = \alpha + \beta_1\log(p) + \beta_2\log(b) + \beta_3\log(r) + \beta_4 n + \epsilon \tag{8}$$

where the main interest consists in estimating the coefficient β_4, which measures the impact of one additional year of life expectancy on the present value of pension liabilities. To deal with potential endogeneity stemming from the fact that longevity assumptions reflect lagged characteristics of the pension plan, i.e. our results in Section 3, we will also present results following an instrumental variable approach.

[26]In reality, the promised periodical payment b would differ across employees. However, using the average payment across employees leads to a similar valuation than computing the present value of the liability using different b_i's.

[27]The valuations presented in equation (5) and equation (6) will be exactly equal to each other in case (i) the survival curve is rectangular or (ii) the discount rate r equals zero. Recent evidence in International Monetary Fund (2012) points to a rectangularization of survival curve and thus suggests that the approximation is useful.

4.2 The impact of longevity assumptions on pension liabilities

We now relate the simple pension valuation model to the Form 5500 and focus on those plan participants that are already receiving the annuity, i.e. the retired plan participants. Specifically, we use data on the value of pension liabilities for retired participants and beneficiaries receiving payments (entry 2(b)(3)(1) Schedule B), the number of retired participants and beneficiaries receiving payments (entries 7(b) and 7(e) General Information) the value of total benefit payments (entry 2(e)(4) Schedule H), the employed interest rate (entry 6(a) Schedule B) and the longevity assumptions as given by Proposition (1).

To guarantee a consistent estimation, we drop obvious data errors such as when the value of (reported) pension liabilities for retired participants and beneficiaries exceeds the total value of all (reported) pension liabilities or in case both liability measures are non-positive. We also exclude observations in case the value of (reported) pension liabilities for retired participants and beneficiaries is less than the total current benefit payments to this group as this indicates that the pension has not factored in future retirees or beneficiaries and, in all likelihood, this represents a data error. Finally, we drop observations for which the interest rate is below (above) the 0.5 (99.5) percent level.

Table (6) summarizes corresponding results under OLS estimation (columns 1 and 2) and fixed-effect estimation (columns 3 and 4). Using the actual life expectancy assumptions, column 1 reveals that U.S. pension funds face a longevity risk that would see their liabilities to retired participants increase by 4.4 percent for each year that their retirees live longer than expected. Even though the estimate is significant, it is likely biased downward as more risky plans tend to make lower life expectancy assumptions. To account for this fact, we therefore instrument longevity assumptions using the regression framework given in equation 3. Column 2 displays corresponding results and shows that each year of life expectancy increases pension liabilities (to retired plan participants) by approximately 5 percent. Furthermore, the regression explains 95 percent of the variation in (the logarithm) of pension liabilities and suggests that the estimation provides a good proxy for the true (unknown) valuation model. Results of the fixed-effect estimation are qualitatively similar and the instrumented estimates suggest that liabilities increase by 4 percent for each additional year of life expectancy.

This finding is largely consistent with estimates that can be derived from the partial derivative of equation (6) and those reported by the pension industry. In that context, see for example Aegon (2011) who estimates that each additional year of life expectancy adds about 3-4 percent to liabilities of major pension funds or Hymans and Robertson (2011) who reports that each additional year of life expectancy adds about 3 percent to the pension liabilities of U.K. firms.

We further investigate whether the size of the pension fund - as measured by the total number of plan participants - affects the impact of longevity assumptions on pension liabilities and therefore split the sample into three equally sized subgroups. Table (7) shows that the estimation performs well across all subsamples. Focusing on the instrumental variable estimations, we find that the economic effect varies between 3.3 and 6.7 percent under OLS estimation and between 2.7 and 3.8 percent when fixed effects are being accounted for.

Before discussing the economic significance of our findings, it is important to gauge the robustness of the results. Specifically, it was shown in Table 1 that in the last years of the sample period an increasing fraction of funds has not specified a mortality table, i.e. the table was classified as "Other." Given the missing information on mortality tables, the estimates above thus do not reflect these funds. However, anecdotal evidence suggests that pension plans may have used the RP-2000 Table which is not specifically mentioned in the Form 5500 database and which would consequently be classified as "Other." We therefore test how a reclassification of these plans would affect existing results and therefore assume that funds classified as "Other" actually used the RP-2000 Table.

The reclassification of those pension plans increases sample size by approximately 18,000 plan-year observations. Panel A of Table (9) shows that the funding status of a pension plan continues to be a strong determinant of life expectancy assumptions. In fact, the importance of the funding status slightly increases (relative to Table 4), specially for underfunded plans. The results thus suggest that the regression framework in Panel A continues to be a good instrument for observed life expectancy assumptions. Panel B thus displays the impact of an additional year of life expectancy, using again equation 3 as an instrument. The resulting estimates are qualitatively similar to our previous results and suggest that an additional year of life expectancy increases pension liabilities by approximately 5 percent.

4.3 Economic Significance of Findings

The findings in this paper suggest that an additional year of life expectancy increases pension liabilities by 4 to 5 percent. From an aggregate perspective, the potential impact of longevity improvements is large. At the end of the sample period, aggregate corporate DB pension liabilities equaled $2.2 trillion and plans were underfunded by approximately $81 billion. A one-year longevity shock would increase aggregate pension liabilities by as much as $110 billion, more than doubling the degree of underfunding. Pension plan sponsors would in turn need to substantially increase annual contributions in order to make up for the pension shortfall.

Future adjustments to life expectancy constitute a likely event–past forecasts of life expectancy consistently underestimate realized improvements (Bongaarts and Bulatao, 2000; Shaw, 2007; International Monetary Fund, 2012). In addition, mortality tables are based on such forecasting methods and they are not updated continuously. In fact, the Pension Protection Act of 2006 only implies that tables need to be updated at least every ten years, thereby increasing the chance of lumpy adjustments.

Moreover, our findings show that underfunded pension plans are more likely to bias life expectancy assumptions downward. The potential impact can be further illustrated with a subsequent final analysis. Given the evidence in Table 1 which shows that only a fraction of pension plans switched to the most recent mortality table in 2007, we compute the implied adjustment in longevity for all plans in the final year of the sample. Doing so, we find that for the mean (median) pension plan, longevity assumptions would need to be increased by 1.4 (2) years. Figure 10 displays the distribution of potential adjustments and shows for some plans the implied increase may even exceed 4 years.

Confirming our findings in Section 3, potential longevity adjustments are correlated with the plan's funding status. To illustrate, we perform the following regression

$$\text{adj}_{i,t} = \beta \text{retirement}_{i,t} + \gamma \text{funding}_{i,t-1} + \delta X_{i,t-1} + \epsilon_{i,t} \tag{9}$$

where $\text{adj}_{i,t}$ is the potential adjustment in life expectancy relative to the 2007 mortality table. Table 10 displays corresponding results. The findings show that a plan's lagged funding status is again strongly related to the potential adjustment and that this effect is stronger for underfunded plans. All in all our results suggest, that future adjustments to life expectancy are likely and that they are larger for underfunded pension plans.[28]

These findings matter because markets are not frictionless and external financing is costly. While there is disagreement about the potential reduction in investment for underfunded pension plans (Bakke and Whited, 2012; Rauh, 2006), unexpected improvements in life expectancy will need to be financed and these exogenous shocks will reduce investment for firms without financial slack and only costly access to external funds. From a policy perspective, it is thus important that financially risky pension plans do not use out-dated mortality assumptions.

5 Conclusion

This paper investigates the relation between longevity assumptions and pension liabilities for a large sample of U.S. DB corporate pension plans. Using detailed actuarial and financial data from the U.S. Department of Labor, we construct a longevity variable for each pension plan by computing the implied life expectancy using information on retirement age and the mortality table employed in the calculation of pension liabilities.

[28] Note that because the switch to the 2007 mortality table only occurred in 2007, no results under plan fixed estimation are available.

Our first contribution is to show that life expectancy assumptions are systematically related to the funding status of pension plans. These findings are robust to the inclusion of industry, plan- and year-fixed effects as well as several plan specific control variables. Further analysis shows that the result is mostly driven by underfunded pension plans which make substantially lower life expectancy assumptions. When merging our pension data with Compustat, we also show that characteristics of the plan sponsor impact longevity assumptions. Small sponsors, firms with more leverage, more growth opportunities or lower dividend yields make lower life expectancy assumptions.

We then show that longevity assumptions have a statistically significant impact on pension liabilities. Specifically, it turns out that each additional year of life expectancy increases liabilities by around 4 to 5 percent. This effect is robust with respect to different specifications and tests and it is also economically significant. At the end of the sample period, private DB pension liabilities in the United States amount to approximately $2.2 trillion. This implies that a one-year shock to longevity would raise U.S. private DB pension liabilities by as much as $110 billion. This would increase the amount by which private DB pension funds are underfunded by more than 100 percent and imply that corporate pension sponsors have to make many multiples of typical annual pension contributions to match these extra liabilities.

The recognition of additional pension liabilities due to the realization of longevity risk is a likely event. Past forecasts have systematically underestimated improvements in future life expectancy. Mortality tables are based on such forecasts and their accuracy thus depends on the quality of the forecasting technique and the frequency with which they are updated. Given the performance of past forecasts and the fact that in the United States mortality tables have to be updated only at least every ten years, the potential realization of a large and lumpy increase in pension liabilities is a likely scenario.

Taken together, the results suggest that sponsors of not so well funded plans may be making inadequate life expectancy assumptions to artificially reduce their actuarial liabilities, clearly not be in the best interests of pensioners and the Pension Benefit Guaranty Corporation.

References

Aegon. Paying the price for living longerwhat is the right price for removing longevity risk? *Aegon Global Pensions View*, 2011.

Pablo. Antolin. Longevity risk and private pensions. *OECD Working Papers on Insurance and Private Pensions*, 3:1–28, 2007.

Tor-Erik Bakke and Toni Whited. Threshold events and identification: a study of cash shortfalls. *Journal of Finance*, 25:1286–1329, 2012.

Daniel Bergstresser, Mihir Desai, and Joshua Rauh. Earnings manipulation, pension assumptions and managerial investment decisions. *Quarterly Journal of Economics*, 121:157–195, 2006.

Enrico Bifis and David Blake. Mortality-linked securities and derivatives. In M. Bertocchi and W.T. Schwartz, S.L. Ziemba, editors, *Optimizing the Aging, Retirement and Pensions Dilemma.* John Wiley Sons, 2009.

John Bongaarts and Rodolfo A. Bulatao. *Beyond Six Billion: Forecasting the Worlds Population.* Washington: National Academy Press), 2000.

Continuous Mortality Investigation CMI. Projecting future mortality: a discussion paper. *Working Paper No. 3*, 2004.

Continuous Mortality Investigation CMI. The mortality projections model. *Working Paper No. 55*, 2011.

Guy Coughlan, David Epstein, Alen Ong, Amit Sinha, Javier Hevia-Portocarrero, Emily Gingrich, Marwa Khalaf-Allah, and Praveen Joseph. LifeMetrics - A toolkit for measuring and managing longevity and mortality risks. Technical report, JP Morgan, 2007.

Johan De Witt. Value of life annuities in proportion to redeemable annuities. *Assurance Magacine*, 2:232–249, 1671.

Irena Dushi and Antony Webb. Rethinking the sources of adverse selection in the annuity market. In Pierre? Andre Chiappori and Christian Gollier, editors, *Competitive Failures in Insurance Markets: Theory and Policy Implications*, pages 481–503. MIT Press, 2006.

Irena Dushi, Leora Friedberg, and Antony Webb. The impact of aggregate mortality risk on defined benefit pension plans. *Journal of Pension Economics and Finance*, 9:481–503, 2010.

Timothy Erickson and Toni M. Whited. Measurment error and the relationship between investment and q. *Journal of Political Economy*, 108:1027–1057, 2000.

Steven Fazzari, Glenn Hubbard, and Bruce Petersen. Financing constraints and corporate investment. *Brookings Papers Econ. Activity*, 1:141–195, 1988.

Edwin Fischer, Robert Heinkel, and Josef Zechner. Dynamic capital structure choice: Theory and tests. *Journal of Finance*, 44:19–40, 1989.

Joelle H.Y. Fong, Olivia S. Mitchell, and Benedict S. K. Koh. Longevity risk management in singapore's national pension system. *Journal of Risk and Insurance*, 78:961–982, 2011.

Federico Girosi and Gary King. Understanding the lee-carter forecasting method. *Working Paper*, 2007.

Anne Gron and Brigitte C. Madrian. Matching form 500 filings with compustat and crsp. *Working Paper*, 2004.

Christopher A. Hennessy and Toni M. Whited. Debt dynamics. *Journal of Finance*, 60:1129–1165, 2005.

4 H.R. Pension protection act of 2006. *GovTrack.us (database of federal legislation)*, 2006.

Hymans and Robertson. Ias 19 assumptions report. *Note*, 2011.

International Monetary Fund. Global Financial Stability Report (April). 2012.

Internal Revenue Service IRS. Instructions for form 5500. *Department of the Treasury*, 2007.

Michael Jensen and William Meckling. Theory of the firm: Managerial behavior, agency costs and ownership structure. *Journal of Financial Economics*, 3, 1976.

Li Jin, Robert C. Merton, and Zvi Bodie. Do a firm's equity returns reflect the risk of its pension plan? *Journal of Financial Economics*, 81:1–26, 2006.

Lane Clark Peacock LCP. Accounting for pensions uk and europe. *Annual Survey*, 2006.

Ronald D. Lee and Lawrence R. Carter. Modeling and forecasting u.s. mortality. *Journal of the American Statistical Association*, 87:659–671, 1992.

Ronald D. Lee and Timothy Miller. Evaluating the performance of the lee-carter method for forecasting mortality. *Demography*, 38:537–549, 2001.

Olivia S. Mitchell, James M. Poterba, Mark J. Warshawsky, and Jeffrey R. Brown. New evidence on the money's worth of individual securities. *American Economic Review*, 89:1299–1318, 1999.

Franco Modigliani and Merton H. Miller. The cost of capital, corporation finance and the theory of investment. *American Economic Review*, 48:261–297, 1958.

S.C. Myers and N.S. Majluf. Corporate financing and investment decisions when firms have information that investors do not have. *Journal of Financial Economics*, 13:187–221, 1984.

Robert Novy-Marx and Joshua Rauh. Public pension promises: How big are they and what are they worth? *Journal of Finance*, 66:1207–1245, 2011.

Joshua D. Rauh. Investment and financing constraints: Evidence from the funding of corporate pension plans. *Working Paper*, pages 33–71, 2006.

Joshua D Rauh, Irina Stefanescu, and Stephen. Zeldes. Cost shifting and the freezing of corporate pension plans. *Journal of Finance*, 61, 2013.

Internal Revenue Service. Revenue ruling 95-28. *Department of the Treasury*, 1995.

Chris Shaw. Fifty years of united kingdom national population projections: how accurate have they been? In U.K. Office for National Statistics, editor, *Population Trends*. 2007.

Anil Shivdasani and Irina Stefanescu. How do pensions affect corporate capital structure decisions? *Review of Financial Studies*, 23:1287–1323, 2010.

H. Waldron. Literature review of long-term mortality projections. *Social Security Bulletin*, 66, 2005.

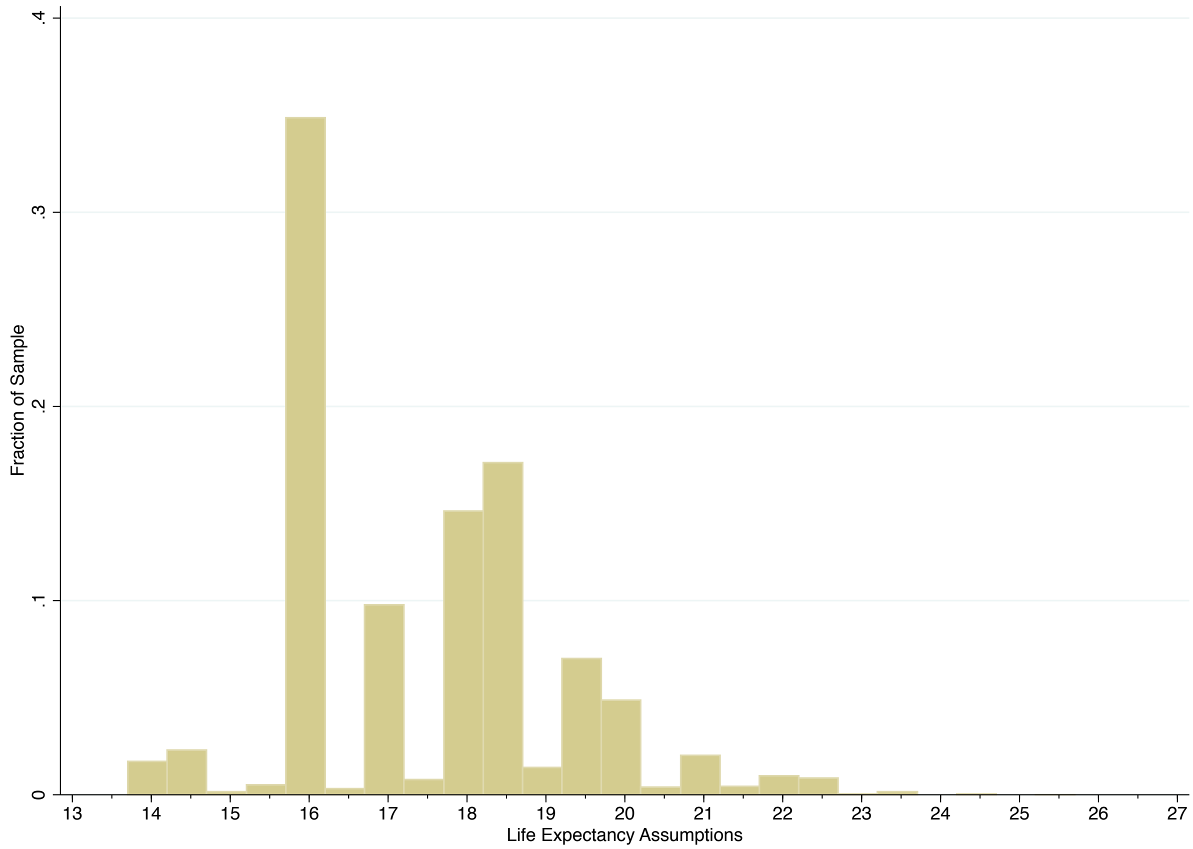

Figure 1: **Life expectancy assumptions.** The figure displays a frequency distribution of life expectancy assumptions. Average (median) life expectancy equals 17.52 (17.51) years. The statistics are based on a sample of 59,144 observations between 1995 and 2007.

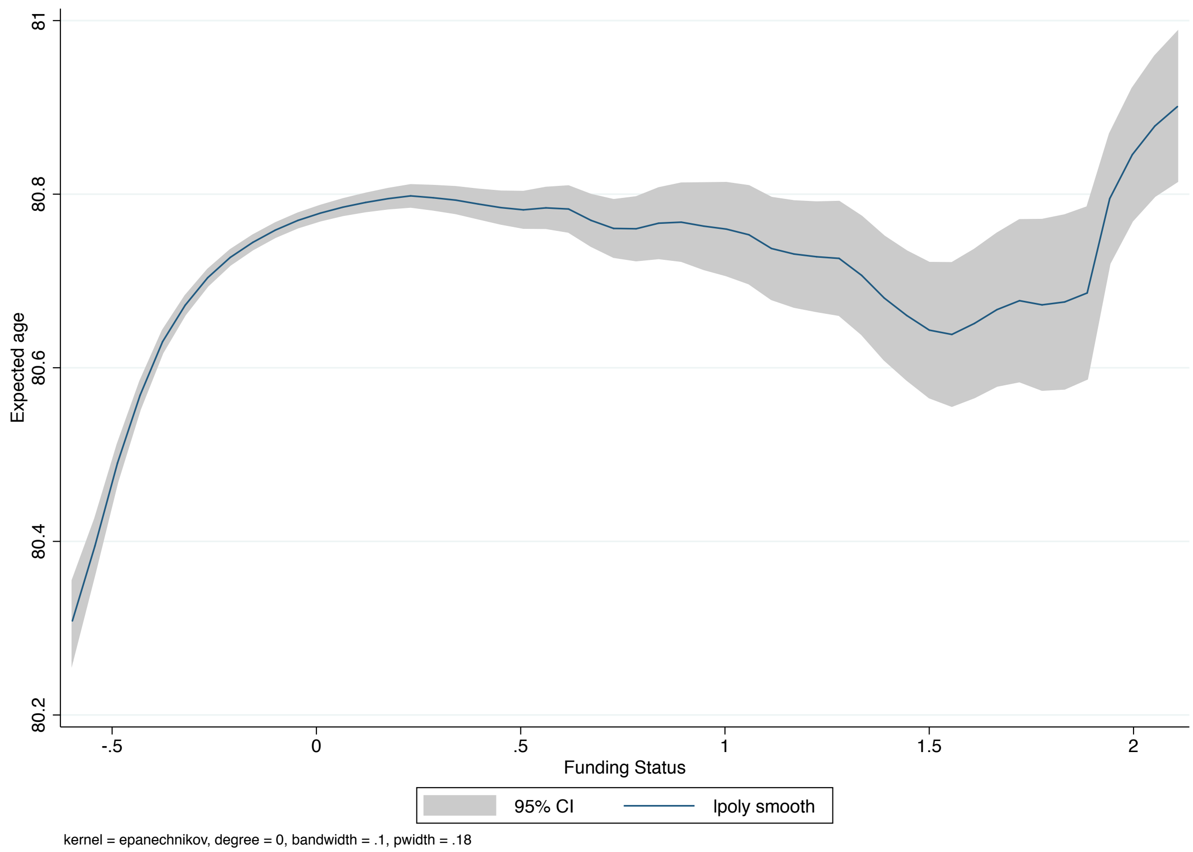

Figure 2: **The composition of the workforce.** The figure plots the univariate relation between expected age (vertical axis) and funding status (horizontal axis). Funding status is defined as the difference between pension assets and pension liabilities, measured relative to pension liabilities. The kernel regression estimation is performed using an Epanechnikov kernel, with a bandwith of 0.1. A 95% confidence interval is included in the shaded region.

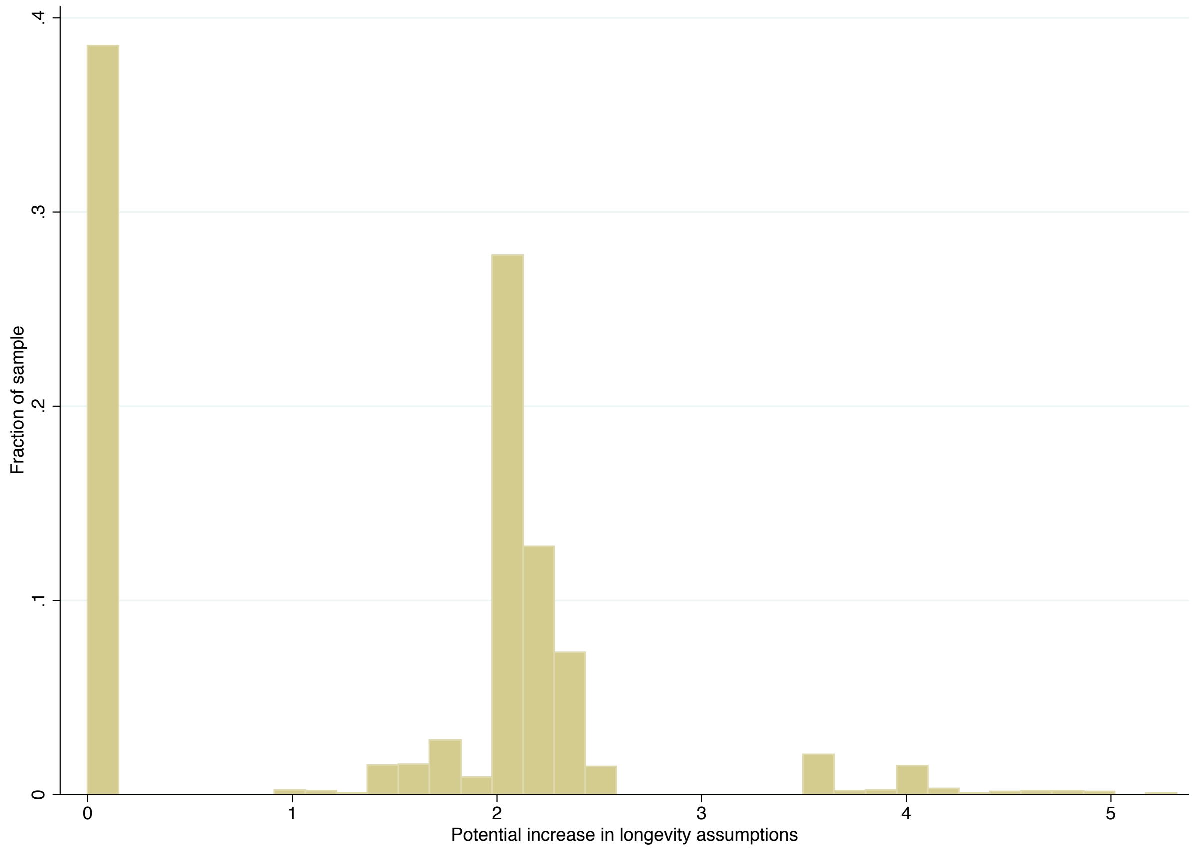

Figure 3: **Implied increase in life expectancy assumptions.** The figure displays a frequency distribution of implied life expectancy adjustments. Average (median) life expectancy adjustment equals 1.4 (2) years. The statistics are based on a sample of 3,209 pension plans with available data in 2007.

Table 1: **Mortality Tables Used between 1999 and 2007 (in percent):** This table displays which mortality tables have been used over the period from 1999 to 2007. Potentially allowed mortality tables include (1) the 1951 Group Annuity Table, (2) the 1971 Group Annuity Table, (3) the 1971 Individual Annuity Mortality, (4) the Unisex Pensioner 1984 Table, (5) the 1983 Individual Annuity Table, (6) the 1983 Group Annuity Table, (7) the 1983 Group Annuity Table (Rev. Rule 95-28), (8) the Uninsured Pensioner Table 1994, (9) the 2007 Mortality Table for 1.412(I)(7)-1 of the Income Tax Regulation, (10) Tables specified as "Other," (11) None, i.e. no tables have been used or (12) Hybrid versions of the former.

Year	1951 GAM	1971 GAM	1971 IAM	UP 1984	1983 IAM	1983 GAM	UP 1994	2007 Table	Other	None	Hybrid
1999	0	5	0	3	0	67	1	0	7	2	14
2000	0	4	0	3	0	68	2	0	7	2	13
2001	0	3	0	2	0	69	2	0	8	2	12
2002	0	3	0	2	0	69	2	0	10	2	11
2003	0	2	0	2	0	66	3	0	13	3	11
2004	0	2	0	1	0	63	3	0	17	3	10
2005	0	1	0	1	0	50	3	0	31	3	10
2006	0	1	0	1	0	28	3	0	55	3	8
2007	0	1	0	1	0	16	2	12	57	3	6
Average	0	3	0	2	0	55	3	1	23	3	11

Table 2: **Liabilities of Pension Funds For Different Mortality Tables** This table displays summary statistics for DB pension fund liabilities for different mortality tables. Pension Liabilities are current liabilities as stated in Schedule B of the Form 5500 [RPA94 Current Liability 1(d)(2)(b)] and are expressed in 1,000 U.S. Dollars. Panel A displays average pension liabilities of firms employing different mortality tables, Panel B the number of plans reporting according to the specific mortality table.

Year	1951 GAM	1971 GAM	1971 IAM	UP 1984	1983 IAM	1983 GAM	UP 1994	2007 Table	Other	None	Hybrid	All
Panel A: Mean Values (in 1000 USD)												
1999	250,487	90,560	4,031	23,603	5,860	82,718	260,817	.	277,445	5,848	162,884	106,051
2000	53,869	109,514	5,753	43,781	10,796	77,816	306,072	.	240,093	7,498	128,905	99,160
2001	54,378	122,587	5,733	42,335	6,990	98,960	276,016	.	365,673	5,339	206,609	135,152
2002	25,273	131,961	4,729	48,806	7,950	105,693	303,920	.	334,361	5,488	240,385	145,067
2003	145,047	122,073	2,936	55,581	10,400	117,944	277,734	.	344,756	6,688	284,107	165,770
2004	222,917	136,376	2,769	74,639	12,272	122,350	337,936	.	285,182	7,448	202,082	161,990
2005	241,092	179,282	3,105	81,090	12,745	126,860	301,766	.	266,566	8,392	233,293	183,074
2006	350,746	173,615	3,931	107,939	18,251	78,087	315,103	.	247,248	10,451	250,215	191,847
2007	64,407	51,460	3,951	54,115	21,820	110,390	262,766	179,405	264,578	12,015	271,137	216,485
Average	131,538	120,044	4,076	52,611	10,908	103,032	296,915	179,405	275,333	7,919	215,344	156,737
Panel B: Number of Plans												
1999	19	479	9	262	30	6,080	129	.	599	219	1,256	9,082
2000	26	415	4	248	34	6,695	192	.	699	210	1,274	9,797
2001	25	418	5	244	39	8,407	280	.	999	273	1,477	12,167
2002	12	321	9	199	36	8,199	294	.	1,157	292	1,352	11,871
2003	13	270	8	179	32	7,582	348	.	1,485	309	1,226	11,452
2004	9	176	5	138	29	6,256	330	.	1,728	270	996	9,937
2005	9	163	4	129	26	5,494	377	.	3,458	345	1,076	11,081
2006	6	134	3	103	23	2,902	320	.	5,756	339	822	10,408
2007	5	97	4	73	16	1,670	229	1,275	5,888	352	645	10,254
Average	18	339	7	199	31	6,713	298	1,275	4,049	298	1,181	10,761

Table 3: **Mortality Rates for Various Mortality Tables:** This table compares mortality rates as assumed in different mortality tables. Specifically, rates are denoted in percent and are displayed for the (1) 1971 GAM, (2) the UP 1984, (3) the 1983 GAM, (4) the UP 1994 and (5) the 2007 Mortality Table. Mortality rates are shown for individuals aged 40, 50, 60, 67 and 80. Panel A displays mortality rates for males, Panel B for females.

Age	1951 GAM	1971 GAM	1971 IAM	UP 1984	1983 IAM	1983 GAM	UP 1994	Table 2007
Panel A: Males								
40	0.2000	0.1633	0.1633	0.2327	0.1341	0.1238	0.1153	0.0904
50	0.6475	0.5285	0.5285	0.6196	0.4057	0.3909	0.2773	0.1557
60	1.5555	1.3119	1.2249	1.5509	0.0834	0.9158	0.8576	0.5177
67	3.0112	2.6316	2.0290	2.9634	1.5717	1.9804	1.9391	1.3349
80	9.9679	8.7431	6.4599	8.8852	5.7026	7.4070	6.6696	5.5919
Panel B: Females								
40	0.1338	0.0938	0.0938	0.1513	0.0742	0.0665	0.0763	0.0506
50	0.3070	0.2151	0.2151	0.3769	0.1830	0.1647	0.1536	0.1184
60	0.7837	0.5489	0.6628	0.9875	0.4467	0.4241	0.4773	0.4640
67	1.6457	1.1621	1.0622	1.8685	0.8888	0.8681	1.1574	1.1132
80	7.4146	5.6085	4.6386	5.7775	3.6395	4.2945	4.2361	4.1582

Table 4: **Life Expectancy Assumptions and Pension Plans:** This table displays estimates of the following regression $n_{i,t} = \alpha_k + \eta_t + \beta \text{retirement}_{i,t} + \gamma \text{funding}_{i,t-1} + \delta X_{i,t-1} + \epsilon_{i,t}$ where $n_{i,t}$ is the life expectancy assumption of plan i at time t, α_k is either an industry-fixed or a firm fixed effect (in which case $k = i$), η_t are time-fixed effects, $\text{retirement}_{i,t}$ is the average retirement age of plan i at time t, $\text{funding}_{i,t-1}$ are one-period lagged control variables for the funding status of the pension plan and $X_{i,t-1}$ is a vector of lagged control variables to be explained below. The funding status is defined as funding = (assets − liabilities)/liabilities where assets correspond to pension assets (ACTRL CURR VALUE AST 01 AMT, entry 1(b)(1) Schedule B) and liabilities to pension liabilities (ACTRL RPA94 INFO CURR LIAB AMT, entry 2(b)(3)(1) Schedule B). The vector X includes lagged values of plan size (logarithm of assets), duration (the ratio of pension liabilities to retirees relative to total pension liabilities) and the plan's assumed return on assets. Industry dummies (19-industry categories based on six-digit NAICS industry classification available in Form 5500 data) and year dummies are included.

	Baseline Estimation		Extended Estimation	
	OLS	Fixed Effects	OLS	Fixed Effects
retirement	-0.811***	-0.795***	-0.814***	-0.795***
funding	0.107***	0.041***		
size	0.014***	0.008*	0.011***	0.008*
duration	-0.128***	-0.05	-0.117***	-0.050
ROA	-0.128***	-0.022	0.025	-0.021
funding(+)			0.019*	0.042**
funding(-)			-0.379***	-0.039+
Industry dummies	yes	no	yes	no
Year dummies	yes	yes	yes	yes
R2	0.899	0.689	0.9	0.689
N	41389	41389	41389	41389

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5: **Life Expectancy Assumptions and Pension Plan Sponsors:** This table displays estimates of the following regression $n = \alpha + \beta \mathrm{RM}^p + \gamma \mathrm{RM}^s + \delta X + \epsilon$ where n is the life expectancy assumption (measured in years), RM^p is the aggregate lagged funding status of a plan sponsor across its pension plans, RM^s is a vector of risk measures of the plan sponsor including its leverage ratio, profitability (the ratio of operating cash flow to the book value of assets), growth options (market-to-book ratio), firm size (the logarithm of the market value of the firm's assets) and dividend yield (the ratio of dividends to the equity value of the firm). Industry dummies (12-industry categories based on Fama and French) and year dummies are included. Panel A presents results using unconsolidated market leverage ratios (net leverage uses gross debt less of cash holdings), Panel B presents results using consolidated market leverage ratios (net leverage uses gross consolidated debt less of cash holdings).

Panel A: Unconsolidated Leverage

	OLS		FE	
	1	2	3	4
retirement	-0.837***	-0.836***	-0.828***	-0.828***
funding	0.057*	0.059*	0.039+	0.039+
size	-0.001	-0.002	-0.014	-0.014
duration	-0.139**	-0.136*	-0.067	-0.069
ROA	-0.258	-0.212	-0.462	-0.482
ML	-0.089+	-0.075+	0.11	0.101
CR		0.172+		-0.128
prof	-0.265*	-0.243+	0.099	0.095
Q	-0.023*	-0.020*	-0.007	-0.008
log(MV)	0.033***	0.034***	-0.003	-0.010
DY	1.251***	1.276***	0.061	0.019
Industry dummies	yes	yes	no	no
Year dummies	yes	yes	yes	yes
R2	0.932	0.933	0.864	0.864
N	2251	2251	2251	2251

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Panel B: Consolidated Leverage

	OLS		FE	
	1	2	3	4
retirement	-0.837***	-0.837***	-0.828***	-0.828***
funding	0.048*	0.051*	0.042+	0.041+
size	0.003	0.002	-0.016	-0.015
duration	-0.132*	-0.129*	-0.069	-0.071
ROA	-0.273	-0.224	-0.465	-0.487
ML	-0.111*	-0.100*	0.053	0.048
CR		0.179+		-0.145
prof	-0.282*	-0.263*	0.068	0.067
Q	-0.024*	-0.022*	-0.011	-0.011
log(MV)	0.028***	0.030***	0.001	-0.007
DY	1.270***	1.295***	0.11	0.058
Industry dummies	yes	yes	no	no
Year dummies	yes	yes	yes	yes
R2	0.933	0.933	0.863	0.863
N	2251	2251	2251	2251

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6: **The impact of longevity assumptions on pension liabilities of retired participants and beneficiaries receiving payments.** This table displays results when estimating the effect of life expectancy assumptions on pension liabilities. The baseline model corresponds to the subsequent regression $\log(L) = \alpha + \beta_1 \log(r) + \beta_2 \log(p) + \beta_3 \log(b) + \beta_4 n + \epsilon$ where L denotes the present value of pension liabilities for retired participants and beneficiaries receiving payments (ACTRL LIAB RTD TOTAL BNFT AMT, entry 2(b)(3)(1) Schedule B), r is the discount rate employed in the computation of future cash flows (ACTRL CURR LIAB RPA PRCNT, entry 6(a) Schedule B), p is the number of retired plan participants and beneficiairies receiving payments (RTD SEP PARTCP RCVG CNT + BENEF RCVG BNFT CNT) b is the per-person amount of pension promises (TOT DISTRIB BNFT AMT/(RTD SEP PARTCP RCVG CNT + BENEF RCVG BNFT CNT), entry 2(e)(4) Schedule H) and the variable n is computed following Definition (1). The robustness model extends the baseline approach by including an additional interaction term $\beta_5 n \times \log(1 + r)$. The estimation is done using both OLS and by accounting for plan-fixed effects. Standard errors are adjusted for heteroskedasticity.

	OLS Estimation		Fixed Effects Estimation	
	1	2	3	4
log(r)	-0.540***	-0.512***	-0.634***	-0.635***
log(p)	1.038***	1.036***	0.884***	0.820***
log(p)	0.735***	0.733***	0.468***	0.441***
n	0.044***	0.051***	0.025***	0.036***
Instrument	no	yes	no	yes
N	50175	35876	50175	35876
R2	0.947	0.948	0.615	0.565

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 7: **The impact of longevity assumptions on pension liabilities when controlling for the size of pension funds.** For variable definition and details regarding the estimation, please see Table (6). Columns (1) to (4) display the coefficients associated with the four different quartiles of the size of pension liabilities.

Panel A: Small

	OLS Estimation		Fixed Effects Estimation	
	1	2	3	4
log(r)	-0.398***	-0.434***	-0.724***	-0.738***
log(p)	1.135***	1.144***	0.809***	0.775***
log(p)	0.803***	0.802***	0.400***	0.365***
n	0.031***	0.033***	0.018*	0.033***
Instrument	no	yes	no	yes
N	12510	8802	12510	8802
R2	0.862	0.866	0.533	0.505

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Panel B: Medium

	OLS Estimation		Fixed Effects Estimation	
	1	2	3	4
log(r)	-0.537***	-0.540***	-0.671***	-0.716***
log(p)	1.147***	1.147***	0.868***	0.786***
log(p)	0.786***	0.787***	0.424***	0.406***
n	0.039***	0.041***	0.024***	0.029***
Instrument	no	yes	no	yes
N	12487	9029	12487	9029
R2	0.874	0.877	0.563	0.512

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Panel C: Large

	OLS Estimation		Fixed Effects Estimation	
	1	2	3	4
log(r)	-0.552***	-0.487***	-0.586***	-0.569***
log(p)	1.047***	1.046***	0.861***	0.784***
log(p)	0.701***	0.701***	0.494***	0.471***
n	0.057***	0.067***	0.030***	0.038***
Instrument	no	yes	no	yes
N	25178	18045	25178	18045
R2	0.933	0.934	0.609	0.557

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 8: **Life Expectancy Assumptions and Pension Plan Sponsors:** This table displays results for a larger sample of firms. Specifically, it is assumed that funds which classify the underlying mortality table as "Other," follow the RP-2000 Table and the longevity variable n is updated accordingly. Panel A displays results following the procedure outlined in Table 4. The regression framework used in Panel A is the basis for the first stage regression in Panel B, which follows the procedure detailed in Table 6.

Panel A: The determinants of longevity assumptions

	Baseline Estimation		Extended Estimation	
	OLS	Fixed Effects	OLS	Fixed Effects
retirement	-0.826***	-0.813***	-0.828***	-0.813***
funding	0.131***	0.065***		
size	0.032***	0.010*	0.029***	0.006
duration	-0.162***	-0.069+	-0.148***	-0.071+
ROA	-0.162***	-0.028	-0.196	-0.054
funding(+)			0.023*	0.038*
funding(-)			-0.440***	-0.136***
Industry dummies	yes	no	yes	no
Year dummies	yes	yes	yes	yes
R2	0.892	0.691	0.892	0.692
N	59346	59346	59346	59346

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Panel B: Impact of longevity assumptions on pension liabilities

	OLS Estimation		Fixed Effects Estimation	
	1	2	3	4
log(r)	-0.472***	-0.407***	-0.691***	-0.669***
log(p)	1.035***	1.033***	0.898***	0.838***
log(p)	0.725***	0.721***	0.489***	0.472***
n	0.043***	0.049***	0.034***	0.052***
Instrument	no	yes	no	yes
N	68395	51569	68395	51569
R2	0.949	0.95	0.655	0.618

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 9: **Robustness Check: Unclassified Mortality Tables.** This table displays results when estimating the baseline regression of Table (6) for a larger sample of firms. Specifically, it is assumed that funds which classify the underlying mortality table as "Other," follow the RP-2000 Table and the longevity variable n is updated accordingly. Results are presented for the baseline model and the robustness check including the interaction term.

Panel A: OLS Estimation

	Baseline				Robustness			
	All	Small	Medium	Large	All	Small	Medium	Large
log(r)	-0.480***	-0.406***	-0.431***	-0.364***	-0.149	-0.027	0.028	-0.282
log(p)	1.035***	1.056***	0.880***	0.965***	1.035***	1.056***	0.880***	0.965***
log(p)	0.725***	0.727***	0.581***	0.650***	0.725***	0.727***	0.581***	0.650***
n	0.042***	0.013***	0.033***	0.058***	0.061***	0.037	0.060*	0.062**
n X log(1+r)					-0.322	-0.385	-0.45	-0.077
N	67953	22203	22433	23317	67953	22203	22433	23317
R2	0.949	0.812	0.687	0.899	0.949	0.812	0.687	0.899

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Panel B: Fixed Effect Estimation

	Baseline				Robustness			
	All	Small	Medium	Large	All	Small	Medium	Large
log(r)	-0.708***	-0.798***	-0.750***	-0.572***	-0.184	0.576	0.051	0.427*
log(p)	0.900***	0.850***	0.785***	0.806***	0.899***	0.850***	0.784***	0.805***
log(p)	0.489***	0.386***	0.440***	0.530***	0.489***	0.386***	0.439***	0.528***
n	0.033***	0.042***	0.030***	0.035***	0.063***	0.125***	0.077***	0.089***
n X log(1+r)					-0.509***	-1.397***	-0.783**	-0.936***
N	67953	22203	22433	23317	67953	22203	22433	23317
R2	0.656	0.567	0.587	0.646	0.656	0.567	0.587	0.646

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 10: **Implied increase in life expectancy assumptions:** This table displays estimates of the following regression $adj_{i,t} = \gamma \text{funding}_{i,t-1} + \delta X_{i,t-1} + \epsilon_{i,t}$ where $adj_{i,t}$ is the the potential increase in life expectancy relative to the 2007 mortality table. Regressors are lagged by one period and are defined analogously to Table 4. The sample consists of all pension plans in 2007 for which lagged regressors are available.

	OLS	
	1	2
funding	-0.601***	
size	0.019	0.022
duration	0.523***	0.462***
ROA	5.01	5.912
funding(+)		-0.228
funding(-)		1.162***
Industry dummies	yes	yes
Year dummies	no	no
R2	0.093	0.098
N	2304	2304

A Appendix

A.1 Extended Valuation Model

To derive the extended regression setup, we first modify the initial valuation model by recognizing that the present value of an annuity starting t years in the future is equal to the present value of an annuity starting one period into the future, discounted over the additional (t-1) periods. The extension thus requires information regarding the time until expected retirement age for the underlying pension plans. The age-workforce distribution in Figure (**??**) contains information on 44 different age buckets (i.e. each year of age between 21 and 65), which allows to rewrite equation (6) as follows

$$L \approx pb\left[\frac{1-(1+r)^{-n}}{r}\right]\sum_{i=1}^{44}\left(\frac{w_i}{(1+r)^{(t_r-\min[t_r,t_i])}}\right) \tag{10}$$

where t_r and t_i denote retirement (age) and current age, w_i denotes the fraction of the workforce for age bucket i where $i \in (1, 2, ..., 10)$. That is, in case a plan participant has not reached retirement age yet, future pension payouts are discounted over an additional period reflecting the difference between current age and the expected retirement age. To make sure that we don't employ a negative time-to-retirement, the minimum of current age and retirement age is applied. Applying the same set of transformations as to equation (6) implies the following testable equation

$$\log[L] = \alpha + \beta_1\log(p) + \beta_2\log(b) + \beta_3\log(r) + \beta_4 n + \beta_5\log(r) \times n + \beta_6 X\epsilon \tag{11}$$

where $X = \log\left(\sum_{i=1}^{44}\left(\frac{w_i}{(1+r)^{(t_r-\min[t_r,t_i])}}\right)\right)$.