DE-RISKING PENSION PLANS OR NOT? FACTS FROM U.S. EMPIRICAL DATA

ABSTRACT. This paper investigates de-risking activities of U.S. defined benefit (DB) pension plans using empirical data from 1993 to 2018. We identify multiple avenues for pension risk reduction by expanding the scope of de-risking to shift, freeze, termination, buyout, buyin, and longevity hedge. We find heterogeneity in de-risking behaviors across different industries. Our empirical results indicate that active management of pension risk contributes to the firm value. In addition, the firms with smaller size, less tangible assets, higher return volatility, or lower profitability are more likely to de-risk their pension plans. Furthermore, we propose two theoretical models to verify the soundness of plans' empirical de-risking activities. The theoretical models can provide *ex ante* strategic suggestions to the DB firms that plan to conduct de-risking.

Keywords: Defined benefit pension plan; De-risking strategies, Freeze; Buyin and buyout; Longevity hedge.
JEL: J32; G32; G22

1. INTRODUCTION

Pension-related risks have been found to expose unfavorable distractions to an organization, especially to those non-financial companies. In the recent 20 years, defined benefit (DB) pension plan sponsors have been facing more severe under-funding challenges. The interest rate has been maintained at historically low level over the past quarter century, placing tremendous pressure to retirement plans. On the one hand, lower interest rates mean lower returns for pension funds, which invest around 40% or more of their assets in fixed-income securities. On the other hand, lower interest rates lead to higher pension liabilities. The market drops of 2008 worsened the financial environment. In addition, the new regulation such as Pension Protection Act of 2006 (PPA) also impacted the way that plan sponsors view and evaluate their pension plans.

Firms suffering the issue of unsustainable retirement plans have been making every effort to control and reduce pension-related risks such as investment risk, interest rate risk, credit risks, and longevity risk. There are a variety of methods for DB firms to de-risk their pension-related risks. In this study, we expand the scope of "de-risking" that includes not only the traditional buyouts, buyins, and longevity hedges, but also those alternative avenues such as shifts, freezes, and terminations. The de-risking market has faced a consistently high level of demand and become

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increasingly attractive in recent years as more DB scheme sponsors look to reduce pension-related risks.

Studies in the existing literature have analyzed pension de-risking strategies with either theoretical or empirical models. The majority of existing literature is theoretical research that either examine hypothetical hedging products or model de-risking strategies mathematically with arbitrary market assumptions. Theoretical works include Blake (2000), Lin et al. (2015), D'Amato et al. (2018), among others. Blake (2000) discusses the choice between defined benefit (DB) and defined contribution (DC) retirement plans from a pensioner's point of view, focusing on the U.K. markets. Lin et al. (2015) develop theoretical models to investigate the impact of transaction cost, counter-party default probability, and under-funding ratio on the total pension cost (TPC) of a DB pension plan if a de-risking strategy of a buyout, a buyin, or a longevity hedge is adopted. D'Amato et al. (2018) analyzes longevity spread buyins based on a similar framework to Lin et al. (2015)'s.

Most empirical DB pension analyses focus only on shifts and pension freezes but seldom investigate the other de-risking alternatives, mainly due to the data availability, or the difficulty of pension data collection.[1] Stone (1991) is one of the earliest papers that discuss the switches from DB plans to DC plans. Analyzing a sample of 40 firms switching to defined contribution plans and 16 firms continuing defined benefit plans during the period from 1981 to 1985, Stone (1991) finds that the switching firms were less able to pay dividends and were more financially stressed. His results are somewhat counter-intuitive, which may due to the small data sample investigated. Atanasova and Hrazdil (2010) examine the firms' decisions in freezing their defined-benefit pension plans and and its effect on shareholders' wealth with data from 2002-2006. They find evidence that a pension plan freeze has a positive impact on sponsors' equity returns and credit ratings. Considering a data sample ranging from 1991 to 2008, Comprix and Muller (2011) provide evidence that, when "hard" freezing their defined benefit pension plans, employers select downward biased accounting assumptions to exaggerate the economic burden of their benefit plans. An et al. (2013) point out that for financially distressed DB sponsors and sponsors that freeze, terminate, or convert DB to

[1]The most complete U.S. pension data are for the period from 1990 to 2007, from the 5500-CRR database compiled by the Center for Retirement Research at Boston College (CRR), which uses the information from Form 5500 collected by U.S. Department of Labor (DOL). After 2007, firm-level data with detailed pension information are not directly available from any public databases.

DC plans, the risk-shifting incentive (moral hazard) dominates their pension fund investment given data from Compustat and Form 5500 from 1990 to 2007. Choy et al. (2014) examine the impact of a DB pension plan freeze on the sponsoring firm's risk and risk-taking activities using a sample of firms declaring a hard freeze on their plans between 2002 and 2007. They find an increase in risk-taking following DB plan freezes, consistent with theories that DB plans act as "inside debt" that aligns managers' interests with bondholders'. Vafeas and Vlittis (2018) study the role of outside directors in DB pension plan freezes by using firm-level data between 2000 and 2015. Pedersen (2018) however finds little evidence of managerial shift risk to corporate pension plans following an exogenous shock to the firms long-term liabilities.

Empirical studies on buyouts and buyins are even more scarece. As the UK pension de-risking market has a longer history and is more mature than the U.S. de-risking market, more enriched UK data are available for researchers and practioners. Although the U.S. is the largest global retirement market in terms of total pension assets, as far as we know, Cantor et al. (2017) is the only empirical study that targets the U.S. buyouts and buyins. The paper employs an event study approach for a small window of time (2012-2016) that consists of only 22 buyout cases. It examines the stock market reaction to the adoption of buyout strategy.

The lack of studies in this area triggers our interest in collecting data and conducting more comprehensive empirical analysis of de-risking transactions in the United States. Our study is to fill the gap of DB pension de-risking literature by providing empirical evidences from the U.S. market. We intend to focus on the six de-risking strategies that include shifts from DB to DC, freezes, terminations, buyouts, buyins, and longevity hedges. Strictly speaking, a termination should not be considered as a de-risking strategy since it terminates a pension plan and ceases the accrual of benefits. But one can regard it as an extreme de-risking case that completely removes the pension-related risks.

We plan to make the following contributions in this study. First, we will examine the major determinants of choosing an appropriate de-risking strategy based on the market conditions as well as the firm-specific and industry-specific features of a pension scheme. Second, we would like to evaluate the economic outcomes of adopting a de-risking strategy based on firm-level empirical

data. We are interested in investigating the impact of a de-risking strategy on the firm's stock price, leverage, and the magnitude of pension risk and cost. Third, a key barrier to de-risking is the "regret risk" that DB pension sponsors won't benefit from a rise in interest rates. In a rising interest rate environment, liabilities will decline, and if there isn't the same level of decline in the plan assets, it will improve the financial position of the plan, making de-risking strategies less attractive. Therefore, we want to explore if it's still beneficial for plan sponsors to consider de-risking strategies in a high-interest-rate environment. Fourth, we proposed two theoretical models in Section 4. These two models are designed to assess the soundness of the DB firms' de-risking activities. If the recommendations from the theoretical models are in line with the plans' empirical de-risking choices, we would believe the proposed models can provide *ex ante* strategic suggestions to those who plan to conduct de-risking.

The rest of the paper is organized as follows. In Section 2, we discuss the six DB de-risking strategies considered in the paper. We present our preliminary empirical results in Section 3. Section 4 develops two theoretical models to investigate firms' de-risking strategies. The first model is a Markov-switching model that depicts a pension plan's state switching process based on the parameters calibrated from historical data. The model is to verify the empirical results obtained in Section 3. The second model is to determine a firm's optimal de-risking strategy that minimizes the firm's total pension cost (TPC), based on a set of firm-specific and industry-specific control variables. Section 5 concludes the paper.

2. Overview of De-Risking Strategies and Hypotheses Development

In this section, we discuss and compare the six de-risking strategies considered in the paper. It is critical to understand the key features of the de-risking strategies before we present the empirical results and explain the theoretical models.

2.1. **Shift from DB to DC.**

There are two types of retirement plans-defined benefit (DB) plans and defined contribution (DC) plans, depending on how benefits are determined. In a DB plan, benefits are calculated based on a formula that takes into account an employer's salary upon retirement and service year. The plan takes the responsibility for managing the money in the funds and paying

the retirement benefits. By contrast, in a defined contribution plan, benefits are dependent on both the amount of money contributed (by the employer, employee or both) into the account and the investment performance of the funds. Employees in DC plans are the risk takers of financial market risk and longevity risk. In addition, some retirement plans (e.g., cash-balance plans) are hybrid plans that carry combined features of both DB and DC schemes.

DB plans were initially instituted to provide retirement benefits to veterans. Afterwards, the number of DB plans increased to meet the demands of employers, legislators, and participants, especially in the 1940s and 1950s. As DB plans are more costly for employers, traditional DB pension plans have gradually lost their dominance. Over the last four decades, there has been a significant shift in retirement plan schemes, from DB plans to DC plans (Office (2009)). 1982 marks the first year that a Fortune 500 firm adopted a DC plan such as 401(k). In 2009, there were only 29,000 single employer DB plans compared to about 92,000 single employer plans in 1990. According to the Willis Towers Watson 2015 FTSE Survey and the 2016 Fortune 100 Survey, 71% of the FTSE 100 in 2015 offer only DC plans, leaving 29% of FTSE 100 provide DB plans (traditional or hybrid) to newly hired salaried employees. The Fortune 500 companies report a similar trend. As of 2015, "only 20% of Fortune 500 companies offered a DB plan (traditional or hybrid) to salaried new hires, down from 59% among the same employers back in 1998".

The shift from DB towards DC pensions actually provides benefit to both employees and sponsor companies. The shift is favorable to employers since it transfers the primary responsibility of preparing for retirement along with corresponding risks (e.g., investment and longevity risks) to employees. On the other hand, DC plans make employees' benefits portable from one employer to another. Traditional DB benefit formulas are "back-loaded", favoring long-tenured employees. The shift increases the workforce mobility, which protects mobile workers from losing benefits when changing employers.

Figure 1 is drawn based on the statistic data provided by the Investment Company Institute (ICI). It shows the market shares of pension assets of the five major types of retirement schemes (*i.e.*, IRA, DC Plans, Private-sector DB plans, Government DB plans, and Annuities) over the period from 1974 to 2017. The assets of DB plans counted only 32.4% of the total retirement assets in 2017,

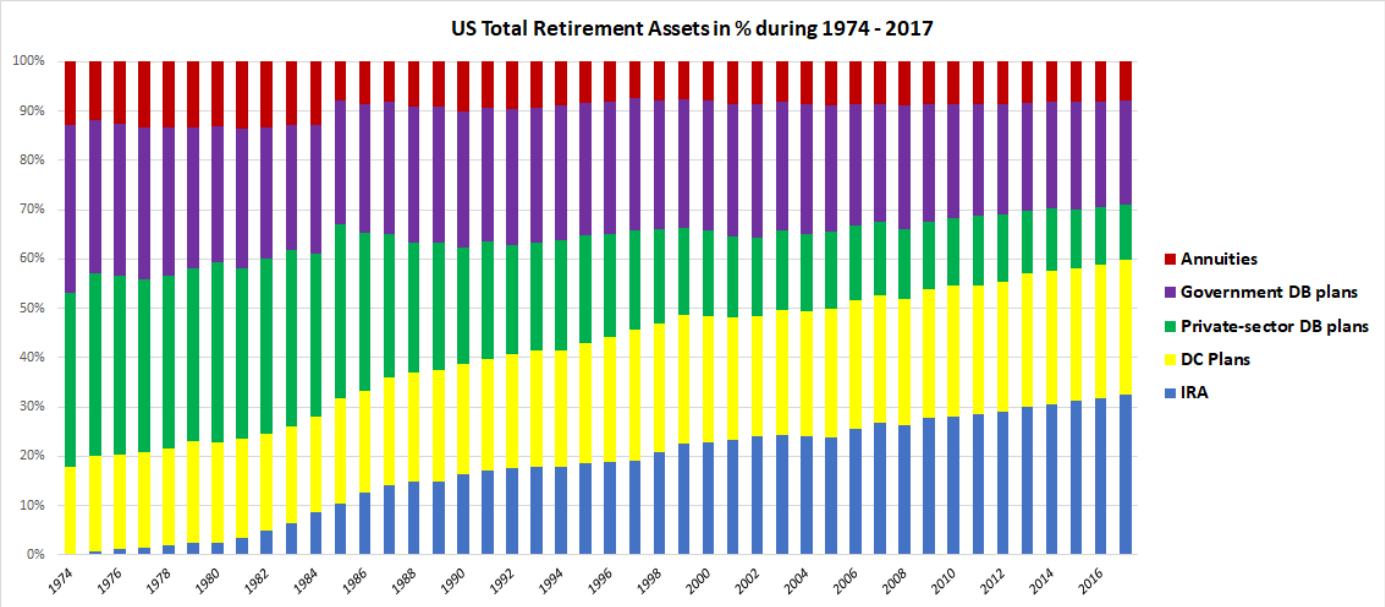

FIGURE 1. The Constitution of the U.S. Total Retirement Assets during 1974 - 2017.

Source: ICI - Retirement Market.

while they counted 60.5% in 1985. Note that if we count IRA, annuity, and some hybrid retirement plans separately, the market share of DC plans' pension assets does not dominate, which was only 27.3% in 2017. It is because the remained DB plans typically are offered by big firms, who hold large amounts of pension assets.

Figure 2 was presented by Willis Towers Watson (Watson (2018)) in its annual pension report. The DC split in Figure 2 has counted all types of retirement schemes other than the traditional DB plans.[2] The last ten-year trend shows that even the market share of DB plans has been declining over time, it still counted around 40% of the total pension assets in 2017. This supports the necessity of analyzing the U.S. DB pension plans.

2.2. **Freeze.** Besides shifting to DC plans, many companies chose to freeze or terminate their DB plans. When a company freezes its DB pension plan, benefits of some or all the employees' stop accruing, but the plan continues to exist and the assets remain in the plan. The company cannot

[2]The 2018 Willis Towers Watson report mentioned that "in January 2017, the UKs Office for National Statistics stated that the figures previously disclosed for DC entitlements were significantly overestimated".

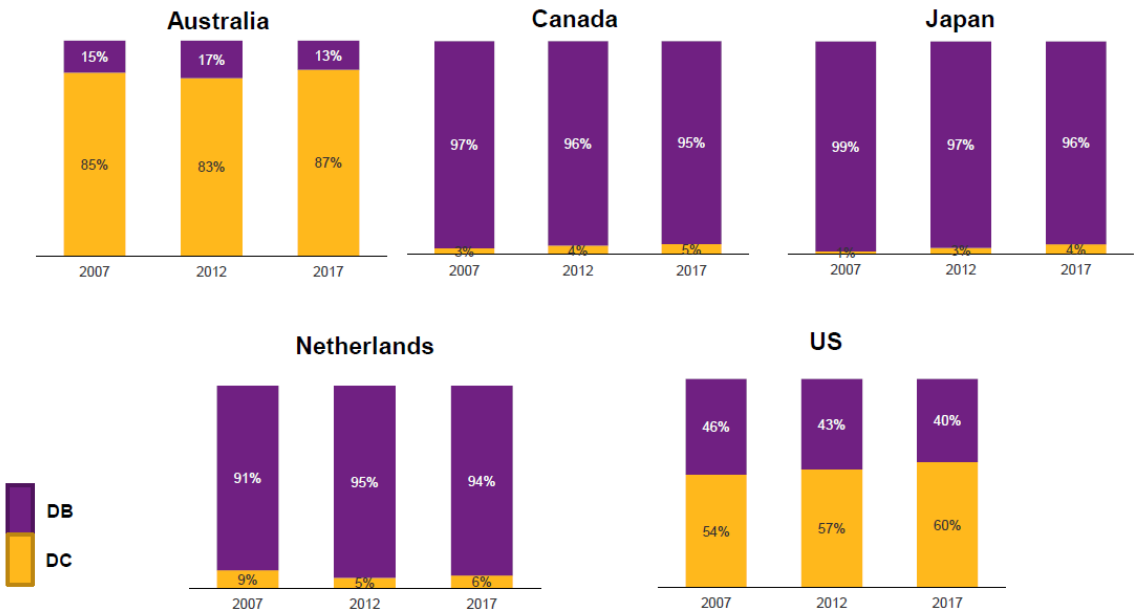

FIGURE 2. DB/DC Split Over the Last Ten Years in Australia, Canada, Japan, Netherlands, and the U.S.

Source: Willis Towers Watson and secondary sources.

take away any benefit that its employees have already earned up to the point of the freeze. The benefits will be paid to the employees when they reach retirement age.

In the 1980s and early 1990s, DB-plan freezes (or terminations) were limited mostly to financially-strapped companies facing bankruptcy or engaged in mergers and acquisitions. However, in the last 20 years, even profitable companies have joined the chorus of freezing their DB plans. Following Choy et al. (2014), we consider three different types of freezes that a firm can impose on its DB pension plan, *i.e.*, the hard/total, soft, and partial freezes.

A. Hard/total freeze: The firm completely stops the accrual of future benefits to all participants. That is, there is no further accrual of benefits even to existing plan participants.
B. Soft freeze: The plan is closed to new entrants but the accrual of benefits of current participants continues (potentially with a change in the formula used to compute the future plan benefits).
C. Partial freeze: The firm ceases or limits the accrual of further benefits for some but not all participants.

Most academic studies focus only on hard freezes (e.g., Comprix and Muller (2011), Choy et al. (2014), and Vafeas and Vlittis (2018)) since cases of "soft freeze" and "partial freeze" are hard to judge.

2.3. **Termination.** A pension termination is different from a pension freeze. In a termination, a company must pay out all benefits in no longer than one year after the termination date. The benefits can be distributed as a lump sum or an annuity that pays benefits to employees over time. The Pension Benefit Guaranty Corporation (PBGC), a federal government agency that insures pension plans, allows for two types of pension terminations, *i.e.*, the standard and distress terminations. In a standard termination, a plan will meet all benefit obligations accrued to the termination date. A distress termination happens when a company bankrupts. The company in bankruptcy will transfer its pension liabilities to the PBGC. After distribution, the plan ceases. Strictly speaking, a pension termination is not a de-risking strategy. First, it will cease a plan. Second, a termination takes place typically when a company is facing severe financial difficulties. But in this study, we still include it as an option that a DB pension plan can choose to reduce (here, permanently remove) its pension obligations and the corresponding risks.

2.4. **Buyout.** In the late 2000s, a buyout became popular as it frees a portion of a DB pension fund sponsor's liabilities as well as assets. A buyout transfers all or part of the pension obligations and assets to an insurer using a bulk annuity contract, hence it transfers not only longevity risk but also other risks including interest rate risk, inflation risk, and asset risk. Under a buyout contract, the transferred liabilities are completely removed from the pension plan and the company's balance sheet. A full buyout of a plan's pension liabilities to retirees and non-retirees winds up the plan. Manganaro (2017) declaims that "single premium pension buyout sales totaled $1.4 billion in the first quarter of 2017, marking the highest first-quarter results in at least 15 years."

2.5. **Buyin.** A buyin, on the other hand, is the process by which a pension plan purchases an annuity contract as an investment to match some or all of its future obligations to retirees. A buyin also "de-risks" all types of pension-related risks. Different from a buyout in which both the assets and liabilities of a pension scheme are transferred to an insurer, the assets and liabilities

TABLE 1. Comparison of De-Risking Strategies

	Shift	Freeze	Buyout	Buyin	Longevity Hedge
Structure	Sophisticated	Sophisticated	Sophisticated	Sophisticated	Simple
Transaction costs	Median	Medium	Highest	Higher	Lowest
Transferred risks	All risks	–	All risks	All risks	Longevity risk
Counter-party risk	–	–	No	Yes	Yes
Transfer liabilities	Yes	–	Yes	No	No

in a buyin remain on the sponsor's balance sheet. The trustee still maintains the plans and is subject to counter-party risk. It means that the plan sponsor has the responsibility to pay benefits to retirees when a chosen insurer (who offers the bulk annuity) becomes insolvent or defaults on its obligations at some point in the future. Buyins are cheaper than buyouts and they typically face less stringent under-funding restrictions. Buyins actually can be the first stage in a full buyout process, or at least a buyout is anticipated at some stage in the future.

2.6. **Longevity hedge.** Longevity hedges such as longevity swaps and longevity insurance allow a pension plan to transfer the risk of retirees living longer than expected to a third party. Different from buyouts and buyins, longevity hedges through longevity-linked securities "de-risk" only the longevity risk but not the interest rate or inflation risks. Few pension plans have directly tackled the longevity risk. However, if a plan has effectively improved its funding position and reduced investment risk, the longevity risk becomes a much larger proportion of its total risk. For such a DB plan, a longevity hedge may serve as a cheap but effective de-risking strategy. Longevity hedges are also subject to counter-party risk - if the insurer (who offers the longevity swaps or longevity insurance) defaults, the DB pension sponsor is still responsible for paying the pension benefits.

Table 1 compares the key features of the de-risking strategies shift, freeze, buyout, buyin, and longevity hedge. We exclude the termination because strictly speaking, it is not a de-risking strategy. In terms of transaction costs, buyouts (especially full buyouts) are the most expensive one, followed by buyins. A longevity hedge is the cheapest option as it transfers only longevity risk. We expect shifts and freezes are cheaper than buyouts and buyins, but we need to collect more data and facts to support this prior expectation. As a shift or a freeze does not physically transfer

the pension-related risks to a third-party insurer, it's not proper to discuss the counter-party risk in either of their cases. A freeze deals with the cease of accrual of future benefits to all participants (hard freeze), new entrants (soft freeze), or some participants (partial freeze). So it actually does not transfer but conclude liabilities.

The most complete U.S. pension data are for the period from 1990 to 2007, from the 5500-CRR database compiled by the Center for Retirement Research at Boston College (CRR), which uses the information from Form 5500 collected by U.S. Department of Labor (DOL). After 2007, firm-level data with detailed pension information are not directly available from any public databases. We conduct extensive web crawling and text mining on the SEC EDGAR website to recognize the de-risking activities in the U.S. market for the period of 1993[3] to 2018. Then we verify the de-risking cases manually. The database built through web-crawling and manual identification are compiled with the Compustat database, the 5500-CRR database, and data from the Department of Labor. Based on the updated database, we plan to bring the most up-to-date analysis concerning the newly available de-risking strategies such as buyouts, buyins, and longevity hedges. To our best knowledge, this will be the first study that investigates the U.S. DB pension de-risking activities with a relatively complete range of empirical data.

3. Empirical Results

3.1. **Sample Collection and Variables.** We construct the sample by merging multiple databases pertaining to firms' pension information, de-risking strategies, and other firm financial characteristics. First, to extract firms' pension data, we use the information from Form 5500 database, which covers the defined benefit plans and defined contribution plans. Required by Employee Retirement Income Security Act (ERISA), corporate pension plan sponsors with 100 or more active participants need to file annually to the U.S. Department of Labor (DOL) and the Internal Revenue Service (IRS) with detailed plan information including the assets and liabilities of the plans, the participants, and the fund administrators. We construct our sample from year 1990 since the Form

[3]1993 is the first year for the SEC to initiate EDGAR.

TABLE 2. Summary Statistics at Plan-level

Plan Level	DB Plans			DC Plans			Other Plans		
Variables	N	Mean	P50	N	Mean	Median	N	Mean	Median
Plan Risk									
Plan Assets ($m)	34,677	315.50	33.38	86,135	171.10	16.06	40,517	54.00	0.00
Plan Liabilities ($m)	34,677	2.03	0.00	86,135	1.20	0.00	40,517	1.01	0.00
Plan Assets/Firm Assets	34,677	0.07	0.02	86,135	0.08	0.04	40,517	0.01	0.00
Net Plan Assets/Plan Assets	33,158	0.97	1.00	81,807	0.98	1.00	5,185	-7.08	1.00
Net Plan Assets/Firm Assets	34,677	0.07	0.02	86,135	0.08	0.04	40,517	0.01	0.00
Plan Asset Beta	16,507	0.61	0.71	76,389	0.80	0.95	4,450	0.56	0.72
Plan Liability Beta	34,710	0.13	0.13	86,179	0.13	0.13	162,068	0.13	0.13
Plan Net Beta	16,507	0.05	0.01	76,389	0.05	0.02	4,450	0.03	0.00
De-risking									
Freeze	27,796	0.02	0.00	64,793	0.00	0.00	n/a	n/a	n/a
Termination	27,796	0.01	0.00	64,793	0.01	0.00	n/a	n/a	n/a
Buyout	34,710	0.00	0.00	86,179	0.00	0.00	162,068	0.00	1.00

5500 database is accessible to the public since 1990.[4] We also utilize the pension information from Compustat which contains firm-level aggregated pension assets and liabilities data.

To identify firms' pension de-risking information, we follow the literature in accounting research to examine the filings from 1993 to 2018 in the SEC EDGAR database. In particular, we perform a keyword search for pension de-risking in the filings from the EDGAR system[5]. For example, to identify buyouts, we use the following set of keywords: "pension buyout", "defined benefit buy-out", "retirement buyout", etc.[6] When a key term is found, we review the context in which the key term appears in the report to confirm/disconfirm the adoption of a pension de-risking strategy. For the firm-year analysis of firms' pension de-risking policy, we also require the valid firm financial information available in Compustat and valid stock price information in CRSP.

Table 2 reports the summary statistics of the key measures[7] for DB and DC pension plans during the period from 1990 to 2014 at plan level. The data will be updated to 2018 to match the web crawling database. Although our target group (treatment group) is the DB plans, the DC group is

[4]We collected data from the Department of Labor website for the time period of 2000 through 2018. For the years before 2000 (1990-1999), we use the Form 5500 data released by the Center for Retirement Research at Boston College (5500-CRR data: Panel of Current and Usable Form 5500 Data. Chestnut Hill, MA).

[5]`https://www.sec.gov/Archives/edgar/full-index/`.

[6]Please refer to Appendix B for the web crawling and text mining strategy and the keywords for the six de-risking strategies.

[7]Please refer to the Appendix A for the variable definitions.

considered here are the control group for analytical purposes. Based on the 5500-CRR database by the Center for Retirement Research at Boston College (CRR) for the period of 1990 to 2007, we also report the statistics of the three types of de-risking strategies (*i.e.*, freeze, termination, and buyout) at plan level. All continuous variables are winsorized at the 1^{th} and 99^{th} percentiles. At current stage, our data sample is unbalanced and the de-risking strategies of shift, buyin, and longevity hedge have not been identified in our sample.

The summary statistics at firm level for the period of 1990 through 2014 is reported in Table 3. Again, our sample will be extended to 2018 to include the most recent available data. We classify the firms into three categories - firms with only DB and other plans, firms with only DC and other plans, and firms with both DB and DC and other plans. We present the firm characteristics variables as well as the variables of firm pension risk. Again, all continuous variables are winsorized at the 1^{th} and 99^{th} percentiles. Same as the data at plan level, the data sample at firm level is unbalanced and we still need to collect data for the de-risking strategies of shift, buyin, and longevity hedge. Comparing the group with only DB (and other) plans to the group with only DC (and other) plans, the number of DB plans is only 3-4% of the number of DC plans. But on average the total assets of a DB plan are three times of the total assets owned by a DC plan. If the group of both DB and DC (and other) plans is counted towards both the DB and DC groups, the number of DB plans is 30-34% of the number of DC plans.

Table 4 presents the correlation matrix between de-risking dummies (Freeze, Termination, Buyout) and selected variables of interest for the plan-level sample. Notice almost all statistically significant correlation coefficients are negative, except the correlation coefficient between "Freeze" and "Plan Asset Beta". It's interesting to observe that "Termination" is negatively correlated with both "Plan Assets" and "Plan Liabilities". When "Plan Assets/Firm Assets" and "New Plan Assets/Firm Assets" are considered, we observe that if the plan assets count a bigger proportion of total assets, the plan is less likely to adopt a de-risking strategy such as freeze or termination. All the correlation coefficients for "Buyout" are statistically insignificant.

TABLE 3. Summary Statistics at Firm-level

Firm Level	Only DB or Other Plans			Only DC or Other Plans			DB-DC and Other Plans		
Variables	N	Mean	Median	N	Mean	Median	N	Mean	Median
Firm Risk									
Total Assets ($m)	1,784	7131.00	747.30	47,577	2190.00	234.00	18,210	11105.00	1814.00
Leverage	1,784	0.26	0.22	47,577	0.16	0.08	18,210	0.21	0.17
Interest Coverage	1,543	35.70	6.04	39,498	66.88	6.49	16,289	27.60	7.04
Cash Holding	1,784	0.07	0.03	47,577	0.20	0.11	18,210	0.07	0.04
Private Debt	1,784	0.16	0.08	47,577	0.09	0.04	18,210	0.12	0.07
Tangible Assets	1,784	0.94	1.00	47,577	0.89	0.97	18,210	0.89	0.96
Altman Z-score	1,784	1.79	1.46	47,577	1.81	2.14	18,210	2.16	2.10
Firm Return Volatility	1,193	0.09	0.07	42,997	0.14	0.11	16,405	0.08	0.07
Stock Return Volatility	1,196	0.11	0.09	43,220	0.16	0.13	16,450	0.10	0.08
S&P Rating	1,658	7.34	7.00	43,719	2.72	0.00	16,838	9.56	12.00
Distance to Default	959	0.10	0.00	31,397	0.12	0.00	14,702	0.06	0.00
Asset Volatility	959	0.32	0.26	31,397	0.48	0.38	14,702	0.27	0.22
Profitability									
Profitability	1,784	0.11	0.11	47,577	0.06	0.09	18,210	0.12	0.12
Earnings Volatility	1,746	0.04	0.02	46,154	0.08	0.04	17,952	0.03	0.02
Marginal Tax Before-tax	1,449	0.32	0.34	38,127	0.27	0.32	14,915	0.33	0.34
Marginal Tax After-tax	1,449	0.29	0.33	38,127	0.24	0.30	14,915	0.31	0.34
Firm Investment									
CAPX/TA	1,784	0.05	0.04	47,577	0.05	0.03	18,210	0.05	0.04
R&D/TA	1,784	0.01	0.00	47,577	0.05	0.00	18,210	0.01	0.00
Market Valuation									
Market-to-book	1,784	1.26	1.04	47,577	1.89	1.36	18,210	1.46	1.22
S&P 500 Index Dummy	1,784	0.06	0.00	47,577	0.03	0.00	18,210	0.12	0.00
Pension Risk									
Pension Assets (FVPA) ($m)	1,565	549.80	39.13	5,972	369.80	8.96	17,159	1081.00	143.10
Pension Liabilities (PBO) ($m)	1,560	493.70	38.32	6,103	393.60	16.60	17,141	1188.00	162.00
Pension Deficit Ratio	1,244	0.00	0.00	5,680	0.01	0.00	15,884	0.01	0.00
Plan Risk									
Plan Assets ($m)	1,784	312.00	25.65	47,577	104.20	12.07	18,210	1225.00	246.60
Plan Liabilities ($m)	1,784	2.06	0.00	47,577	0.66	0.00	18,210	9.82	0.18
Plan Assets / Firm Assets	1,784	0.12	0.06	47,577	0.11	0.06	18,210	0.24	0.17
Net Plan Assets/Plan Assets	1,713	0.99	1.00	45,706	0.99	1.00	18,188	0.99	1.00
Net Plan Assets/Firm Assets	1,784	0.12	0.06	47,577	0.11	0.06	18,210	0.24	0.17
Plan Asset Beta	1,157	0.59	0.68	44,433	0.80	0.95	17,686	0.76	0.85
Plan Liability Beta	706	0.13	0.13	14,471	0.13	0.13	13,468	0.13	0.13
Plan Net Beta	531	0.10	0.02	14,210	0.07	0.03	13,185	0.14	0.09
De-risking									
Freeze	1,587	0.02	0.00	34,669	0.00	0.00	14,089	0.01	0.00
Termination	1,587	0.02	0.00	34,669	0.00	0.00	14,089	0.01	0.00
Buyout	1,784	0.00	0.00	47,577	0.00	0.00	18,210	0.00	0.00

Table 5 provides the correlation matrix between de-risking dummies (Freeze, Termination, Buy-out) and the selected variables of interest for the firm-level sample. Most of the statistically significant correlation coefficients for "Freeze" and "Termination" are negative, while the significant coefficients for "Buyout" are typically positive.

TABLE 4. Correlation Matrix at Plan Level

	DB Plan			DC Plan		
Plan Level	[1]	[2]	[3]	[1]	[2]	[3]
Freeze [1]	1			n/a		
Termination [2]	-0.0014	1		n/a	1	
Buy-out [3]	-0.0038	-0.0027	1	n/a	-0.0018	1
Plan Assets [4]	-0.0319*	-0.0386*	-0.0024	n/a	-0.0260*	0.0105*
Plan Liabilities [5]	-0.0074	-0.0178*	-0.0047	n/a	-0.0048	0.0103*
Plan Assets / Firm Assets [6]	-0.0198*	-0.0362*	0.009	n/a	-0.0354*	0.0056
Net Plan Assets/Plan Assets [7]	0.0008	-0.0011	0.0001	n/a	-0.0231*	0.0002
Net Plan Assets/Firm Assets [8]	-0.0197*	-0.0372*	0.0091	n/a	-0.0361*	0.0054
Plan Asset Beta [9]	0.0436*	-0.0795*	0.0034	n/a	-0.0506*	0.0043
Plan Net Beta [11]	-0.0218*	-0.0392*	-0.0037	n/a	-0.0369*	0.0143*

* denotes statistical significance at the 5 percent (or lower) level.

Our statistics may need further modification. Studies that focus on freezez (e.g., Comprix and Muller (2011) and Vafeas and Vlittis (2018)) typically identify only hard freezes while exclude "freezes of acquired DB plans following a takeover, freezes of subsidiary DB plans or DB plans that only cover foreign employees, freezes of multi-employer DB pension plans, freezes resulting from bankruptcy proceedings or as part of a reorganization, and pre-2000 freezes" (Vafeas and Vlittis (2018)). We need to make further efforts to identify these cases of freezes.

TABLE 5. Correlation Matrix at Firm Level

	DB Plan			DC Plan		
Firm level	[1]	[2]	[3]	[1]	[2]	[3]
Freeze [1]	1			1		
Termination [2]	-0.0145	1		-0.0013	1	
Buy-out [3]	-0.0046	-0.0039	1	-0.002	-0.0021	1
Total Assets [4]	0.0149	-0.0007	0.013	0.0459*	0.0105*	0.0263*
Leverage [5]	-0.0173*	0.0018	0.0162*	0.0073	0.0274*	-0.0026
Interest Coverage [6]	0.0072	-0.0123	-0.0036	-0.0065	-0.0079	-0.0091*
Cash Holding [7]	0.0445*	0.0067	-0.0085	-0.0333*	-0.0314*	-0.0065
Private Debt [8]	-0.0212*	-0.0112	0.0273*	-0.0047	0.0141*	0.0007
Tangible Assets [9]	-0.0847*	0.0207*	0.0002	-0.0441*	0.0142*	-0.003
Altman Z-score [10]	-0.0033	0.0046	-0.0104	0.0038	-0.0034	-0.002
Firm Return Volatility [12]	-0.0103	0.0605*	0.0009	-0.0515*	-0.0252*	-0.0069
Stock Return Volatility [13]	-0.0099	0.0542*	0.0123	-0.0540*	-0.0179*	-0.007
S&P Rating [14]	-0.0211*	-0.0306*	0.0034	0.0615*	0.0231*	0.0071
Distance to Default [15]	-0.0069	0.0292*	0.0338*	-0.0205*	-0.002	0.0138*
Asset Volatility [16]	-0.0059	0.0382*	-0.0111	-0.0500*	-0.0121*	-0.0066
Profitability [17]	-0.0298*	-0.0329*	-0.0078	0.0152*	0.0041	-0.003
Earnings Volatility [18]	0.0076	0.0228*	-0.0119	-0.0320*	-0.0097*	-0.0046
Marginal Tax after-tax [19]	-0.0381*	-0.0477*	-0.0125	0.0278*	0.0055	0.0022
CAPX/TA [20]	-0.0438*	-0.0116	-0.0091	-0.0196*	-0.0009	-0.0110*
R&D/TA [21]	-0.0111	-0.0132	-0.0055	-0.0342*	-0.0262*	-0.0006
Market-to-book [22]	0.0131	-0.0042	-0.0167*	-0.0169*	-0.0247*	-0.0058
S&P 500 Index Dummy [23]	-0.0064	-0.0054	-0.0015	0.0259*	0.0076	0.0133*
Pension Assets (FVPA) [24]	-0.0034	-0.0155	-0.0029	0.0072	-0.0149	0.0004
Pension Liabilities (PBO) [25]	0.0011	-0.0195*	-0.0041	0.0117	-0.0172*	0.0009
Pension Deficit Ratio [26]	0.0573*	-0.0289*	0.0327*	0.0496*	-0.0154	0.0170*
Plan Assets [27]	-0.0046	-0.0344*	-0.0037	0.0460*	-0.0056	0.0035
Plan Liabilities [29]	-0.0192*	-0.0101	-0.0035	0.0189*	0.0101*	0.0036
Plan Assets / Firm Assets [30]	-0.0185*	-0.0334*	0.0132	0.0220*	-0.0074	0.0064
Net Plan Assets/Plan Assets [31]	0.0053	-0.0136	0.0008	0.0027	-0.0147*	0.0001
Net Plan Assets/Firm Assets [32]	-0.0177*	-0.0347*	0.0134	0.0224*	-0.0089*	0.0063
Plan Asset Beta [33]	0.0444*	-0.0445*	0.012	0.0177*	-0.0260*	0.0042
Plan Net Beta [34]	-0.0101	-0.0202*	-0.0069	0.012	-0.0092	-0.0048

* denotes statistical significance at the 5 percent (or lower) level.

TABLE 6. Overview of Pension Risk across Industries

Panel A: Plan Level

Fama-French 12-Industry Category	Industry Names	DB Plans	DC Plans	Plan Assets / Firm Assets	(Plan Assets-Plan Liab.) /Plan Assets	(Plan Assets-Plan Liab.) /Firm Assets	Plan Asset Beta	Plan Net Beta	Freeze	Termination
1	Consumer NonDurables	0.216	0.324	0.062	0.865	0.061	0.704	0.051	0.75%	1.09%
2	Consumer Durables	0.234	0.328	0.060	0.846	0.059	0.730	0.057	1.10%	1.18%
3	Manufacturing	0.265	0.355	0.074	0.910	0.073	0.695	0.061	0.81%	0.85%
4	Energy	0.095	0.167	0.024	0.984	0.024	0.770	0.024	1.58%	1.03%
5	Chem.& Allied Prod.	0.260	0.270	0.063	0.830	0.062	0.728	0.053	1.07%	1.13%
6	Business Equipment	0.056	0.385	0.101	0.987	0.101	0.770	0.074	0.21%	0.59%
7	Telecom.	0.120	0.239	0.042	0.974	0.041	0.748	0.034	0.52%	1.51%
8	Utilities	0.223	0.249	0.045	0.928	0.044	0.747	0.043	0.48%	0.59%
9	Shops	0.102	0.393	0.052	-0.016	0.052	0.760	0.046	0.82%	1.21%
10	Healthcare	0.048	0.328	0.061	-2.188	0.061	0.768	0.040	0.38%	0.88%
11	Money	0.076	0.249	0.016	0.892	0.016	0.802	0.014	0.89%	1.09%
12	Other	0.055	0.259	0.075	0.937	0.074	0.768	0.063	0.61%	0.94%

Panel B: Firm Level

Fama-French 12-Industry Category	Industry Names	DB Plans	DC Plans	Plan Assets / Firm Assets	(Plan Assets - Plan Liab.) /Plan Assets	(Plan Assets - Plan Liab.) /Firm Assets	Plan Asset Beta	Plan Net Beta	Freeze	Termination
1	Consumer NonDurables	0.108	0.286	0.082	0.988	0.082	0.732	0.128	0.60%	0.89%
2	Consumer Durables	0.093	0.298	0.086	0.989	0.085	0.777	0.140	0.74%	0.80%
3	Manufacturing	0.120	0.318	0.133	0.992	0.132	0.759	0.188	0.69%	0.65%
4	Energy	0.031	0.111	0.011	0.993	0.011	0.803	0.060	0.70%	0.78%
5	Chem.& Allied Prod.	0.148	0.227	0.105	0.992	0.104	0.788	0.160	0.97%	0.77%
6	Business Equipment	0.021	0.383	0.078	0.994	0.077	0.786	0.115	0.11%	0.35%
7	Telecom.	0.054	0.182	0.031	0.993	0.031	0.788	0.083	0.33%	1.23%
8	Utilities	0.151	0.165	0.060	0.985	0.059	0.753	0.146	0.50%	0.56%
9	Shops	0.049	0.368	0.050	0.992	0.050	0.775	0.085	0.48%	0.84%
10	Healthcare	0.018	0.310	0.039	0.994	0.039	0.794	0.057	0.21%	0.42%
11	Money	0.043	0.200	0.009	0.974	0.009	0.827	0.026	0.66%	0.75%
12	Other	0.021	0.215	0.041	0.983	0.041	0.788	0.129	0.41%	0.68%

Table 6 provides an overview of the DB & DC plans and the de-risking strategies (now only freeze, termination, and buyout are considered) by industry, at the plan level (Panel A) and firm level (Panel B). We use the Fama-French 12 industry categories to group firms. The results suggest that DB plans are more prevalent in the manufacturing industry (0.265) and the chemicals & allied production industry (0.260), while DC plans are more commonly adopted in the Shops industry (0.393) and the Business Equipment industry (0.385). In addition, the Money industry has the lowest level of plan assets relative to firm assets (0.016) and the pension assets in Money industry are exposed to the highest level of risk (with the highest beta).

Also notice that the pension funding ratios for the Shops and Healthcare industries are negative. A negative pension funding ratio, *i.e.*, (Plan Assets-Plan Liabilities)/Plan Assets, indicates the plan is actually underfunded. The Healthcare industry that has the lowest pension funding ratio (-2.188) is deeply underfunded. Theoretical studies normally suggest that underfunded plans are more likely to conduct de-risking. However, the Healthcare industry is not the most active one who is seeking freeze or termination de-risking resolution. Regarding to the considered de-risking strategies, the firms in Energy, Chemicals & Allied Production, and Consumer Durables tend to freeze their pension plans while the firms in Business Equipment and Utilities are likely to use pension termination.

3.2. **Baseline Regressions for DB Freezes and Terminations.** In this section, we present our preliminary results for DB freezes and terminations based on a complied database for the period from 1990 to 2014. Table 7 shows a univariate comparison of the propensity of de-risking strategy between the firms categorized by different operation and risk characteristics. The column "Mean" reports the probabilities of a company adopting a de-risking strategy of either freeze or termination. For example, in the first row, the number 0.017 under "DB-Freeze Mean" shows that 1.7% companies out of our full sample of 15,676 companies chose to freeze their DB plans during the sample period. The numbers in the second and third rows (0.018 and 0.015) corresponding to the "Above P50" and "Below P50" sub-samples under the variable "Total Assets" indicate that, among the companies whose total assets are above and below average, 1.8% and 1.5% of them froze their

TABLE 7. Univariate Tests at Firm Level

	DB-Freeze	N	Mean	DB-Termination	N	Mean
Full Sample		15,676	0.017		15,676	0.009
Total Assets ($m)	Above P50	7,091	0.018	Above P50	7,091	0.004
	Below P50	8,585	0.015	Below P50	8,585	0.013
	Difference		0.003*	Difference		-0.009***
Leverage	Above P50	8,033	0.015	Above P50	8,033	0.009
	Below P50	7,643	0.019	Below P50	7,643	0.010
	Difference		-0.004**	Difference		-0.001
Market-to-book	Above P50	7,818	0.018	Above P50	7,818	0.008
	Below P50	7,858	0.015	Below P50	7,858	0.011
	Difference		0.003*	Difference		-0.003**
Tangible Assets	Above P50	8,475	0.010	Above P50	8,475	0.009
	Below P50	7,201	0.024	Below P50	7,201	0.009
	Difference		-0.014***	Difference		0.000
S&P Rating	Above P50	7,099	0.010	Above P50	7,099	0.005
	Below P50	7,197	0.025	Below P50	7,197	0.014
	Difference		-0.014***	Difference		-0.009***
Distance to Default	Above P50	6,124	0.017	Above P50	6,124	0.010
	Below P50	5,956	0.015	Below P50	5,956	0.008
	Difference		0.002	Difference		0.003*
Asset Volatility	Above P50	5,988	0.015	Above P50	5,988	0.011
	Below P50	6,092	0.017	Below P50	6,092	0.007
	Difference		-0.002	Difference		0.004**
Profitability	Above P50	8,053	0.012	Above P50	8,053	0.008
	Below P50	7,623	0.022	Below P50	7,623	0.011
	Difference		-0.010***	Difference		-0.003**
Earnings Volatility	Above P50	7,937	0.017	Above P50	7,937	0.012
	Below P50	7,739	0.016	Below P50	7,739	0.007
	Difference		0.001	Difference		0.005***
Marginal Tax after-tax	Above P50	6,813	0.013	Above P50	6,813	0.006
	Below P50	6,465	0.020	Below P50	6,465	0.012
	Difference		-0.007	Difference		-0.006***
CAPX/TA	Above P50	8,252	0.010	Above P50	8,252	0.008
	Below P50	7,424	0.023	Below P50	7,424	0.010
	Difference		-0.013***	Difference		-0.002
S&P 500	Above P50	1,927	0.012	Above P50	1,927	0.007
	Below P50	13,749	0.017	Below P50	13,749	0.010
	Difference		-0.005**	Difference		-0.002
Pension Deficit Ratio	Above P50	5,667	0.023	Above P50	5,667	0.007
	Below P50	7,511	0.014	Below P50	7,511	0.008
	Difference		0.008***	Difference		-0.001
Net Plan Assets/Plan Assets	Above P50	7,834	0.019	Above P50	7,834	0.009
	Below P50	7,790	0.014	Below P50	7,790	0.008
	Difference		0.005***	Difference		0.002
Plan Asset Beta	Above P50	7,148	0.025	Above P50	7,148	0.009
	Below P50	7,460	0.010	Below P50	7,460	0.008
	Difference		0.016***	Difference		0.000

*, ** and *** denote significance at the 10, 5 and 1 percent level, respectively.

DB plans, respectively. The "Difference" in the "Mean" column is tested by the T-test with unequal variances.

After the univariate comparison, we move to the multivariate models. In Table 8 and Table 9, respectively, we present the results of the Probit and OLS regressions of firms' de-risking decisions. The dependent variable is the dummy variable of de-risking which takes the value of one if a firm implements a de-risking strategy of freeze or termination in a given year, and otherwise takes the value of zero. The robust standard errors are used to calculate the Z-statistics. We follow the literature to include the firm and pension plan characteristics variables and control for industry effects and time effects by using industry dummies and year dummies. We consider three model specifications: (i) the specification with only firm variables; (ii) the specification with firm, pension risk, and plan risk variables; and (iii) the specification with firm, pension risk, plan risk variables and control variables. For both the Probit and OLS models, the specifications with all characteristics and control variables (*i.e.*, specification (iii)) yields the highest Pseudo R^2, for both the freeze and terminations cases. Since the dependent variable is binary, the OLS regression does not fit the data very well as the Adjusted R^2 for all the specifications is lower than their Probit counterparts.

The results from these two types of regressions are somewhat consistent to each other. For example, in both Table 8 and Table 9, the variable of "Total Assets" is statistically significant in all the model specifications for the freeze and termination cases. Interestingly in the freeze models, the coefficient of "Total Assets" turns from positive to negative when controlling for the industry and time effects. In the termination models, the coefficient of "Total Assets" is always negative, indicating that a firm with more total assets is less likely to terminate its DB pension plan.

In specifications (ii) and (iii), we consider three pension risk and plan risk variables, which are the "Pension Deficit Ratio", the pension funding ratio "Net Plan Assets/Plan Assets", and the "Plan Asset Beta". The empirical results show that these characteristics variables are statistically significant in making a de-risking decision. However, these determinants typically have opposite impacts on the pension freeze and pension termination, suggesting that the firms have different motivations in conducting these two de-risking strategies. For example, in both types of the regressions, the coefficient of "Plan Asset Beta" is statistically positive in the freeze cases, while it is statistically

negative in the termination cases. This indicates that a higher risk of pension plan increases the propensity of pension freeze but decreases the propensity of pension termination. The pension risk variable "Pension Deficit Ratio" and the pension funding ratio "Net Plan Assets/Plan Assets" are significant covariates in both the freeze and termination cases when the Probit models are adopted, while the variables lose their explanatory significance in the OLS regressions. The "Pension Deficit Ratio" in specification (iii) of the Probit model for the freeze case is statistically negative, suggesting that a higher level of pension deficit results in a lower probability of pension freeze. This can be explained by the fact that a severe financial deficit in pension plans makes it difficult to reach an agreement between employees and firms to stop contributing to pension plans. On the other hand, we find a positive correlation between the "Pension Deficit Ratio" and the decision of termination in the Probit model specification (iii), which is consistent to the claim in the literature that the pension plans are more likely to be terminated when the sponsors are deeply insolvent.

We believe the results will be refined and become more reliable after we finish data collection and more accurately identify the six de-risking strategies (including "shift", "freeze", "termination", "buy-out", "buy-in", and "longevity hedge"). When the full sample is constructed, we would like to test the following three hypotheses:

Hypothesis 1. The determinants of a DB pension plan's de-risking strategy include the firm's underfunding status, the initial cash requirement, the proportion of equity in pension assets, the transaction costs, the default probability of pension insurers, the size of longevity risk, and the industry features.

Hypothesis 2. A proper de-risking strategy improves the firm's underfunding status, increases the firm's stock price, and raises the firm's financial leverage and beta.

Hypothesis 3. A low-interest-rate environment not only provides detrimental to the funding levels of DB pension plans, but also offers a unique opportunity for sponsors of underfunded plans who can borrow at attractive rates to reduce their pension deficit[8].

[8]This is consistent to Mathur and Kaplan (2015).

TABLE 8. Regressions of Baseline Probit Model on DB Plans

	Freeze						Termination					
	(i)		(ii)		(iii)		(i)		(ii)		(iii)	
	β	t	β	t	β	t	β	t	β	t	β	t
Log(Total Assets)	0.074***	2.777	0.083***	2.969	-0.160***	-3.662	-0.147***	-3.542	-0.145***	-3.485	-0.136***	-2.700
Leverage	-0.498*	-1.754	-0.358	-1.232	0.470	1.253	0.430	1.230	0.435	1.115	0.106	0.228
Tangible Assets	-0.867***	-4.197	-0.716***	-3.332	-0.188	-0.567	-0.813***	-2.725	-1.030***	-3.057	-1.031***	-2.780
Altman Z-score	0.020	0.455	0.021	0.448	-0.088	-1.355	0.125***	2.784	0.116**	2.429	0.142**	2.480
Firm Return Volatility	1.850***	2.911	1.827***	2.763	3.596***	3.133	1.234	1.582	1.774**	2.119	1.974**	2.448
S&P Rating	-0.032***	-4.837	-0.032***	-4.643	-0.008	-0.853	0.000	0.009	-0.000	-0.025	0.004	0.305
Distance to Default	0.072	0.447	0.083	0.509	0.318	1.357	0.026	0.135	-0.138	-0.517	-0.046	-0.180
Asset Volatility	-0.249	-1.171	-0.217	-0.943	0.011	0.040	-0.053	-0.187	-0.457	-1.235	-0.554	-1.367
Profitability	-1.904**	-2.558	-1.561*	-1.955	-1.651	-1.471	-1.729**	-2.108	-2.069**	-2.339	-1.697*	-1.943
Earnings Volatility	-4.413***	-2.805	-4.121**	-2.449	-4.417**	-2.068	0.421	0.274	2.117	1.258	2.905*	1.702
Marginal Tax after-tax	-1.828***	-3.545	-1.743***	-3.115	-0.772	-1.047	0.418	0.554	0.707	0.754	0.178	0.163
CAPX/TA	0.313	0.291	0.254	0.227	0.971	0.787	0.149	0.162	0.188	0.195	-0.394	-0.396
Market-to-book	0.086**	2.008	0.088*	1.911	0.099	1.109	-0.049	-0.662	-0.022	-0.255	-0.079	-0.943
S&P 500 Index Dummy	-0.086	-0.822	-0.136	-1.165	-0.011	-0.069	0.255*	1.950	0.345**	2.381	0.301*	1.737
Pension Deficit Ratio			2.192***	3.299	-3.387***	-2.843			-0.187	-0.278	2.131**	2.078
Net Plan Assets/Plan Assets			12.204***	3.126	8.414*	1.818			-0.055**	-2.094	-0.058*	-1.885
Plan Asset Beta			0.397***	2.650	0.097	0.540			-0.447**	-2.545	-0.399**	-2.034
Constant	-0.885***	-2.656	-13.659***	-3.511	-7.777*	-1.685	-1.094**	-2.080	-0.691	-1.206	0.544	0.729
Industry Control	No		No		Yes		No		No		Yes	
Year Control	No		No		Yes		No		No		Yes	
Number of Obs.	9,586		8,795		2,682		9,586		8,795		5,146	
Pseudo R^2	0.052		0.075		0.207		0.057		0.073		0.150	

*, ** and *** denote significance at the 10, 5 and 1 percent level, respectively.

TABLE 9. Regressions of Baseline OLS Model on DB Plans

	Freeze						Termination					
	(i)		(ii)		(iii)		(i)		(ii)		(iii)	
	β	t	β	t	β	t	β	t	β	t	β	t
Log(Total Assets)	0.003**	2.508	0.003**	2.343	-0.005***	-3.607	-0.003***	-3.296	-0.002***	-3.254	-0.002**	-2.396
Leverage	-0.022*	-1.876	-0.019	-1.489	0.001	0.050	0.009	0.945	0.007	0.918	0.005	0.470
Tangible Assets	-0.039***	-3.567	-0.034***	-3.002	0.001	0.083	-0.013*	-1.830	-0.016**	-2.165	-0.018**	-2.220
Altman Z-score	0.000	0.210	0.000	0.018	-0.006**	-2.115	0.003**	2.361	0.002**	1.982	0.003**	2.433
Firm Return Volatility	0.092**	2.084	0.095**	2.012	0.170***	3.246	0.029	0.935	0.041	1.290	0.046	1.383
S&P Rating	-0.001***	-4.086	-0.001***	-4.040	-0.000	-0.680	0.000	0.035	0.000	0.100	0.000	0.113
Distance to Default	0.002	0.235	0.004	0.465	0.004	0.504	0.001	0.117	-0.003	-0.549	-0.002	-0.344
Asset Volatility	-0.011	-1.122	-0.009	-0.792	0.002	0.183	-0.000	-0.012	-0.009	-1.273	-0.009	-1.295
Profitability	-0.073**	-2.317	-0.061*	-1.784	-0.000	-0.006	-0.050**	-2.009	-0.051**	-2.048	-0.053**	-2.065
Earnings Volatility	-0.168***	-3.393	-0.181***	-3.398	-0.181***	-3.384	0.025	0.515	0.065	1.257	0.083	1.579
Marginal Tax after-tax	-0.095***	-2.935	-0.096***	-2.692	-0.041	-1.216	0.004	0.163	0.011	0.524	-0.001	-0.056
CAPX/TA	0.020	0.474	0.017	0.385	0.065	1.379	-0.001	-0.045	0.005	0.305	-0.006	-0.329
Market-to-book	0.004*	1.771	0.004*	1.788	0.004*	1.816	-0.001	-0.513	-0.000	-0.033	-0.001	-0.397
S&P 500 Index Dummy	-0.002	-0.744	-0.004	-1.300	0.004	1.185	0.004	1.583	0.005*	1.886	0.004	1.384
Pension Deficit Ratio			0.104***	3.113	-0.040	-1.088			-0.008	-0.638	0.029*	1.702
Net Plan Assets/Plan Assets			0.001	0.991	0.001	1.104			-0.002	-0.814	-0.002	-0.794
Plan Asset Beta			0.016***	3.221	0.010**	2.022			-0.011**	-2.228	-0.010**	-2.085
Constant	0.080***	4.368	0.061***	3.086	-0.027	-1.100	0.033**	2.429	0.039***	2.842	0.044**	2.241
Industry Control	No		No		Yes		No		No		Yes	
Year Control	No		No		Yes		No		No		Yes	
Number of Obs.	9,586		8,795		8,795		9,586		8,795		8,795	
Adjusted R^2	0.008		0.010		0.063		0.004		0.004		0.012	

*, ** and *** denote significance at the 10, 5 and 1 percent level, respectively.

3.3. **Value Creation (Destruction) of Freezes and Terminations.** To provide a novel insight into the influence of de-risking strategy on the firm value, we adopt two measures of firm value. The first measure is Tobin's Q defined as the ratio of the market value of a firm to the replacement cost of its assets. Another proxy is to follow Faulkender and Wang (2006) to measure the annual excess equity return calculated from a firm's stock return over year $t-1$ to year t, net of the benchmark return based on the Fama and French (1993)'s size and book-to-market matched portfolio from year $t-1$ to year t.

The results based on Tobin's Q are reported in Table 10. Model [1] suggests that the freeze policy reduces the firm value, and this reduction impact keeps significant after controlling for the industry-fixed and year-fixed effect. However, after we include the pension risk and plan risk variables, the pension freeze shows an insignificant coefficient, suggesting that the freeze policy will not hurt the firm valuation if such policy is adopted based on properly assessed pension risk and plan risk. We also find the consist results from Model [4] through Model [6] that the termination of a pension plan does not cause a significant loss to the firm value on the condition of the net plan assets ratio.

As a robustness check, the results based on the annual excess equity return are presented in Table 11. Unlike the measure of Tobin's Q, the annual excess equity return mainly gauges the shareholder value. The results in Models [1] and [2] in Table 11 indicate that the policy of freeze has a marginal positive impact on the excess equity return, suggesting that the shareholders benefit from the implementation of a pension freeze. In contrast, the person termination actually introduces a loss to shareholders, though this loss is not strongly statistically significant. Considering that the excess equity return captures the equity market reaction, such contrasting results may not be surprising as the pension termination may be regarded as an indicator of constraints of financial resources while the freeze is usually taken as an active change of a firm's policy to accommodate the risk.

TABLE 10. Value Creation (Destruction) of Pension Risk-shifting Strategies

	Dependent Variable: Tobin's Q											
	[1]		[2]		[3]		[4]		[5]		[6]	
	β	t	β	t	β	t	β	t	β	t	β	t
Freeze	-0.125***	-2.682	-0.125***	-3.091	0.033	0.936						
Termination							-0.214***	-4.196	-0.193***	-4.101	-0.067	-1.153
Log(Total Assets)	0.077***	12.938	0.061***	9.915	0.064***	9.669	0.076***	12.840	0.061***	9.894	0.064***	9.666
Leverage	-2.238***	-50.326	-1.870***	-39.796	-1.184***	-13.327	-2.236***	-50.309	-1.870***	-39.803	-1.184***	-13.322
Tangible Assets	-0.165***	-5.001	0.047	1.198	-0.226***	-5.168	-0.165***	-4.986	0.045	1.144	-0.227***	-5.176
Altman Z-score	0.180***	17.693	0.204***	17.665	0.219***	9.263	0.180***	17.701	0.204***	17.668	0.219***	9.272
Firm Ret Vola.	1.975***	11.722	2.229***	12.733	0.426*	1.700	1.972***	11.703	2.227***	12.723	0.431*	1.720
S&P Rating	0.015***	10.751	0.018***	13.566	0.012***	10.030	0.015***	10.819	0.018***	13.575	0.012***	10.031
Distance to Default	-0.313***	-12.458	-0.293***	-12.017	-0.084***	-3.420	-0.314***	-12.475	-0.293***	-12.027	-0.084***	-3.417
Asset Vola.	-0.019	-0.601	-0.054*	-1.753	0.187***	4.457	-0.019	-0.584	-0.054*	-1.765	0.187***	4.446
Profitability	0.027	0.214	0.143	1.071	2.611***	10.233	0.026	0.201	0.141	1.053	2.610***	10.227
Earnings Vola.	4.244***	18.164	3.980***	17.183	4.162***	10.186	4.247***	18.184	3.983***	17.200	4.160***	10.178
Marginal Tax	-2.330***	-19.232	-2.092***	-16.945	-1.513***	-12.855	-2.327***	-19.225	-2.094***	-16.963	-1.515***	-12.856
Pension Deficit Ratio					-0.077	-0.620					-0.074	-0.596
Net Plan Assets Ratio					0.011***	4.552					0.011***	4.303
Plan Asset Beta					0.008	0.335					0.008	0.316
Constant	1.597***	24.409	1.405***	14.445	1.344***	4.614	1.599***	24.441	1.407***	14.447	1.348***	4.631
Industry Control	No		Yes		Yes		No		Yes		Yes	
Year Control	No		Yes		Yes		No		Yes		Yes	
Number of Obs.	28,673		28,669		11,175		28,673		28,669		11,175	
Adjusted R^2	0.296		0.373		0.548		0.296		0.373		0.548	

*, ** and *** denote significance at the 10, 5 and 1 percent level, respectively.

TABLE 11. Value Creation (Destruction) of Pension Risk-shifting Strategies

	Dependent Variable: Market Excess Return											
	[1]		[2]		[3]		[4]		[5]		[6]	
	β	t	β	t	β	t	β	t	β	t	β	t
Freeze	0.061*	1.855	0.055*	1.681	0.038	1.060						
Termination							-0.155	-1.509	-0.143*	-1.695	-0.128	-1.384
Log(Total Assets)	0.016***	2.865	0.010*	1.662	0.012*	1.861	0.016***	2.876	0.010*	1.662	0.012*	1.770
Leverage	-0.359***	-7.630	-0.409***	-8.319	-0.407***	-5.383	-0.356***	-7.582	-0.406***	-8.280	-0.404***	-5.357
Tangible Assets	0.118***	4.360	0.058*	1.825	0.029	0.599	0.119***	4.415	0.061*	1.907	0.032	0.654
Altman Z-score	0.016***	3.016	0.021***	3.598	0.001	0.055	0.016***	3.003	0.021***	3.579	0.000	0.037
Firm Return Vola.	0.997***	4.325	1.055***	4.531	0.906**	2.132	0.998***	4.332	1.055***	4.535	0.914**	2.153
S&P Rating	0.000	0.235	0.000	0.093	-0.002	-1.478	0.000	0.238	0.000	0.100	-0.002	-1.504
Distance to Default	-0.159***	-3.511	-0.137***	-3.023	-0.121**	-1.992	-0.158***	-3.497	-0.136***	-3.012	-0.120**	-1.975
Asset Vola.	0.000	0.007	-0.007	-0.146	0.204***	3.342	-0.000	-0.006	-0.007	-0.156	0.204***	3.335
Profitability	0.544***	6.919	0.491***	5.843	0.723***	4.680	0.544***	6.915	0.491***	5.850	0.719***	4.654
Earnings Vola.	-0.108	-0.593	-0.205	-1.112	-0.546	-1.529	-0.113	-0.620	-0.209	-1.135	-0.546	-1.533
Marginal Tax	-0.348***	-2.809	-0.399***	-3.180	0.030	0.157	-0.343***	-2.767	-0.393***	-3.136	0.039	0.204
Pension Deficit Ratio					-0.318	-1.109					-0.325	-1.133
Net Plan Assets Ratio					0.113	0.567					0.124	0.624
Plan Asset Beta					-0.005	-0.156					-0.005	-0.160
Constant	-0.199***	-3.241	0.177	0.809	-0.253	-1.039	-0.201***	-3.264	0.175	0.798	-0.262	-1.077
Industry Control	No		Yes		Yes		No		Yes		Yes	
Year Control	No		Yes		Yes		No		Yes		Yes	
N of Obs	4,922		4,922		2,108		4,922		4,922		2,108	
Adjusted R^2	0.095		0.114		0.150		0.095		0.114		0.150	

*, ** and *** denote significance at the 10, 5 and 1 percent level, respectively.

4. Optimal Risk-shifting

In this section, we build two theoretical models to analyze pension de-risking strategies. The Markov-switching model proposed in Section 4.1 helps to verify the soundness of firms' de-risking choices based on the empirical data. It can also be used to assess the subsequent influence of a de-risking strategy on the firm's performance. While, the optimization model proposed in 4.2 is to determine the optimal de-risking strategy that minimizes a firm's total pension cost (TPC). The theoretical models can provide *ex ante* strategic suggestions to the firms that plan to conduct de-risking strategies.

4.1. **Markov-Switching Model.**

For any targeted pension plan, it has two non-reversible states, *i.e.*, before-de-risking and after-de-risking states. The seminal work of Hamilton (1989) introduces a Markov-switching model to identify "turning points" of a time series, a tractable approach to model changes in regimes. Our de-risking indicator is also a binary series, but it processes a special non-reversible feature. Specifically, once a de-risking strategy is implemented, the decision cannot be "undone" to bring the pension plan back to the original status. This is different from the typical binary time series that allows both switches from 0 to 1 and 1 to 0.

In this paper, we propose a unidirectional Markov-switching model to identify the point at which the de-risking occurs. Suppose a pension plan conducts a de-risking strategy (e.g., shift, freeze, termination, buyout, buyin, etc.) at time τ. Let D_t be the de-risking indicator at time t that takes value 0 if $t \leq \tau$ and 1 otherwise. A two-state Markov-switching model assumes that D_t may be in one of two states S_1 and S_2 with probabilities that depend on its state in the previous period. Here, $S_i, (i = 1, 2)$ takes either 0 or 1, where 0 stands for the before-de-risking state while 1 represents the after-de-risking state. For example, if the "shifting from DB to DC" strategy is analyzed, the "before-de-risking" and "after-de-risking" states are DB and DC, respectively. The transition

between states is governed by a first-order Markov process:

$$\begin{cases} \Pr[S_t = 0 | S_{t-1} = 0] = \pi_t, \\ \Pr[S_t = 1 | S_{t-1} = 0] = 1 - \pi_t, \\ \Pr[S_t = 0 | S_{t-1} = 1] = 0, \\ \Pr[S_t = 1 | S_{t-1} = 1] = 1. \end{cases} \tag{1}$$

Notice that different from the typically first-order Markov process, the process is non-reversible. In other words, a firm's pension status can only be transferred from 0 to 1, but not vice versa. We further assume the time-dependent probability π_t is determined by the following logit link:

$$\pi_t = \Phi(\beta' X_t), \tag{2}$$

where $\Phi(\cdot)$ is the cumulative distribution function of standard normal [9], $X_t = [1, X_{1t}, X_{2t}, \ldots, X_{nt}]^T$ is the vector of predictor variables at time t, n is the number of the predictor variables, and $\beta = [\beta_0, \beta_1, \ldots, \beta_n]^T$ is the coefficient vector.

Based on the transition process defined in (1), the expected value of the K-period ahead prediction of the de-risking indicator equals

$$\begin{aligned} D_{t+K}^t &= \mathrm{E}[D_{t+K} | \mathcal{F}_t] \\ &= \mathrm{E}[(1 - D_t)(1 - \pi_t) + D + t] \\ &= 1 - \pi_t(1 - D_t), \end{aligned} \tag{3}$$

where $\mathcal{F}_t$ is the σ-algebra that contains all available information till time t.

Sometimes D_{t+K}, the de-risking status at time $t+K$, is driven not only by the values of predictor variables in time t, but by the values of predictor variables in the last p periods (*i.e.*, $\{X_t\}_{t=t-p}^t$). In this case, equation (2) is modified as

$$\pi_t = \Phi(\beta^{0\prime} X_t + \beta^{1\prime} X_{t-1} + \cdots + \beta^{p\prime} X_{t-p}), \tag{4}$$

[9] Alternatively, π_t can be determined by a logit link where $\log \frac{\pi_t}{1-\pi_t} = \beta' X_t$. Our preliminary results show that there is no significant difference between using a logit-link and a probit-link to determine π_t.

TABLE 12. Economic Impact of Pension Risk-shifting Strategies

	Panel A: Pension Freeze							
	Tobins Q		**Freeze**		**Tobins Q**		**Freeze**	
	β	t	β	t	β	t	β	t
Freeze	-0.828**	-2.013			-0.829***	-2.731		
Net Plan Assets			0.798***	5.006				
Plan Asset Beta							0.626*	1.869
Markov-switching Probability	0.311*	1.742			0.357**	2.485		
Log(Total Assets)	0.061***	10.884	0.028	0.834	0.069***	10.641	0.006	0.144
Leverage	-1.864***	-40.706	0.886***	3.056	-1.586***	-27.847	0.489	1.267
Tangible Assets	0.052	1.261	0.354	1.551	-0.143***	-2.786	0.440	1.459
Altman Z-score	0.204***	50.210	-0.027	-1.042	0.241***	36.560	-0.067*	-1.673
Firm Return Volatility	2.233***	21.047	0.896	1.146	1.567***	10.364	1.431	1.394
S&P Rating	0.018***	12.409	-0.003	-0.340	0.015***	9.362	-0.003	-0.291
Distance to Default	-0.292***	-11.255	0.137	0.754	-0.199***	-6.122	-0.015	-0.065
Asset Volatility	-0.053**	-2.133	0.005	0.023	0.025	0.729	0.112	0.450
Profitability	0.146**	2.321	0.924*	1.731	0.716***	7.372	0.483	0.599
Earnings Volatility	3.967***	35.049	-5.916***	-3.759	4.420***	23.182	-8.233***	-3.710
Marginal Tax after-tax	-2.089***	-22.375	-0.051	-0.087	-2.132***	-17.817	-1.148	-1.587
Constant	1.361***	15.373	-2.058***	-4.477	1.246***	11.138	-1.327**	-2.321
Indutry Control	Yes		Yes		Yes		Yes	
Year Control	Yes		Yes		Yes		Yes	
Number of Obs.	28,669				12,853			

	Panel B: Pension Termination							
	Tobins Q		**Termination**		**Tobins Q**		**Termination**	
	β	t	β	t	β	t	β	t
Termination	1.118**	2.011			1.394***	3.035		
Net Plan Assets			-0.915***	-3.528				
Plan Asset Beta							-1.355**	-2.325
Markov-switching Probability	-0.510**	-2.380			-0.629***	-3.473		
Log(Total Assets)	0.062***	10.881	-0.043	-1.400	0.070***	10.643	-0.024	-0.555
Leverage	-1.877***	-40.871	0.207	0.892	-1.597***	-27.772	0.351	0.965
Tangible Assets	0.054	1.300	-0.371*	-1.739	-0.131**	-2.524	-0.742**	-2.416
Altman Z-score	0.203***	49.813	0.033	1.155	0.240***	35.724	0.126***	2.591
Firm Return Volatility	2.233***	20.967	-0.736	-1.033	1.560***	10.230	-0.856	-0.693
S&P Rating	0.018***	12.186	0.013*	1.703	0.015***	9.124	0.007	0.627
Distance to Default	-0.292***	-11.231	0.001	0.007	-0.197***	-6.003	-0.022	-0.103
Asset Volatility	-0.053**	-2.124	-0.122	-0.952	0.026	0.779	-0.184	-0.865
Profitability	0.155**	2.451	-0.712*	-1.899	0.739***	7.504	-1.423**	-2.086
Earnings Volatility	3.980***	35.112	-0.110	-0.168	4.499***	23.634	-1.264	-0.908
Marginal Tax after-tax	-2.085***	-22.228	-0.289	-0.597	-2.066***	-17.042	-1.426*	-1.924
Constant	1.316***	14.761	-1.618***	-4.005	1.124***	9.867	-0.725	-1.228
Indutry Control	Yes		Yes		Yes		Yes	
Year Control	Yes		Yes		Yes		Yes	
Number of Obs.	28,669				12,853			

*, ** and *** denote significance at the 10, 5 and 1 percent level, respectively.

where $\beta^t = [\beta_0^t, \beta_1^t, \ldots, \beta_n^t]^T$ for $t = 0, 1, \ldots, p$.

TABLE 13. Market Reaction of Pension Risk-shifting Strategies

	Panel A: Pension Freeze							
	Tobins Q		**Freeze**		**Tobins Q**		**Freeze**	
	β	t	β	t	β	t	β	t
Freeze	0.006	0.024			-0.436*	-1.897		
Net Plan Assets			0.920***	4.677				
Plan Asset Beta							0.773*	1.774
Markov-switching Probability	0.023	0.200			0.242**	2.147		
Log(Total Assets)	0.010*	1.710	0.024	0.577	0.006	0.852	0.034	0.618
Leverage	-0.407***	-7.905	0.897**	2.477	-0.350***	-4.665	0.304	0.608
Tangible Assets	0.060	1.628	0.883***	3.063	0.087	1.619	1.032***	2.603
Altman Z-score	0.021***	5.327	-0.056*	-1.833	0.007	0.964	-0.106**	-2.129
Firm Return Volatility	1.056***	8.382	0.836	0.835	1.153***	5.468	1.559	1.259
S&P Rating	0.000	0.093	-0.006	-0.535	0.001	0.308	-0.005	-0.337
Distance to Default	-0.136***	-3.788	0.120	0.457	-0.215***	-3.870	-0.138	-0.364
Asset Volatility	-0.007	-0.201	0.015	0.055	0.090	1.578	0.113	0.310
Profitability	0.492***	7.533	0.944	1.491	0.563***	4.394	0.457	0.451
Earnings Volatility	-0.210	-1.536	-5.457***	-2.869	-0.636**	-2.526	-8.047***	-3.017
Marginal Tax after-tax	-0.396***	-3.743	1.513*	1.662	-0.193	-1.261	-0.678	-0.610
Constant	-0.216**	-2.468	-3.242***	-4.936	-0.200	-1.586	-2.579***	-3.239
Indutry Control	Yes		Yes		Yes		Yes	
Year Control	Yes		Yes		Yes		Yes	
Number of Obs.	4,922				2,090			

	Panel B: Pension Termination							
	Excess Return		**Termination**		**Excess Return**		**Termination**	
	β	t	β	t	β	t	β	t
Termination	-0.564	-0.475			-0.050	-0.224		
Net Plan Assets			0.346	0.593				
Plan Asset Beta							10.205	1.152
Markov-switching Probability	0.138	0.357			-0.050	-0.315		
Log(Total Assets)	0.010*	1.695	-0.044	-0.373	0.006	0.792	3.345	1.044
Leverage	-0.405***	-7.995	0.393	0.403	-0.371***	-5.202	-7.698	-0.914
Tangible Assets	0.059*	1.673	-0.588	-1.018	0.049	1.018	6.615	0.828
Altman Z-score	0.021***	5.351	-0.060	-0.653	0.010	1.433	0.261	0.263
Firm Return Volatility	1.053***	8.346	-3.768	-0.627	1.083***	5.413	-55.395	-0.985
S&P Rating	0.000	0.080	-0.008	-0.276	0.001	0.280	-1.422	-1.116
Distance to Default	-0.136***	-3.775	0.352	0.468	-0.208***	-3.895	23.682	1.090
Asset Volatility	-0.008	-0.239	-1.380	-0.864	0.087	1.598	-33.098	-1.266
Profitability	0.490***	7.507	-0.715	-0.498	0.553***	4.471	-49.418	-1.156
Earnings Volatility	-0.204	-1.508	2.417	0.889	-0.449**	-2.003	68.387	1.117
Marginal Tax after-tax	-0.388***	-3.656	3.348	1.148	-0.170	-1.154	-32.296	-0.936
Constant	-0.216**	-2.465	-2.636**	-1.985	-0.191	-1.575	-21.337	-0.009
Indutry Control	Yes		Yes		Yes		Yes	
Year Control	Yes		Yes		Yes		Yes	
Number of Obs.	4,922				2,090			

*, ** and *** denote significance at the 10, 5 and 1 percent level, respectively.

Based on the Markov-switching Model proposed above, we treat the firms' risk-shifting decision as a regime switch. Using the collected empirical data for freeze and termination, in the following analysis, we assume a firm will choose to either freeze or terminate its pension plan. With

the consideration of this endogenous switch, we take account of invisible factors that affect firms' decisions. The results in Section 3 show that the status of pension assets (measured by net plan assets) and the level of pension risk (measured by pension beta) have statistically significant impact on firms' decisions of freeze or termination. Therefore, we first use the structure model to estimate the markov-switching probability based on these pension status variables. We then re-run the regressions in Section 3.3 with the endogeneity considered through the estimated Markov-switching probability. The results of Tobin's Q are reported in Table 12. From Panel A we find that the freeze policy significantly reduces the firm value, and this reduction impact remains significant after the inclusion of the Markov-switching probability. However, the pension termination shows an positive and significant coefficient, suggesting that the termination policy will increase the firm market valuation if such policy is designed according to the properly assessed pension risk. We also find the consist results from Panel A and Panel B that the variable of markov-switching probability has significant explanatory powers. The results for the long-term market access return are reported in Table 13. Although the variables of interest primarily do not show statistic significance, we notice that the freeze policy still leads to a weakly significant loss to the firm value when such policy is triggered by a high plan beta. We will do more sophisticated analysis after the data for all the six de-risking strategies are collected.

4.2. **Optimization Model.** Lin et al. (2015) develop an optimization model that minimizes the expected total pension cost (TPC) subject to a conditional value at risk (CVaR) constraint on pension funding level. They investigate three pension de-rising strategies (*i.e.*, buyout, buyin, and longevity hedge) by considering de-risking costs that include a risk premium, search and information cost, underfunding cost, and counter-party risk cost. They find these de-risking costs have a significant impact on the de-risking decision.

Following a similar idea to Lin et al. (2015), in our paper, we identify the optimal de-risking strategy by minimizing the total pension cost. Since we expand the scope of "de-risking" to include not only the traditional buyout, buyin, and longevity hedge, but also shift, freeze, and termination, we define the total pension cast in a more general way. Specifically, the total pension cost (TPC) of a DB pension plan is calculated as the sum of the de-risking cost and the present values of the plan's

all future periodic pension expenses. For a given period, the periodic pension expense includes the plan's contribution, possible withdrawal, service cost, and any other expenses related to the company's DB pension plan. Pensions are a type of off-balance-sheet financing. The empirical data of pension expenses can be collected by recognizing various components on the P&L or in OCI under IFRS and US GAAP.

We focus our analysis at time τ when the plan's de-risking strategy is implemented. The total pension cost at $t = \tau$ is calculated as

$$TPC_\tau = DeRC_j + \sum_{t=\tau}^{\infty} \frac{PExp_t}{(1+r)^t}, \tag{5}$$

where $DeRC_j$ is the cost paid at time τ to implement de-risking strategy j (shift, freeze, termination, buyout, buyin, or longevity hedge), $PExp_t$ is the periodic pension expense at time t, and r is the pension discount rate.

The de-risking cost $DeRC_j$ is a function of the plan's de-risking choice j. To simplify our calculation, we assume a DB plan's de-risking cost is a proportion ρ_j of the plan's total pension assets, where $j = ST, FZ, TM, BO, BI$ or LH representing the de-risking choice shift, freeze, termination, buyout, buyin, or longevity hedge. That means,

$$DeRC_j = \rho_j \times PA, \text{ for } j = ST, FZ, TM, BO, BI, LH, \tag{6}$$

where PA is the plan's pension assets at the de-risking time τ. In our study, the level of ρ_j is determined by the empirical data.

The goal of our optimization model is to determine the optimal de-risking strategy. Specifically, we minimize the total pension cost at time τ with respect to the de-risking decision j, $(j = ST, FZ, TM, BO, BI, LH)$:

$$\underset{j}{\text{Minimize}} \qquad DeRC_j + \sum_{t=\tau}^{\infty} \frac{PExp_t}{(1+r)^t}. \tag{7}$$

One should note that both the empirical analysis in Section 3 and the Markov-switching analysis in Section 4.1 are "macro" analysis based on a pooled pension group, while the optimization model

is used to determine the optimal de-risking decision of an individual plan when its future periodic pension expense $PExp_t,\ t = \tau, \tau + 1, \ldots$ can be properly estimated.

5. CONCLUSIONS

DB pension de-risking, as an avenue to manage the imbalance between pension assets and liabilities, has drawn more and more attention to pension providers, pensioners, and a broader group of market participants in the new millennium. As such, how to design an appropriate de-risking mechanism to relieve DB firms' financial burden and meanwhile foster employees' welfare security constitutes a challenge to corporate sponsors, pension schemes, and trustees. Few studies examine the determinants of de-risking strategies and the subsequent influence on firms, which however is of considerable interest in this study.

Using a large sample of firms across various industries and over the last three decades, our paper first identifies multiple avenues of de-risking in DB pension plans. We find that firms operating in different business sectors have remarkable heterogeneity in their choices of de-risking strategies. Our results show that typically the firms in service sectors prefer DC plans as oppose to DB plans, while manufacturing firms are more likely to freeze their DB plans. In addition, the decision of pension termination is found evenly across the industries with exception of telecommunication.

Our results also indicate that the firms with smaller size, less tangible assets, higher return volatility, or lower profitability are more likely to perform de-risking strategies. This is consistent with the prediction by the theoretical models in the literature and casts light on the firms that plan to conduct de-risking strategies. Our analysis suggests that optimal outcomes of a de-risking strategy can be reached by reallocating the firm's disposable assets and shifting pension risk out of the firm. The empirical results in this study also support that the active management of pension risk contributes to the firm value.

Taken together, this research contributes to the extant literature of pension management by exploring empirical evidence about the functions and outcomes of de-risking strategies. Our results warrant further studies and attention to evaluate the structure of pension plans and the optimal design of benefit contracts among employees, shareholders, and other stakeholders.

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Appendix A: Variable Construction I

Variables	Variable Definitions
Pension Risk	
Pension Assets (FVPA)	Before 1997, pension plan assets equal to the sum of overfunded (Compustat item PPLAO) and underfunded (Compustat item PPLAU) pension assets; after 1997, pension plan assets equal to pension plan assets (Compustat item PPLAO)
Pension Liabilities (PBO)	Before 1997, projected pension benefit obligations equal to the sum of overfunded (Compustat item PBPRO) and underfunded (Compustat item PBPRU) pension benefit obligations; after 1997, projected benefit obligations equal to projected benefit obligations (Compustat item PBPRO)
Pension Deficit Ratio	calculated as (PBO-FVPA) divided by firms' total market value (the sum of equity market value (E) and debt book value (D))
Plan Risk	
Plan Assets	Total value of pension plan assets for a given firm and a give year
Plan Liabilities	Total value of pension plan liabilities for a given firm and a give year
Plan Asset Beta	Weighted average of all pension plans' asset beta with the plan assets as weights
Plan Liability Beta	Weighted average of all pension plans' liability beta with the plan liabilities as weights
Plan Net Beta	Estimated as pension asset beta minus pension liabilities beta, adjusted by total value of all pension assets and total value of pension liabilities as a percentage of firms total market value (the sum of equity market value (E) and debt book value (D))
De-risking	
Freeze	Proportion of pension plans when the accrual of benefits has been suspended for a given firm and given year
Termination	Proportion of pension plans when the accrual of benefits has been terminated for a given firm and given year
Buyout	An indicator variable when a given firm's de-risked through buy-out strategy

Appendix A: Variable Construction II

Variables	Variable Definitions
Firm Risk	
Total Assets	It's measured by CPI-adjusted book value of total assets. The logarithm of total assets is finally used in regressions.
Leverage	Total debt divided by total market value of assets, where the market value of assets is the sum of total debt and market value of equity.
Interest Coverage	The ratio of EBITDA (earnings before interest, taxes, depreciation, and amortization) to interest charges.
Cash Holding	The ratio of cash plus marketable securities to total assets.
Private Debt	The proportion of private debt capital to market value of assets. We extract private debt from the balance sheet by subtracting the amount of notes, subordinated debt, debentures and commercial papers from total debt.
Tangible Assets	A ratio of book value of tangible assets to book value of total assets.
Altman Z-score	It's computed as: $Z = 1.2 \times (\text{Working Capital}/\text{Total Assets}) + 1.4 \times (\text{Retained Earnings}/\text{Total Assets}) + 3.3 \times (\text{EBIT}/\text{Total Assets}) + 0.6 \times (\text{Market Value of Equity}/\text{Total Liabilities}) + 0.999 \times (\text{Sales}/\text{Total Assets})$.
Firm Return Volatility	The standard deviation of monthly asset returns over up to preceding 24-month period. We first compute equity return based on monthly stock returns, and then convert it to assets return according to Hamada's equation.
Stock Return Volatility	The standard deviation of monthly stock returns over up to preceding 24-month period.
S&P Rating	It's S&P long term rating and we follow a similar conversion process from Klock et al. (2005) to assign numbers to rating categories.
Distance to Default	The 12-month moving average of monthly distance to default by following KMVMerton methodology described in.
Asset Volatility	1-year asset volatility, estimated by using the market value of equity, 1-year equity volatility, the 3-month Treasury bill rate, and debt value to solve Merton (1974)'s model of pricing a firm's debt and equity in a 1-year time horizon
Profitability	
Profitability	The ratio of EBITDA (earnings before interest, tax, depreciation, and amortization) to total assets
Earnings Volatility	The standard deviation of the first difference in EBITDA scaled by book value of assets over the period of 4 years preceding a given fiscal year
Marginal Tax (after-interest)	Marginal tax rate after interest deduction from Blouin et al. (2010)
Firm Investment	
CAPX/TA	Capital expenditure divided by total assets
R&D/TA	Research and development expenses divided by total assets
Market Valuation	
Market-to-book	The ratio of market value of assets to book value of assets
S&P 500 Index Dummy	An indicator variable of S&P500 constituents

APPENDIX B: WEB CRAWLING AND TEXT MINING

To construct our de-risking database, we conduct a two-layer keyword search on the SEC EDGAR website. The Level 1 keywords include "defined benefit(s)", "pension(s)", and "retirement". The Level 2 keywords target the six considered de-risking strategies individually. In Table 14, we present the keywords or combination of keywords for the Level 2 web crawling. Specifically, we follow the following three steps to identify firms' de-risking activities from the SEC EDGAR database:

Step 1: Do the Level 2 keyword search. If a de-risking keyword is found (e.g., freeze, termination, etc.), the case is recognized and recorded as a Level A match.

Step 2: Do the Level 1 keyword search in the Level A pool. If a Level 1 keyword is found in the same sentence, the sentence is extracted and the case is marked as a Level B match. If more than one Level B sentences (for different de-risking strategies) within one SEC filing are found, all the matched sentences are extracted and reported.

Step 3: Based on the extracted sentences that contain both Level 1 and Level 2 keywords, we conduct manual judgements to identify DB pension plans' de-risking activities.

TABLE 14. Level 2 De-Risking Keywords

Strategy	Keywords
Shift	shift/shifts/shifting + defined benefit/DB + defined contribution/DC
	switch/switches/switching + defined benefit/DB + defined contribution/DC
	defined benefit/DB + to + defined contribution/DC
	from + defined benefit/DB + to
	to + defined contribution/DC
Freeze	freeze/freezes/froze/frozen/freezing + pension
	freeze/freezes/froze/frozen/freezing + plan/plans
	freeze/freezes/froze/frozen/freezing + defined benefit/DB
	benefit/ benefits + accruals/accrued + frozen
	benefit/ benefits + frozen
Termination	Terminate/terminates/termination/terminated + pension
	Terminate/terminates/termination/terminated + defined benefit/DB
	Terminate/terminates/termination/terminated + plan
	wind-up/winds-up + pension
	wind up/winds up/winding up + pension
	wind up/winds up/winding up + DB scheme
	wind up/winds up/winding up + defined benefit
Buyout	Pension + buyout/buy-out/buyouts/buy out/buy outs
	defined benefit/DB + buyout/buy-out/buyouts/buy out/buy outs
	plan/plans + buyout/buy-out/buyouts/buy out/buy outs
Buyin	Pension + buyin/buy-in/buyins/buy in/buy ins
	defined benefit/DB + buyin/buy-in/buyins/buy in/buy ins
	plan/plans + buyin/buy-in/buyins/buy in/buy ins
Longevity hedge	longevity swap/swaps
	longevity hedge/hedging/hedges
	longevity reinsurance
	hedge/hedging/hedges + longevity risk
	longevity-hedging
	longevity risk transfer

Note: "/" means "or"; "+" means "and".