WP/12/170

IMF Working Paper

The Impact of Longevity Improvements on U.S. Corporate Defined Benefit Pension Plans

Michael Kisser, John Kiff, Erik S. Oppers, and Mauricio Soto

INTERNATIONAL MONETARY FUND

WP/12/170

IMF Working Paper

Monetary and Capital Markets and Fiscal Affairs Department

The Impact of Longevity Improvements on U.S. Corporate Defined Benefit Pension Plans

Prepared by Michael Kisser, John Kiff, Erik S. Oppers, and Mauricio Soto

Authorized for distribution by Laura Kodres and Benedict Clements

June 2012

Abstract

This paper provides the first empirical assessment of the impact of life expectancy assumptions on the liabilities of private U.S. defined benefit (DB) pension plans. Using detailed actuarial and financial information provided by the U.S. Department of Labor, we construct a longevity variable for each pension plan and then measure the impact of varying life expectancy assumptions across plans and over time on pension plan liabilities. The results indicate that each additional year of life expectancy increases pension liabilities by about 3 to 4 percent. This effect is not only statistically highly significant but also economically: each year of additional life expectancy would increase private U.S. DB pension plan liabilities by as much as $84 billion.

JEL Classification Numbers: G23, J1, J32

Keywords: Pension Plans; Longevity Risk; Life Expectancy; Mortality

Author's E-Mail Address: michael.kisser@nhh.no; jkiff@imf.org; soppers@imf.org and msoto@imf.org

Contents Page

I 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. Unfortunately, for defined benefit (DB) pension plans this increases the average length of time over which benefits are provided and, given that the size of global DB pension promises is substantial, means the potential costs of longevity risk are worthy of serious examination.

This paper aims to provide an empirical assessment of the impact of longevity risk on DB pension plans. To answer to this question, we focus on data provided by the U.S. Department of Labor (DOL), specifically on the Form 5500 data. This dataset contains detailed information on various actuarial assumptions, including the mortality table used in the computation of a plan's pension liabilities, which allows us to estimate the effect of life expectancy assumptions on the value of pension liabilities.

The results show that each year of life expectancy raises pension liabilities by 3 to 4 percent. The economic magnitude of this effect is substantial. As of 2007, U.S. private DB pension plans were underfunded by \$83 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 \$84 billion, thereby doubling the degree of underfunding.[1] Corporate pension sponsors would have to make many multiples of typical annual pension contributions to match these extra liabilities.

---

[1] Underfunding is computed by comparing pension funds' actuarial value of assets and 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 1.5 percent of U.S. 2007 Gross Domestic Product (GDP).[2] On a global basis, the aggregate value of private DB pension liabilities amounts to $23 trillion, implying that a similar longevity shock could raise global private pension liabilities by as much as $2.8 trillion.[3]

To our knowledge, this paper provides the first empirical assessment of the impact of longevity risk on pension plans. Previous studies generally rely on hypothetical or what-if-type analyses to derive the effect of life expectancy assumptions on pension liabilities, see for example Antolin (2007) or Dushi, Friedberg, and Webb (2010). One advantage of the approach used in this paper is that, by using actual data, it provides an average estimate of the longevity impact for private DB pension plans in the United States. Furthermore, we are able to estimate the impact of a longevity shock on different subsamples of plans and, in this regard, find that the effect is similar across different types of funds. Finally, the proposed method disentangles the effect of an additional year of life expectancy on pension liabilities and therefore does not depend on exogenous assumptions regarding the magnitude of improvement in life expectancy.

The realization of longevity risk - and thus an increase in pension liabilities - constitutes

---

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

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 in each successive forecast.[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] 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. While the Pension Protection Act of 2006 has constrained the freedom pension plan sponsors had in using (outdated) mortality tables, it is not able to mitigate the problem of underestimating improvements in life expectancy. Moreover, the Pension Protection Act of 2006 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.

The paper proceeds as follows. Section (II) provides a short literature review on longevity risk and its relation to private and public pension funds. Section (III) presents the underlying dataset and Section (IV) estimates the impact of longevity assumptions on corporate pension plans.

---

[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 IMF (2012).

II Related Literature

This section provides a short overview of the literature on longevity risk and its impact on private and public pension plans. Specifically, we first present a brief review of longevity forecasting methods, then discuss papers investigating the impact of longevity risk on pension plans and conclude with a discussion of more broadly related literature.

In general, mortality projections are the result of extrapolative approaches based on historical trends, which may be complemented by a mix of expert opinion and process-based methods focusing on the evolution of causes of death. Process-based methods use biomedical assumptions to forecast death rates stemming from various causes of death. A potential shortcoming is that they necessitate a model for which factors drive aggregate death rates and, if they are used for forecasting purposes, a projection of the same factors.[6] For a detailed literature review on mortality projections, see Waldron (2005).

Extrapolative approaches focus on past trends and attempt to forecast future life expectancy using historical data on death rates. 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.

---

[6] For more details, see CMI (2004).

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. For more details, see for example Lee and Miller (2001), CMI (2004), CMI (2011) and Girosi and King (2007).

Antolin (2007) provides a numerical analysis on the impact of longevity risk on defined benefit pension plans. He computes pension liabilities for a hypothetical pension fund that is closed to new entrants and then analyzes the effect of deterministic improvements in life expectancy on the funds pension liabilities. Antolin 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 impact of updating mortality tables used to estimate the pension liabilities reported on Forms 10-K, which typically reflect mortality rates in the early 1980s.[7] They find that updating mortality tables according to the Lee-Carter model – which suggest an increase of life expectancy at age 60 of about 3 years since the early 1980s – would increase liabilities by 12 percent for the average male plan participant.

Given the documented magnitude of longevity risk, the paper also indirectly relates to the

---

[7] 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).

literature on longevity risk transfer. DB pension plan providers can hedge longevity risk using market based solutions such as pension 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 IMF (2012), while the use of capital market based solutions to manage longevity risk has been growing, the overall global activity remains rather small.[8]

A more pragmatic way for pension plan sponsors to mitigate longevity risk is to offer defined contribution (DC) plans instead.[9] In that case, the risk is shifted 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 general populations. 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.

---

[8] Note that this does not hold for the United Kingdom and the Netherlands who host an active longevity risk transfer market.

[9] Defined contribution (DC) plans only require the sponsor to make regular contributions to the plan but shift the expected payout (i.e. benefit) risk to the employee.

III Data

This study uses the filings of the Form 5500 pension plan data from the Department of Labor (DOL).[10] 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.[11] Any administrator or sponsor of a plan must file this information once a year.

This study focuses on the general information section and the corresponding actuarial and financial information for fillings submitted to the DOL between 1995 and 2007. The starting point is motivated by the fact that as of 1995 information regarding the underlying mortality tables used in actuarial computations have become 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.

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. 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. While the Form 5500 also includes

---

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

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

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.[12]

When computing the present value of future pension obligations, corporations have to make and 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. Since 1995, information on the underlying mortality tables for men and woman is available and has been reported to the DOL.[13]

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

---

[12] 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).

[13] Specifically, the Form 5500 includes information on pre- and post-retirement mortality tables for both men and women.

1994 Uninsured Pensioner Table and (8) the 2007 Mortality Table.[14] 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 69 percent and 16 percent over the sample period. Also, 12 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 2000 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.[15] Thus, this paper uses robustness checks below to 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 per plan.[16] Panel B

---

[14] 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).

[15] This is consistent with the anecdotal evidence highlighted in Dushi, Friedberg, and Webb (2010) suggesting that larger plans are more likely to use more up to date mortality tables.

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

Table 1: **Mortality Tables Used between 1995 and 2007 (in percent):** This table displays which mortality tables have been used over the period from 1995 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
1995	1	13	0	7	1	48	6	0	3	0	22
1996	0	11	0	6	0	57	1	0	6	0	19
1997	0	9	0	4	0	62	1	0	6	0	17
1998	0	7	0	4	0	66	1	0	6	0	15
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	3	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	49	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	4	6
Average	0	6	0	3	0	56	2	1	16	2	14

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.

In order to measure the impact of longevity assumptions on pension liabilities, it is crucial to get an understanding of how these tables differ. Table (3) therefore 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. Table (3) also shows that simply ranking mortality tables by the year mentioned in their title would lead to incorrect inferences regarding the underlying longevity assumptions. 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. Besides, the tables also differ with respect to the underlying sample.[17]

In order to rank the tables by the underlying mortality assumptions, we compute the implied life expectancy at age 63 for working males.[18] Life expectancy can be derived from mortality rates by first computing survival rates and then summing up all successive multi-period survival rates. It should be noted that this ranking is superior to a simple ranking based

---

[17] 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.

[18] Note that the average retirement age for our sample is equal to 63.18 years.

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)												
1995	78,296	46,464	5,014	24,649	7,127	47,372	211,916	.	3,953	.	113,425	67,823
1996	44,467	53,589	2,888	29,389	8,676	53,678	39,267	.	326,374	1,548	93,041	71,236
1997	99,081	65,034	2,982	27,772	9,560	63,623	232,953	.	279,963	4,442	108,966	79,679
1998	114,845	73,340	3,319	51,726	6,384	76,505	252,867	.	277,315	5,190	130,102	92,665
1999	253,639	90,020	4,031	23,679	5,671	82,125	260,817	.	272,738	5,640	159,554	99,069
2000	53,869	109,001	5,753	44,339	10,525	77,268	302,917	.	239,408	7,382	128,009	96,545
2001	54,378	121,717	5,733	41,652	6,990	97,650	272,337	.	362,151	5,228	205,708	129,400
2002	25,273	131,598	4,729	47,855	7,950	104,914	300,850	.	331,780	5,238	238,302	140,349
2003	145,047	121,623	2,936	55,030	10,085	117,168	275,360	.	341,799	6,361	281,617	160,214
2004	222,917	136,376	2,769	74,149	12,272	122,042	335,901	.	283,226	7,106	201,478	157,519
2005	241,092	179,282	3,105	81,090	12,745	126,676	300,968	.	265,654	8,132	232,647	177,087
2006	302,408	172,359	3,931	106,901	18,251	77,955	315,103	.	246,276	10,070	248,727	186,773
2007	64,407	51,260	3,951	54,115	21,820	110,324	262,766	178,691	263,629	11,683	269,472	209,350
Panel B: Number of Plans												
1995	93	2,182	21	1,067	83	7,812	1,003	.	458	.	3,597	17,217
1996	66	1,697	15	856	60	8,771	96	.	902	2	2,920	16,463
1997	60	1,336	14	647	56	9,115	95	.	906	9	2,503	15,759
1998	46	1,013	12	552	43	9,256	173	.	881	2	2,087	15,095
1999	20	482	9	264	31	6,157	129	.	610	228	1,283	9,833
2000	26	417	4	251	35	6,745	194	.	701	214	1,283	10,107
2001	25	423	5	248	39	8,536	284	.	1,009	280	1,492	12,796
2002	12	322	9	203	36	8,263	297	.	1,166	306	1,364	12,295
2003	13	271	8	181	33	7,636	351	.	1,498	325	1,237	11,874
2004	9	176	5	139	29	6,272	332	.	1,740	283	999	10,227
2005	9	163	4	129	26	5,502	378	.	3,470	356	1,079	11,464
2006	7	135	3	104	23	2,907	320	.	5,781	352	827	10,733
2007	5	98	4	73	16	1,671	229	1,282	5,910	362	649	10,634

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

on age specific death rates as the concept of life expectancy incorporates all future expected death rates beyond that age. The ranking is used to construct a longevity variable which is introduced in Definition (1).

Definition 1 *We define the following longevity variable which summarizes the implied life expectancy for males aged 63 for the various mortality tables. Specifically, life expectancies are as follows.*

Looking at the mortality tables which are still in use in 2007, the difference in implied life expectancy between the oldest and most current mortality table amounts to 4.20 years.[19]

---

[19] The most outdated table still in use is the 1971 Group Annuity Table.

Longevity Variable	Value (years)
No Table	14.32
1951 Group Annuity Table	14.32
Unisex Pensioner 1984 Table	14.74
1971 Group Annuity Mortality	15.34
1983 Group Annuity Table	17.20
1971 Individual Annuity Mortality	17.41
Uninsured Pensioner Table 1994	17.76
1983 Individual Annuity Table	18.24
2007 Mortality Table	19.54

Focusing on the large fraction of firms employing the 1983 Group Annuity Table, the difference with respect to the most recent table is still substantial and equals 2.34 years. This longevity variable will be employed in the regression analysis below to capture the effect of mortality assumptions on pension liabilities across firms and over time.[20]

In order to create the final sample, we proceed as follows. Starting with the full sample for which information on pension liabilities and mortality information are available (157,320 plan-year observations), we first exclude all observations for which information on the underlying mortality assumptions is not available, i.e. those classified as "Other." This reduces the sample to 132,288 plan-year observations. As a next step, we delete all plan-year observations which can not be clearly assigned (i.e. those classified as "Hybrid") to the categories mentioned in Table (3). The final sample consists of 110,968 plan-year observations and captures both cross-sectional as well as plan-specific variability in the underlying mortality tables.

---

[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).

IV Analysis

This section estimates the impact of longevity assumptions 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 final dataset. The section concludes by presenting several robustness checks.

A 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

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

where p is the number of plan participants, T is the assumed maximum life span, s_i denotes the survival probability over i periods, b is the promised amount of periodical payouts and r denotes the discount rate.[21] To capture the impact of longevity assumptions, we will proxy for equation (1) by using

---

[21] 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.

$$L \approx pb\left[\frac{1-(1+r)^{-n}}{r}\right] \tag{2}$$

where n is the expected length of future payouts.[22] Rearranging terms and taking the logarithm, it follows that

$$\log(L) \approx \log(p) + \log(b) - \log(r) + \log\left[(1+r)^{n} - 1\right] - n\log(1+r) \tag{3}$$

Linearizing the last two terms of equation (3), we obtain the following regression specification

$$\log[L] = \alpha + \beta_1\log(p) + \beta_2\log(b) + \beta_3\log(r) + \beta_4 n + \beta_5\log(r) \times n + \epsilon \tag{4}$$

which will be estimated in a panel regression, accounting for plan specific effects. 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.

---

[22] Note that the life expectancy is equal to the sum of the individual survival probabilities, i.e. $n = \sum_i^T s_i$. The valuations presented in equation (1) and equation (2) will be exactly equal to each other in case the discount rate r equals zero. If we assume that r is low, as it is in the current low interest rate environment, then the approximation is reasonable.

B Main Results

We start the analysis by relating the simple pension valuation model to the Form 5500 and focusing 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 Definition (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 it is negative. 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 1 (99) percent level.

Results are displayed in Table (4) and imply that U.S. pension funds face a longevity risk that would see their liabilities to retired participants increase by about 3 percent for each year that their retirees live longer than expected.[23] Furthermore, the regression explains 74 percent of the variation in (the logarithm) of pension liabilities and suggests that the estimation provides a good proxy for the true valuation model.

Table 4: **The impact of longevity assumptions on pension liabilities of retired participants and beneficiaries receiving payments.** This table displays results when estimating 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 as given by Definition (1). The estimation is done by accounting for plan-fixed effects and standard errors are adjusted for heteroskedasticity.

	(1) Coefficient
log(r)	-0.945***
log(p)	0.914***
log(b)	0.519***
n	0.030***
Observations	89552
R^2	0.742

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

This finding is largely consistent with estimates that can be derived from the partial derivative of equation (2) and those reported by the pension industry. 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.

---

[23] Due to the high correlation between the interaction term, the interest rate and the longevity index, all three variables are statistically insignificant such that we only report results without including the interaction term.

firms.

To make sure that results are not driven by the size of pension funds, we split the sample into four equally sized subgroups based on the distribution of the overall pension liabilities. Table (5) shows that the estimation performs well across all subsamples. It turns out that an additional year of life expectancy increases pension liabilities to retired plan participants by 2.4 percent to 3.6 percent.

Table 5: **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 (4). Columns (1) to (4) display the coefficients associated with the four different quartiles of the size of pension liabilities.

	(1) Small	(2) Medium	(3) Large	(4) Very Large
log(r)	-1.226***	-0.932***	-0.924***	-0.820***
log(p)	0.809***	0.719***	0.707***	0.832***
log(b)	0.405***	0.380***	0.413***	0.559***
n	0.032***	0.024***	0.036***	0.036***
Observations	21410	22594	22709	22839
R^2	0.610	0.553	0.616	0.730

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

The results displayed in Tables (4) and (5) present estimates for the subsample of retired plan participants which correspond to the pension valuation model of equation (4), i.e. we focus on those plan participants that are already receiving the annuity. We now test whether the results are robust with respect to the full sample and therefore 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.

While the Form 5500 database does not contain detailed information on the composition and age structure of a firm's workforce, we gratefully acknowledge data assistance by the Pension Benefit Guaranty Corporation who provided this information for a subsample of 447 pension plans covering the period between 2005 and 2007. For each pension plan, the dataset reports the fraction of participants for each year of age between 20 and 64.[24] Using this information, we then compute the average fraction of participants at each age across the sample. Results are shown in Figure (1) which visualizes the underlying distribution of actual ages of the workforce. Note that half of the average workforce is older than 50 years and thus close to retirement. Moreover, it seems that a large fraction of the workforce retires at the ages of 50, 55 and 60 (relative to the ages between them) as indicated by the large declines at these ages.

To estimate the impact of life expectancy assumption on pension liabilities of the full sample, we use the age-workforce distribution implied by the subsample of 447 pension funds as a proxy for the average age-workforce distribution of the funds included in the full sample. Specifically, we first infer the corresponding age deciles and then compute the distance to retirement for each decile. This number is then used to discount the present value of pension liabilities at retirement to the time implied by the average age of the decile. For more details and a derivation of the estimation approach, please see the Appendix.

Table (6) displays corresponding results. Specifically, the table displays results for all funds between 2005 and 2007 as this is the time period for which data on the age-workforce distribution is available. Results show that the estimation seems to work reasonably well,

---

[24] The original data uses attachments to the Schedule SB and reports the number of participants in 5-year groups of age/service combinations. The data is then uniformly spread within each of the 5-year groups.

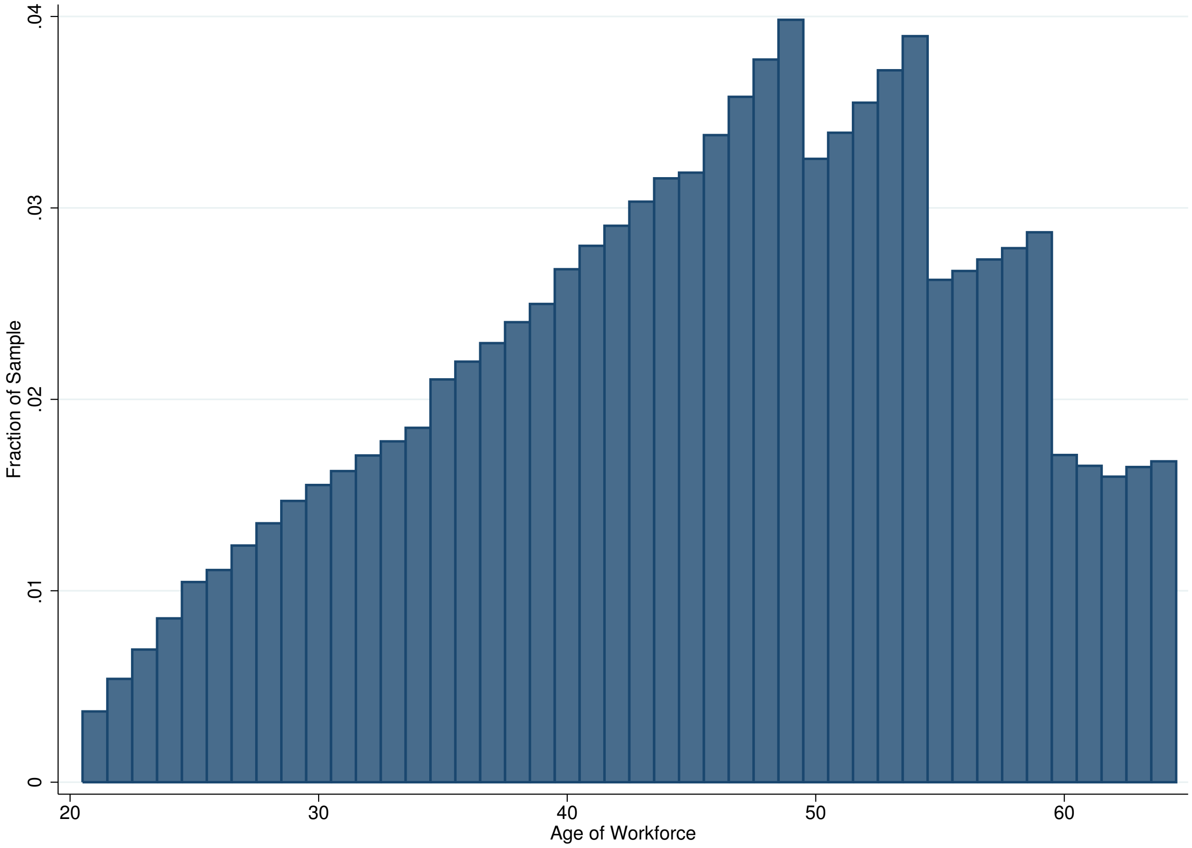

Figure 1: **The composition of the workforce.** The figure displays a frequency distribution of the age of the workforce. Average (median) age equals 46.04 (47.25) years. The statistics are based on a sample of 447 pension plans over the period from 2005 to 2007.

thereby suggesting that the age-workforce distribution implied by the subsample of funds works as a good proxy for the age-workforce distribution during that period. Specifically, it is shown that an additional year of life expectancy raises pension liabilities by 3.7 percent.[25]

---

[25] Unreported results show that, when using the proxy for the full sample, the impact of an additional year of life expectancy on pension liabilities increases to 7.8 percent. However, given that the distribution of the workforce has most likely changed over the period from 1995 to 2007, we do not think that the age distribution of 2005-2007 is a good proxy for the full sample.

Table 6: **The impact of longevity assumptions on total pension liabilities.** This table displays results when estimating the subsequent regression $\log[L] = \alpha + \beta_1 \log[r] + \beta_2 \log[p] + \beta_3 \log[b] + \beta_4 n + \gamma_1 X + \epsilon$ where L denotes the present value of total pension liabilities (ACTRL RPA94 INFO CURR LIAB 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 total plan participants (TOT PARTCP BOY 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 as given by Definition (1). The variable X controls for the effect of the age-workforce distribution and is specified in the Appendix. The estimation is done by accounting for plan-fixed effects and standard errors are adjusted for heteroskedasticity.

	(1) Coefficient
log(r)	-1.675***
log(p)	0.613***
log(b)	0.054***
n	0.037***
X	-0.007
Observations	11154
R^2	0.531

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

C Additional Robustness Checks

This section presents additional robustness checks regarding the impact of longevity assumptions on pension liabilities. Specifically, Section (III) has shown that in the last years of the sample an increasing fraction of funds has not specified a concrete mortality table, i.e. the table was classified as “Other.”

Anecdotal evidence suggests that funds may have used the RP-2000 Table which is not specifically mentioned in the Form 5500 database and thus the corresponding mortality table would be classified as “Other.” To test how this would affect existing results, we therefore assume that these funds actually used the RP-2000 Table and compute the corresponding life expectancy at age 63.

Table 7: **Robustness Check: Unclassified Mortality Tables.** This table displays results when estimating the baseline regression of Table (4) 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. Columns (1) displays the coefficients for the full sample, columns (2) to (5) for four different quartiles of pension liabilities.

	(1) All	(2) Small	(3) Medium	(4) Large	(5) Very Large
log(r)	-0.915***	-1.174***	-0.976***	-0.886***	-0.763***
log(p)	0.933***	0.848***	0.720***	0.738***	0.852***
log(b)	0.526***	0.408***	0.384***	0.436***	0.559***
n	0.034***	0.031***	0.032***	0.045***	0.043***
Observations	110607	26475	27845	28024	28263
R^2	0.764	0.635	0.571	0.656	0.755

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

We then estimate the effect of longevity assumptions both for the full sample and across different sizes of pension funds. Table (7) displays corresponding results. It can be seen that an additional year of life expectancy raises pension liabilities by 3.4 percent. Controlling additionally for the size of pension funds, it turns out that longevity assumptions have a stronger impact for larger funds as liabilities increase by 4.5 percent (4.3 percent) for medium (large) funds. Summing up, results are robust with respect to the the possibility that funds use the RP-2000 Mortality Table.

Alternatively, we conduct two additional robustness checks regarding funds with unclassified mortality tables. Specifically, we assume that they either use the most conservative table (the 2007 Mortality Table) or the most common table, i.e. the 1983 GAM Table. Similar to above, we then re-estimate the model and present results both for the full sample as well as when controlling additionally for the size of pension funds. Both robustness checks do not alter the results and imply that an additional year of life expectancy raises pension liabilities between 2.4 percent to 3.4 percent. More details can be found in the Appendix.

The final robustness check analyzes whether results are robust with respect to a more recent time period. We therefore focus on the period between 2001 and 2007 for which we then re-estimate the benchmark model. Results are again presented for the full sample as well as when controlling additionally for the size of pension funds. Table (8) shows that results are qualitatively unchanged.

Table 8: **Robustness Check: More recent evidence.** This table displays results when estimating the baseline regression of Table (4) for the more recent period between 2001 and 2007. Columns (1) displays the coefficients for the full sample, columns (2) to (5) for four different quartiles of pension liabilities.

	(1) All	(2) Small	(3) Medium	(4) Large	(5) Very Large
log(r)	-0.655***	-0.812***	-0.631***	-0.601***	-0.486***
log(p)	0.814***	0.738***	0.710***	0.769***	0.695***
log(b)	0.431***	0.285***	0.344***	0.362***	0.515***
n	0.034***	0.019*	0.046***	0.036***	0.046***
Observations	40663	9770	10252	10264	10377
R^2	0.550	0.442	0.453	0.538	0.511

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

Summing up, the robustness checks demonstrate that the findings are robust with respect to the size, the time period, and the exclusion of funds with unspecified mortality tables.

V Conclusion

To our knowledge, this paper provides the first empirical assessment of the impact of longevity assumptions on pension liabilities in the United States.

Using detailed actuarial and financial data on U.S. pension funds, we construct a longevity variable for each pension plan by computing the implied life expectancy under the mortality table employed in the calculation of pension liabilities. We then infer the impact of longevity increases across funds and from instances when plans shift to a more recent mortality table.

Results 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 3 percent to 4 percent. This effect is robust to the size of pension plans and also with respect to different specifications and tests.

The effect is also economically significant. 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 $84 billion. This would increase the amount by which private DB pension funds are underfunded by approximately 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.

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.

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.

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.

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.

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

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

IMF. Global financial stability report. 2012.

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

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.

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.

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.

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

VI Appendix 1

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. Assuming that we split the sample into deciles based on the age distribution implied by Figure (1), we can rewrite equation (2) as follows

$$L \approx pb\left[\frac{1-(1+r)^{-n}}{r}\right]\left(\frac{0.1}{(1+r)^{(t_r-\min[t_r,t_1])}}+\frac{0.1}{(1+r)^{(t_r-\min[t_r,t_2])}}+\ldots+\frac{0.1}{(1+r)^{(t_r-\min[t_r,t_{10}])}}\right) \tag{5}$$

where t_r and t_i denote retirement (age) and current age 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 (2) implies the following testable equation

$$\log[L] = \alpha + \beta_1 \log(p) + \beta_2 \log(b) + \beta_3 \log(r) + \beta_4 n + \beta_5 \log(r) \times n + \beta_6 X \epsilon \tag{6}$$

where $X = \log\left(\frac{0.1}{(1+r)^{(t_r-\min[t_r,t_1])}} + \frac{0.1}{(1+r)^{(t_r-\min[t_r,t_2])}} + ... + \frac{0.1}{(1+r)^{t_r-\min([t_r,t_{10}])}}\right)$.

Table 9: **Robustness Check: Unclassified Mortality Tables (2007 Table).** This table displays results when estimating the baseline regression of Table (4) for a larger sample of firms. Specifically, it is assumed that funds which classify the underlying mortality table as Other, follow the 2007 Mortality Table. Columns (1) displays the coefficients for the full sample, columns (2) to (5) for four different quartiles of pension liabilities.

	(1) All	(2) Small	(3) Medium	(4) Large	(5) Very Large
log(r)	-0.906***	-1.164***	-0.964***	-0.877***	-0.763***
log(p)	0.931***	0.847***	0.718***	0.736***	0.850***
log(b)	0.525***	0.408***	0.384***	0.435***	0.558***
n	0.024***	0.024***	0.024***	0.030***	0.025***
Observations	110607	26475	27845	28024	28263
R^2	0.764	0.636	0.571	0.657	0.755

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

Table 10: **Robustness Check: Unclassified Mortality Tables (1983 GAM).** This table displays results when estimating the baseline regression of Table (4) for a larger sample of firms. Specifically, it is assumed that funds which classify the underlying mortality table as Other, follow the 1983 GAM Table and the longevity variable n is updated accordingly. Columns (1) displays the coefficients for the full sample, columns (2) to (5) for four different quartiles of pension liabilities.

	(1) All	(2) Small	(3) Medium	(4) Large	(5) Very Large
log(r)	-0.952***	-1.193***	-1.006***	-0.934***	-0.807***
log(p)	0.937***	0.850***	0.724***	0.747***	0.863***
log(b)	0.529***	0.409***	0.386***	0.442***	0.567***
n	0.027***	0.026***	0.023***	0.034***	0.034***
Observations	110607	26475	27845	28024	28263
R^2	0.763	0.635	0.569	0.653	0.753

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