Firm-Level Longevity Risk: Measurement and the Role of Enterprise Risk Management

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1 Motivation

2 Longevity Risk Measurement

3 Empirical Analysis: ERM Adoption and Longevity Risk

4 Conclusion

Motivation

Longevity risk: uncertainty stemming from increasing life expectancy.

- Increasingly significant challenges for firms.
- Despite its importance, no empirical measure exists to assess longevity risk at the firm level.
- A firm-level measure is needed to understand variation in exposures and potential management strategies.

Motivation: Why Longevity Risk Matters

- Longevity risk: risk that people live longer than expected.
- Firm's exposure: via defined benefit (DB) pension plans.
- In 2022, $3.7 trillion in DB assets, covering 34.4M Americans (Boivie and Doonan, 2023; Topoleski et al., 2023).
- Each extra year of life expectancy $\Rightarrow +4$–5% liabilities, $\approx \$84B$ (Kisser et al., 2012; Chen et al., 2022).

Motivation: Why Firm-Level Study?

- Firm's DB pension bears direct financial exposure.
- Heterogeneity across firms: workforce demographics, state life expectancy, industry structure.

Motivation: Research Gap

No empirical measure of *firm-level* longevity risk exists.

- Actuarial research: focuses on population-level models (Blake et al., 2006; Denuit et al., 2011; Biffis and Blake, 2013; Coughlan et al., 2013; Wong et al., 2015; Zhu and Bauer, 2022).
- Finance literature: more on investment risks, not longevity.
  - Recent literature highlights pension obligations as a key driver of corporate behavior (Shivdasani and Stefanescu, 2010; Phan and Hegde, 2013; Bartram, 2016; Chen et al., 2019).
  - Earlier studies use DB pension plans to test theories of financial constraints, investment–stakeholder conflicts, and managerial risk-shifting under distress (Rauh, 2006; Bartram, 2017; Dambra, 2018).
- Extend ERM literature by showing its role in managing long-term actuarial risks and helping firms adapt to broader macroeconomic trends (Ellul and Yerramilli, 2013; Eckles et al., 2014; Lundqvist and Vilhelmsson, 2018; Lin et al., 2017; Kamiya et al., 2021; Li et al., 2024; Neel and Xu, 2025).

Motivation: Our Approach

- Develop a novel **firm-level longevity risk measure**.
- Data: IRS Form 5500 + state/industry demographics.
- Explore whether **ERM adoption** mitigates longevity exposure.

Motivation

This study makes contributions by bridging actuarial models with firm-level longevity risk assessment: it documents systematic variation in firms’ exposures, and provides empirical evidence of the effectiveness of ERM in mitigating such a persistent risk.

- We develop a novel firm-level longevity risk measure using IRS pension data and demographic trends.
- Significant variation across firms, driven by workforce age structure, geography, and industry.
- ERM effect: ERM adoption reduces firms’ longevity risk exposure.

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Pension Plan Types & Longevity Risk

- Two primary U.S. pension systems:
  - Defined Contribution (DC) Plans:
    - Individual accounts; contributions by employer and employee.
    - Employer bears no longevity risk; risk rests with employee.
  - Defined Benefit (DB) Plans:
    - Employers guarantee lifetime annuities.
    - Employers bear both investment and longevity risks.
- Longevity risk challenges the sustainability of DB pension schemes.
- Life expectancy improvements $\uparrow \Rightarrow$ Present value of DB pension liabilities $\uparrow \Rightarrow$ Pressure on corporate balance sheets.

Country-Level Longevity Risk

- Longevity risk measures in empirical literature are mostly at the **population/country level** Chen and Yang (2019).
- Country-level longevity risk is computed as first-order difference of weighted average period life expectancy E_t:

$$E_t = \frac{\sum_{x=0}^{99}(x + e_{x,t})n_{x,t}}{\sum_{x=0}^{99} n_{x,t}} = \sum_{x=0}^{99}(x + e_{x,t})w_{x,t}, \qquad (1)$$

$$w_{x,t} = \frac{n_{x,t}}{\sum_{x=0}^{99} n_{x,t}} \qquad (2)$$

- Longevity shocks:

$$dE_t = E_t - E_{t-1} \qquad (3)$$

Positive dE_t increase in longevity.

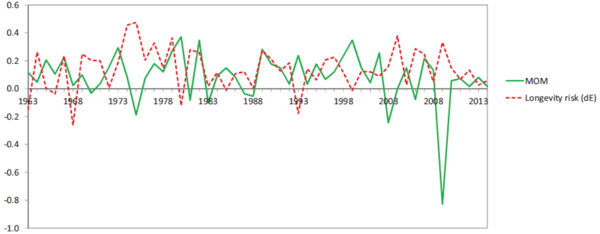

Fig. 1. Annual momentum factor and longevity risk. This figure plots the annual momentum factor (*MOM*) and innovations in the weighted average period life expectancy (*dE*), i.e., the longevity risk, over 1963–2014.

Fig. 1. U.S. Country-Level Longevity Risk, from Chen and Yang (2019)

- For Pension: Adapt age range for pension context: $x = 16$ to 99.
- Pension starts at age 65; extended pension life expectancy (PLE) for firm:

$$PLE_t = \sum_{x=16}^{99} \left(e_{x,t} - \max(65 - x, 0)\right) w_{x,t} \tag{4}$$

- Pension longevity risk (LR) computed as annual change:

$$LR_t = PLE_t - PLE_{t-1} \tag{5}$$

Industry-State-Level Longevity Risk

- Consider a firm i in industry j and state k.
- Longevity risk (LR) is computed at:
  - Industry-state level: $LR(j, k)$
  - Firm level: $LR(i)$
- Public U.S. data are used, calibrated from empirical observations.

Industry-State-Level Longevity Risk

- Industry-state LR is defined as:

$$LR(j,k) = PLE_t(j,k) - PLE_{t-1}(j,k) \tag{6}$$

- Weighted life expectancy:

$$LE_t(j,k) = \sum_{x=16}^{99} \big(e_{x,t}(k) - \max(65 - x, 0)\big) w_{x,t}(j,k) \tag{7}$$

  - $e_{x,t}(k)$: life expectancy for age x in state k.
  - $w_{x,t}(j,k)$: age distribution weight for DB plan participants.
- Age distribution weights:

$$w_{x,t}(j,k) = \begin{cases} w^{R}_{x,t}(k), & x > 65, \\ w^{nonR}_{x,t}(j), & 16 \le x \le 65. \end{cases} \tag{8}$$

  - $w^{nonR}_{x,t}(j)$: non-retired DB participants (Bureau of Labor Statistics)
  - $w^{R}_{x,t}(k)$: retired participants, state-level population (SEER)

Industry-State-Level Longevity Risk Over Time

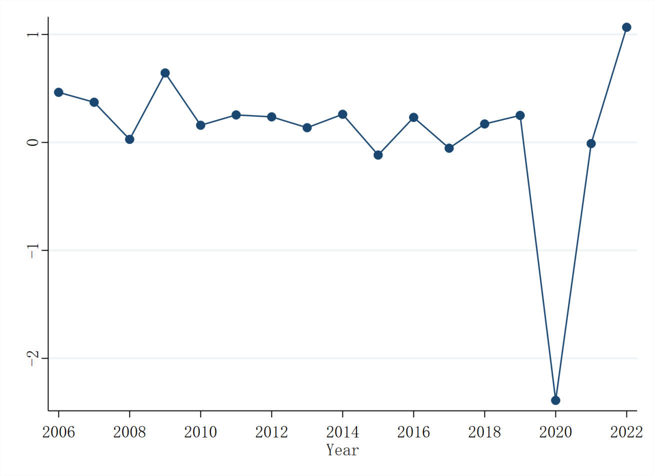

Fig. 2. Industry-State-Level Longevity Risk $LR(j,k)$

Firm's aggregated FLR can be given by:

$$A\_FLR(i) = LE_t(i) - LE_{t-1}(i) \tag{9}$$

with the firm-level life expectancy:

$$LE_t(i) = \sum_{x=16}^{65} n_{x,t}(i)[e_{x,t}(k) - 65] + \sum_{x=66}^{99} n_{x,t}(i)[e_{x,t}(k) - x] \tag{10}$$

where

$$N_t(i) = N_t^{nonR}(i) + N_t^{R}(i) \tag{11}$$

$$n_{x,t}(i) = \begin{cases} w_{x,t}^{R}(k,g) \cdot N_t^{R}(i), & x > 65, \\ w_x^{nonR}(j,t) \cdot N_t^{nonR}(i), & 16 \le x \le 65. \end{cases} \tag{12}$$

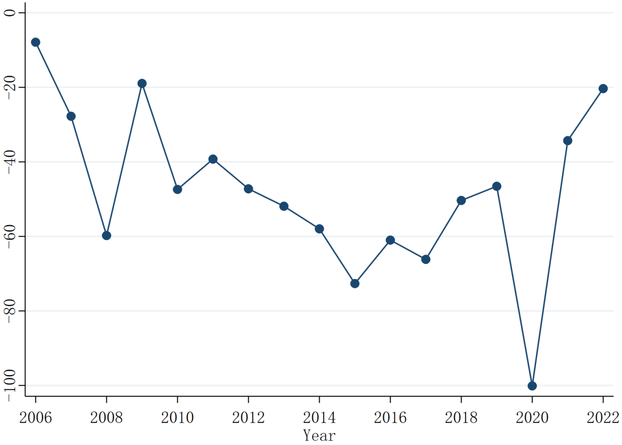

Fig. 3. $A\_FLR(i)$ Over Time

Firm-Level Longevity Risk: Considering Age Structure

- The FLR measure should account for the average exposure to industry–state level longevity risk, defined as

$$M\_FLR(i) = \frac{A_{FLR}(i)}{N_t^{DB}(i) + N_t^{DC}(i)}.$$

- The FLR measure should also capture the firm ' s absolute size, assigning greater weight to larger firms within the same industry–state category:

$$weight(i) = \frac{N_t^{DB}(i) + N_t^{DC}(i)}{\overline{N}_t^{DB}(i) + \overline{N}_t^{DC}(i)}.$$

$$FLR(i) = \frac{N_t^{DB}(i) + N_t^{DC}(i)}{\overline{N}_t^{DB}(i) + \overline{N}_t^{DC}(i)} \cdot \frac{A\_FLR(i)}{N_t^{DB}(i) + N_t^{DC}(i)} \tag{13}$$

$$= \frac{A\_FLR(i)}{\overline{N}_t^{DB}(i) + \overline{N}_t^{DC}(i)} \tag{14}$$

Firm-Level Longevity Risk: Considering Age Structure

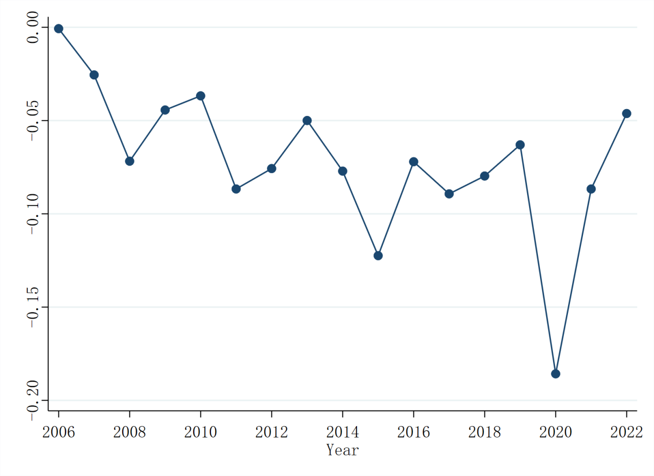

Fig. 4. $FLR(i)$ Over Time

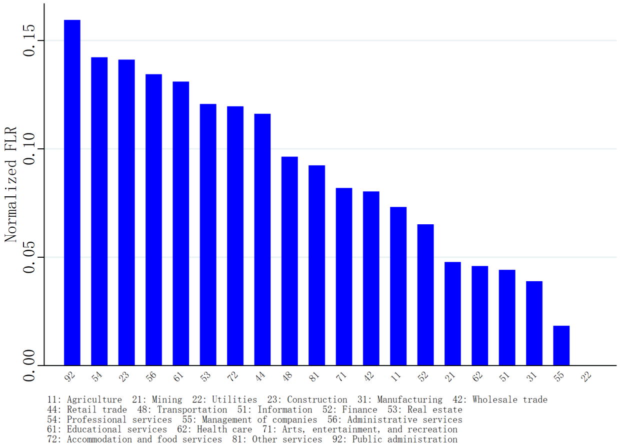

Fig. 5. Industry Heterogeneity: $FLR(i)$ (Normalized by diminishing the lowest)

Industry Heterogeneity

- **Higher risk:** Construction, Administrative Services, Public Administration, Educational Services, Professional Services.
- **Lower risk:** Utilities, Management of Companies, Manufacturing, Information.
- **Heterogeneity drivers:**
  - Workforce age structures.
  - Prevalence of DB pension plans across sectors.

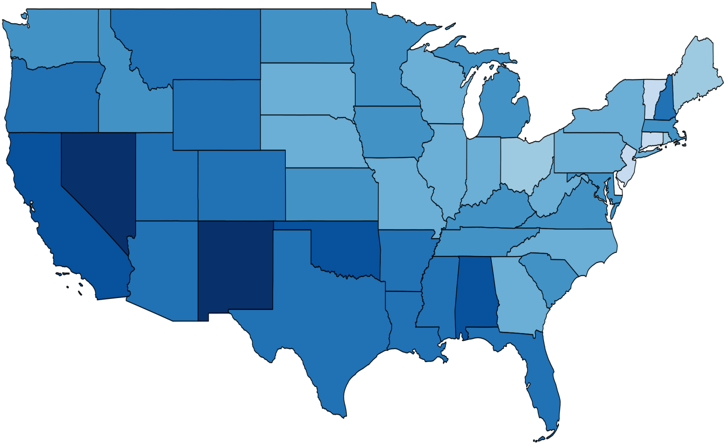

Fig. 6. Geographic Heterogeneity: $FLR(i)$

Geographic Heterogeneity

- **Higher risk:** Western states (e.g., California, Washington).
- **Lower risk:** Central states (e.g., Nebraska, Iowa).
- **Potential drivers:**
  - State-level demographic trends.
  - Economic development.
  - Labor market dynamics.

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Data and Sample
Main Result
Robust Analysis
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Data Sources

- Financial statement data: Compustat
- Stock market data: CRSP
- Pension plan information: IRS Form 5500 filings
- Demographic data: U.S. Bureau of Labor Statistics, SEER Population Data
- Life tables: United States Mortality Database

- Universe: all S&P 500 firms (Jan 1, 1990 – Jun 30, 2022)
- Hand-collected ERM adoption data from:
  - SEC filings (EDGAR, Thomson One)
  - Press releases, media (Factiva, Google)
  - Keywords: "enterprise risk management", "chief risk officer", "risk committee", etc.
- ERM indicator: 1 if firm has ERM in a given year, 0 otherwise
- Sample period: 2006–2022
- Selection criteria:
- Final sample: 522 unique firms, 6,059 firm-year observations
- Continuous variables winsorized at 1% and 99% levels

Descriptive Statistics: Pension and ERM

- 22.9% of firms offer defined benefit (DB) plans
- DB plan participants: 21.5% of total pension participants
- 45.5% of firms implemented ERM

Descriptive Statistics Table

Variable	N	Mean	SD	P25	P50	P75
Ln Scale_FLR	5,890	6.567	3.205	7.808	8.160	8.160
Ratio_FLR	5,890	-0.105	0.523	-0.041	0.000	0.000
ERM	5,861	0.455	0.498	0.000	0.000	1.000
Size	5,861	8.886	1.313	8.007	8.835	9.734
MB	5,831	1.995	1.531	1.038	1.522	2.376
Leverage	5,831	0.283	0.185	0.148	0.264	0.400
ROA	5,861	0.058	0.087	0.027	0.062	0.104
Age	5,861	3.418	0.648	2.996	3.466	4.025
PPE	5,641	0.264	0.225	0.094	0.179	0.382
ProfitMargin	5,861	0.073	0.163	0.031	0.079	0.141
EarnVol	5,641	0.039	0.052	0.010	0.020	0.043
Cash	5,733	0.106	0.099	0.030	0.079	0.149
AbschgROA	5,529	0.045	0.064	0.008	0.022	0.052
OrgGrowth	5,668	-0.002	1.268	-0.684	-0.190	0.414
Complexity	5,860	0.006	1.183	-0.956	-0.018	0.928
FinChallenge	5,609	-0.001	1.349	-0.714	-0.358	0.048

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We employ a **staggered difference-in-differences (DiD)** model to examine the effect of ERM implementation on corporate longevity risk.

$$\mathsf{FLR}_{i,t} = \beta \mathsf{ERM}_{i,t} + \mathbf{X}_{i,t-1} + \alpha_i + \alpha_t + \epsilon_{i,t} \tag{15}$$

- i and t denote firm and year, respectively
- Dependent variable: FLR, measured using $FLR(i)$ or $Scale\_FLR(i)$
- Key independent variable: $\mathsf{ERM}_{i,t}$, indicator $= 1$ if firm adopted ERM in year t
- $\mathbf{X}_{i,t-1}$: time-varying firm controls:
    - Size, market-to-book ratio (MB), leverage, ROA
    - Firm age, PPE, profit margin
- α_i: firm fixed effects; α_t: year fixed effects
- $\epsilon_{i,t}$: clustered at firm level

ERM Adoption and Longevity Risk

VARIABLES	(1) AdjM_FLR	(2) AdjM_FLR
ERM	-0.7585***	-0.6988***
	(-3.99)	(-3.32)
Size		0.0110
		(0.08)
MB		0.0350
		(0.69)
Leverage		-0.2867
		(-0.60)
ROA		0.3394
		(0.11)
Age		1.0694*
		(1.75)

ERM Adoption and Longevity Risk (Full Sample) – Part 2

VARIABLES	(1) AdjM_FLR	(2) AdjM_FLR
Collateral		-0.5338
		(-0.49)
Profit Margin		-0.1069
		(-0.17)
Earn Vol		-1.2411
		(-0.97)
Cash		0.5452
		(0.63)
Cash Flow		0.3373
		(0.11)
Revenue Growth		0.0549
		(0.17)
Firm F.E.	Yes	Yes
Year F.E.	Yes	Yes
Observations	7,053	6,273
R-squared	0.1405	0.1435

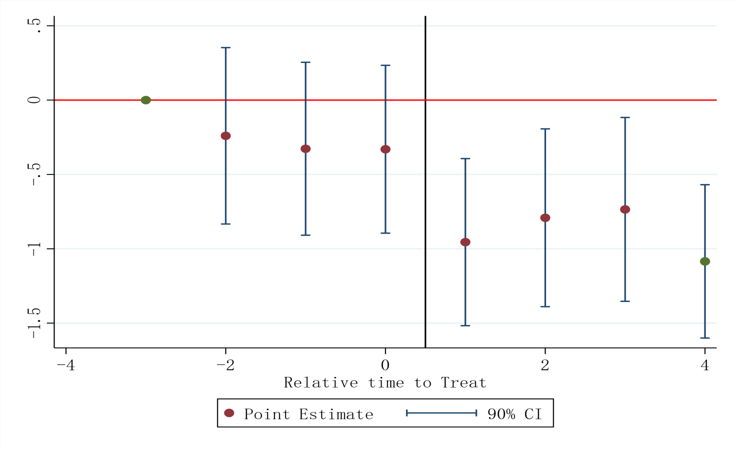

Fig. 7. Event Study of the Effect of ERM Adoption on the Longevity Risk

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Subsample: ERM Adoption and Longevity Risk

VARIABLES	(1) AdjM_FLR	(2) AdjM_FLR
ERM	-1.3151***	-1.1897***
	(-3.51)	(-2.97)
Controls	Yes	Yes
Firm F.E.	Yes	Yes
Year F.E.	Yes	Yes
Observations	3,404	3,183
R-squared	0.1360	0.1415

Key finding: ERM adoption significantly reduces firm-level longevity risk.

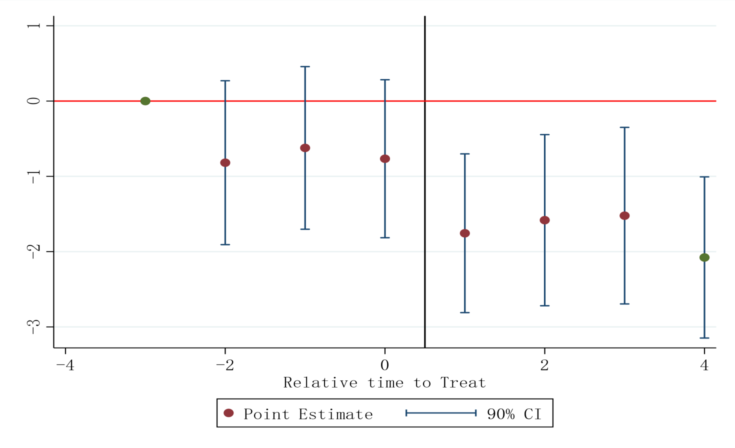

Fig. 8. Event Study of the Effect of ERM Adoption on the Longevity Risk

PSM Sample: ERM Adoption and Longevity Risk

VARIABLES	(1) AdjM_FLR	(2) AdjM_FLR
ERM	-0.7212***	-0.6599***
	(-3.24)	(-2.90)
Controls	Yes	Yes
Firm F.E.	Yes	Yes
Year F.E.	Yes	Yes
Observations	4,652	4,476
R-squared	0.1397	0.1443

Key finding: Even after PSM, ERM adoption significantly reduces FLR, confirming robustness of the main results.

Propensity Score Matching (PSM) Sample

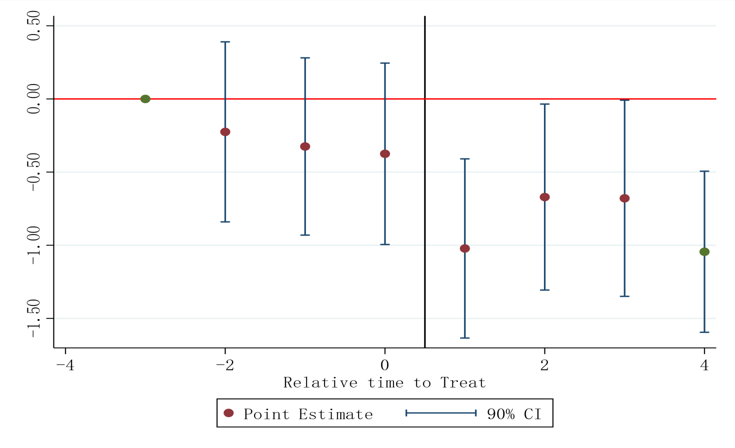

Fig. 9. Event Study of the Effect of ERM Adoption on the Longevity Risk

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Based on the FLR measures, firms' actions are reflected through the behavior of DB pension participants:

- Mean age-dependent FLR:
  $M\_FLR(i) = \frac{N_t^{DB}(i)}{N_t^{DB}(i)+N_t^{DC}(i)} \cdot LR_t(j,k)$
- Adjusted-Mean age-dependent FLR:
  $AdjM\_FLR(i) = \frac{N_t^{DB}(i)}{\overline{N}_t^{DB}(j,k)+\overline{N}_t^{DC}(j,k)} \cdot LR_t(j,k)$

Accordingly, we construct the following Firm Action Measures (FAM):

- **FAM1:** Change in DB plan ratio, i.e., the year-over-year difference in the share of DB plans: $\Delta \frac{\#_t^{DB}(i)}{\#_t^{DB}(i)+\#_t^{DC}(i)}$.
- **FAM2:** Change in DB participant number, i.e., the year-over-year difference in the number of DB participants: $\Delta N_t^{DB}(i)$.
- **FAM3:** Change in DB participation ratio: $\Delta \frac{N_t^{DB}(i)}{N_t^{DB}(i)+N_t^{DC}(i)}$.
- **FAM4:** Change in DB participant number relative to the industry average number of pension participants: $\Delta \frac{N_t^{DB}(i)}{\overline{N}_t^{DB}(j,k)+\overline{N}_t^{DC}(j,k)}$.

Heterogeneity in industry age structure: Old vs. Young (tercile)

	FAM_1		FAM_2		FAM_3		FAM_4	
VARIABLES	Old	Young	Old	Young	Old	Young	Old	Young
ERM	-0.0046	-0.0127**	-344.7927**	-257.7498	-0.0027	-0.0106**	-0.0999	-0.1290
	(-0.99)	(-2.30)	(-2.01)	(-1.11)	(-0.63)	(-2.10)	(-1.24)	(-1.43)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,449	2,585	3,449	2,585	3,445	2,580	3,449	2,585
R-squared	0.0636	0.0748	0.1854	0.3199	0.0515	0.0808	0.0727	0.0921
Coefficient Test	diff = 0.008		diff = -87.043		diff = 0.008		diff = 0.029	
	p = 0.030		p = 0.290		p = 0.010		p = 0.500	

Heterogeneity in financial constraint: WW index (tercile)

	FAM_1		FAM_2		FAM_3		FAM_4	
VARIABLES	Low	High	Low	High	Low	High	Low	High
ERM	0.0023	-0.0147**	-167.6849	-355.9892***	-0.0017	-0.0103***	-0.1179	-0.1843***
	(0.30)	(-2.59)	(-0.45)	(-2.81)	(-0.24)	(-2.98)	(-0.79)	(-2.69)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,046	2,068	2,043	2,066	2,046	2,068	2,046	2,068
R-squared	0.0559	0.1309	0.0512	0.1217	0.0780	0.1919	0.0780	0.1919
Coefficient Test	diff = 0.017		diff = 188.304		diff = 0.009		diff = 0.066	
	p = 0.000		p = 0.180		p = 0.070		p = 0.260	

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This study develops the first empirical measure of firm-level longevity risk (FLR), addressing a critical gap in the literature.

- **Novel Measurement:** Construct firm-level FLR using detailed plan-level data and demographic trends.
- **Heterogeneity in Exposure:** Longevity risk varies by workforce composition, geographic location, and industry structure.
- **ERM as Mitigation:** Evidence that enterprise risk management (ERM) effectively aligns pension strategy with firms' risk appetite and long-term objectives.
- **Broader Contributions:**
  - Bridges actuarial longevity models with firm-level applications.
  - Enriches corporate finance research by linking demographic shocks to firms' risk profiles.
  - Provides a foundation for policymakers to refine pension governance, risk disclosure, and hedging practices.

Thank You!

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