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

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Contribution: First Empirical Assessment

- Paper provides first empirical assessment of the impact of longevity risk on U.S. Defined benefit (DB) pension liabilities
- We construct a longevity variable using detailed actuarial information from the U.S. Department of Labor
- We then show that each year of life expectancy increases pension liabilities by 3 to 4%
- Effect is robust across a variety of robustness checks

Contribution: The Economic Effect is Substantial

- In 2007, underfunding of U.S. DB pension funds equals $83 billion and total liabilities amount to $2.2 trillion
  - A one-year longevity shock would double underfunding
  - Would require a substantial increase in annual contributions
- Aggregate public and private U.S. DB pension liabilities equal approximately $5.4 trillion
  - A one-year longevity shock could increase these liabilities by as much as 1.5% of U.S. 2007 GDP
- Global private DB pension liabilities amount to $23 trillion
  - A one-year longevity shock could increase these liabilities by as much as $2.8 trillion

Underestimation of Life Expectancy is a Likely Event

- Past forecasts have consistently underestimated improvements in future life expectancy:
  - Shaw (2007): 10-year forecasts in U.K. underestimate improvements in future life expectancy by nearly 2 years
  - Bongaarts and Bulatao (2000): 20 year forecasts in multiple countries underestimate improvements by on average 3 years
- Mortality Tables are based on mortality forecasts:
  - Pension Protection Act (2006): mortality tables need to be updated only every ten years
  - Increases likelihood of a lumpy and significant increase in pension liabilities due to discrete update of mortality table

Literature: Longevity Risk and Pension Plans

In general

Existing literature using hypothetical or what-if type analysis

- Dushi et al. (2010): Journal of Pension Economics and Finance
  - Updating tables to Lee-Carter method increases life expectancy by three years
  - Pension liabilities would increase by 12%
- Antolin (2007): OECD Working Paper
  - Computes pension liabilities for hypothetical pension fund
  - Analyzes deterministic improvements in longevity risk on liabilities
  - Finds that an improvement of one-year per decade increases liabilities by 8-10%

Data Source

- Form 5500 pension plan data from U.S. Department of Labor:
  - General information on plan
  - Actuarial information: Schedule B
  - Financial information: Schedule H
- Period from 1995 to 2007
- Selected Information as of 2007
  - DB pension plans covered approximately 42 million participants
  - Aggregate value of pension liabilities is $2.2 trillion

Use of Mortality Tables over Sample Period

Year	1951 GAM	1971 GAM	1971 IAM	UP 1984	1983 IAM	1983 GAM	UP 1994	2007 Table	Oth.	None	Hybr.
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
Avg.	0	6	0	3	0	56	2	1	16	2	14

Mortality Tables and Life Expectancy

- Substantial amount of variation in use of tables
- In 2007: 12% of funds switched to most recent table
- Unclassified tables constitute 57% of sample in final year
- Average size of pension liabilities has increased over time
- Funds using the 2007 mortality table or unspecified tables are substantially larger (robustness check)

Mortality Tables and Death Rates

Age	1951 GAM	1971 GAM	1971 IAM	UP 1984	1983 IAM	1983 GAM	UP 1994	Table 2007
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

- Death rates provide snapshot for given age
- However, picture is still incomplete
- Therefore compute survival rates and life expectancy for each table

Longevity Variable

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

Regression Setup (1)

Going back to as early as DeWitt(1671), it is known that the present value of a pension liability L is given by

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

We then approximate equation [1] by

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

where n is the expected length of future payouts.

Regression Setup (2)

Log-linearizing the previous equation, we get that

$$\log[L] = \alpha + \beta_1 \log(p) + \beta_2 \log(b) + \beta_3 \log(r) + \beta_4 n + \beta_5 \log(r) \times n + \epsilon \quad (3)$$

Equation [3] will be applied to our sample.

Estimation Results: Baseline Regression

Equation (3) technically fits to a subsample of the data, i.e. those plan participants that already receive the annuity

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

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

Does Size Drive Results?

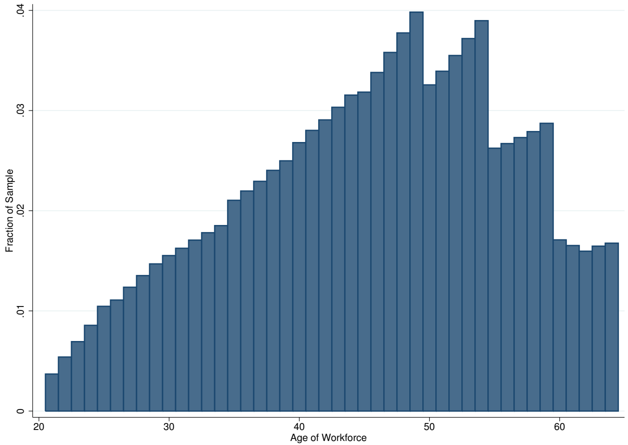
	(1) Small	(2) Medium	(3) Large	(4) Very Large
log(r)	-1.226***	-0.932***	-0.924***	-0.820***
log(p)	0.809***	0.719***	0.707***	0.832***
log(b)	0.405***	0.380***	0.413***	0.559***
n	0.032***	0.024***	0.036***	0.036***
Observations	21410	22594	22709	22839
R^2	0.610	0.553	0.616	0.730

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

What about the full sample?

- So far, equation (3) has only been estimated for a subsample of the data
- To do the estimation for the full sample, need to adjust for age of workforce
  - Form 5500 Data does not contain this information
  - However, the Pension Benefit Guarantee Corporation (PBGC) provided the data for a subsample of 447 plans for the period from 2005 to 2007
- The following figure visualizes the age-workforce distribution

Age-Workforce Distribution for 2005 to 2007



Adjustment for full sample

Benefit payments must be discounted to current age of employee decile

$$L \approx pb\left[\frac{1-(1+r)^{-n}}{r}\right]\left(\frac{0.1}{(1+r)^{(t_r-\min[t_r,t_1])}}+\frac{0.1}{(1+r)^{(t_r-\min[t_r,t_2])}}+\ldots+\frac{0.1}{(1+r)^{(t_r-\min[t_r,t_{10}])}}\right) \tag{4}$$

This translates into the following regression

$$\log[L]=\alpha+\beta_1\log(p)+\beta_2\log(b)+\beta_3\log(r)+\beta_4 n+\beta_5\log(r)\times n+\beta_6 X\epsilon \tag{5}$$

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

Estimation Results: Full Sample (2005 to 2007)

	(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

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

Robustness Checks

- Initial evidence has shown that in 2007, a substantial fraction of pension plans have been classified as "Other"
- Exclusion of these funds might drive results
- In fact, anecdotal evidence suggests that these funds use the RP-2000 mortality table (i.e. a table which is not captured by the Form 5500 data)
- We therefore propose the following robustness checks
  - Treat "Other" as RP-2000 mortality table
  - Treat "Other" as most common table (i.e. 1983 GAM)
  - Treat "Other" as most conservative table (i.e. 2007 Mortality Table)
- Finally, we also check whether effect is robust to most recent time period

Robustness Check: RP-2000 Mortality Table

	(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

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

Robustness: Most Commonly Used Table (1983 GAM)

	(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

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

Robustness: Most Conservative Table (2007 Table)

	(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

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

Robustness: Most Recent Time Period (2001 to 2007)

	(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

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

Conclusion (1)

- Paper provides first empirical assessment of the impact of longevity improvement on U.S. DB Pension Liabilities
- Find that each year of life expectancy increases liabilities by roughly 3-4%
- Effect is robust across variety of robustness checks:
  - Size
  - Time Period
  - Subsample
  - Definition of Unclassified Tables

Conclusion (2)

- Effect is also economically highly significant
  - A 1-year longevity shock would double underfunding
  - Assuming shock has similar effect for public D.B. plans, the overall effect would correspond to an amount equal to 1.5% of U.S. 2007 GDP
  - Assuming shock has similar effect for global private D.B. plans, the overall effect would amount to $2.3 trillion
- Most importantly, the realization of longevity improvement is highly likely given (i) past underestimations in life expectancy improvements and (ii) the widespread use of mortality tables which even today only need to be updated every 10 years