Pension Risk Management in the Enterprise Risk Management Framework

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Outline

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Motivation and Contribution

- **Enterprise risk management (ERM)** assesses all enterprise risks and coordinates various risk management strategies in a holistic fashion and is claimed to be superior to the silo risk management (**SRM**) approach.
  - Lam (2001); Liebenberg and Hoyt (2003); Nocco and Stulz (2006); Hoyt and Liebenberg (2011); Lin et al. (2012); Ai et al. (2012)

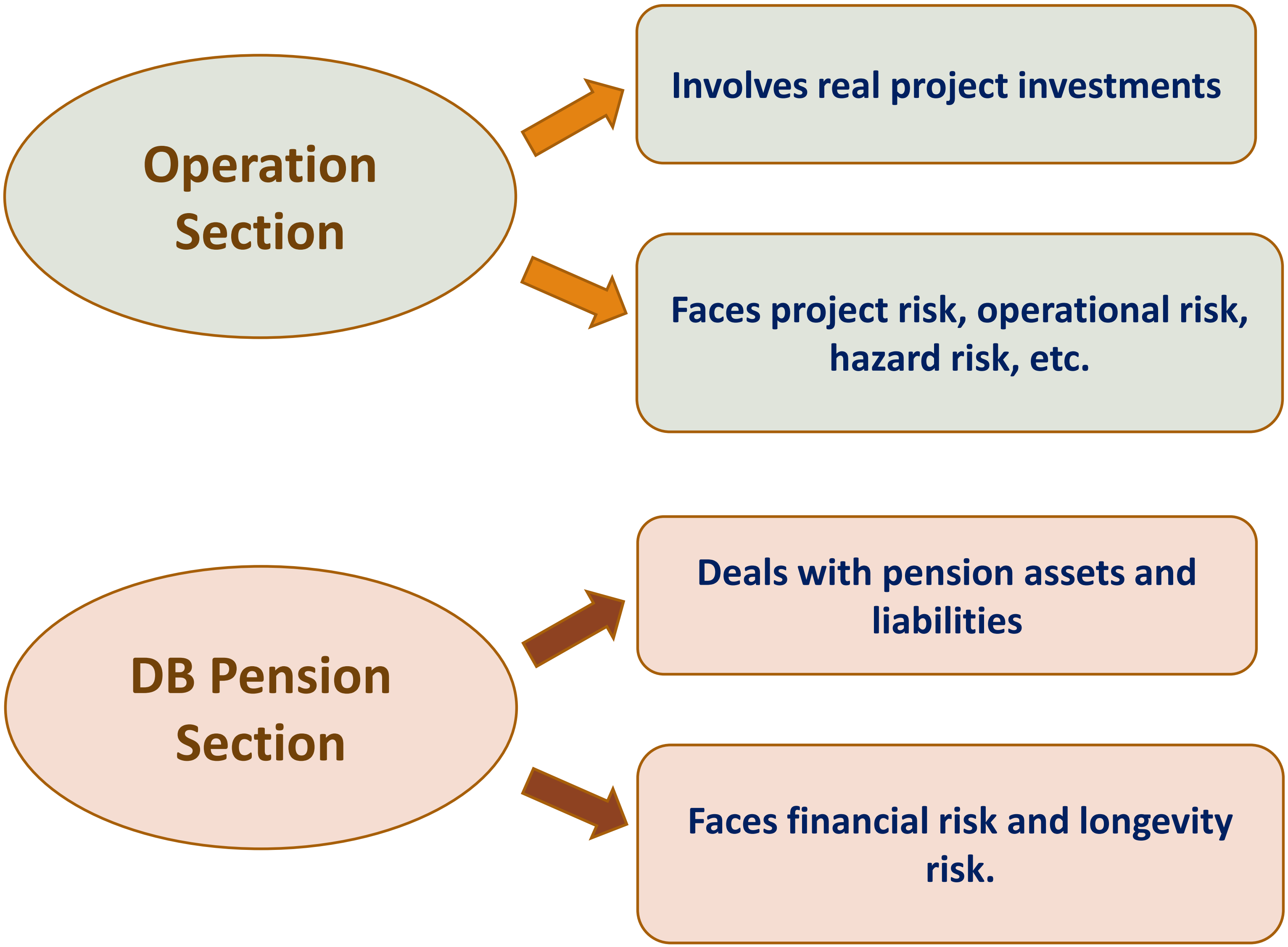
- The current ERM practice and literature target risks that affect the balance sheet and **disregards the off-balance-sheet items** that could impose a significant impact on a firm.
  - The total value of pension assets provides the greatest off-balance-sheet item for firms with defined benefit plans.

Motivation and Contribution

- Currently there is no ERM model in the literature that integrates the pension scheme into the firm's decision making. **Our paper contributes to the literature by incorporating pension risk into an ERM model.**
  - The proposed model maximizes the expected firm value net of total pension cost subject to separate project, operational, hazard, and pension risk constraints as well as an enterprise-wide risk constraints.
  - Considering pension risk with other enterprise-wide risks in a holistic way greatly improves the firm's performance.

- Over the last decade, DB firms have sought to de-risk their DB plans. **We analyze the efficiency of two de-risking strategies using an ERM framework.**
  - When subject to enterprise-wide risk constraints, the excess-risk de-risking strategy (e.g., longevity hedging) is less effective than the ground-up strategy (e.g., buy-in and buy-out) in improving overall firm performance.
  - This result modifies the conclusion drawn by Lin and Cox (2008), Cox et al.(2013), and Lin et al. (2013).

Two Sections of a DB Pension Firm



Enterprise Risks

- **Project risk**: the risk of potential losses due to unsatisfactory performance of a firm's real project operations.

- **Hazard risk**: The risk related to safety, fire, theft and natural disasters. Suppose the unit hazard loss per period of time, h, is a lognormal random variable:

$$h = e^{\mu + \sigma Z}$$

where Z is a standard normal random variable.

Enterprise Risks

- **<u>Pension risk</u>**: the pension investment risk and longevity risk together assuming:
  - We focus our analysis on a pension cohort that joins the plan at the age of x_0 at time 0 and <u>retires at the age of x at time T</u>. $x_{0+\tau}$ is the maximum possible age of the cohort.
  - The plan participants are entitled to <u>a nominal annual survival benefit, B</u>, after reaching the retirement age x at time T.
  - The pension fund is invested in <u>n assets</u>.
  - The periodic pension cost (PC) generated by the pension section is undertaken by the operation fund.
    - The pension cost considers a constant normal contribution (NC), and a supplementary contribution (SC) if the plan has unfunded liability or a withdrawal if the plan is over-funded.

Enterprise Risks

- **Operational risk**: The risk of unexpected changes in elements related to operations arising, directly or indirectly, from people, systems and processes.
  - Following the Standardized Approach from Basel II and Ai et al. (2012), we assume per dollar project investment, the loss caused by the operational risk from project j at time t, op_{jt} , equals a proportion, $\gamma_p \geq 0$, of project j's total return R

$$op_{jt} = \gamma_p \left(1 + r_t^j\right)$$

where r_t^j is the net return of the project j in period t.

Enterprise Risks

- **Overall risk**: considers different risks at a holistic level. It requires that the total value of all projects net of costs of operational risk, pension contributions and retained hazard losses should be sufficient to cover the entire financial obligations.

$$\Pr\left[F_{\tau}'^{*} \leq cF_0\right] \leq \alpha_5$$

Basic ERM Problem

- Our ERM optimization model is to solve for the optimal project investment proportions $w_p=[w_{1p},w_{2p},\ldots,w_{mp}]$, the hazard insurance ratio **u**, the pension asset weights $w=[w_1,w_2,\ldots,w_n]$ and the pension normal contribution **NC**, so as to maximize the expected value of the adjusted operation fund at time τ:

$$\underset{u,w,w_p,NC}{\text{Maximize}}\ \mathrm{E}[F_\tau^{\prime}],$$

Subject to the following constraints:

- **Constraint 1: Project risk**
 Given the risk appetite parameter α_1 and the minimal acceptable periodic return r_{p0}, the VaR-type project risk constraint is written as:

$$\Pr\left[\sum_{j=1}^{m} w_{jp}\left(\prod_{t=1}^{\tau}(1+r_t^j)\right) \le \sum_{j=1}^{m} w_{jp}(1+r_{p0})^\tau\right] \le \alpha_1,$$

Basic ERM Problem

- **Constraint 2: Operational risk**
  - In each period, suppose the pension firm specifies its operational risk limit for each real project equal to a proportion, l_{op}, of the expected available fund based on a minimal acceptable periodic return r_{p0}. Then the overall operational risk limit across all projects over τ periods equals:

$$l_{op} \cdot \mathrm{E}[\sum_{j=1}^{m} \sum_{t=1}^{\tau} F_{t-1}^{j,r_{p0}} (1 - u(1+d)\mu_h)(1 + r_{p0})(1+\rho)^{\tau - t}],$$

where

$$F_{t-1}^{j,r_{p0}} = F_{t-2}^{j,r_{p0}} [(1 - u(1+d)\mu_h)(1 - \gamma_p)(1 + r_{p0}) - (1 - u)h] - Nw_j \cdot PC_{t-1}$$

  - The operational risk constraint requires that the probability that the firm's operational loss exceeds the risk limit should be less than or equal to α_2

$$\Pr[\gamma_p \sum_{j=1}^{m} \sum_{t=1}^{\tau} (F_{t-1}^{j}[(1 - u(1+d)\mu_h)(1 - \gamma_p)(1 + r_t^j) - (1-u)h] - Nw_j \cdot PC_t)$$

$$\geq l_{op} \cdot \mathrm{E}[\sum_{j=1}^{m} \sum_{t=1}^{\tau} F_{t-1}^{j,r_{p0}} (1 - u(1+d)\mu_h)(1 + r_{p0})(1+\rho)^{\tau - t}]] \leq \alpha_2 .$$

Basic ERM Problem

❖ **Constraint 3: Hazard risk**

- Assume in each period the firm is willing to retain a hazard loss up to l_h per unit of the operation fund, subject to a risk appetite α_3. The possibility that the retained hazard risk exceeds the maximum allowable loss should be not higher than α_3 :

$$\Pr[(1-u)h\sum_{t=1}^{\tau}F_{t-1}(1+\rho)^{\tau-t} \geq \mathrm{E}[l_h\sum_{t=1}^{\tau}F_{t-1}(1+\rho)^{\tau-t}]] \leq \alpha_3.$$

Basic ERM Problem

- **Constraint 4: Pension risk I**
  - We require the expected present value of total unfunded liability at time 0 to equal zero. That is,

$$\mathrm{E}(TUL^{\tau}) = 0.$$

- **Constraint 5: Pension risk II**
  - We require the likelihood of the present value of total unfunded liability exceeding some predetermined upper limit ζ_{TUL} to not be greater than the firm's pension risk appetite α_4:

$$\Pr[TUL^{\tau} \geq \zeta_{TUL}] \leq \alpha_4.$$

Basic ERM Problem

- **Constraint 6: Overall risk**
  - Assume the total financial obligations equal a proportion c of F_0, the operation fund before purchasing the hazard insurance at time 0. Then the overall risk constraint is formulated as:

$$\Pr[F_{\tau}^{\prime *} \leq cF_0] \leq \alpha_5,$$

  - where $F_{\tau}^{\prime *}$ is the adjusted operation fund after the hazard insurance.

- **Constraint 7: Budget constraint**

$$w_1 + w_2 + \cdots + w_n = 1.$$

Basic ERM Problem

- **Constraint 8: Strategic constraint**
  - A minimum proportion γ_{rp} of the firm's total capital M_0 is required to invest in real projects at time 0:

$$\gamma_{rp} \leq w_{1p} + w_{2p} + \cdots + w_{mp} \leq 1.$$

- **Constraint 9: Range constraints**

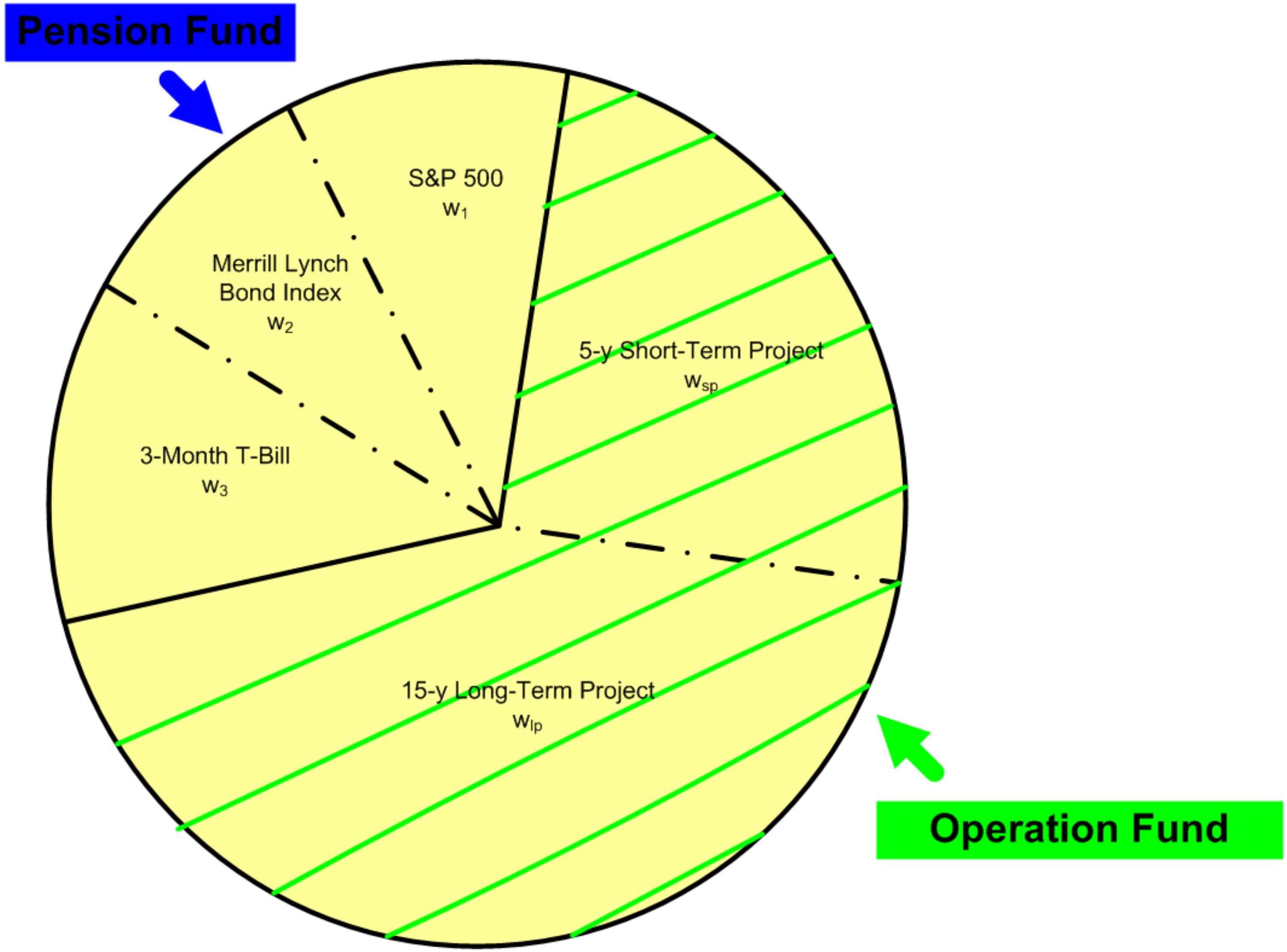
$$0 \leq w_{jp} \leq 1, \qquad j = 1, 2, \cdots, m$$

$$0 \leq w_i \leq 1, \qquad i = 1, 2, \cdots, n$$

$$0 \leq u \leq 1$$

$$NC \geq 0.$$

Numerical ERM Example



Numerical ERM Example

TABLE 1. Assessment of Projects and Pension Assets

Expected Returns and Standard Deviations					
	SP	LP	S&P500	Corp. Bond	T-Bill
Annual expected return	0.100	0.120	0.095	0.088	0.020
Annual standard deviation	0.100	0.120	0.164	0.077	0.017
Correlations					
	SP	LP	S&P500	Corp. Bond	T-Bill
SP	1	0.500	0.050	-0.025	-0.050
LP	0.500	1	0.050	-0.025	-0.050
S&P500	0.050	0.050	1	-0.533	-0.135
Corp. Bond	-0.025	-0.025	-0.533	1	-0.295
T-Bill	-0.050	-0.050	-0.135	-0.295	1

Numerical Example

TABLE 2. Parameter Values

Risk Appetite					Risk Limits			
α_1	α_2	α_3	α_4	α_5	r_{p0}	l_{op}	l_h	ζ_{TUL}
0.025	0.025	0.025	0.025	0.01	0.05	0.3	0.015	125
Hazard Risk					Op Risk Factor		Strategic Factor	Borrowed Capital
μ	σ	μ_h	d		γ_p		γ_{rp}	c
-6.913	2.148	0.01	0.2		0.02		0.8	1
Pension Risk								
ρ	r	ψ_1	ψ_2	g				
0.05	0.05	0.2	0.5	-0.17				

Numerical ERM Example Solution

TABLE 3. Optimal Investment, Insurance and Pension Decisions Based on One-Stage ERM Optimization Model (16)

w_{sp}	w_{lp}	u	w_1	w_2	w_3	NC	$\mathrm{E}[F'_\tau]$	$\mathrm{E}[TPC]$
58.82%	21.18%	100.00%	9.25%	32.05%	58.70%	2.78	10857.02	45.45

What if Pension Risk is not Integrated?

- Assume the firm manages its pension risk separately. Consistent with Lin et al. (2014), we minimize the expected total pension cost E[TPC] with respect to the pension asset weights and normal contribution where τ=60:
  - To make the ERM and Silo management comparable, we keep the upper/lower bounds of the constraints the same as those in the ERM example. We also assume that the firm allocates an amount 40 at t = 0 to the pension fund as in the ERM case.

$$\begin{aligned}
\underset{w,NC}{\text{Minimize}} \quad & \mathrm{E}\left[TPC^{\tau}\right] \\
\text{subject to} \quad & \mathrm{E}(TUL^{\tau}) = 0 \\
& \Pr[TUL^{\tau} \geq \zeta_{TUL}] \leq \alpha_4 \\
& 0 \leq w_i \leq 1, \qquad i = 1, 2, \cdots, n \\
& \sum_{i=1}^{n} w_i = 1, \\
& NC \geq 0.
\end{aligned}$$

What if Pension Risk is not Integrated?

TABLE 4. Optimal Pension Decision Based on Silo Pension Optimization Model (20)

w_1	w_2	w_3	NC	$\mathrm{E}[TPC^{\tau}]$
9.25%	32.05%	58.70%	2.78	45.45

- Given the available fund of 160 at time 0 for the real project investment, we maximize the expected value of the operation fund for the firm at time τ:

$$\underset{w_p, u}{\text{Maximize}}\ \mathrm{E}[F_{\tau}^{silo}].$$

- The overall fund considering both operation section and DB pension section at time τ is:

$$\mathrm{E}[F_{\tau}^{\prime silo}] = \mathrm{E}[F_{\tau}^{silo}] - \mathrm{E}[TPC^{\tau}](1+\rho)^{\tau}.$$

Numerical Silo Solution

TABLE 5. Optimal Investment and Insurance Decisions with Silo Pension Risk Management Strategy

w_{sp}	w_{lp}	u	$\mathrm{E}[F_\tau^{\prime silo}]$	$\mathrm{E}[TPC]$
96.38%	3.62%	100.00%	9012.34	45.45

- In this scenario when the real project and the pension plan are managed separately, the optimal total return is notably reduced to 9012.34 from the previous optimum with ERM of 10857.02, **a 17% drop**!!

TABLE 3. Optimal Investment, Insurance and Pension Decisions Based on One-Stage ERM Optimization Model (16)

w_{sp}	w_{lp}	u	w_1	w_2	w_3	NC	$\mathrm{E}[F_\tau^{\prime}]$	$\mathrm{E}[TPC]$
58.82%	21.18%	100.00%	9.25%	32.05%	58.70%	2.78	10857.02	45.45

Ground-up De-Risking Strategy In the ERM Framework

- The pension ground-up de-risking strategy is essentially a partial buy-in since it transfers a proportion of the entire pension liability to a third party.
- The ground-up strategy has an additional range constraint in constraint 9 as follows: $HP^G < PA^G$ which ensures the hedge price does not exceed the fund allocated to the pension plan at $t = 0$.
- Here we continue the numerical ERM example but now assume that the plan implements a ground-up hedging strategy by transferring a proportion of its total pension obligations to an insurer at time 0.

Numerical Buy-in Example

TABLE 6. Optimal Ground-up Hedging Strategies with Different Assumptions on Hedge Cost Parameter δ^G

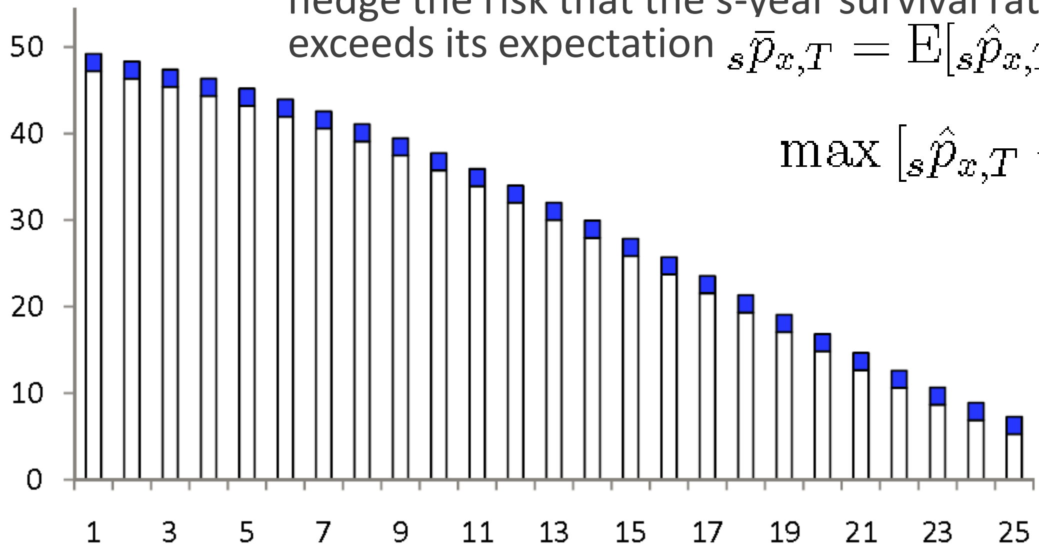
δ^G	w_{sp}^G	w_{lp}^G	u^G	w_1^G	w_2^G	w_3^G	NC^G	h^G	$E[F_\tau'^G]$	$E[TPC^G]$
0.00	54.70%	25.30%	93.86%	21.96%	66.88%	11.15%	0.39	48.58%	13218.20	25.30
0.05	54.92%	25.08%	99.33%	20.60%	63.70%	15.70%	0.67	46.27%	12806.14	30.33
0.10	55.25%	24.75%	100.00%	19.50%	60.98%	19.53%	0.93	44.17%	12475.70	34.97
0.15	55.73%	24.27%	100.00%	17.85%	59.18%	22.97%	1.19	42.25%	12134.65	39.41
0.20	56.12%	23.88%	100.00%	16.62%	55.77%	27.61%	1.40	38.39%	11883.26	42.63
0.25	56.59%	23.41%	100.00%	16.62%	54.05%	29.33%	1.61	37.59%	11579.71	46.51

- As long as the firm hedges some of its pension risk with a hedge ratio $h^G > 0$ the firm can achieve a value of the operation fund higher than the value when the firm does not hedge, i.e., as in the numerical ERM example.
  - At zero hedge cost, the ground-up de-risking strategy notably increases to 13218.20, a 21.75% rise compared to the no hedge case.
  - Even when the hedge cost is high 0.25, the firm value is still 6.66% higher than the no hedge case.

Excess-Risk De-Risking Strategy In the ERM Framework

- The **pension excess-risk de-risking strategy**, such as longevity insurance, only cedes a proportion of the high-end longevity risk embedded in a pension plan to a risk taker.
- Suppose, at time 0, the pension firm implements the excess-risk strategy to hedge the risk that the s-year survival rate of the retirees of age x at time T exceeds its expectation ${}_s\bar{p}_{x,T} = \mathrm{E}[{}_s\hat{p}_{x,T}]$ at time T + s:

$$\max\left[{}_s\hat{p}_{x,T} - {}_s\bar{p}_{x,T}, 0\right] \quad s = 1, 2, \cdots .$$



- Again, the optimization requires: $HP^E < PA_0^E$

Numerical Swap Example

Here we continue the ERM Example but now assume that the plan implements an excess-risk hedging strategy by transferring a proportion h^E of its high-end longevity risk. The strike level at time T + s is specified at the expected s-year survival rate, $B_s\bar{p}_{x,T}$, s = 1, 2,… where T = 15 and x = x_0+T=65.

TABLE 7. Optimal Excess-Risk Hedging Strategies with Different Assumptions on Hedge Cost Parameter δ^E

δ^E	w^E_{sp}	w^E_{lp}	u^E	w^E_1	w^E_2	w^E_3	NC^E	h^E	$\mathrm{E}[F'^E_\tau]$	$\mathrm{E}[TPC^E]$
0.00	58.42%	21.58%	100.00%	8.52%	33.61%	57.87%	2.69	100.00%	10994.12	44.65
0.05	58.42%	21.58%	100.00%	8.52%	33.62%	57.86%	2.69	100.00%	10990.42	48.80
0.10	58.42%	21.58%	100.00%	8.52%	33.62%	57.86%	2.69	100.00%	10986.71	52.96
0.15	58.43%	21.57%	100.00%	8.52%	33.62%	57.86%	2.70	100.00%	10983.01	57.11
0.20	58.43%	21.57%	100.00%	8.52%	33.62%	57.86%	2.70	100.00%	10979.30	61.27
0.25	58.43%	21.57%	100.00%	8.52%	33.62%	57.86%	2.70	100.00%	10975.60	65.43

Numerical Swap Example

- The hedge ratio h^E and the pension asset allocation of **the excess-risk strategy are not sensitive to the hedge cost in all scenarios of interest**.
- While the excess-risk strategy has a much higher hedge ratio than the ground-up strategy, it achieves a lower improvement in firm performance.
  - When $\delta^E = 0$, the excess-risk strategy has an adjusted operation fund or firm value of at time τ, 1.26% higher than that without the hedge, .
- Subject to the enterprise-wide risk constraints, **the buy-in de-risking strategy is more effective** in improving the overall firm performance than the swap strategy.
  - Compared to the ground-up hedging, the excess-risk hedging only transfers the high-end longevity risk and leaves the firm holding more risk. As a result, it is subject to a higher pension cost and has less leeway in achieving a higher end-of-horizon firm value.

Concluding Remarks

- **We study how to make an optimal strategic decision considering pension effects in an ERM framework.**
- We first propose a one-stage ERM optimization model that maximizes the expected value of an operation fund subject to different pension and business risk constraints as well as an overall risk constraint.
- Our analysis indicates that the performance of a DB firm will be improved if integrating the pension risk management in the ERM framework.
- We then extend our one-stage ERM model to a dynamic multi-stage model.
    - The multi-stage ERM optimization model is more flexible and could achieve a better firm performance than the one-stage model since it allows the firm to reassess its optimal business decisions upon arrival of new information.

Concluding Remarks

- **This paper brings a pension hedging component to the study of the ERM optimization model.**
- Our results suggest that, while a longevity swap is less capital intensive than a buy-in, it underperforms the buy-in in terms of value creation in an ERM framework.

Future works:

- Implement the ERM optimization using other downside risk measures, e.g., CVaR.
- Consider a DB firm that makes hedging decisions on pension asset and liability risks as well as business risks.
- Allow the firm to terminate a project before completion if it does not do well, i.e., include real options.