Do Corporates Set Pension Discount Rates Strategically?

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Abstract

Corporations can choose to reduce the magnitude of their pension liabilities through their choice of pension discount rates. We document that the majority of U.S. firms set pension discount rates above benchmark rates. Since mandatory contributions to underfunded pensions constrain corporate investments, setting higher pension discount rates improve firm value of more productive firms. Consistent with this idea, we find higher discount rates help to improve investments of underfunded firms, particularly for financially constrained firms most vulnerable to lower rates. Imperfect elasticity of pension discount rates to market interest rates offers firms leeway to alleviate the constraints from defined benefit pension plans.

JEL Codes: G11; G22

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1 Introduction

Defined-benefit (DB) pension plans guarantee a specific benefit or payout upon retirement. Corporations contribute funds to their employees' retirement plans based on the projected liabilities adjusted by pension discount rates. However, corporations have some discretion in the choice of the pension discount rate that is used. While the current standard practice for setting pension discount rates states that " ... the projected benefit obligation would equal the current market value of a portfolio of high-quality zero coupon bonds whose maturity dates and amounts would be the same as the timing and amount of the expected future benefit payments" (SFAS 158), exactly what constitutes "the market value of a portfolio of high-quality zero coupon bonds" is undefined so firms retain some discretion on the choice of discount rates for future pension liabilities. Thus, although the guidance would suggest uniformity in pension discount rates, this discretion has resulted in substantial variability, both cross-sectionally and across time.

Corporate interest rates have been in a historic decline since 1980 – the average rate for Moody's AAA bonds dropped from 10% in 1990 to below 3% at the end of 2019 - which resulted in substantially lower pension discount rates and inflated pension liabilities (see Figure 1).[1] This decline has contributed to a widespread underfunding of plans: since 2000, around 90% of U.S. firms sponsoring DB pension plans have a deficit in their pension funding each year. This decline has also dramatically increased the likelihood of default; the Pension Benefit Guarantee Corporation (PBGC), the insurer for corporate pensions, notes that the likelihood that the multiemployer program will run out of money before the end of fiscal year 2025 has grown to over 90 percent, and the single-employer program is also struggling with funding deficit (PBGC, 2018).

Sharp declines in equity markets followed by a decrease in interest rates (due to actions by the Federal Reserve or market forces) can further exacerbate underfunding, adding economic pressure to already vulnerable firms. During and after the 2007-2009 financial crisis, many

[1] SFAS 87 (1985) and SFAS 158 (2006) recognize that "assumed discount rates shall be reevaluated at each measurement date. Thus in case the general level of interest rates rises or declines, the assumed discount rates shall change in a similar manner."

firms suffered a double hit on the gap between pension assets and pension liabilities — firms were still recovering from the large devaluation of their pension assets due to the dramatic market downturn for equities and bonds, while the decreasing interest rates increased the value of their pension liabilities.[2] More generally, by lowering the present value of pension obligations by retaining higher pension discount rates, firms are less underfunded and thus have less mandatory contribution charges against internal funds. However, since the guidance is only guidance, firms retain valuable discretion in the setting of their pension discount rates, particularly for firms near bankruptcy where this discretion may be used strategically.

In this paper, we examine the effects of the strategic choice by firms to use their discretion in setting pension discount rates. We start by developing a simple model to motivate the effect that mandatory pension contributions have on the choice of a pension discount rate. We then examine the strategic choices of firms in choosing a pension discount rate over the period 1994 to 2018. We find notable asymmetry based on the interest rate environment: pension discount rates are sticky if benchmark rates decline, but rise rapidly when benchmark rates rise. Consistent with the implications of the model, we find that underfunded firms with significant financing constraints use higher discount rates, and this effort improves firm operating efficiency.

Our simple model demonstrates that, if unconstrained, optimal corporate choices regarding pension contributions and capital investment depend on the marginal rate of substitution between these two: firms with high marginal investment productivity rationally choose to invest more and contribute less to pensions. However, this optimization could be constrained by mandatory pension contributions. In the United States, the Employee Retirement Income Security Act (ERISA) of 1974 requires firms to set aside a certain amount of assets to meet

[2] According to the U.S. Government Accountability Office (GAO) in 2014, "because average interest rates over the past 25 years are significantly higher than more recent market rates, the MAP-21 changes had the effect of significantly increasing ERISA discount rates over what they would otherwise have been, thereby lowering measurements of plan liabilities and reducing minimum funding requirements and potentially putting plan participants and PBGC at greater risk". The GAO was commenting on the changes in 2012 from the Moving Ahead for Progress in the 21st Century Act (MAP-21), which permitted pension discount rates based on a 25-year average of high-quality corporate bond rates instead of 2-year smoothing. (See Section A for more details.)

their pension obligations. These pension liabilities are considered as an integral part of a firm's financial liabilities (Treynor, 1977; Friedman, 1982; Bodie, Light, Morck, and Taggart Jr, 1985; Jin, Merton, and Bodie, 2006). The amount of pension contribution (known as normal cost or service cost) and assets needed to be held for the pension plan is therefore a function of the present value of the pension liabilities and not just the marginal rate of substitution. Consequently, firms wanting to increase capital investment are incentivized to inflate pension discount rates to lower their pension liabilities. While the incentive to set a high discount rate and thus minimize pension contributions prevalent across firms facing financial constraints, it is not an option that firms can repeatedly exercise. As a result, we expect such an incentive to be particularly strong for significantly underfunded firms which face large mandatory contributions since this saves them from using the limited resource for mandatory pension contributions.[3]

Empirically, we start by demonstrating that firms do, in fact, choose higher pension discount rates than those suggested by current market rates: a supermajority of U.S. firms, 85%, apply a higher rate than the benchmark rate suggested (but apparently not required) by regulators to discount their pension plans, with spread averaging nearly 1% in our sample period. Even so, we find that pension discount rates are positively associated with the presumptive benchmark rate, i.e., 10-year Aa corporate bond yields (following e.g., Brown and Wilcox (2009); Brown and Weisbenner (2014) and the changes in pension discount rates are positively correlated with changes in benchmark rates. Notably, however, we detect an important *asymmetry*: while changes in pension discount rates closely follow rising benchmark rates, they do not do so for declining rates: when benchmark rates fall, the sensitivity

[3]Rauh (2006) estimates that for every dollar of mandatory contribution to underfunded pension plans, a firm is forced to reduce its capital expenditure by $0.60 to $0.70. Firms' R&D investments and acquisition decisions could be similarly affected. For a plan that is less than 90% funded, ERISA requires the sponsoring firm to make additional contributions to the plan to reduce the funding deficits within three to five years. If a plan is over 80% funded today and was more than 90% funded for the past two years, the additional contribution requirement is waived. However, the Pension Equity Act 2006 set new funding targets. Beginning in 2008, sponsors are required to fund 100% of all liabilities (including lump sum distributions and early retirement benefits) accrued to participants and beneficiaries within seven years. It should be further noted that the Pension Relief Bill passed in 2008 provides pension funding relief for plan sponsors affected by the economic downturn, by allowing underfunded firms to fund their plans over an extended period.

of pension discount rates to the benchmark rates is only half of that when rates rise. The stickiness of pension discount rates during interest rate declines leads to greater differences between pension discount rates and the benchmark rates at lower interest rates, and suggests strategic behavior on the part of firms when setting rates.

Having established that firms are more likely to use their options in pension discount rates when interest rates significantly drop, we then examine how these effects vary cross-sectionally with corporate investment opportunities and their financial strength. We start by investigating the cross-sectional effects of firm reliance on capital and pension underfunding that affect their choices of pension discount rates. Our findings are in line with the model prediction: financially constrained firms, i.e., poorly rated firms or those having borrowing constraints, with relatively high marginal productivity of capital (abbreviated as *MPK*) are more likely to set higher pension discount rates and the effect is particularly strong among underfunded firms. Specifically, a 1 standard deviation increase in *MPK*, among underfunded firms, leads to an increase of 4 basis points (bps) in excess pension discount rates (abbreviated as *EDR*) for non-financially constrained firms while the resulted excess pension discount rate is 14 basis points higher for financially constrained firms. Notably, the effect is intensified during periods of large drops in interest rates. Among underfunded firms, a one standard deviation increase of *MPK* in years when interest rates drop significantly (specifically defined as years when the benchmark rates, yields of the 10-year AA bonds, are reduced by more than 7.5% of the year-beginning rates),[4] on average, results in an additional 10 bps increase in excess pension discount rates relative to the effect in other years.

Moreover, we present evidence that setting a high pension discount rate indeed helps to improve corporate investments. To do so, we look at the effects of pension discount rates on corporate investment sensitivity to *MPK* *separately* for underfunded and overfunded firms. In the underfunded subsample, the coefficient on the interaction of *MPK* and *EDR* is strongly positive while it is just weakly significant in the overfunded subsample, and the

[4]These years are 2001 to 2003, 2010-2012, and 2014. In the first wave (2001-2003), the Fed cut interest rates 13 times during 2001 and 2003, lowering the federal fund rate from 5% in the beginning of 2001 to 1% in June 2003. The Fed's quantitative program easing program implemented in late 2009 kept interest rates near zero.

difference in the coefficients is significant. That is, we observe a greater improvement in corporate investment for those having greater investment opportunities among underfunded firms, which supports our arguments in two ways: first, it furthers the argument that more underfunded firms are more likely to setting high discount rates by showing setting the rate higher leads to more investments, and second, significantly underfunded firms are likely constrained financially which are also inclined to inflate discount rates. The difference in the *EDR* effects on investment sensitivity to *MPK* offers support to the financing constraint effect as well. Among underfunded firms, a one standard deviation increase in excess pension discount rate (0.75%) leads to a 50% increase in firms' investment sensitivity to marginal productivity. We also test whether the effect of pension discount rate inflation differs in different interest rate environments. The result shows that excess pension discount rate leads to a greater investment-productivity sensitivity when interest rates sharply decline.

Few academic works systematically studied the practice of corporate pension discount rate setting.[5] Our study focuses on inflation in pension discount rates in light of the significant underfunding in U.S. corporate pensions and cross-sectionally in the tension between funding pension and corporate investments under financing constraints. This tension increases during periods of larger economic financial distress when interest rates drop. For example, the overall level of interest rates in the US were low during the financial crisis and became ultra-low after the implementation of Federal Reserve's quantitative easing programs. Dropping interest rates have dual effects on corporate pension obligations: first, it significantly inflates pension liabilities as such liabilities have a long duration and second, low interest rates further elongate pension liabilities. We therefore also focus on strategic pension discount rate choices in a falling interest rate environment.

Overall, due to the requirements to fund pension obligations, there is a real cost to the

[5] A notable exception is Bergstresser, Desai, and Rauh (2006), which suggest that firms could manipulate earnings by managing the expected rates of return on pension plan assets, but focuses more on the value of plan assets and not on the use of pension liability discount rates to manipulate mandatory pension contributions. Other papers include Stefanescu, Wang, Xie, and Yang (2018) show large U.S. firms modify top executives' compensation before a pension plan freeze and a year before retirement through lowering pension discount rates. Our work complements Stefanescu, Wang, Xie, and Yang (2018) by examining corporate incentives to inflate pension discount rates.

variance in interest rates and therefore pension discount rates. Due to the high duration of long-distant pension obligations, minor changes in long-term pension discount rates could result in notable changes in the present value of pension obligations. Firms could reasonably prefer not to have additional drain on their earnings during the low interest rate environment or a recession when revenues and earnings are already under pressure, only to see the pressure reversed during a recovery period when interest rates rise (and underling revenues and earnings recover). Yet, the opportunity to choose pension discount rates provides defined benefit plan firms an opportunity to gain some flexibility to handle the difficult conditions.[6] By showing a relaxation of pension contribution constraints, i.e., lower investment constraint, improves investments and firm value, our paper complements Rauh (2006)'s finding that mandatory pension contributions add to investment constraints.[7] Our evidence suggests that the ability of firms to use their discretion to set pension plan assumptions and use the pension plan to exploit potential benefits for the interests of shareholders may be a possible reason for continuing existence of defined benefit pensions.

Finally, our findings may have policy implications. Among two types of retirement plans in practice — defined benefit corporate pension and defined contribution plans — corporations using defined benefit plans have a relative lack of flexibility to cope with financial difficulties. With defined benefit pensions, firms are mandated to contribute to the plans while firms with defined contribution plans do not have such constraints (Franzoni, 2009). High service costs of defined benefit pension plans make them less favorable relative to defined contribution retirement plans (Rauh and Stefanescu, 2009). However, the flexibility demonstrated here slightly ameliorates this effect by providing options to managers in distress, thus reducing slightly some of the relative disadvantage of defined benefit plans.

[6]This is observed in practice: Richardson (2006) notes that "a company can manage its earnings by changing various assumptions such as pension discount rates. This is likely to affect many industries, particularly industrial, health-care and biotechnology companies."

[7]Underfunding a pension comes with additional important constraints. According to the Pension Protection Act of 2006 aiming to improve the funded status, for firms with underfunded plans, if pension assets are less than 80% of pension liabilities, they are not allowed to adopt amendments that increase plan liabilities and provide lump sum distributions or other accelerated forms of benefits. In a more serious case, if a firm's pension assets are less than 60% of pension liabilities, firms are prohibited from all future benefit accruals.

The remainder of the paper is organized as follows. In Section 2, we provide background information about the pension discount rate practice. We formulate a theoretical framework for the tradeoff between pension contributions and corporate investments and discuss empirical predictions in Sections 3. Section 4 describes the data and section 5 presents the empirical findings. Section 6 concludes.

2 Model and Empirical Predictions

2.1 Model

We present a simple model to demonstrate the role of pension funding constraints in firms' decisions on setting corporate pension discount rates.

The firm makes decisions in the beginning of each period to maximize its value, v_t, considering the tradeoff between pension contributions and capital investment. Applying the Bellman equation, we express firm value recursively:

$$v_t = \underbrace{[f(i_t) - i_t] + [h(c_t) - c_t] - \lambda e_t}_{\text{profit in year t}} + \underbrace{\beta v_{t+1}}_{\text{PV}(v_{t+1})} \tag{1}$$

where $f(i_t)$ is the firm's production expressed as a function of the firm's initial investment (i_t); c_t is the firm's pension contribution made in the beginning of year t; $h(c_t)$ is the accrued benefit to the firm (e.g. improved employee incentives or loyalty as in Treynor (1977); Ippolito (1985a,b)) from corporate pension contribution made in the beginning of the period; e_t is the external fund the firm borrows (when $e_t > 0$) or lending (when $e_t < 0$); λ is the unit cost on external funds or the lending rate; β is the discount rate; v_{t+1} is the firm value in year $t + 1$ after paying pension contribution c_t. The income tax rate is assumed to zero for simplicity.[8].

The firm's aggregate pension contribution, c_t, and investment, i_t, shall equate the sum of firm internal and external funding:

$$c_t + i_t = d_t + e_t \tag{2}$$

[8]We obtain the consistent analytical results when dropping the zero income tax rate assumption.

d_t is the firm's available internal funds and e_t, as noted earlier, is its external funds.[9]

Inserting Equation (2) to (1), we have:

$$v_t = [f(i_t) - i_t] + [h(c_t) - c_t] - \lambda(c_t + i_t - d_t) + \beta v_{t+1} \tag{3}$$

Under ERISA, a firm is required to maintain a sufficient level of pension assets. Following Picconi (2006) and Rauh (2006), the required contribution, c_t^r, to underfunded pension is the sum of the service costs, present value of the projected retirement benefits earned by plan participants during the current period, and the amortization of any funding shortfall in n years while the required contribution to overfunded pension only contains the service cost. Thus, when a firm is overfunded, it faces a lower level of required pension contribution than the required pension contribution when the firm is underfunded:

$$c_t \geq c_t^r = \begin{cases} s_t, & \eta_t \geq l_t \\ s_t + (l_t - \eta_t)/n, & \eta_t < l_t \end{cases} \tag{4}$$

where s_t denotes the service cost; l_t is the projected pension obligations; η_t denotes pension assets in the beginning of year t; n refers to the amortization horizon to close the pension funding shortfall.[10]

Suppose the optimal pension contribution to maximize the value function Eq. (3) is c_t^*. Jointly considering the required pension constraint, Eq. (4), we expect that each firm makes the contribution decision based on

$$c_t \quad = \quad max(c_t^*, c_t^r) \tag{5}$$

We first work on the optimal pension contribution, c_t^*, which results in the first two hypotheses. Given that the funding constraint is not only applicable in year t, but also in the subsequent year t+1,

$$c_{t+1} \geq s_{t+1} + (l_{t+1} - \eta_{t+1})/n, \tag{6}$$

[9]Note that funding is no longer costly when λ equals zero and Eq. (2) does not bind firms' investment and pension decisions. This is the first best condition that firm decisions on investments and pension contributions are independent from each other.

[10]Following Rauh (2006), the amortization horizon for pension funding shortfall, n varies between 5 and 30 years. See IRC 430(a) for details.

which can be rewritten as

$$c_{t+1} + (\eta_t + c_t - s_t)r_p/n \geq s_{t+1} + l_{t+1}/n \quad (7)$$

where r_p is pension asset return. This implies an inter-temporal pension contribution constraint:

$$\frac{\partial c_{t+1}}{\partial c_t} = -r_p/n \quad (8)$$

That is, a \$1 increase in the pension contribution in year t results in a reduction of r_p/n of pension contribution in year $t+1$.

Consider the inter-temporal relationship to maximize the firm value function, v_t, specified in Equation (3), with respect to its pension contribution, c_t. Given a time consistent expectation $\frac{\partial v_t}{\partial c_t} = \frac{\partial v_{t+1}}{\partial c_{t+1}}$, we have

$$\frac{\partial v_t}{\partial c_t} = \frac{[f'(i_t) - 1 - \lambda]\frac{\partial i_t}{\partial c_t} + [h'(c_t) - 1 - \lambda]}{1 + \beta r_p} \quad (9)$$

$\frac{\partial v_t}{\partial c_t}$ in Eq. (9) is comprised of two elements: i) marginal productivity of capital investments after transaction costs, and ii) the net pension on firm production effect after transaction costs.

Solving for $\frac{\partial i_t}{\partial c_t}$ by setting the first order condition to zero, we specify the following condition for the optimal pension contribution, c_t^*:

$$\frac{\partial i_t}{\partial c_t} = -\frac{h'(c_t) - 1 - \lambda}{f'(i_t) - 1 - \lambda} \quad (10)$$

Firms substitute pension contributions for investments when their marginal investment productivity net of transaction costs is greater than that of retirement pensions, and vice versa. The productivity of pension contributions is considered to be low (Ippolito, 1995; Rauh and Stefanescu, 2009). As such those firms with a higher investment productivity contribute less to their pension plans. This point is illustrated in Figure 2. There are two marginal rate substitution curves. The budget constraint is specified in the thin 135-degree line. A higher cost of capital will force firms to borrow fewer external funds and thus push the budget constraint to the northwest side as the thick one. When $h'(c_t)$, the marginal pension productivity, is held constant, a high investment productivity, $f'(i_t)$, flattens the marginal substitution curve. That is, the optimal pension contribution and investment combination, c_t, i_t, for the high investment productivity firm, A, lies above, the combination, B, for the low investment productivity firm.[11] Consequently, using superscripts "h" and "l" to denote high and low investment productivity firms, we have $c_t^h < c_t^l$ and $i_t^h > i_t^l$. We summarize this in the following proposition.

Proposition 1. *In equilibrium, firms with a higher net investment productivity relative to net pension productivity, i.e., a lower* $\frac{h'(c_t)-1-\lambda}{f'(i_t)-1-\lambda}$*, would invest more and make smaller pension contributions.*

Further along, to understand the effect of financing costs on investment and pension contribution relationship, we differentiate $\frac{\partial i_t}{\partial c_t}$ with respect to λ,

$$\frac{\partial^2 i_t}{\partial c_t \partial \lambda_t} = \frac{f'(i_t) - h'(c_t)}{(f'(i_t) - 1 - \lambda)^2} \tag{11}$$

$\frac{\partial^2 i_t}{\partial c_t \partial \lambda_t}$ is positive given $f'(i_t) > h'(c_t)$. As $\frac{\partial i_t}{\partial c_t}$ is negative, a positive $\frac{\partial^2 i_t}{\partial c_t \partial \lambda_t}$ suggests a less steep slope for the marginal substitution rate curve between pension contributions and corporate investment, depicted as the dotted curve shown in Figure 2 — the substitution of corporate investment against pension contributions is intensified under a higher λ. $c_t^{h'} < c_t^h$ and $i_t^{h'} > i_t^h$. This results in the second proposition:

Proposition 2. *Holding $f'(i_t) > h'(c_t)$, the substitution of investments to pension contributions intensifies under higher financing costs, λ.* $\frac{\partial^2 i_t}{\partial c_t \partial \lambda_t} > 0$.

Intuitively, Proposition 2 suggests that when a firm has a low financing cost, it can resort to external funding for the capital need for investments and pension contributions. Firms would rationally cut pension contributions, which has a relatively lower productivity, when

[11] Holding of Eq. (10) mandates i) $f'(i_t) - 1 - \lambda > 0$ and ii) $h'(c_t) - 1 - \lambda > 0$. As we focus on the case that $f'(i_t) - 1 - \lambda > 0$, consider $h'(c_t) - 1 - \lambda < 0$. Following Eq. (9, we have firm investment policy to be independent of its pension contribution. In this case, firms shall make a minimum contribution to their pension plans. The main conclusion of the model remains valid.

it has a high funding cost. This is consistent with Franzoni (2009) which suggests a negative effect of financing constraints on investments.

Now we return to Eq. (5) – firm pension contribution c_t is the maximum of c_t^* and c_t^r. Consider that optimal contribution, c_t^*, exceeds the required contribution, c_t^r, the firm would choose the optimal contribution, c_t^*. Conversely, if the required contribution, c_t^r, exceeds the optimal contribution, c_t^*, the firm has to contribute more to pension plans than their desired level. This is illustrated in Figure 3 where required pension contributions lead to a less optimal combination of firm investment and pension contributions — the budget line crosses the marginal substitution curve at C. Since the firm's pension liability, l_t, is negatively associated with its pension discount rate, δ, setting a higher discount rate lowers a firm's pension ability and required pension contribution, allowing the firm to deviate less from its optimal investment position.

Following Proposition 2, holding others constant, c_t^* is lower when a firm faces greater external financing costs, which may be achieved through setting a higher pension discount rate. This is summarized in the following proposition.

Proposition 3. *The condition c_t^r exceeds c_t^* holds for firms facing high external funding costs. Therefore, they are more likely to inflate their pension discount rates, δ, to lower their pension contributions.*

Now we consider the effect of pension funding. This may be viewed as a scenario where corporate financing costs, λ, stays constant while the firm's internal capital d, is low. According to Eq. (4), underfunded firms generally have higher required contributions, c_t^r, than overfunded firms. With Eq. (5), therefore, underfunded firms are more likely to have to make c_t^r instead of c_t^*. As shown in Figure 3, a firm with c_t^* would stay on the higher up indifference curve than that with c_t^r given the same budget constraint. Therefore, both underfunded and overfunded firms have incentive to manage pension liabilities (l_t) when c_t^r is higher than c_t^* to reduce c_t^r (or even make c_t^r lower than c_t^* and only contribute c_t^r). With discussions on Proposition 3, underfunded firms with higher $f'(i)$ and λ are more likely to inflate pension discount rates to reduce l_t and save more funds from pension contributions to invest. This leads to the last proposition:

Proposition 4. *Underfunded firms with greater marginal investment productivity and financing costs set higher pension discount rates.*

2.2 Empirical Predictions

The simple setup results in three empirical predictions regarding i) the overall pattern in corporate pension discount rates, ii) the effect of financing constraints and pension underfunding on corporate pension discount rate choices, and iii) such choices on firm investments.

First, the model predicts that firms have an incentive to inflate pension discount rates when pension productivity is low and the marginal substitution between capital investments and pension contributions is high. Given the relatively lower productivity of defined benefit pension, e.g., Rauh and Stefanescu (2009), we expect positive excess pension rates (i.e., pension discount rates in excess of the benchmark interest rate) to be widespread in practice. Positive excess pension rates are more likely when a low pension discount rate substantially inflates pension liability. To see this, consider a representative employee with age a and she will retire at age R with a retirement wage w_R. Then the projected pension liability, l, can be expressed as

$$l = b(R-a)w_R e^{-\delta(R-a)} \tag{12}$$

where δ is the pension discount rate and b represents the pension's generosity factor.

Projected pension liabilities may be affected by interest rates through the the duration (D) and convexity (C) channels which can be expressed as $\frac{\Delta l}{l} = -D(\Delta\delta)+\frac{1}{2}C(\Delta\delta)^2$. Further denoting $\widehat{D}$ (adjusted duration) as $D - \frac{1}{2}C\Delta\delta$, we obtain a simple relation between pension discount rate adjustments and the associated adjustment in pension liabilities:

$$\frac{\Delta l}{l} = -\widehat{D}\Delta\delta \tag{13}$$

Equation (13) states first that a change in pension discount rates leads to a large change in pension liabilities since pension liabilities have a long payment horizon (i.e, a long duration

D), and the convexity of pension bond inflates $\widehat{D}$ when there is a drop in pension discount rates ($\widehat{D}$).

This results in two testable conditions. First, a high pension discount rate should result in a substantial drop in corporate liabilities. Second, a lower pension discount rate should lead to substantial increase in pension liabilities, particularly in a low interest environment where pension convexity is high (Fabozzi, 2016). We summarize both conditions in the first hypothesis:

Hypothesis 1 (Pension Discount Rates over Time)**.** *Corporates are more likely to set higher pension discount rates when interest rates significantly drop.*

As suggested in Propositions 3 and 4, firms have incentives to set higher pension discount rates when they have higher investment productivity and face greater financing constraints. Holding investment productivity constant, more tightened financial constraint leads to greater sensitivity in firm productivity and pension discount rates. This gives rise to the second hypothesis:

Hypothesis 2 (Cross Sectional Determinants of Pension Discount Rates)**.** *More productive firms are more likely to set higher pension discount rates. The positive association between pension discount rates and investment productivity intensifies among financially constrained firms.*

We consider the first effect (the positive effect of investment productivity on pension discount rates) the investment effect and the second effect the financing constraint effect.

Next, considering that mandatory pension contributions for underfunded pension plans are greater than overfunded plans, underfunded firms have greater incentives to set higher pension discount rates to satisfy the investment and financial constraint conditions.

Hypothesis 3 (Underfunding Effect)**.** *The investment effect and the financing constraint effect become stronger among underfunded firms.*

Finally, we study the relation between pension discount rates and investments. Rauh (2006) and Campbell, Dhaliwal, and Schwartz (2012) show that mandatory pension contributions lower firm investments. Therefore, if setting a higher pension discount rate offers a remedy to this problem, improving the alignment between investment opportunities and corporate investments, we would see that underfunded firms setting higher pension discount rates have a higher investment sensitivity to firm marginal productivity than overfunded firms acting similarly. This is our fourth hypothesis.

Hypothesis 4 (Effect on Capital Investments)**.** *Setting higher pension discount rates improves underfunded firms' investment efficiency more than it does to overfunded firms.*

3 Data

3.1 Sample

We start with firms having a positive pension discount rate (item PBARR) from the Compustat database. Since the data for pension discount rates is noisy in early years, our sample begins in 1994 and ends in 2018. To identify the set of firms sponsoring defined benefit (DB) pension plans, we keep pensions having both PA and PL jointly existing, where PA is calculated as the sum of overfunded pension plans assets (item PPLAO) and underfunded pension plans assets (item PPLAU), and PL is calculated as the sum of overfunded pension projected liabilities (item PBPRO) and underfunded pension projected liabilities (item PBPRU).[12] We keep firms with positive pension assets, leaving us 48,615 observations in the final sample.

Following Brown and Wilcox (2009) and Brown and Weisbenner (2014), we obtain the benchmark of pension discount rates, yields of 10-year AA bonds, primarily from Trade Re-

[12]Note that pension projected liabilities are also known projected pension obligations (PBO). A projected benefit obligation (PBO) is an actuarial measurement of what a company will need at the present time to cover future pension liabilities. An alternative measure of pension liabilities is accumulated benefit obligations (ABO). ABO refers to the present value of retirement benefits earned by employees using current compensation levels. PBOs are typically used to assess firm future pension liabilities (Ippolito, 1985b).

porting and Compliance Engine (TRACE). As July 2002 is the starting point of TRACE, we augment the benchmark rate data using bond yields reported in the National Association of Insurance Commissioners (NAIC), a common approach used on the corporate bond research (e.g., Chung, Wang, and Wu, 2019). Bond characteristics, such as corporate bond ratings, are from the Mergent FISD database. We keep all the plain-vanilla corporate bonds issued by U.S. firms, while excluding bonds with optionality (e.g., callable and putable bonds, and bonds with sinking-fund, convertibility, and exchangeability features), asset-backed securities, bonds with credit enhancements, floating-rate bonds, foreign-currency denominated bonds, and bonds with odd frequency of coupon payments. We additionally exclude bonds with missing data on key characteristics such as issue date, maturity date, issue price, issuance size, coupon rate, and bonds with missing credit ratings. Firm characteristics are from Compustat annual fundamental database.

3.2 Variables and Summary Statistics

Table 1 provides distributional statistics including mean, median, standard deviation, and skewness of the key variables employed in the subsequent analysis. All the variables included in the table, and the remaining analysis, are winsorized at the lowest and highest 1 percentiles. The mean value of pension discount rate is 5.80%. The mean of excess pension discount rate (*EDR*), which is the difference between pension discount rate and the benchmark rate, is 0.83%, showing on average firms set a higher pension discount rate than the benchmark rate. In addition, the reported skewnesses for *PensionDR* and *EDR* are both positive, respectively 0.35 and 0.32, implying the presence of high positive numbers in both variables. This is confirmed by the distribution of *EDR* plotted in Figure 4 where we form the distribution by pooling together all observations over years and across firms. As plotted, while *EDR*s are generally normally distributed around the sample average, the right tail density is greater than the density of the left tail. Almost the entire distribution is positive, so that almost all pension rates are higher than their benchmark.

The key explanatory variable of excess pension discount rates is a firm's marginal productivity of capital investment. Marginal productivity of capital, i.e., corporate investment opportunity, is notoriously known to be hard to measure (e.g., Abel and Blanchard, 1986; Abel and Eberly, 1994). We follow Gilchrist, Himmelberg, and Huberman (2005) and Xing (2008) to quantify the marginal productivity of capital (MPK) using the value of sales divided by the lagged book value of property, plant, and equipment scaled by the average ratio of the industry multiplied by 0.2. We do not use Tobin's Q to measure investment opportunity because Tobin's Q is affected by market valuation while MPK is mainly driven by corporate fundamentals (e.g., Gilchrist and Himmelberg, 1995; Panageas, 2005). Our measure of MPK was introduced by Gilchrist and Himmelberg (1995) and subsequently refined in Gilchrist et al. (2005). In our sample, the expected value of MPK is 0.21 and its standard deviation is 0.14. The magnitude is comparable to existing studies.

The panel further reports variables associated with firm investments, financing constraints, and other variables. We follow Gilchrist et al. (2005) and Xing (2008) in measuring corporate investment with I/K (the ratio of firm capital expenditures to the lagged book value of property, plant, and equipment) and IG (investment growth, the growth rate in firm's capital expenditure). As reported, the median value of capital expenditure ratio is 15.35% and the capital expenditure growth rate is around 9.17%.[13]

We employ three proxies for firm financing constraints. First, we follow Campbell et al. (2012) and consider firms which are non investment-grade debt issuers as financially constrained firms.[14] We create a low credit rating (LOW) dummy equal to 1 for firms which are non investment-grade debt issuers, and 0 otherwise. In addition, two other financing constraint variables are the KZ index calculated based on the work of Kaplan and Zingales (1997) and the WW index calculated based on the work of Whited and Wu (2006). Details of these financing constraint measures are provided in the appendix. The median value of KZ and WW is 0.79 and -0.38. To ease interpretation, we use the KZ dummy (equal to 1

[13]The correlations between MPK and I/K as well as IG are respectively 0.23 and 0.12, suggesting that firms with higher marginal productivity of capital have higher corporate investment and a higher investment growth rate.

[14]We assign numerical ratings from 1 to 22 to letter ratings with 22 for a AAA rated bond and 1 for a D rated bond.

for firms with *KZ* above the median in each year, and 0 otherwise) and *WW* dummy (equals 1 for firms with *WW* above the median in each year, and 0 otherwise) instead.

Next, we report distributions of key control variables, including *SIZE* (firm size, measured by the logarithm of a firm's total assets), *ROA* (the ratio of a firm's net income to the total assets at the beginning of the year), *PR* (pension actual return on plan assets), and *TAX* (the simulated corporate marginal tax rate based on income after interest expense has been deducted).[15] In the sample, the median value of *ROA* is 3.18%, and the standard deviation is 6.07%. The mean value of pension return is 5.79%, and the mean value of marginal tax rate is 25.62%.

Moreover, we inspect the correlations across variables and report them in Appendix Table A1 to conserve space. As reported, *EDR* is positively associated with *MPK* with a correlation of 0.06, showing preliminary support to the notion that high marginal investment productivity firms set a higher pension discount rate mentioned in the hypothesis section. We also detect a negative relationship between excess pension discount rates and firm size (-0.26); three financing constraint measures, *LOW*, *KZ* and *WW*, are positively correlated and they all have a positive correlation with *EDR*. The pattern suggests a positive association between corporate financing constraint and pension discount rates. The correlations between *MPK* and *I/K* as well as *IG* are 0.23 and 0.12, respectively, confirming the conventional wisdom that corporates with higher investment productivity generally invest more.

Table 2 reports the year to year distributional statistics of pension discount rates (*PensionDR*) and excess discount rates (*EDR*) in each year. Each year there are around 2,000 sample firms with a DB pension. As shown in the left-hand columns, the mean of reported pension discount rates fall heavily. The mean *PensionDR* is 8.03% in 1994 while it is 3.72% in 2018. In contrast, the dispersion (i.e., the standard deviation) of pension discount rates increases over time. The standard deviation of *PensionDR* is 0.74% in 1994 and it is 1.29% in 2018. As shown in the right-hand columns, average *EDR*s in sample years are *all positive.*

[15] According to Graham (1996), we also tried simulated corporate marginal tax rate based on income before interest expense has been deducted and get similar results. Data is made available by John Graham via website: https://faculty.fuqua.duke.edu/~jgraham/taxform.html.

Moreover, cross-sectional standard deviations of *EDR*s in individual sample years increase over time: 0.49% in 1994, 0.55% in 2010, and 0.87% in 2018. Note that benchmark rates (set to be constant for all firms in a given year) generally decrease in the sample period, the increase in standard deviations of *EDR* suggests a greater dispersion in pension discount rates in later sample years. The final column shows that each year almost all firms have a pension rate in excess of the benchmark rate: at least three-quarters of all firms had a pension rate higher than the benchmark rate even in the lowest year (2006), varying to a high of 97% of the firms in 2011.

In Panel A of Figure 5, we plot the median value of pension discount rates across sample firms and the annual benchmark rates in each year. The annual benchmark rates are measured by the par value weighted average yields of Aa rated corporate bonds with 8- to 12-year maturities at the end of each year.[16] Consistent with Table 2, pension discount rates move along with the benchmark rates, suggesting that the regulatory "guidance" on discount rates, in a larger sense, is effective. Moreover, as shown in the figure, pension discount rates lie above the benchmark rates.[17] Moreover, as displayed in Panel A of Figure 5, we set the 95% two-sided confidence intervals for benchmark rates, which are the average benchmark rates in different years plus or minus 1.96 times the standard deviations in each year. It is fairly clear that discount rates are below the upper bound of the confidence interval before 2002 and they go above the upper bound of the confidence interval after 2010. Given the declining trend in interest rates, our finding is consistent with the claim that firms, on average, set a higher pension discount rate during periods when interest rates significantly drop.

Panel B of Figure 5 displays i) the fraction of underfunded firms and ii) overall pension funding for firms having defined benefit pensions. We assess a firm's pension funding using the ratio of the firm's aggregate pension assets in a given year to its aggregate pension

[16]For the robustness sake, we apply different filters (such as 9- to 11-year maturity bandwidth) as well as the average Aa rated bond yields in the June of each year to estimate the benchmark rates and have similar patterns.

[17]Shown in Figure A1, we also apply longer-term treasury bond rates, e.g., the yields of Aa rated corporate bonds with around 15-year and 20-year maturities, as benchmark rates, and find these rates are also persistently below pension discount rates.

liabilities. about 60% of firms underfund their pensions before 2000, while the fraction of underfunded firms jumps to 90% after 2001. Consistent to the surging underfunded pension percentage, the overall pension funding ratio decreased to 80% in 2002 from 122% in 1999.

4 Empirical Findings

4.1 Pension Discount Rates over Time

As reported in the last column of Table 2, on average 85% of firms set their pension discount rates above the benchmark rates in our sample. The ratios are even higher when the benchmark rates rapidly decline — 95% of firms set their pension discount rates above the benchmark in years between 2002 and 2004 and between 2010 and 2012. The average *EDR* in these years is 1.65%, as opposed to 0.98% in the entire sample period.

In this section, we explore the drivers for pension discount rates over time. Denoting pension discount rates and corresponding benchmark rates as *PensionDR* and *BenchRate*, we run the following panel regressions to see how discount rates of individual firms interact with contemporaneous benchmark rates (the 10-year AA bond yield at the end of December) and corresponding lagged discount rates.

$$\begin{aligned} PensionDR_{i,t} &= \beta_1 * BenchRate_t \\ &+ \beta_2 * PensionDR_{i,t-1} + \mu_i + \epsilon_{i,t} \end{aligned} \tag{14}$$

where μ_i represents the firm fixed effect and $\epsilon_{i,t}$ represents the error term. In Equation (14), β_1 measures the dependence of individual firm pension discount rate on benchmark rate, while β_2 measures the dependence of corporate pension discount rates on their lag values. To account for potential correlations in error terms across time and firms, we estimate two-way clustering standard errors along time and individual firm dimensions. We also include firm fixed effects to control for un-identified heterogeneities such as firm demographic characteristics that might potentially affect actuarial assumptions for pension discount rates, such as pension withdrawal or termination rate, retirement rate, disability rate, mortality rate, (American Academy of Actuaries, 2014).

Table 3 reports the empirical findings. The first column displays the results for the regression when the benchmark rate is the key explanatory variable. The reported coefficient on benchmark rate, $\hat{\beta}_1$, of 0.74 is statistically significant at the 1% level, suggesting a positive relationship between pension discount rate and benchmark rate. Moreover, considering the case that firms closely abide the benchmark discount rates, we expect the coefficient on *BenchRate* to be one. Therefore we test this by using a one-side Wald test for the null hypothesis of $\beta_1 = 1$ versus the alternative hypothesis of $\beta_1 < 1$. The resulting F-value and p-value are respectively 4,012 and 0.00, clearly rejecting the null but favoring the alternative hypothesis, inferring that benchmark rates are not the sole force driving corporate pension discount rates.

When we further include the lagged pension discount rate $PensionDR_{i,t-1}$ in the regression, the estimated coefficient on *BenchRate*, as shown in Column (2), drops to 0.46 (t=25.32) but remains statistically significant at the 1% level. The coefficient on $PensionDR_{i,t-1}$ is 0.45 and also is statistically significant at the 1% level, suggesting a strong persistence in individual firms pension discount rate, and the adjusted R^2, climbs from 0.65 to 0.75. Overall, the results reported in the first two columns suggest that while firm pension discount rates are related to the benchmark — Aa rated bond yield, pension discount rates also demonstrate persistence over time.

Next, we perform the analysis to shed direct light on the first hypothesis that excess pension discount rates are greater in the low interest rate environment. The following panel regressions on the change of pension discount rates are performed:

$$\begin{aligned} \Delta PensionDR_{i,t} &= \beta_1 * \Delta BenchRate_t \\ &+ \beta_2 * \Delta BenchRate_t^- + \mu_i + \epsilon_{i,t} \end{aligned} \tag{15}$$

$\Delta BenchRate$ denotes the changes in benchmark rates while $\Delta BenchRate^-$ equals $\Delta BenchRate$ when $\Delta BenchRate$ is negative and zero otherwise. Like Eq. (14), we include the firm fixed effect, μ_i, in the regression.

In Column (3) of Table 3, we solely include $\Delta BenchRate_t$ in the regression. Consistent with our expectation that the changes of pension discount rates are strongly correlated with the change of benchmark rates, we find that the coefficient on the change in the benchmark rate ($\hat{\beta_1}$) is 0.44, and is significant at the 1% level. Despite the strong statistical significance, the magnitude of β_1 is well below 1, which is what it would be if pension discount rates moved lockstep with benchmark rates, suggesting that other factors are driving firm pension discount rates.

In Column (4) we additionally include $\Delta BenchRate^{-}$ in the regression which allows for an asymmetric effect of benchmark rates on firms' assumed discount rates. We find that the coefficient on $\Delta BenchRate$ is 0.61, and is significant at the 1% level. The significantly positive coefficient on changes in the benchmark rate ($\hat{\beta_1}$) supports the argument that firms are likely to increase pension discount rates when the benchmark rate increases. On the other hand, the corresponding coefficient on $\Delta BenchRate^{-}$ is negative ($\hat{\beta_2}$=-0.33) and statistically significant at the 1% level. A 1% increase in the benchmark rate corresponds to a 0.61% increase in the pension discount rate, while a 1% decrease in the benchmark rate results in a 0.28% (0.61-0.33) decrease in the pension discount rate. Therefore, the magnitude of pension discount rate change after negative benchmark rate changes is lower than that after positive changes. This implies that firms are more willing to follow the benchmark rate tightly when the rate is increasing and increase pension discount rate, but are less likely to decrease their pension rate when the benchmark rate is decreasing. The finding is consistent with the pattern reflected in Panel A of Figure 5. Quite visibly, the pension discount rate spread is larger during the benchmark rate slumping period (i.e., from 2001 to 2003 and from 2010 to 2012), which implies that firms are relatively reluctant to decrease pension discount rates when benchmark rates are dipping.

In Figure 6, we contrast the distributions of excess pension discount rates in years when interest rates significantly drop and years when interest rates are relatively stable periods as defined in Figure 5. Excess pension discount rates are much greater in when rates drop than when rates are stable – over 40% firms set their pension discount rates 150 basis points higher than their benchmarks when treasury rates are dropping while the rate is less than

5% when interest rates are relatively stable; by contrast, 15% firms set pension discount rates below their benchmarks when treasury rates are relatively stables while the rate is less than 3% when interest rates sharply decrease.

Pensions have a long-horizon liability which are significantly inflated when interest rates are lowered. Consider a pension has a duration of 15 years – an 1% drop in the pension discount rate indicates a 15% increase in pension liability. Moreover, a low interest rate leads to a longer pension duration (i.e., the effect of convexity), which inflates the pension liability in a greater magnitude as indicated in Equation (13). A decline in pension discount rates would strongly increase the current estimated value of future pension liabilities, and thus significantly increase current pension payment obligations. It is not surprising that firms therefore strategically delay decreasing their pension discount rate as rates decline, but are quick to raise their pension discount rates as rates rise, as that would reduce estimated liabilities and therefore current payments to the pension fund.

4.2 Effect of Investment Productivity on Excess Pension Discount Rates

4.2.1 Full Sample Analysis

We then evaluate how pension discount rates are associated with investment productivity. Specifically, we examine first whether high investment productivity firms set higher pension discount rates (to lower their pension contributions) and second whether the relation between investment productivity and pension discount rates becomes stronger for firms facing higher financing costs. To test the first predictions, we perform the following regression on excess pension discount rates, *EDR*.

$$EDR_{i,t} = \beta_1 MPK_{i,t-1} + Control_{i,t-1} + \gamma_t + \varepsilon_{i,t} \tag{16}$$

where *MPK* measures firm productivity and γ_t denotes year fixed effect. Firm and year clustered standard errors are estimated to account for potential correlations in error terms across firms and years.

Control variables include firm size, return on assets, pension actual return on plan assets, pension funding ratio, marginal tax rate and financing constraint measures. In particular, firms with better pension investment performance are more willing to contribute to their pensions, thus less likely to inflate pension discount rates, so we include the pension actual return on plan assets as a control variable. Similarly, we include the marginal tax rate to control for the tax effect on pension contributions as well — to lower their tax payments, firms with high marginal tax rates incline to contribute more to their pension plans (Ippolito, 1985b).

The coefficient on *MPK*, β_1, assesses the marginal effect of firm productivity on *EDR*, which is expected to be positive, since firms with better investment opportunities are expected to be more motivated to inflate pension discount rate and save more funds for investments.

The results for the overall analyses are reported in Table 4. Column (1) reports the baseline regression results when *MPK* is included as the sole key explanatory variable. The coefficient for *MPK* is 0.36 (t=2.47), indicating a positive relationship between firms (marginal) investment opportunities and excess pension discount rates. Pension discount rates are closer to the benchmark rate for larger firms, for firms with better actual return on pension assets and higher marginal tax rate. Firms having a greater productivity set pension discount rates higher. The coefficients on pension funding ratio (*FR*) are all insignificant and in a small economic magnitude, which suggests that there is no direct relationship between pension funding and excess pension discount rates.

Next, to test the second predictions, we additionally incorporate financing constraint measures, *FC*, and interact it with *MPK* as below:

$$EDR_{i,t} = \beta_1 MPK_{i,t-1} + \beta_2 MPK_{i,t-1} * FC_{i,t-1} + \beta_3 FC_{i,t-1} + Control_{i,t-1} + \gamma_t + \varepsilon_{i,t} \qquad (17)$$

The coefficient on *MPK*FC*, β_2, captures the influence of financing constraints on the marginal effect *MPK* on *EDR*, i.e., β_1. We expect β_2 to be positive. As these *FC* measures are often strongly correlated with corporate financial conditions, β_3 may be interpreted as how firms' financial status affects their choices of pension discount rates.

We further include the interaction term between the marginal productivity of capital *MPK* and our three financial constraint variables (to which we refer collectively as *FC*) to check the effect of financial constraints on pension discount rates specified in the second hypothesis. The results are included in Column (2) to (4) as we have three *FC* measures. The finding confirms the expectation that more financially constrained firms set a high discount rate. The regression coefficients on the interaction term are positive (0.59, 0.58, 0.62, respectively) and statistically significant at the 1% level, while the coefficients on the marginal productivity of capital (*MPK*) become less significant, suggesting it is the financially constrained firms that drive the effect of *MPK* on the excess pension discount rate. The significantly positive $\hat{\beta}_2$s of all three proxies for financial constraints support the second hypothesis that the positive correlation between *MPK* and spread is intensified among financially constrained firms. On the other hand, none of the coefficients on the three *FC* measures is statistically significant at the 5% level. The weak relationship between *FC* and *EDR* does not support the argument that firms set high pension discount rates simply because they are financially distressed.

4.2.2 Over- vs. Under-funded Firms

In this subsection, we breakdown sample firms into underfunded firms (*UF*), i.e., firms whose pension plan assets value is lower than projected pension liabilities, and overfunded firms (*OF*) and perform regressions separately for underfunded and overfunded firms. To address the concern that underfunded firm percentage is growing after the year of 2002 because of the decreasing interest rate, we include time fixed effects in our analysis to reduce the concern that the results are distorted by time varying effects.

In Column (1) to (4) of Table 5 we report the regression results of underfunded firms. Like Table 4, we first solely include *MPK* as the key explanatory variable to see the relationship between corporate investment opportunities and excess pension discount rates. As shown in Column (1), the coefficient for *MPK* is 0.39 (t=2.52), suggesting the relationship between excess pension discount rates and firm productivity is positively correlated among underfunded firms. In the next three columns (Columns 2, 3, and 4), we report regressions additionally including the interaction term between *MPK* and *FC*. As reported, the regression coefficients on the interaction term are positive, respectively 0.76, 0.77, and 0.79, all significant at the 1% level. Interestingly, the magnitude and significance level of the coefficients on the marginal productivity of capital (*MPK*) here become lower than those reported in Column (1). This is consistent with the second hypothesis that the effect of *MPK* on the excess pension discount rate is partly attributed to corporate financing constraints. Economically, a one standard deviation increase in the firm *MPK* leads to a 4 (14) bps increase in excess discount rates for non-financially (financially) constrained firms with underfunded pension, accounting for 5% (19%) of the standard deviation of excess pension discount rates.

We report the regression results for overfunded firms in the subsequent columns (Column (5) to (8)). As reported in Column (5), when we only *MPK* as the key explanatory variable (without involving *FC*), the coefficient on *MPK* is 0.29 basis points and it is significant at the 5% level. In columns (6) to (8) whereas *MPK*FC* are included, the reported coefficients on *MPK* (0.27, 0.27, 0.26) are similar to that reported in Column (5). Nevertheless, different from the results reported in columns (2) to (4); while for underfunded firms the coefficients on *MPK*FC* are positive and significant, for overfunded firms the coefficients on the interaction term are not statistically significant.

We further compare the difference in the coefficients of *MPK* and *MPK*FC* between underfunded and overfunded firms. To do so, we pool two subsamples together to perform the regression specified in Eq. (17) while interacting all the explanatory variables with an indicator for underfunding firms. The coefficients and t-statistics of the interactive terms are reported as the differences and test statistics in Panel B of Table 5 (where we only report the differences in coefficients of key variables). In Column 1, also labeled "(1)-(5)", without involving *MPK*FC*, we report the difference in the coefficients on *MPK* to be 0.11, which is statistically significant at the 5 percent level. However, the difference in the coefficient on *MPK* is no longer statistical significant after *MPK*FC* is included in the regression. This is shown in columns 2 to 4 of Panel B. Rather the differences in the coefficients on

*MPK*FC* are all positive and statistically significant at the 1% level. Therefore, we conclude that firms with higher marginal productivity of capital set higher pension rates, and the effect is intensified for financially constrained firms (i.e., non investment-grade debt issuers) with underfunded pension in order to save mandatory pension contributions for corporate investment. The result suggests financing constraints play a more important role to drive the investment productivity and pension discount rate relationship among underfunded firms.

Inspired by the finding in Table 3 that sharply drop in interest rates drives more firms to set higher pension discount rates, we test whether the association between corporate investment productivity and pension discount rates differs in years of stable interest rates and when interest rates sharply drop. We apply the rule that the annual percentage change of the 10-year AA bond yields exceed 7.5% to define years of large interest rate drops, *Large Drop Period*, which results in the following years meeting the condition: from 2001 to 2003, from 2010 to 2012 and 2014, and consider other years as the *Stable Rate Period*. Noted earlier, the Large Drop Period includes the Fed's 13-consecutive interest rate cut during 2001 and 2003 (lowering the federal fund rate from 5% in the beginning of 2001 to 1% in June 2003) and the Fed's quantitative program easing program implemented in late 2009.

Restricting the sample to underfunded firms, we perform separate regressions on the relationship between investment and pension discount rates in the *Large Drop Period* and during the *Stable Rate Period* and report the empirical findings in Table 6. During the large drop period, the coefficients on the interaction term are all significantly positive under three proxies for financing constraints. Comparably, while the coefficients of $MPK * FC$ keep the same sign during the stable rate period, the magnitudes are much smaller: the coefficients in the large drop period are at least double that of the stable period. As reported in the last three columns, the coefficient difference of $MPK * FC$ between the large drop period and stable rate period is 0.68, 0.57, and 0.67, respectively, which are all significantly positive at the 1% level. This is consistent with the expectation that financially constrained firms with higher marginal productivity of capital are more likely to set higher excess pension discount rates during the lowering interest rate period. The effect is also economically significant: for proxy financing constraints with the indicator for non-investment grade bond issuers (LOW), the coefficient difference on $MPK * FC$ is 0.68, so a 1 standard deviation increase of marginal productivity of capital during the large drop period leads to an extra 10 bps improvement in excess pension discount rate compared with the stable rate period for financially constrained underfunded firms.

4.3 Pension Discount Rate Effects on Capital Investments

Rauh (2006) finds that firm capital expenditures decline with the pension mandatory contributions — a \$1 mandatory contribution would reduce capital expenditures by \$0.60 to \$0.70. Setting a higher corporate pension discount rate might improve firm investments. To examine this, we follow the corporate investment literature that connects investment opportunities with firm investments (Hayashi, 1982; Gilchrist and Himmelberg, 1995; Andrei, Mann, and Moyen, 2019) to perform the following regression:

$$X_{i,t} \quad = \quad \beta_1 MPK_{i,t-1} + \beta_2 MPK_{i,t-1} * EDR_{i,t-1} + Control_{i,t-1} + \gamma_t + \varepsilon_{i,t} \tag{18}$$

The dependent variable X is firm investment, alternatively proxied by capital expenditures (I/K) and investment growth (IG). Two key explanatory variables are 1) MPK, marginal productivity of capital that is detailed in the variable section, and the interaction between MPK and excess pension discount rate, EDR. The coefficient on the interaction term captures how pension discount rates affect corporate investment-growth opportunity sensitivities. Control variables include excess pension discount rates, firm size, return on asset, pension actual return on plan assets, and firms marginal tax rate. We separately perform the regression in order to capture the difference in the discount rate effects on the alignment between investment and growth opportunities between under- and overfunded firms.

The results for underfunded firms are reported in the first four columns of Table 7, and first two columns are based on using capital expenditure (I/K) as the corporate investment measure. Shown in Column (1), the coefficient on MPK is 0.25 (t=6.27) when MPK is the only key independent variable (plus controls), consistent with the expectation that firms with higher marginal productivity of capital have higher capital investment.[18] Such an effect is also of economic significance – a one standard deviation increase in marginal productivity of capital leads to around 3.5% increase in capital expenditure. Subsequently in Column (2), we include the interaction term, *MPK*EDR*. The significantly positive coefficient on the interaction term (0.12 with a t-stat=2.97) suggests that the inflation of excess pension discount rate helps firms to increase capital investment. In terms of economic significance, a one standard deviation increase in *EDR* results in a 50% increase in firms' investment sensitivity to marginal productivity of capital.[19] We find similar results when using *IG* as the dependent variable.

Similarly, we conduct analyses employing overfunded firms only and report the results in Columns (5) to (8). Compared to the results for underfunded firms, the coefficients on *MPK* stay significantly positive, however, the coefficients on the interaction term turn out to be insignificant at the 5% level. Panel B indicates that when using *I/K* to quantify corporate investment, the coefficient differences on *MPK*EDR* between underfunded and overfunded firms is 0.09, and the difference is significant at the 1% level. The findings are supportive of our fourth hypothesis that underfunded firms with higher excess pension discount rates have stronger positive relationships between *MPK* and capital expenditure, and suggests that firms inflate the excess pension discount rate to lower pension contributions and improve its investments. Our findings therefore supports Rauh (2006)'s finding that mandatory pension contributions add to investment constraints — holding financing constraint constant, a relaxation in investment constraint improves corporate investments.

In the final set of analysis, we investigate how a large drop in interest rates affect the pension discount rate effect on firm investment efficiency. In Table 8, we separate the sample into "large drop period" (from 2001 to 2003 and from 2010 to 2012) and "stable rate period"

[18] For robustness, we alternatively use Tobin's Q as a measure for investment opportunities and obtain a marginally significant coefficient on Tobin's Q. This confirms findings in Gilchrist and Himmelberg (1995) that *MPK* does a better job in measuring marginal productivity.

[19] The economic magnitude is estimated in the following way: for underfunded firms, the original I/K-MPK sensitivity is 0.20, an one standard deviation increase in *EDR* (0.75) corresponds to an increase of 0.12*0.75=0.09 in the I/K-MPK sensitivity, which is around 50% increase.

and, within underfunded firms, test and compare the effects of pension discount rates on investment sensitivity to *MPK* in two subsample periods. As shown in Column (1) and (2), the coefficients on *MPK* and *MPK*EDR* are significantly positive during the large drop period using *I/K* and *IG* as the dependent variable respectively. The signs for key variables stay positive during the stable rate period (Columns (3) and (4)), but the coefficient of the interaction term is again less than half of those of the large drop period and are both economically and statistically smaller. Using the analysis on *I/K* as an example, a one standard deviation increase in *EDR* leads to a 60% increase in firms' investment sensitivity to marginal productivity during the large drop period, but it only results in a 33% sensitivity improvement during the stable rate period. We further compare the difference in the coefficients on *MPK*EDR*. Shown in Panel B of Table 8, we find the differences on the coefficients under both *MPK* measures are both positive and significant at 1% level. Since setting higher pension discount rates improves firm investment efficiency in the large drop interest rate environment, this finding underscores the significant impact of lowering interest rates, and of setting a relatively high pension discount rates, of underfunded firms to investments.

Overall, the findings support our expectations that underfunded firms are more motivated to inflate pension discount rates during large drop periods than stable interest rate periods in order to increase corporate capital expenditures.

5 Conclusions

Despite the notorious inflexibility of defined benefit pension plans, a supermajority of S&P 500 firms use DB pension plans. In this study, we provide an extra source of benefit of DB pension plans to the firm (in addition to the conventional benefits documented in the literature, such as increasing employee retention rate and improving productivity) — flexibility in the regulation of pension discount rates, which provides leeway for firms to manipulate their pension contributions.

We find that a significantly larger number of firms failed to increase their pension discount rates when interest rates decreased due to the Fed's implementation of quantitative easing (and other periods when interest rate declined), consistent with the suggestion that firms manually inflate their earnings through setting a relatively high pension discount rate. Additionally, we find that pension discount rates are set higher among firms with good investment opportunities facing tight financing constraints. More importantly, our evidence suggests that setting higher pension discount rates improves the alignment between corporate investments and marginal productivity for those facing financial constraints and with significant pension underfunding. This alignment improvement effect is stronger in the lower interest rate environment.

The flexibility for corporate pension discount rates makes defined benefit pension plans can provide valuable options — those firms experiencing negative financial outcome in a low interest rate environment could delay lowering pension discount rates relative to their peers, and therefore understate their liabilities and possibly overstate their earnings and retain excess cash flow to the detriment of the pension plan. Of course, whether and when interest rates might increase is highly uncertain. Therefore, a strategy that firms may employ to "improve" their financial status is to respond only slowly to the lowering of general interest rates. Such a strategy smooths, but understates, pension liabilities. Pension discount rate smoothing therefore not only hides the true financial health of a firm, but it also may artificially boost earnings. In addition, the delay of lowering pension discount rates may have other cash flow effects, such as preventing firms from making additional contributions to PBGC that they might otherwise be obligated to make if their real financial status were revealed. Thus, the flexibility provided to firms documented here to delay or slow the decrease in their pension discount rates could have real effects for the firm and the firm's short or long-term viability, and appears to be used by precisely those firms to whom the delay may matter the most.

Appendix A Pension Discount Rate Regulations

Defined benefit pensions are overseen by the Employee Retirement Income Security Act (ERISA), a federal United States tax and labor law that establishes minimum standards for pension plans in private sectors. Specific rules on pension funding and pension discount rates are provided in Paragraph 44 of the Statement of Financial Accounting Standards (SFAS) 87 and 158 published by the Financial Accounting Standards Board (FASB). Effective in December 1986, SFAS 87 states that "assumed discount rates shall reflect the rates at which the pension benefits could be effectively settled. In making those estimates, employers may also look to rates of return on high-quality fixed-income investments currently available and expected to be available during the period to maturity of the pension benefits." It also states that "assumed discount rates are used in measurements of the projected, accumulated, and vested benefit obligations and the service and interest cost components of net periodic pension cost". Subsequently, SFAS 158 effective in 2006 provides more specific requirements on pension discount rates applicable to projected benefit obligations. The projected benefit obligation would be the same as the value of a portfolio of high-quality zero coupon bonds whose maturity dates and amounts are identical to the timing and amount of the expected future benefit payments.

Neither SFAS 87 nor 158 offers a definition of "high quality" bonds. To make the discount rates consistent across firms, the FASB published the Emerging Issues Task Force (EITF) report No. D-36 in the year of 2008, suggests that "fixed-income debt securities that receive one of the two highest ratings given by a recognized ratings agency be considered high quality (for example, a fixed-income security that receives a rating of Aa or higher from Moody's Investors Service, Inc.)". Note that such requirements on discount rates of *high-quality* bonds mentioned in the EITF report offer merely guidance, rather than being mandated.

Historical averages of high-quality corporate bond interest rates are applied by firms to determine their pension discount rates. Specifically, under ERISA (1974), firms are allowed to set discount rates based on a 2-year average of high-quality corporate bond rates until 2012.[1]

[1] For reference, see IRS notice 2013-11: https://www.irs.gov/irb/2013-11_IRB#NOT-2013-11.

In 2012 and afterwards, this 2-year smoothing was further lengthened to 25-year smoothing, tying pension discount rates to a 25-year historical average of high-quality corporate bond rates (Moving Ahead for Progress in the 21st Century Act, 2012; GAO, 2014). This sets a legal ground for firms to set relatively high discount rates in a lowering interest rate environment.[2]

A similar debate on discount rates for public pensions deserves attention. Brown and Wilcox (2009) suggest that state and local pensions would be more underfunded than reported if using the appropriate discount rate reflecting the riskiness of liabilities, not the expected return on the assets held in the pension trust. Consistent with this view, Novy-Marx and Rauh (2011) find the relatively large differences between their calculated pension liabilities and the state's calculated pension liabilities mostly stem from the inconsistent discount rate. The discount rate used by most states at all horizons is around 8%, which is far too high. Public pension liabilities should be discounted based on much lower Treasury note yields while lowering the discount rate could mean governments would have to contribute more to pension funds with the money coming from taxpayers or employees (Corkery, 2010). Conversely, Mixon (2015) argues that as pension liabilities should be estimated based on benefits expected to be paid — i.e., future cash flows, it is more appropriate to value future cash flows using a discount rate that reflects the riskiness of the payments. Therefore, the literature appears unsettled in terms of the basic question regarding appropriate discount rate for public pensions.

Appendix B Estimating Financing Constraint Measures

Three financing constraint measures are employed in the paper. First, following Campbell et al. (2012), we consider firms which are non investment-grade debt issuers are firms with external financing constraints. Accordingly, we create a low credit rating (LOW) dummy

[2]The low interest rate environment in the U.S. and around the world imposes significant pressure on corporates given the long-term nature of defined benefit pensions. In its 2013 annual filing, for example, Boeing indicated in a securities filing that a 0.25-percentage-point decrease in its discount rate would add $3.1 billion to its pension liabilities.

equal to 1 for firms which are non investment-grade debt issuers, and 0 otherwise.

Secondly, We follow Kaplan and Zingales (1997) to construct the KZ index as follows:

$$\begin{aligned} KZ &= -1.001909 * \textit{Cash Flow/K} + 0.2826389 * \textit{Tobin's } Q + 3.139193 * \textit{Debt/Total Capital} \\ &- 39.3678 * \textit{CashDividends/K} - 1.314759 * \textit{Cash/K} \end{aligned} \quad \text{(A1)}$$

where *Cash Flow* is computed as Income Before Extraordinary Item + Total Depreciation and Amortization, *K* as PP&E, *Tobins' Q* as (Total Asset + Total Shareholder's Equity - Book Value of Common Equity - Deferred Tax) / PP&E, *Debt* as Debt in Current Liabilities + Total Long Term Debt, *Total Capital* as Total Debt + Total Shareholder's Equity, *Cash-Dividends* as Total Cash Dividends Paid, and *Cash* as Cash + Short-Term Investments. In this paper, the *KZ* dummy equals 1 for firms with *KZ* value above the median in each year, and equals 0 otherwise.

Last but not least, following Whited and Wu (2006), we compute the WW index as:

$$\begin{aligned} WW &= -0.091 * CF - 0.062 * DIVPOS + 0.021 * TLTD - 0.044 * LNTA \\ &+ 0.102 * ISG - 0.035 * SG \end{aligned} \quad \text{(A2)}$$

where *CF* is the ratio of cash flow to total assets, *DIVPOS* is an indicator that equals one when a firm pays cash dividends and 0 otherwise, *TLTD* is the ratio of long-term debt to total assets, *LNTA* is the natural logarithm of total assets, *ISG* is a firm's industry sales growth, and *SG* is a firm's sales growth. The *WW* dummy equals 1 for firms with *WW* value above the median in each year, and equals 0 otherwise.

Table A1: Determinants for Excess Pension Discount Rate

Table A1 reports the correlation matrix of key variables defined in Table 1. The variables including excess pension discount rate, marginal productivity of capital, capital expenditure, investment growth, indicator of non investment-grade debt issuers, KZ index of Kaplan and Zingales (1997), WW index of Whited and Wu (2006), pension funding ratio, and firm size. The sample period is from 1994 to 2018.

	EDR	MPK	I/K	IG	LOW	KZ	WW	FR	SIZE
EDR	1.00								
MPK	0.06	1.00							
I/K	0.05	0.23	1.00						
IG	0.04	0.12	0.45	1.00					
LOW	0.06	-0.01	0.01	0.04	1.00				
KZ	0.11	-0.02	-0.11	0.02	0.21	1.00			
WW	0.15	0.06	0.06	0.10	0.57	0.21	1.00		
FR	0.02	-0.01	0.01	-0.01	-0.17	-0.08	-0.17	1.00	
SIZE	-0.26	-0.05	-0.06	-0.06	-0.49	-0.06	-0.51	0.08	1.00

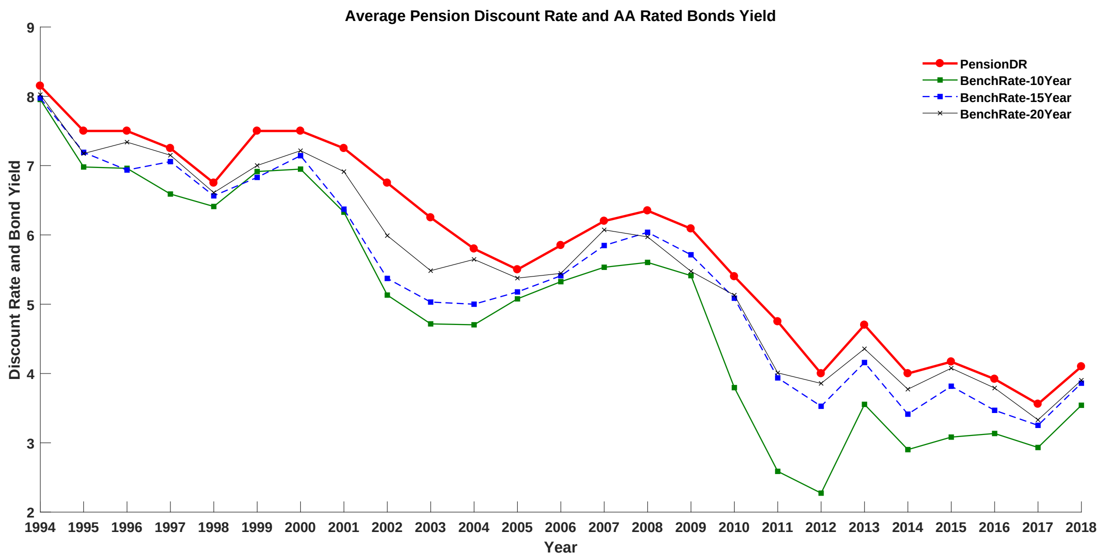

Figure A1: This figure shows the relationship between firm pension discount rate and AA rated corporate bonds with different years of remaining maturity from 1994 to 2018. The discount rate is the average corporate pension discount rates. The benchmark rates respectively are the par value weighted Aa-rated (Moody's ratings) corporate bond yields with 10-year, 15-year, and 20-year maturity.

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Table 1: Summary Statistics

Table 1 reports the cross-sectional distributions of firm pension discount rate and other key variables for the entire sample. We restrict the sample to firms having positive pension discount rates, non-missing pension plan assets and projected pension liabilities. The distributions characteristics include mean, median, standard deviation (SD), and skewness. The reported variables are broken down into four groups. The first group includes three variables directly related to corporate pension discount rates: 1) reported pension discount rates (*PensionDR*, in percent), 2) benchmark rates (*BenchRate*, in percent, measured by 10-year Aa rated corporate bonds yields), and 3) the excess rate between pension discount rates and benchmark rates (*EDR*, in percent). The second group of variables are related to investment and firm financing constraints, including 1) marginal productivity of capital (*MPK*, measured by the ratio of sales to the lagged property, plant, and equipment scaled by the average ratio of the industry multiplied by 0.2), 2) capital expenditure (I/K, measured by the ratio of firm capital expenditures to the lagged book value of property, plant, and equipment), 3) investment growth (*IG*, the growth rate in firm's capital expenditure), 4) indicator of non investment-grade debt issuers (*LOW*, equals 1 for firms which are non investment-grade debt issuers, and 0 otherwise), 5) the *KZ* index of Kaplan and Zingales (1997), and 6) the *WW* index of Whited and Wu (2006). The last category contains other variables, including 1) the natural logarithm of firm total assets (*SIZE*), 2) return on assets (*ROA*, the ratio of firm's net income to total assets), 3) pension actual return on plan assets (*PR*), and 4) marginal income tax rate (*TAX*, the simulated corporate marginal tax rate based on income after interest expense has been deducted from John Graham). The sample period is from 1994 to 2018.

Variable	Mean	Median	SD	Skewness
Pension Discount Rates				
PensionDR (%)	5.80	5.75	1.51	0.35
BenchRate (%)	4.97	5.01	1.66	-0.03
ExcessDiscountRate (EDR, %)	0.83	0.77	0.75	0.32
Investment and Financing Constraint				
Marginal Productivity of Capital (%)	21.14	15.44	14.08	3.01
Capital Expenditure (%)	18.64	15.35	8.83	0.76
Investment Growth (%)	18.44	9.17	13.16	0.91
LOW	0.38	0	0.48	0.51
KZ Index	0.32	0.79	4.73	-0.85
WW Index	-0.38	-0.38	0.11	0.24
Other Variables				
Size	7.68	7.63	1.92	0.05
Return on Assets (%)	3.47	3.18	6.07	-0.24
Pension Actual Return (%)	5.79	7.45	9.98	-1.00
Marginal Tax Rate (%)	25.62	31.17	19.70	-1.21

Table 2: Pension Discount Rates over Time

Table 2 reports the distribution of pension discount rates (*PensionDR*, in percent) and excess discount rates (*EDR*, in percent) in each year. The excess rate is the spread between pension discount rates and benchmark rates measured by 10-year Aa rated corporate bonds yields. The number of observations, mean, standard deviation, and the percentage of firms with a positive excess discount rate in each sample year are reported. The sample period is from 1994 to 2018.

		PensionDR		EDR		% of firms
Year	N	Mean	SD	Mean	SD	(EDR>0)
1994	1,928	8.03	0.74	0.50	0.49	79%
1995	1,889	7.51	1.00	0.53	0.46	93%
1996	1,919	7.54	0.68	0.58	0.31	88%
1997	1,844	7.30	0.60	0.71	0.37	92%
1998	1,817	6.83	0.65	0.42	0.36	84%
1999	1,791	7.35	0.82	0.43	0.57	81%
2000	1,953	7.38	0.82	0.43	0.54	85%
2001	1,966	7.08	0.85	0.75	0.48	89%
2002	2,197	6.65	0.87	1.52	0.46	96%
2003	2,218	6.12	0.82	1.40	0.39	97%
2004	2,210	5.81	0.88	1.11	0.41	95%
2005	2,204	5.41	0.91	0.43	0.50	81%
2006	2,180	5.57	0.88	0.35	0.53	74%
2007	2,089	5.91	0.96	0.48	0.55	78%
2008	2,034	6.19	1.12	0.64	0.77	88%
2009	1,986	5.86	1.16	0.45	0.68	84%
2010	1,943	5.31	1.05	1.51	0.55	95%
2011	1,932	4.73	1.15	2.14	0.60	97%
2012	1,926	3.96	1.50	1.69	0.53	96%
2013	1,896	4.51	0.99	0.96	0.58	90%
2014	1,879	3.82	1.16	0.92	0.69	88%
2015	1,803	3.95	1.15	0.86	0.77	87%
2016	1,728	3.62	1.24	0.48	0.85	79%
2017	1,684	3.33	1.14	0.40	0.73	80%
2018	1,599	3.72	1.29	0.26	0.87	76%

Table 3: Effect of Benchmark Interest Rates on Pension Discount Rates

This table reports the results of the analysis of benchmark interest rates on pension discount rates reported by firms. The benchmark interest rate is the average 10-year Moody's Aa bond rate in a year weighted by individual bond par value. In the first two columns, the dependent variable is the level of pension discount rates (*PensionDR*). The explanatory variables are the benchmark rate (*BenchRate*) and the lagged pension discount rate, $PensionDR_{-1}$. In the latter two columns, the dependent variable is the change of pension discount rates. The explanatory variables include $\Delta BenchRate$, the change of benchmark rate and $\Delta BenchRate^{-}$, which equals $\Delta BenchRate$ when $\Delta BenchRate$ is negative, and zero otherwise. The sample period is from 1994 to 2018. The firm fixed effects are included. The t-statistics reported in the parentheses are based on two-way clustering (by year and by firm) standard errors. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Dependent Variable:	PensionDR		ΔPensionDR	
	(1)	(2)	(3)	(4)
BenchRate	0.74***	0.46***		
	(57.10)	(25.32)		
PensionDR_{-1}		0.45***		
		(15.36)		
ΔBenchRate			0.44***	0.61***
			(30.90)	(21.66)
$\Delta\text{BenchRate}^{-}$				-0.33***
				(-13.12)
Firm FE	Yes	Yes	Yes	Yes
Adj R^2	0.65	0.75	0.14	0.28
N	48,615	43,144	43,144	43,144

Table 4: Determinants of Excess Pension Discount Rates

This table reports the results of panel regression for the pension discount rate spreads:

$$EDR_{i,t} = \beta_1 MPK_{i,t-1} + \beta_2 MPK_{i,t-1} * FC_{i,t-1} + \beta_3 FC_{i,t-1} + Control_{i,t-1} + \gamma_t + \varepsilon_{i,t}$$

The dependent variable, *EDR*, is the difference between pension discount rate and the benchmark rate measured by the yield of Aa-rated bonds. *MPK* is the firm marginal productivity of capital. Financially constrained firms (*FC*) are proxied by three variables: i) *LOW* (an indicator for firms which are non investment-grade debt issuers, and 0 otherwise), ii) *KZ* (the *KZ* index of Kaplan and Zingales (1997), equal to 1 for firms with *KZ* above the median in the year, and 0 otherwise), and iii) *WW* (the *WW* index of Whited and Wu (2006), equal to 1 for firms with *WW* above the median in the year, and 0 otherwise). Control variables include firm size, return on asset, pension actual return on plan assets, the ratio of pension assets to pension liabilities, and marginal tax rate. The time fixed effects are included. The sample period is from 1994 to 2018. The t-statistics reported in the parentheses are based on two-way clustering (by year and by firm) standard errors. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

FC Proxy:		LOW	KZ	WW
	(1)	(2)	(3)	(4)
MPK	0.36**	0.27**	0.22*	0.25**
	(2.47)	(2.06)	(1.67)	(2.04)
MPK*FC		0.59***	0.58***	0.62***
		(2.79)	(2.72)	(3.01)
FC		0.06	0.01	0.08*
		(1.09)	(0.46)	(1.66)
SIZE	-0.02***	-0.02**	-0.02***	-0.02**
	(-3.42)	(-2.47)	(-3.08)	(-2.41)
ROA	0.29*	0.23	0.32**	0.42*
	(1.73)	(1.41)	(2.31)	(1.93)
PR	-0.64***	-0.48***	-0.63***	-0.64***
	(-9.58)	(-6.36)	(-9.14)	(-9.22)
FR	0.05	0.09	0.04	0.12
	(0.91)	(1.22)	(0.79)	(1.31)
TAX	-0.21***	-0.07	-0.21***	-0.22***
	(-3.18)	(-1.26)	(-3.92)	(-2.96)
Time FE	Yes	Yes	Yes	Yes
Adj R^2	0.53	0.56	0.53	0.54
N	41,232	33,114	35,888	34,587

Table 5: Excess Pension Discount Rates by Pension Funding Status

Panel A reports the results of panel regression for the pension discount rate spreads across underfunded and overfunded pension groups:

$$EDR_{i,t} = \beta_1 MPK_{i,t-1} + \beta_2 MPK_{i,t-1} * FC_{i,t-1} + \beta_3 FC_{i,t-1} + Control_{i,t-1} + \gamma_t + \varepsilon_{i,t}$$

The dependent variable, *EDR*, is the difference between pension discount rate and the benchmark rate measured by the yield of Aa-rated bonds. *MPK* is the firm marginal productivity of capital. Financially constrained firms (*FC*) are proxied by *LOW*, *KZ*, and *WW* defined in Table 4. Control variables include firm size, return on asset, pension actual return on plan assets, and marginal tax rate. Firms with pension assets value lower than pension projected liability are in underfunded pension group (*UF*), otherwise are in overfunded pension group (*OF*). The time fixed effects are included. Panel B reports the differences in the coefficients on *MPK*, *MPK*FC*, and *FC* among underfunded firms and overfunded firms. The sample period is from 1994 to 2018. The t-statistics reported in the parentheses are based on two-way clustering (by year and by firm) standard errors. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Panel A: Determinants of Excess Pension Discount Rates

	Underfunded				Overfunded			
FC Proxy:		LOW	KZ	WW		LOW	KZ	WW
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
MPK	0.39**	0.26*	0.19	0.23*	0.29**	0.27**	0.27**	0.26*
	(2.52)	(1.80)	(1.25)	(1.69)	(2.23)	(2.12)	(2.03)	(1.91)
MPK*FC		0.76***	0.77***	0.79***		0.17	0.19*	0.14
		(3.16)	(3.29)	(3.42)		(1.42)	(1.71)	(1.06)
FC		0.05	0.01	0.07*		0.06	0.01	0.07
		(0.76)	(0.44)	(1.95)		(0.93)	(0.25)	(1.11)
SIZE	-0.02***	-0.01	-0.02***	-0.01	-0.01	-0.02*	-0.01	-0.03
	(-3.80)	(-0.74)	(-3.43)	(-0.50)	(-0.98)	(-1.70)	(-1.02)	(-1.54)
ROA	0.32*	0.47***	0.31*	0.37**	0.54	0.02	0.61	0.62
	(1.91)	(2.75)	(1.72)	(2.06)	(1.10)	(0.10)	(1.29)	(1.19)
PR	-0.66***	-0.50***	-0.65***	-0.66***	-0.39***	-0.16	-0.40***	-0.41***
	(-8.87)	(-6.02)	(-8.44)	(-8.53)	(-2.98)	(-0.97)	(-2.89)	(-2.97)
TAX	-0.19***	-0.07	-0.18***	-0.18***	-0.10	-0.06	-0.13	-0.16
	(-3.43)	(-1.20)	(-3.17)	(-3.18)	(-1.09)	(-0.62)	(-1.23)	(-1.41)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj R^2	0.56	0.60	0.55	0.56	0.55	0.58	0.54	0.54
N	31,985	25,703	27,801	26,683	9,247	7,411	8,087	7,904

Panel B: Coefficient Difference between Underfunded and Overfunded Firms

	(1)	(2)	(3)	(4)
	(1)-(5)	(2)-(6)	(3)-(7)	(4)-(8)
MPK	0.11**	-0.02	-0.08	-0.03
	(2.01)	(-0.37)	(-0.99)	(-0.46)
MPK*FC		0.60***	0.58***	0.65***
		(3.01)	(2.86)	(3.09)
FC		-0.01	0.00	0.01
		(-0.15)	(0.08)	(0.32)

Table 6: Low Interest Rates and Corporate Excess Pension Discount Rates

Panel A reports the results of panel regressions for the pension discount rate spreads among underfunded pensions in periods when interest rates drop significantly versus relatively stable interest rate periods. The large interest rate drop period is set between 2001 to 2003, between 2010 and 2012, and 2014, denoted as *Large Drop Period* with other years considered as *Stable Rate Period*. The dependent variable, *EDR*, is the difference between pension discount rate and the benchmark rate measured by the yield of Aa-rated bonds. *MPK* is the firm marginal productivity of capital. Financially constrained firms (*FC*) are proxied by *LOW*, *KZ*, and *WW* defined in Table 4. Control variables include firm size, return on asset, pension actual return on plan assets, and marginal tax rate. Firms with pension assets value lower than pension projected liability are in underfunded pension group (*UF*). The time fixed effects are included. Panel B reports the differences in the coefficients on *MPK*, *MPK*FC*, and *FC* between the large drop period and the stable rate period. The sample period ranges from 1994 to 2018. The t-statistics reported in the parentheses are based on two-way clustering (by year and by firm) standard errors. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Panel A: Large Drop Period and Corporate Excess Pension Discount Rates

	Large Drop Period			Stable Rate Period		
FC Proxy:	LOW	KZ	WW	LOW	KZ	WW
	(1)	(2)	(3)	(4)	(5)	(6)
MPK	0.30**	0.21	0.27*	0.25*	0.18	0.22
	(2.08)	(1.58)	(1.90)	(1.88)	(1.32)	(1.52)
MPK*FC	1.18***	1.14***	1.19***	0.51***	0.57***	0.53***
	(3.91)	(3.89)	(4.12)	(2.93)	(3.09)	(2.88)
FC	0.07*	0.02	0.10**	0.01	0.01	0.02
	(1.86)	(0.53)	(2.18)	(0.13)	(0.16)	(0.42)
SIZE	-0.01	-0.02**	-0.01	-0.01	-0.02	0.01
	(-1.22)	(-2.37)	(-0.19)	(-0.96)	(-1.30)	(0.77)
ROA	0.57***	0.45**	0.41**	0.25	0.22	0.33
	(2.74)	(2.39)	(2.19)	(1.33)	(1.02)	(1.54)
PR	-0.36***	-0.47***	-0.47***	-0.63***	-0.83***	-0.84***
	(-3.70)	(-5.25)	(-5.22)	(-4.45)	(-6.41)	(-6.48)
TAX	-0.03	-0.13*	-0.13*	-0.09	-0.21***	-0.21***
	(-0.38)	(-1.94)	(-1.94)	(-1.30)	(-3.14)	(-3.13)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj R^2	0.46	0.42	0.43	0.30	0.25	0.25
N	8,040	8,907	8,489	17,663	18,894	18,194

Panel B: Coefficient Difference in Large Drop and Stable Rate Periods

	(1)	(2)	(3)
	(1)-(4)	(2)-(5)	(3)-(6)
MPK	0.05	0.03	0.06
	(0.58)	(0.34)	(0.89)
MPK*FC	0.68***	0.57***	0.67***
	(3.17)	(2.89)	(3.13)
FC	0.06	0.01	0.08*
	(1.45)	(0.33)	(1.87)

Table 7: Effect of Pension Discount Rates on Corporate Investment and Productivity Relationship

Panel A reports the results of panel regression for the capital expenditure across underfunded and overfunded pension groups:

$$X_{i,t} = \beta_1 MPK_{i,t-1} + \beta_2 MPK_{i,t-1} * EDR_{i,t-1} + Control_{i,t-1} + \gamma_t + \varepsilon_{i,t}$$

The dependent variable, X, is respectively proxied by the ratio of firm capital expenditures to the lagged book value of property, plant, and equipment (I/K), and the growth rate in firm's capital expenditure (IG). MPK is the firm marginal productivity of capital. EDR is an excess pension discount rate. Control variables include firm size, return on asset, pension actual return on plan assets, and firms marginal tax rate. Firms with pension assets value lower than pension projected liability are in underfunded pension group (UF), otherwise are in overfunded pension group (OF). The time fixed effects are included. Panel B reports the differences in the coefficients on MPK and $MPK*EDR$ among underfunded firms and overfunded firms. The sample period is from 1994 to 2018. The t-statistics reported in the parentheses are based on two-way clustering (by year and by firm) standard errors. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Panel A: Firms Capital Expenditure and Marginal Productivity of Capital

	UF				OF			
	I/K		IG		I/K		IG	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
MPK	0.25***	0.20***	0.30***	0.24***	0.27***	0.24***	0.36***	0.34***
	(6.27)	(5.98)	(5.90)	(4.04)	(6.51)	(5.73)	(5.40)	(5.02)
MPK*EDR		0.12***		0.13***		0.04*		0.05*
		(2.97)		(3.12)		(1.69)		(1.91)
EDR	1.61***	1.92***	0.89	1.01	1.15*	0.98	0.48	0.51
	(2.88)	(3.31)	(0.97)	(1.34)	(1.86)	(0.80)	(0.44)	(0.45)
SIZE	0.02**	0.02**	0.02***	0.02***	0.01	0.01	0.01**	0.02**
	(2.11)	(2.39)	(3.01)	(2.81)	(0.87)	(0.27)	(2.02)	(2.19)
ROA	0.50***	0.50***	0.64***	0.64***	0.47***	0.48***	0.52***	0.53***
	(7.23)	(7.26)	(9.17)	(9.15)	(6.03)	(6.21)	(2.62)	(2.64)
PR	-0.03	-0.03	-0.17***	-0.17***	-0.03	-0.03	-0.14*	-0.14*
	(-1.15)	(-1.17)	(-3.91)	(-3.91)	(-0.31)	(-0.29)	(-1.86)	(-1.86)
TAX	-0.04***	-0.04***	-0.05**	-0.05**	-0.10***	-0.10***	-0.05	-0.05
	(-3.63)	(-3.62)	(-2.25)	(-2.27)	(-4.17)	(-4.19)	(-0.72)	(-0.72)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj R^2	0.15	0.15	0.07	0.07	0.12	0.12	0.03	0.03
N	29,094	29,094	28,662	28,662	7,645	7,645	7,492	7,492

Panel B: Coefficient Difference between Underfunded and Overfunded Firms

	(1)	(2)	(3)	(4)
	(1)-(5)	(2)-(6)	(3)-(7)	(4)-(8)
MPK	-0.03	-0.04*	-0.06	-0.10**
	(-0.69)	(-1.74)	(-0.97)	(-2.53)
MPK*EDR		0.09***		0.08***
		(2.89)		(2.61)

Table 8: Effect of Pension Discount Rate and Corporate Investments during Large Drop Period

Panel A reports the results of panel regression for the firm capital expenditure across underfunded pensions in periods when interest rates drop significantly versus relatively stable interest rate periods. The large interest rate drop period is set between 2001 to 2003, between 2010 and 2012, and 2014 denoted as *Large Drop Period* with other years considered as *Stable Rate Period*. The dependent variable is respectively proxied by the ratio of firm capital expenditures to the lagged book value of property, plant, and equipment (I/K), and the growth rate in firm's capital expenditure (IG). *MPK* is the firm marginal productivity of capital. *EDR* is an excess pension discount rate. Control variables include firm size, return on asset, pension actual return on plan assets, and firms marginal tax rate. Firms with pension assets value lower than pension projected liability are in underfunded pension group (UF). The time fixed effects are included. Panel B reports the differences in the coefficients on *MPK* and *MPK*EDR* between the large drop period and the stable rate period. The whole sample period is from 1994 to 2018. The t-statistics reported in the parentheses are based on two-way clustering (by year and by firm) standard errors. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Panel A: Firm Investment and Pension Discount Rate

	Large Drop Period		Stable Rate Period	
	I/K	IG	I/K	IG
	(1)	(2)	(3)	(4)
MPK	0.25***	0.26***	0.18***	0.23***
	(7.17)	(4.58)	(6.04)	(3.59)
MPK*EDR	0.20***	0.18***	0.08**	0.07**
	(4.14)	(3.73)	(2.41)	(2.19)
EDR	2.16***	1.97***	1.54**	0.80*
	(3.81)	(0.94)	(3.02)	(0.59)
SIZE	0.01	0.02**	0.02**	0.02***
	(0.87)	(2.03)	(2.32)	(2.51)
ROA	0.49***	0.51***	0.51***	0.69***
	(6.63)	(4.98)	(7.10)	(8.53)
PR	-0.03	-0.28***	-0.01	-0.17**
	(-1.13)	(-2.90)	(-0.46)	(-2.35)
TAX	-0.02	-0.11**	-0.05***	-0.02
	(-1.26)	(-2.53)	(-3.14)	(-0.84)
Time FE	Yes	Yes	Yes	Yes
Adj R^2	0.16	0.10	0.17	0.09
N	9,408	9,269	19,686	19,393

Panel B: Coefficient Difference in Large Drop and Stable Rate Periods

	(1)	(2)
	(1)-(3)	(2)-(4)
MPK	0.07**	0.04*
	(2.48)	(1.89)
MPK*EDR	0.12***	0.10***
	(3.47)	(3.14)

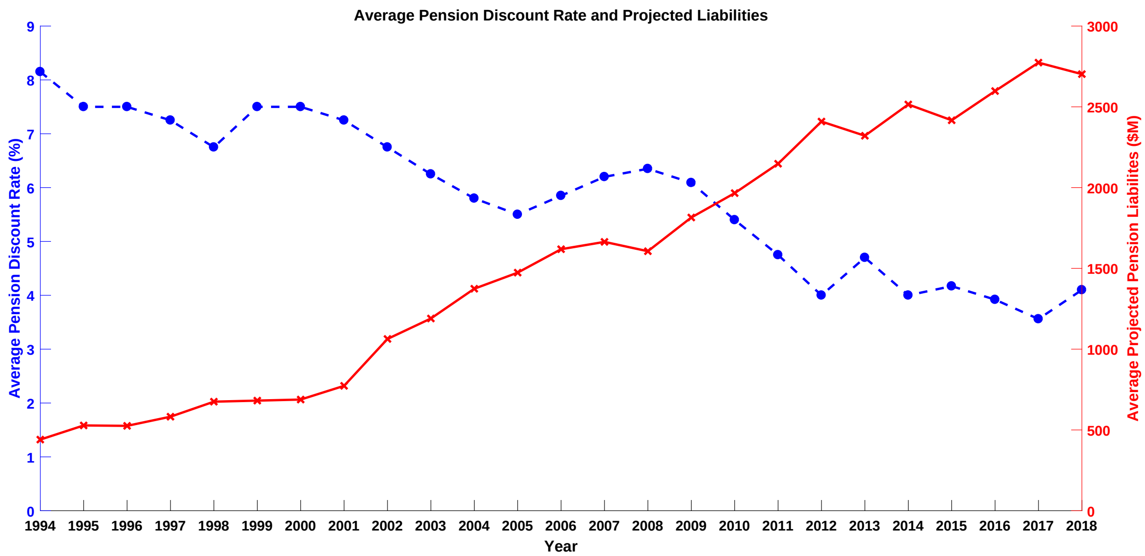

Figure 1: This figure shows the firm pension discount rate and average pension projected liability from 1994 to 2018. The average pension projected liability is defined as the mean value of individual firms projected pension liability (the sum of overfunded pension projected liabilities (item PBPRO) and underfunded pension projected liabilities (item PBPRU)).

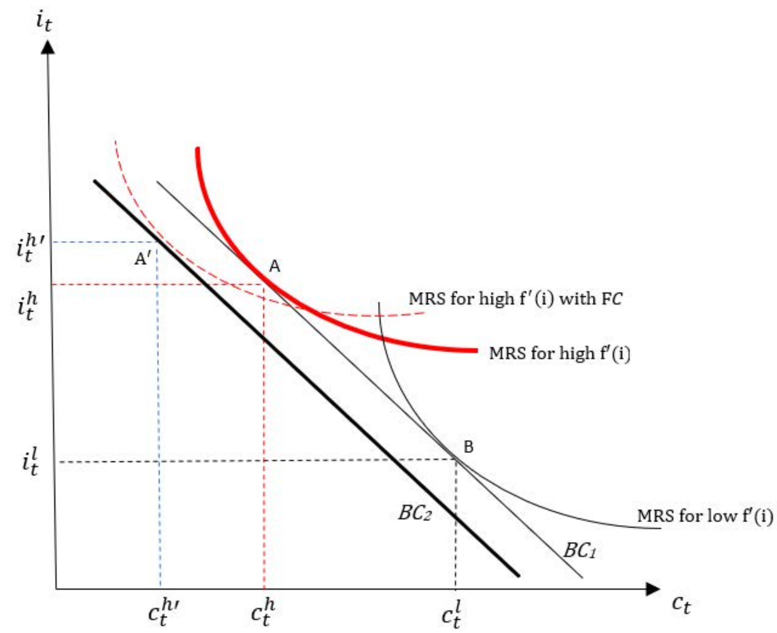

Figure 2: This figure plots the marginal substitution curves for the high marginal investment productivity firm and the low marginal investment productivity firm. A and B are the tangent points with the financing constraint, $c_t + i_t = d_t + e_t$. c_t^h (c_t^l) is the optimal pension contribution and i_t^h (i_t^l) is the capital investment decisions for high (low) marginal investment productivity firms.

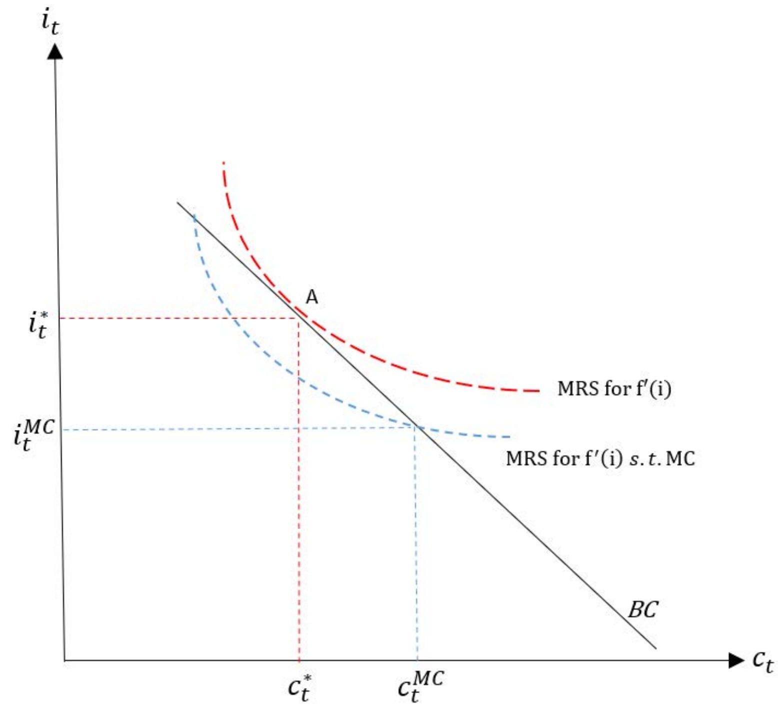

Figure 3: This figure plots the effect of mandatory pension contribution on firm investment. A is the tangent point without mandatory pension contribution. Firms face the financing constraint, $c_t + i_t = d_t + e_t$.

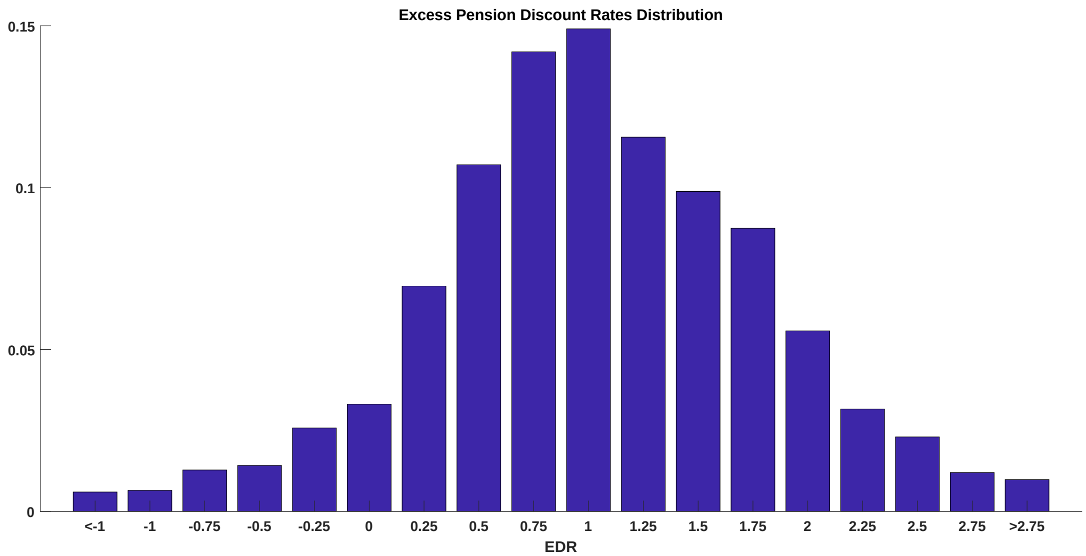

Figure 4: This figure depicts the distribution of excess pension discount rates (EDR).

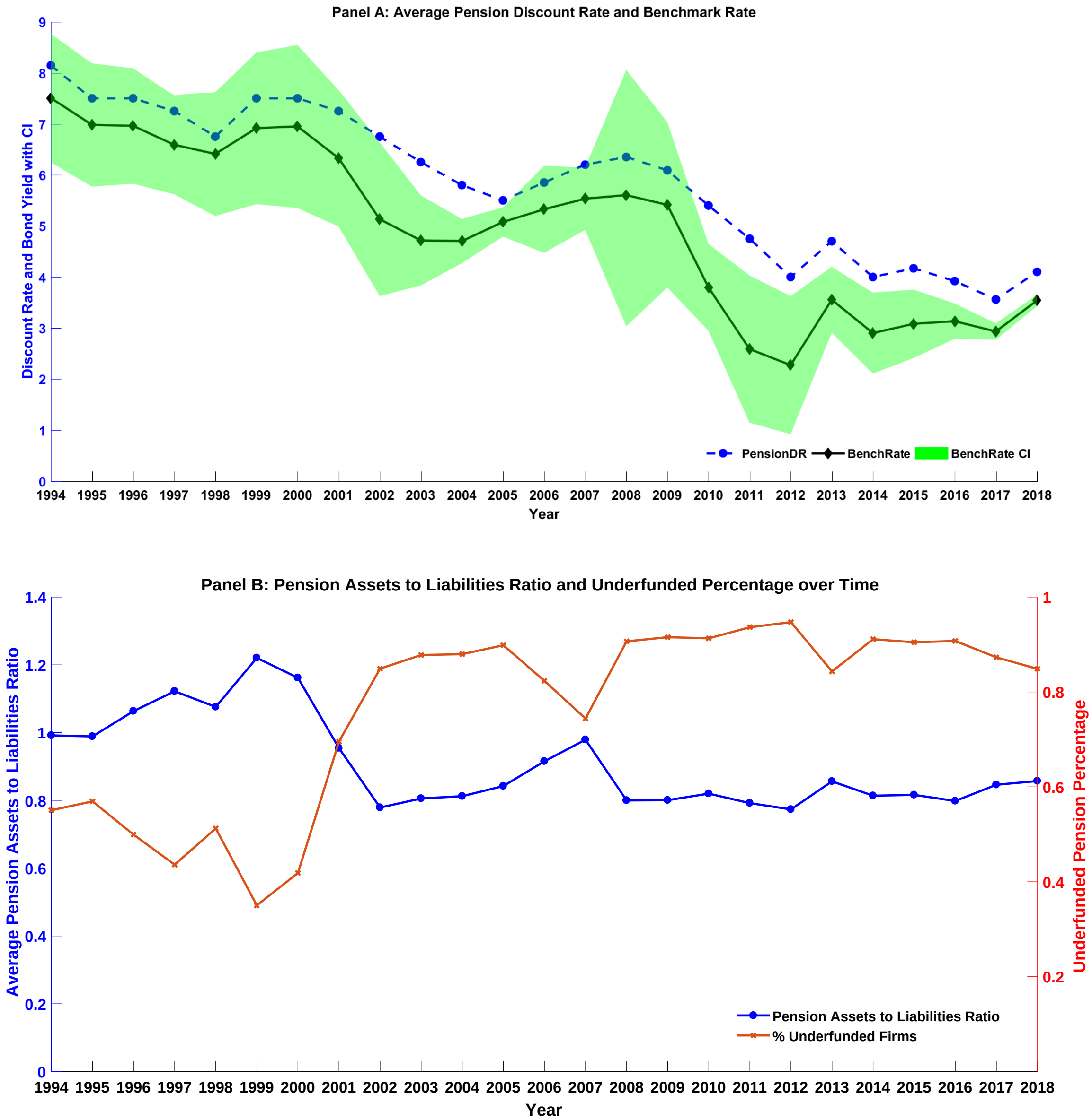

Figure 5: Panel A shows the relationship between firm pension discount rate and benchmark rate from 1994 to 2018. The dash line is the average corporate pension discount rates. The solid line is for benchmark rates which are par value weighted Aa-rated (Moody's ratings) 10-year corporate bond yields. Depicted in the shaded area, the 95% confidence interval (CI) is the average bond yield plus (minus) the 1.96 times standard deviations of benchmark rates in each year. Panel B plots the percentage of underfunded firms in our sample and average firm pension funding (pension assets/pension liabilities) in each year.

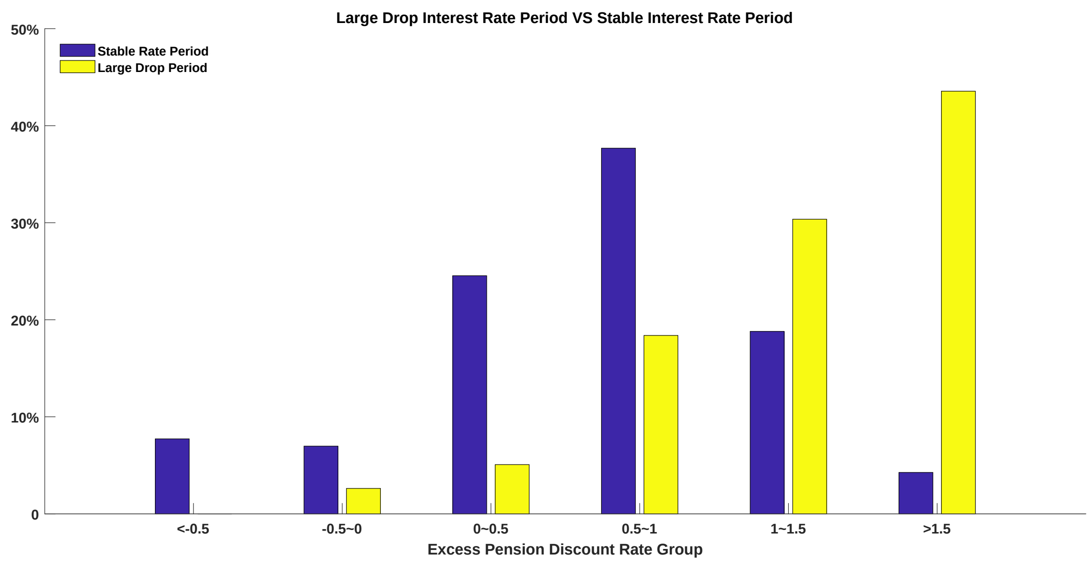

Figure 6: This figure shows the distribution of excess pension discount rate (*EDR*) during *Stable Rate Period* and *Large Drop Period* across excess pension discount rate groups.