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by

Allen Carrion, and John Coughlan

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Public Pension Duration Risk, Interest Rate Swap Usage, and Transparency*

Allen Carrion
University of Memphis

John Coughlan
U.S. Commodity Futures Trading Commission

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We study the usage of interest rate swaps (IRS) by U.S. public defined-benefit pension plans, their role in interest rate risk management, and transparency to the public. We first describe the duration risk of these pensions, show that it is large, and review how it is commonly believed to be hedged with IRS. Using CFTC regulatory data, we document that the pensions collectively hold positions in IRS. However, these positions are held by a minority of funds, are small relative to their duration hedging needs, and are often in the wrong direction to serve as hedges. Swaptions and interest rate futures are not generally used as substitute hedges. We also analyze the public disclosures of pensions identified as IRS users in the data. We find that most are not sufficiently transparent to conduct interest rate risk analysis using public data, and some do not clearly disclose the existence of IRS in their portfolios.

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1. Introduction

U.S. public pension funds invest approximately $5.1 trillion in assets to fund the retirement of over 30 million state and local government employees. The present value of the liabilities owed by these funds to current and future retirees is roughly $9.1 trillion.[1,2] This underfunding suggests that meeting these commitments will require significant future taxpayer contributions. Poor performance in the fund's investment portfolios would increase required future contributions and large losses could create financial distress for the sponsoring municipalities. Therefore, research on public pension portfolios, risk management, and disclosure practices is of great public interest. Such research is also relevant to the extensive academic literature on risk management, derivatives usage, and transparency.

Pension funds are known to face significant interest rate risk. Pension liabilities structurally have very long durations and their assets tend to have moderate or short durations. This implies that their funding gaps will rise with declining interest rates. Using standard duration analysis methods with conservative assumptions, we estimate that U.S. public pension funds will face economic losses of over $800 B if interest rates fall by 1%. We provide further details on the nature this relationship and our estimation of its magnitude in Section 3 below.

We argue that this interest rate risk and pensions' strategies to manage it deserve more scrutiny. Asset-liability duration mismatches have a long history of causing large losses and sometimes financial distress in times of changing interest rates. The recent failure of Silicon

[1] Based on data from the Federal Reserve and the U.S. Census Bureau, as of 2020. See https://www.federalreserve.gov/releases/z1/dataviz/pension/funding_status/table/ and https://www.census.gov/programs-surveys/aspp.html.

[2] The proper method of measuring pension fund liabilities is hotly debated. See Brown and Wilcox (2009), Novy-Marx and Rauh (2009), and Rauh (2017). The value presented here is based on a methodology from the Bureau of Economic Analysis. See https://www.federalreserve.gov/econresdata/notes/feds-notes/2016/state-and-local-pension-funding-in-the-enhanced-financial-accounts-20160205.html.

Valley Bank is a salient example and has been attributed at least partly to mismanaged duration risk. It is widely believed that pension portfolio risk management decisions are influenced by this risk and that pensions employ interest rate swaps (IRS hereafter) to mitigate it. Adams and Smith (2009) provide a roadmap for using IRS in this application and provide a detailed implementation example for a hypothetical corporate pension. Briefly, the strategy entails taking duration-increasing receive-fixed positions in IRS of sufficient size and duration to close the fund's duration gap. However, funds could instead choose to manage duration risk by investing in long maturity bonds or by using other types of derivatives. Klingler and Sundaresan (2019) develop a theoretical model where pensions are assumed to manage their duration risk by some combination of buying long duration bonds and using IRS and show empirical evidence that U.S. public pension funding gaps are related to swap rates, suggesting that they do in fact use IRS for this purpose. Their evidence is indirect, however, as their data does not contain actual swap positions. Several papers have directly documented significant IRS hedging activities by European pensions (Greenwood and Vayanos (2010), Khetan, Neamțu and Sen (2023), Jansen (2023), Palacios and Patel (2023), and Jansen et al. (2024)), but the lack of accessible pension IRS position data has precluded similar studies in the U.S.[3] Other papers arguing that pensions choose to hedge their duration gaps and potentially use IRS in this application include Domanski, Shin, and Sushko (2017), Greenwood and Vissing-Jorgensen (2018), and Hanson, Malkhozov, and Venter (2024).[4]

[3] Jansen (2023) states: "Detailed data on bond holdings, derivative positions, and liabilities are available for the US insurance sector and available for research, see e.g. Sen (2022), but these data do not (publicly) exist for US pension funds." Baker et al. (2021) use CFTC data and show summary statistics for IRS positions of pensions. However, this is not the focus of their paper and they only report aggregated positions of corporate and public pensions.

[4] Pennacchi and Rastad (2011) also argue that pensions optimally hedge duration risk. However, they focus on general asset allocation decisions and do not specifically address IRS as a potential hedge.

There are also factors that that may reduce the incentives of U.S. public pensions to hedge their interest rate risk through any channel. Perhaps the most obvious relates to the valuation method applied to their liabilities. These liabilities are the net present value of retirement benefits owed to beneficiaries and are used in both financial reporting and in formulas to determine future pension contributions by plan sponsors and working plan participants. Following Governmental Accounting Standards Board (GASB) guidelines, U.S. pensions use the expected return on their investment portfolio as the discount rate in this calculation. This discount rate is subjectively determined and is not directly linked to interest rates. This discount rate flexibility is specific to U.S. public pensions, as corporate pensions and most foreign public pensions discount their liabilities with some form of market interest rates.[5] Brown and Wilcox (2009) and Novy-Marx and Rauh (2009), among others, argue that these discount rates do not reflect the economic value of pension liabilities and that market interest rates on risk-free or high-quality fixed income securities would be preferable. The implication is that economic losses in value resulting from adverse interest rate moves need not be reflected promptly in financial reporting or trigger contributions to restore the pensions' ability to pay future retiree benefits. Therefore, the incentive to hedge against these adverse rate moves may be decreased. Further, the literature suggests that the discount rate choices under GASB may be strategically chosen or otherwise distorted by governance issues and political influences (Andonov, Bauer, and Cremers (2017), Bonsall, Comprix, and Muller (2019)). It is also possible that some pension managers prefer not to hedge because they predict favorable interest rate changes. Other factors that may reduce hedging incentives include increased risk appetite when asset yields are low (Lu et al

[5] Boon, Brière, and Rigot (2018) provide an excellent comparative survey of pension regulations across countries and pension types that covers liability valuation methods, Greenwood and Vayanos (2010), Khetan, Neamțu and Sen (2023), Jansen (2023), and Jansen et al. (2024) show evidence of IRS hedging by European pensions, which use market-based liability discount rates.

(2019)), risk-shifting when levels of pension funding are low (Mohan and Zhang (2014)), liquidity concerns (Jansen et al. (2024)), and agency issues related to manager career concerns (Pennacchi and Rastad (2011)).

In this paper, we employ regulatory data from the CFTC to study U.S public pension IRS usage and its role in interest rate risk management. Previous studies investigating these topics are limited by a lack of data on the funds' actual derivative positions. A central question we address is whether their swap usage can be explained by duration hedging of the type advocated by Adams and Smith (2009), suggested by the model and indirect evidence in Klingler and Sundaresan (2019), and observed directly in European public pensions. We also link public disclosures to actual position data to assess the transparency around their IRS usage and the determinants of this transparency.

Our main findings are as follows. We first estimate the duration hedging needs of public pension funds and find that they are large. We then show that public pensions collectively hold material IRS positions, but IRS usage is dramatically too low to constitute a meaningful contribution to their duration hedging needs. Further, IRS usage is absent for the majority of pensions and, when present, is often in the opposite direction of that predicted by their duration exposure. We next examine the public disclosure documents of pensions identified as IRS from the regulatory data and document a wide dispersion in the level of swap transparency. Surprisingly, many of the less transparent pensions do not publicly provide sufficient information to allow outside observers to assess whether their IRS positions hedge or increase their interest rate risk using public data. For many pensions, this can only be achieved using regulatory data as in this paper. In some of the least transparent pensions, it is often not possible to determine whether the pension holds IRS positions or not from the public disclosures. We find

that larger pensions and pensions with large IRS notional positions tend to be more transparent, and that transparency is not significantly related to whether a pension uses IRS in a direction consistent with duration hedging. We next analyze the empirical determinants of public pension IRS usage. While we document a few significant cross-sectional relationships between pension IRS positions and our explanatory variables, our strongest conclusions are that pension IRS usage is not well-explained by our models and appears largely idiosyncratic. Notably, tests for relationships between IRS positions and pension characteristics thought to be related to their risk appetite fail to find significant results. We also investigate the possibility that the lack of expected IRS hedging can be explained by pension positions in interest rate futures or swaptions, which could serve as substitute duration hedges, and find that this is not the case.

The rest of this paper proceeds as follows. Section 2 describes the data and provides summary statistics on the public pension sample. Section 3 discusses the duration risk of public pension funds and provides estimates of its magnitude. Section 4 surveys and analyses the IRS positions of our sample funds and compares them to positions of European pensions reported in other studies. Section 5 explores the transparency of public pension IRS positions and its determinants. Section 6 explores the empirical determinants of public pension IRS usage. Section 7 investigates whether funds use interest rate futures or swaptions as substitutes for IRS in duration hedging applications. Section 8 concludes.

2. Data and Sample Summary Statistics

We use a combination of publicly available municipal pension plan data from the Center for Retirement Research at Boston College Public Plans Database (PPD), regulatory IRS data reported to the CFTC as a requirement of rule 17 CFR Part 45, and interest rate futures and

options data reported through 17 CFR Part 17.[6,7,8,9] We also use a sample of the pensions' comprehensive annual financial reports (CAFRs) to analyze variations in disclosure quality.

The PPD public plans data contains information on over 200 state and local defined benefit pension funds and our initial sample of pension plans is drawn from this list. The PPD website claims that this dataset contains "95% of public pension membership and assets nationwide." The PPD aggregates pension characteristics important for our study from their public disclosures. Also, as this universe is selected by a third party without knowledge of their IRS positions, it allows us to avoid concerns of selection bias when analyzing the determinants of the pensions' IRS usage. Key information in the PPD data used to build quantitative fund characteristics include information on assets, liabilities, participation, benefits, costs, and investments. Pension funds in the sample are matched with the CFTC IRS data using legal entity identifiers (LEIs).[10] LEIs are 20-digit alpha-numeric codes created by international regulators to uniquely identify legal entities participating in financial transactions and have become the standard counterparty identifier in global swaps markets, especially for regulated swaps transactions in the U.S. and Europe.

We define a "core" sample of 153 LEIs that uniquely link to a single pension fund ID in the PPD data. Pensions in the core sample have their fund characteristics from the PPD data mapped directly to IRS positions in the CFTC's regulatory swaps data, which allows for detailed

[6] CRR Public Plans Data: https://crr.bc.edu/data/public-plans-database/

[7] Full Part 45 rule text is available here: https://www.ecfr.gov/current/title-17/chapter-I/part-45?toc=1

[8] Exchange-traded futures and options positions are reported through the CFTC's Large Trader Reporting Program, https://www.cftc.gov/IndustryOversight/MarketSurveillance/LargeTraderReportingProgram/index.htm

[9] Section 8(a) of the Commodity Exchange Act ("CEA" or "Act"), 7 U.S.C. 12(a), prohibits the Commission from disclosing information that would separately disclose the business transactions or market positions of any person or trade secrets or names of customers. Presentations of analyses based on regulatory data in this paper use aggregation and, where warranted, report inequalities in place of exact calculated values to ensure compliance.

[10] See GLEIF for more on LEIs: https://www.gleif.org/en/about-lei/introducing-the-legal-entity-identifier-lei

comparisons of IRS positions to each fund's financial position. Pensions with incomplete PPD data were also excluded. Specifically, we require a PPD record with a fiscal year end within the 2 years prior to the ENNs sample date that contains populated data for the pension's actuarial assets and actuarial ratio for inclusion in the sample. An additional 19 LEIs in the CFTC data were identified as defined benefit public pensions plans or systems of multiple plans holding positions in IRS that could not be uniquely linked to a single pension plan ID in the PPD data. These are included as part of an "extended" sample of public pension IRS positions but are not included in calculations that require linked fund characteristics from the PPD data. Finally, since LEIs have been so widely adopted by IRS market participants (the Part 45 rule update in 2021 also made LEIs required for swap transactions in most circumstances), we assume any fund in the PPD data that we could not match with an LEI had zero IRS positions.

The primary regulatory swaps data source used is a sample of the Entity Netted Notionals (ENNs) data from June 10, 2022. Other studies using this data include Baker, et al. (2021) and McPhail, Schnabl, and Tuckman (2023). The ENNs data is produced on a quarterly basis by the CFTC's Office of the Chief Economist and uses Part 45 IRS positions data as its main input (Baker, et al (2021)). The "entity-netted" notional replaces the gross notional figures often reported in swap analyses with a more meaningful measure of interest rate risk transfer. The ENNs calculations normalize risk across swap types and maturities and accounts for the netting of longs and shorts within counterparty relationships. The ENNs data allows us to identify not only the total size of a counterparty's swap position, but also the net direction long or short in 5-year swap equivalents. 5-year swap equivalents are a measure of duration that is discussed further in Section 3. The ENNs universe includes fixed-float IRS, caps and floors, swaptions, and forward rate agreements. ENNs data includes only swap product types where directionality can

be determined in the underlying Part 45 data. ENNs calculations explicitly exclude exotic swap products (labeled in the underlying data as exotics, basis, debt, inflation, etc.) for this reason. Similarly, any positions in the included swap products are excluded if directionality cannot be clearly determined. For the purposes of this study, we report swaptions separately to focus on the vanilla IRS products thought to be most commonly used for pension interest rate risk management for our main analysis. Finally, cap/floor swaps are excluded due to their de minimis levels in the sample.

Most of the empirical work in this paper relies on data from a single sample date. There are two reasons for this decision. First, the CFTC's Part 45 data underwent a major regulatory data update in December 2022, which dramatically altered the underlying data structure and delayed production of the CFTC's weekly swaps report and ENNs calculations.[11] Second, the ENNs data quality improved over time, making the construction of a panel dataset with consistent data quality impractical. Therefore, we selected June 10, 2022 as our main sample date, which was the latest ENNs date available before the data was restructured, and merged it with PPD data.

To assess the impacts of our focus on a single sample date, we construct a time series of aggregate gross notional IRS positions for public pension funds from January 2014 through June 2022 using CFTC Part 45 open IRS positions and plot the results in Figure 1. Gross notional is a crude measure of IRS holdings compared to the ENNs-derived measures focused on in the rest of the paper, but serves as a useful measure of broad trends in public pension IRS market activity. However, these data give greater insight into the time series variation in pension IRS positions. They are produced on a weekly basis and therefore are more frequently available than the ENNs

[11] CFTC Release Number 8584-22 on September 15, 2022, details the technical specification changes implemented and is available at https://www.cftc.gov/PressRoom/PressReleases/8584-22

data. Also, the gross notional values are measured directly and do not rely on assumptions or calculation methodologies that may have changed over time. Figure 1 shows gross notional for public pensions increased sharply in 2018 but was relatively stable through June 2022. This shows that it is reasonable to focus on the most recent sample date with high-quality data available for the more detailed calculations in the remainder of the paper. While there is some variability in the IRS gross notional over time, these fluctuations are very small relative to the duration exposures and hedging shortfalls that we document later.

Table 1 reports summary statistics from the PPD for key characteristics of the core sample of public pension plans as of the June 10, 2022 sample date. Total assets and liabilities for the 153 core pension plans are $3.308 and $4.482 trillion, respectively. Average assets and liabilities were $21.622 and $29.294 billion, respectively. This underfunding is commonly measured by their funding ratios, which have a mean of 73.27% with a range of 12.23% - 117.90%. The mean return assumption on their investment portfolios is 7.06%, with a range of 4.25% - 8.25%. This is also the discount rate used in actuarial valuations of the pensions' liabilities. There are 7,786,831 total beneficiaries. The mean allocation of their investment portfolios to fixed income is 22.75%, with a large range of 2.90% - 52.72%. Most characteristics are populated for all sample pensions, with the exceptions of fixed income portfolio allocations and the ratios of active to retired beneficiaries.

3. Duration Risk of Public Pension Funds

A central question of this paper is whether U.S. public pension plans use interest rate swaps to hedge duration risk. To facilitate interpretation of their swap positions in this context, we first describe and provide estimates of the duration risks in these plans. Adams and Smith

(2009) describe the duration risk that is inherent in conventional pension structures and demonstrate how it can be hedged with interest rate swaps. Novy-Marx and Rauh (2011) estimate liability durations for U.S. public pension plans using data from their financial disclosures, yields, and standard fixed income risk calculations. We follow the general principles outlined by Adams and Smith (2009) and use estimates from Novy-Marx and Rauh (2011) along with more recent public pension plan data in this exercise. We caution in advance that these estimates are crude due to data limitations and necessary extrapolations and should be viewed as a best-efforts attempt to develop important new insights from imperfect data. However, we believe that they provide useful benchmarks to evaluate the plans' duration hedging behavior and also serve as concrete examples to illustrate pension duration risk and hedging opportunities. We also provide sufficient detail on our methodology to allow other researchers to replace our inputs with their preferred assumptions and repeat our calculations.

Duration is a measure of the interest rate risk of a security or other financial claim that is standard in fixed income analysis.[12] Duration is a linear approximation for the change in value of the claim for a given parallel shift in the yield curve or a change in the yield-to-maturity. Positive durations result in losses (gains) with interest rate increases (decreases). Due to their relationship with maturity for vanilla securities, they are expressed in units of time and a one-year duration implies a 1% loss in value when interest rates rise by 1%.[13] As a linear approximation that assumes parallel shifts in the yield curve, it is not exact, but it is a useful and widely-accepted

[12] For a more in-depth introduction to duration see Blackrock (2004) for a brief practitioner primer and Adams and Smith (2019) for formal textbook treatment.

[13] The percent change in value interpretation is technically not true for all fixed income claims. For some derivatives, including interest rate swaps, the fair value of the position is not closely related to its interest rate risk so by convention the notional value replaces the fair value in the denominator. This duration can be viewed as the duration of a bond with a market value equal to the swap's notional value and the same interest rate sensitivity.

first-order measure of interest rate risk.[14] The duration of a typical pension plan's liabilities is significantly larger than the duration of its assets. This implies that when interest rates fall, the economic value of the liabilities will rise by much more than the value of its assets. This will result in a decrease in the economic value of the pension's funding status.[15] Duration analysis provides tools to quantify this risk and, if desired, to hedge it. Interest rate risk arising from duration mismatches between an entity's assets and liabilities are a well-studied problem and are often referred to as "duration gaps." Duration gap measurement and management is perhaps best-known in the context of banks which, in their natural course of business, fund investments in long term loans and fixed-income securities with short-term deposits. This creates interest rate exposure in the opposite direction of that faced by pensions, where rising rates lead to potentially large economic losses (Bierwag and Kaufman (1985)). Mismanaged duration gaps in times of rising interest rates have been cited as one of the primary causes of the Savings and Loan Crisis in the 1980s (Benston and Kaufman (1997)) and the collapse of Silicon Valley Bank in 2023 (Earle (2023), Siokis (2023)).[16] Fannie Mae, which faces similar duration gap issues to banks, was insolvent on a mark-to-market basis after a sharp rise in interest rates in 1979 and remained so until late 1984 (Kane and Foster (1986), Seiler (2003)). If public pensions do not monitor and manage their duration gaps, it is conceivable that they could experience similar distress when interest rates fall.

[14] A more complete interest rate risk analysis would also consider value changes due to convexity and curve risk, which may be material but are typically smaller than duration risk. Our data are not sufficient to perform this analysis. Our interest rate risk analysis in this study only address value changes due to duration risk.

[15] Economic values do not directly and immediately translate to values reported under GASB accounting rules, as the GASB discount rate is not mechanically linked to market interest rates. This disconnect is discussed in more detail below.

[16] https://esg.gc.cuny.edu/2023/03/28/silicon-valley-bank-failure-explained/, https://www.aier.org/article/silicon-valley-bank-bespoke-woke-and-restoked

As shown in Adams and Smith (2009), pension duration risk can be immunized with an IRS position of the correct size and direction. To fully immunize, the duration exposure of the IRS position should be equal in magnitude and opposite in direction to the duration exposure of the pension's net position (i.e. funding level or net present value of assets less liabilities). Immunization can be thought of as achieving a portfolio composition where the economic loss to the pension's net position from a decrease in interest rates will be roughly offset by a gain in the market value of the IRS. We note that the extent of hedging, or whether to hedge at all, is at the discretion of each plan's managers and sponsors. We also emphasize that we are not making a normative statement that public pensions should duration hedge and there is no general requirement that they do so. Public pensions are given wide discretion to invest in various risky assets in the hopes of benefiting taxpayers and/or pension beneficiaries, and positioning a pension to benefit from rising interest rates at the cost of losing money when rates fall can be viewed analogously. There are also costs, operational and liquidity risks, and expertise requirements involved with a hedging program. However, understanding public pensions' risk profiles, hedging behavior, and derivatives usage is important from academic and stakeholder perspectives, and we believe that these issues are not widely understood.

Prior to presenting our estimation results, we present additional background on some standard fixed income risk analysis methods that we employ. Simple durations are not mechanically additive across positions within a portfolio or across the sides of a balance sheet. Therefore, we first convert them to duration dollars, which are additive, before performing further calculations.[17] Duration dollars gives an estimate of the dollar loss in a position when rates rise by 1% (multiplied by 100 to follow bond pricing conventions). For vanilla fixed

[17] Duration dollars are alternately referred to as dollar durations or money durations.

income claims, duration dollars can be calculated by simply multiplying the duration by the dollar value of the subject position. For IRS, the dollar value of position is disconnected from its interest rate exposure and the calculation is performed slightly differently.[18] Duration dollars can also be expressed as 5-year swap equivalents. This measure gives the notional position of a 5-year benchmark IRS with the same duration dollar exposure as that of the position in the subject security or claim. The benefit of this formulation is that it can be interpreted as the position size of a vanilla benchmark 5-year IRS that would immunize the subject duration exposure. We present 5-year swap equivalents to facilitate interpretation but emphasize that they are simply duration dollars expressed in different units.

Our estimates are reported in Table 2. We first perform the analysis for a representative hypothetical public pension plan. We then repeat the analysis for the universe of pensions in our core sample and for the entire universe of U.S. public pensions. It is important to note that, while we organize our analysis and results in a balance sheet-style format and use some accounting values as inputs, we focus on economic risks that do not necessarily map cleanly to predicted immediate changes in GASB accounting values. We therefore refrain from labelling these items with the GASB names that are familiar to pension researchers and choose names that will likely be more intuitive to a broader audience.

Table 2 Panel A presents our analysis for a representative hypothetical public pension plan that is designed to match key characteristics from our core sample. The assets in the plan's investment portfolio have a value of $21.622 B, which matches the mean value of the GASB actuarial value of plan assets for our core sample. We assume an asset duration of 1.27 years. This is based on a fixed income allocation of 22.75% and a duration estimate of 5.6 years in the

[18] Specifically, in this paper we use the DV01 from Bloomberg to directly calculate the dollar loss for a 1% rise in rates for benchmark interest rate swaps.

fixed income portion of the portfolio. This fixed income allocation is the mean from our core sample and the duration is from a 2017 PPD sample, which is the latest available with sufficient granularity.[19] The liabilities have a value of $29.510 B, which we calculate by dividing the pension's asset values by the mean funding ratio of 73.27% from our core sample.[20] This implies that the pension is underfunded by $7.888 B. We estimate a liability duration of 12.5 years. This is based on the analysis of Novy-Marx and Rauh (2011), who estimate liability durations for a large sample of U.S. public pension plans at a range of discount rates. For the purpose of conservatism, we choose the duration corresponding to a discount rate of 7%, which is likely to overstate the economic discount rate according to their arguments. A lower discount rate would result in a higher liability duration and increase our overall duration risk estimates. We then apply the duration dollar calculation and conversion to swap equivalents described above and net across the pension's assets and liabilities.[21] The duration dollar calculations imply that, for a 1% decrease in rates, the pension's asset values would increase by $.275 B while its liabilities would increase by $3.689 B, netting out to a loss of $3.413 B. The 5-year swap equivalents of -$74.364 B indicate that a 5-year IRS position with this notional value would offset this risk by earning approximately $3.413 B in the same rate shock (subject to duration

[19] We assume that other components of pension investment portfolios have zero durations. Adams and Smith (2009) argue for using zero duration for equity, as it cannot be "relied on" to comove consistently with interest rates and consider this to be the conservative choice. Their arguments apply equally to the other non-fixed income components of a typical pension portfolio. Jansen et. al (2024) also follow our approach and point out that European pension regulations assume that equities have zero duration.

[20] For conservatism, our estimated funding ratio is based on values reported by pensions under GASB guidelines obtained from PPD data. Novy-Marx and Rauh (2011) find that reported liabilities understate their values based on economic principles by greater than 40%. Using a lower funding ratio would result in higher estimated duration risk.

[21] Note that the line labelled "Net" roughly corresponds to the concept of equity for a normal financial institution, but we refrain from using that term because a pension's net position has important differences from a normal entity's equity. It is normal for the net position to be negative and corresponds to a future obligation of the sponsor rather than near-term financial distress, pension residual claimants are not well defined, and in general the pension's net position does not have the rights and risks of standard equity. This is also similar to the typically negative value of GASB Net Pension Liability (NPL) item, but we avoid this term as we are referring to the economic position rather than the related accounting measure.

approximation caveats). The negative sign indicates that the offsetting IRS should be duration-increasing, which corresponds to the pension entering the receive-fixed side of the swap.

Table 2 Panel B presents our analysis for the aggregate core sample. Mechanically, the calculations are identical to those presented for the individual hypothetical pension described above, with the mean GASB actuarial value from our core sample replaced by its aggregate value of $3,308.177 B. Using the mean funding ratio from our core sample, the total liabilities are $4,515.049 B, for underfunding of $1,206.873 B. The net duration dollar exposure implies that, for a 1% decrease in rates, the pensions in the core sample would lose $522.235 B. The exposure in 5-year swaq equivalents indicates that this risk would be immunized by a $11,377.688 B notional receive-fixed position in 5-year IRS.

Finally, Table 2 Panel C presents our analysis for the aggregate U.S public pension plan universe. The calculations are identical to those described above, replacing the asset value with the $5,137.800 B value reported for the universe by the Federal Reserve.[22] Using the mean funding ratio from our core sample results in liabilities of $7,012.147 B, for an aggregate underfunding of $1,874.347 B. The net duration dollar exposure implies a loss of $811.063 B for a 1% decrease in rates, and the 5-year swap equivalents value indicates that an immunizing hedge of $17,670.213 B notional receive-fixed position in 5-year IRS would offset this loss.

The duration estimates in Table 2 help to interpret the IRS usage we document later in this paper. If pensions use IRS to hedge duration risk, we will observe primarily receive-fixed positions. If pensions also hedge yield curve risk, we may see a mix of receive-fixed and pay-fixed positions, but receive-fixed positions will be dominant. If pensions hedge substantially all

[22] See https://www.federalreserve.gov/releases/z1/dataviz/pension/funding_status/table/. We use the value reported for 2020, which is the latest available at the time of this writing.

of their duration risk, we should expect to see IRS positions with a net duration exposure on the order of $11,377.688 B receive fixed 5-year swap equivalents in our core sample. Restating this hedge in terms of the size of the swap position relative to the liabilities also gives rough but useful benchmarks that can be applied at various levels of aggregation to pensions with these representative characteristics. The 5-year swap equivalents of a full hedge would amount to approximately 252% of the liabilities. If pensions chose to use solely 5-year vanilla IRS for this hedge, the swap notional value would also be approximately 252% of the liabilities.

More precise duration estimates are possible. The estimated liability durations could be recalculated using the GASB 67 disclosures of a more recent and comprehensive sample of pensions. The estimated asset duration could also be recalculated using the fixed income allocations and fixed income portfolio durations from a more recent and comprehensive sample. The liabilities could also be re-calculated using lower discount rates that reflect their level of risk as advocated by Novy-Marx and Rauh (2011).[23] These analyses would require extensive data collection from a large number of individual pension plan disclosures and is beyond the scope of this paper. On balance, these enhancements would likely increase the estimated duration risk of the public pension universe significantly above that estimated here. We believe that lowering the liability discount rate would be the most impactful extension. The public pension swap positions we document later in this paper are small relative to these duration exposure estimates. Therefore, our estimates serve as conservative lower bounds that provides useful benchmarks for the purposes of this paper. We also hope that our analysis will inspire future research that pursues richer and more precise estimates of public pension risk.

[23] We find the Novy-Marx and Rauh (2011) arguments to be persuasive but believe that using GASB discount rates is the more conservative choice in the context of this study, as it does not risk overstating the large duration risks we find and does not require us to take a stand on the correct discount rate.

In the preceding discussion, we address the risk of economic losses from interest rate decreases and note that there is a distinction between economic losses and those that are reported on financial disclosures under GASB. Unfortunately, there is not a clear relationship between economic losses and immediately reported accounting losses. While pension assets are primarily valued at fair value, liabilities create confusion. Novy-Marx and Rauh (2011) discuss the importance of discounting pension liabilities at an economically justified discount rate and argues that the risk-free rate is appropriate for public pension liabilities. This perspective supports our use of duration analysis in this paper. If the risk-free rate decreases, then liability duration is an appropriate measure of the increase in economic value of the liability. However, GASB rules allow public pensions to value their liabilities using the projected rate of return on their investment portfolio as the discount rate and give wide discretion on how this is calculated. Therefore, there is a wide range of possible outcomes for the reported changes in value (i.e. decreases in funding levels) after market rates decrease. If the pension sponsor calculates the projected return as the risk-free rate plus a risk premium uncorrelated to the risk-free rate and does not alter the investment portfolio allocation targets, then reported losses should be highly correlated to economic losses and may trigger contributions. However, other scenarios are likely. First, the pension sponsor could choose to increase the risk in the portfolio and justify leaving the discount rate unchanged. Alternately, if the sponsor calculates the projected return using a methodology that does not use the current risk-free rate as an input, it could maintain its previous asset allocations and avoid increasing the liability discount rate. In either case, the pension's economic liability will be higher than its reported liability, and reported underfunding will be understated. Then, assuming expected returns are a function of the current risk-free rate, as suggested by asset pricing theory, future realized returns are more likely to fall short of the

projections underlying the discount rate and future contributions may be required that are not signaled by current financial reporting. Of course, there is a possibility that future risky asset payoffs will surprise to the upside making these future contributions unnecessary. In summary, economic losses due to interest rate declines translate into an increased likelihood of higher-than-expected contributions to the pension with uncertain timing and/or increased risk in the pension's asset portfolio, but do not necessarily result in immediately reported increases in underfunding.

4. IRS Positions of Public Pension Funds

In Section 4.1, we present and discuss our empirical results. In Section 4.2, we compare our results to those reported for European pensions in other studies.

4.1 Empirical Analysis

Table 3 summarizes the IRS positions of the pensions as recorded in the CFTC data on June 10, 2022 in our core and extended samples. As discussed in Section 2, these include the categories of swaps most likely to be used for duration hedging as well as others with easily measured durations.

Table 3 Panel A reports the counts of pensions grouped into various categories based on their IRS usage. 43 of the 153 pensions in our core sample use IRS. 11 have IRS gross notional positions of greater than $500 M.[24] For context, the analysis in Section 3 estimates that a representative pension using solely 5-year vanilla IRS to fully hedge duration risk would have a swap notional value of approximately 252% of the liabilities, which translates to $74 B for the representative fund. This suggests that the vast majority of pensions in our sample have IRS

[24] To ensure compliance with Section 8(a) of the CEA, we refrain from disaggregating the pensions with the largest IRS positions further. See FN (6).

positions that are too small to hedge a material portion of their duration risk. We also break down the IRS-using pensions by the direction of their IRS positions. Based on the duration dollars of their positions, we classify pensions as either "*Net Long*," indicating a net long duration (receive-fixed) IRS position, or "*Net Short*," indicating a net short duration (pay-fixed) position. We find 17 *Net Long* pensions and 26 *Net Short* pensions. Recall that a long position is required to hedge the duration risk of a typical pension plan. This suggests that the majority of IRS-using pensions have IRS positions that actually increase their duration risk. We also classify pensions using a mix of long and short duration IRS positions as "*Spreaders*." We find 10 of the 17 *Net Long* pensions and 18 of the 26 *Net Short* pensions are *Spreaders*. As discussed in Section 3, *Net Long Spreaders* may be using IRS in a way that is consistent with duration hedging. While a simple duration hedge would consist entirely of long-duration IRS, a more sophisticated hedging strategy could involve being short duration at some maturities and long duration at others. Spread positions, either long or short, could also be a part of an intentional investment strategy based on predicted changes in the shape of the yield curve or could result from multiple swap positions being entered into for idiosyncratic reasons.

Applying this analysis to our extended sample, we find 19 additional pensions that use IRS. Four of these pensions have gross notional IRS positions greater than $500 M. The insights we obtain from the extended sample are generally consistent with those from the core sample, and therefore we focus on the core sample in most of this discussion.

Table 3 Panel B reports the notional IRS positions aggregated across pensions in both samples. This gives additional insights into the overall magnitude of IRS positions held by public pensions. IRS gross notional positions total $20.477 B and $28.979 B across the pensions in our core and extended samples respectively. Long IRS notional positions total $10.701 B for the core

sample and $14.398 B for the extended sample. Short IRS notional positions total $9.776 B for the core sample and $14.582 B for the extended sample. These notional amounts are small relative to what we would expect if public pensions were using IRS to manage a meaningful part of their duration risk.

Table 3 Panel C presents totals and distributions of pension IRS positions measured in 5-year swap equivalents. This adds important perspective because, as we discuss in Section 3 and Baker et al. (2021) discuss in greater detail, 5-year swap equivalents are an appropriate measure of interest rate exposure while swap notionals are not.[25]

The aggregate IRS duration is -$1.002 B 5-year swap equivalents for the pensions in our core sample and -$1.156 B 5-year swap equivalents for those in our extended sample. The negative signs indicate that these are short duration or pay-fixed exposures. Again, this is in the opposite direction of what we would expect if the IRS were being primarily used for pension duration hedging.

Turning to the pension-level distribution of IRS positions, the mean (median) pension IRS position is -$23 M (-$5 M) of 5-year swap equivalents for the core sample. All pension IRS positions are between -$500M and $500M 5-year swap equivalents.[26] The distribution of the extended sample is similar. Note that above we counted multiple pension plans with gross notional IRS values above $500 M. The absence of pensions with 5-year swap equivalents above this threshold is consistent with spreading and/or large positions in low duration IRS instruments.

[25] Recall that 5-year swap equivalents are equivalent to duration dollars expressed in different units. In our setting, as netting effects are not significant, 5-year swap equivalents are equivalent to the ENNs measure described in Section 2 and in Baker et al. (2021).

[26] To ensure compliance with Section 8(a) of the CEA, we report inequalities rather than the exact range to represent bounds on positions. See FN (6).

The distribution of pension IRS in 5-year swap equivalents reveals no plans that appear to take large IRS positions relative to those required for the duration immunization of the representative pension. However, it is possible that some pensions have duration exposures smaller than that of the representative pension and do aggressively hedge with IRS. To partially address this possibility, we normalize each plan's IRS 5-year swap equivalent position by its liability value and report the distribution in Table 3 Panel D. Recall that in Section 3 we estimated that a full duration hedge of the representative pension would require 5-year swap equivalents of approximately 252% of the liabilities.[27] We are only able to perform this analysis for our core sample, as we lack plan characteristic data for the extended sample. The mean and median are both very close to zero. The longest pension has an IRS 5-year swap equivalent of less than 10% of its liabilities, which is considerably lower than what we would expect for a meaningful duration hedge.[28]

Overall, this analysis shows that public pensions hold material IRS positions, but IRS positions are absent for the majority of pensions and are often short duration, which is the opposite direction of that needed to hedge a typical pension's duration risk. For pensions that do hold long IRS positions, their position sizes are much too small to be a meaningful component of a duration hedging program.

[27] This benchmark is not precise but is useful as an order-of-magnitude comparison. Normalizing by liabilities only partially addresses variation in duration dollar exposures across pensions. We are not able to adjust for liability durations that differ from the representative fund with our available data, and continue to implicitly assume a liability duration of 12.5 years for all pensions.

[28] To ensure compliance with Section 8(a) of the CEA, we report an inequality in place of the exact maximum to represent the upper bound of positions. See FN (6).

4.2 Comparisons with IRS positions of European Pensions

We cite several papers in the introduction that document IRS hedging by European pensions. Here, we review relevant results documented in these studies and, where possible, compare to ours. Unfortunately, several of these studies focus on other topics and only report limited results or aggregate pension IRS positions with those of other institutions, precluding direct quantitative comparisons with our results. For example, Greenwood and Vayanos (2010) report that U.K. pensions extended durations using IRS by "as much as £50 billion of interest rate exposure" in response to regulatory incentives to increase hedging. However, they do not provide further details and do not report the total position size. Similarly, Khetan, Neamțu and Sen (2023) provide an extensive analysis of the U.K. IRS positions of pensions and insurance sectors combined (P&I). They show large P&I IRS positions that are net long duration in every maturity bucket. Their analysis of trading data shows that the pensions are more active in the IRS markets than the insurers, but their position-based analyses do not report pensions separately from insurance companies. Palacios and Patel (2023) report that over 60% of U.K. defined benefit plans use a liability-driven investment (LDI) strategy where their duration risk is managed, but these strategies combine IRS hedging with duration adjustment through the asset side of the balance sheet. They also report that approximately 25% of U.K. pension's liabilities were matched by IRS and other derivatives, but do not report IRS separately. Overall, while not reporting results directly comparable results to ours, these studies consistently document evidence of IRS usage consistent with interest rate hedging in European pension systems.

One exception is Jansen et al. (2024), who focus on Dutch pensions and provide an extensive analysis of their IRS positions. They report that 93% (100%) of the pensions in their full sample (42 large pension subsample) use IRS in 2022. This compares to 28% of our U.S.

public pension core sample as reported in Table 3. They also report IRS gross notional positions of $694 B for a sample of pensions with liabilities of approximately $1.84 trillion, counting only IRS with maturities greater than 5 years. This compares IRS gross notional of $20.477 B in our core sample for IRS of all maturities, reported in Table 3, for pensions with aggregate liabilities of $4.482 trillion. Jansen et al. (2024) also show that Dutch pension IRS positions are net long, especially in longer maturity buckets, while our results in Table 3 show that U.S. public pension IRS positions are much closer to balanced.

Another exception is Jansen (2023), who studies Dutch P&I bond and IRS positions. Much of the empirical work uses aggregations that preclude comparison with our results. However, a particularly useful analysis of the duration hedging behavior of large Dutch pensions is presented. She reports pension durations with and without IRS positions and finds that the pensions hedge slightly over half their duration risk with IRS. In contrast, Table 3 shows that the mean IRS 5-year equivalent position in our core U.S. public pension sample is 0.09% of liabilities and the maximum is less than 10%. Consider the heuristic we develop in Section 3 that a full hedge duration hedge would be approximately 252% of liabilities. This implies that the mean U.S. public pension hedges essentially none of its duration risk, and the pension with the longest position hedges less than 4% of its duration risk. Jansen (2023) also shows that Dutch pensions reduced their IRS position in response to a regulatory change the reduced incentives to hedge, although the level of hedging remained substantial.

The differences in interest rate hedging strategies between U.S. public pensions and European pensions that face similar risks are striking. We note that U.S public pensions operate in a very different regulatory regime than Dutch and U.K pensions, and we further discuss potential reasons for these different hedging strategies in the Conclusion.

5. Transparency Analysis

The insights into public pension IRS usage and interest rate risk management that we develop above rely on the use of non-public regulatory data. An important question is to what degree stakeholders or researchers who must rely solely on the pensions' public disclosures would be able to reach similar conclusions. We view this as especially important for taxpayers who may be required to cover potential losses resulting from adverse interest rate movements, constituents of services who compete with pension funds for a share of state and local budgets, and plan participants concerned about the safety of their promised benefits. In this section, we collect and analyze the public disclosures for pensions identified in the data as holding IRS positions to assess the degree of transparency around their IRS usage. We also analyze the cross-sectional determinants of transparency, and in particular test if the degree of transparency is related to whether a pension uses IRS in a direction consistent with hedging duration risk.

Public pensions often release their disclosures with a significant delay. As of this writing, a number of plans still have not released their disclosures for the fiscal year covering June 10, 2022, the sample date used in our previous analysis. Therefore, we use a sample of regulatory data from September 11, 2020 that was prepared for an earlier release of the CFTC's quarterly ENNs report. We identify 64 public pensions holding IRS positions on this date.

The primary financial disclosure document for U.S. public pensions, like many other state and local government entities, is the Comprehensive Annual Financial Report, or CAFR. Many pension systems have standalone CAFRs, while others are consolidated into the CAFR of a parent government entity. We collect the relevant CAFRs for the pensions we identified as IRS users in the exercise described from the websites of the sponsoring government entities. For each

pension, we select the CAFR with the reporting period covering September 11, 2020. We were able to obtain CAFRs for 60 of the 64 pensions identified as swap users.

We inspect each CAFR and classify pensions into High, Medium, and Low Transparency categories, which we define as follows. High Transparency pensions disclose information sufficient to estimate the impact of the fund's interest rate swap positions on its interest rate profile. This requires both the notional amount and the direction of the IRS positions.[29] An example of a High Transparency disclosure is provided in Figure 2 Panel A. Medium Transparency pensions clearly disclose the existence of IRS positions and generally provide some quantitative data, but lack sufficient details to assess their impact on the fund's interest rate risk. Some funds in this category report position sizes as fair values rather than notional amounts. Others lack information on the directionality of their IRS, sometimes aggregating pay-fixed and receive-fixed swaps in the same line item. Low Transparency pensions do not disclose sufficient information to determine whether the fund holds positions in IRS.[30] The nature of Low Transparency pensions IRS-related disclosures varies across funds. These disclosures often report aggregate positions in swaps without specifying whether the swaps are IRS or other types.[31] In some cases, the disclosures may be even less granular or missing altogether. Some report in the text that they are permitted to use IRS or more general categories of derivatives that may include IRS, but do not state whether they in fact held positions during the reporting period. Others did not produce a CAFR at all for more than a year after their fiscal year end. An example

[29] A stricter criteria for the High Transparency category could require that IRS durations or maturities also be disclosed, but we find that pension CAFRs rarely contain these details. Without this information it is still possible to estimate ranges of plausible swap portfolio durations, so we chose not to impose this as a requirement.

[30] Four pensions did not release CAFRs between 9/11/2020 and the last date we updated our sample (5/24/2022). We classify these in the low transparency category.

[31] Pension funds also hold positions in credit default swaps, total return swaps, basis swaps, and currency swaps. These swaps may have little or no impact on duration risk.

of a Low Transparency disclosure is provided in Figure 2 Panel B. We provide our detailed coding procedures in Appendix A.

Our process ensures that IRS positions were held during the relevant reporting period. A limitation to this analysis is that our sample date for the IRS position measurements does not coincide with the end of their fiscal years, and it is possible that IRS positions changed between our sample date and the reporting date. Therefore, we do not attempt to reconcile the precise positions reported in disclosures with those in the CFTC data, and we caution against interpreting our results in this section as proving that Low Transparency funds had unreported IRS positions on the last day of their fiscal year.

We also merge key fund characteristics from the PPD and IRS position data from the CFTC data with the transparency codes. This allows us to analyze whether the level of transparency is related to fund characteristics or IRS positions. For the pensions in our extended sample, we only have IRS position data. For the pensions in our core sample, we have both fund characteristics and IRS position data.

Table 4 summarizes the results of this exercise. Panel A covers the extended sample. Only 19 of 64 pensions in our extended sample meet our criteria for inclusion in the High Transparency category. This means that 45 pensions do not provide sufficient information for stakeholders to assess the impact of IRS on their duration risk. 17 of these pensions are in the Low Transparency category, meaning that it is not possible to clearly determine whether they hold IRS positions at all. We also report the means of IRS gross notional, net notional, and five-year swap equivalents for each category, and t-tests of the significance of differences in means between the High and Low transparency categories. High and Medium Transparency pensions have mean IRS gross notional positions of $557 million and $553 million respectively. Low

Transparency pensions have mean IRS gross notional positions of $188 million, which is lower than the corresponding value for High Transparency pensions at the 10% significance level. Both mean net measures of IRS position sizes (notional and five-year swap equivalents) are small for all transparency categories, and their differences across High and Low Transparency categories are not significant. If disclosure choices were driven by the incentive to publicize duration hedging or hide its absence, we would expect High Transparency pensions to have significantly longer interest rate swap positions as measured by net notional and 5-year swap equivalents than Low Transparency pensions.

Table 4 Panel B reports results for the core sample. Only 13 out of 44 pensions are in the High Transparency category, which is similar to the proportion of High Transparency pensions in the extended sample. Pension size as measured by liabilities is the variable with the strongest relationship to transparency. Mean liabilities are $90.7 billion for High Transparency pensions, $49.6 billion for Medium Transparency pensions, and $21.0 billion for Low Transparency pensions. The difference in mean liabilities between High Transparency pensions and Low Transparency pensions is significant at the 1% level. We repeat our analysis for several other pension-specific characteristics and swap position variables normalized by pension size and find no other significant relationships. Again, we include tests designed to detect a relationship between disclosure choices and duration hedging and fail to find significant results.

Our results in this section can be summarized as follows. Transparency around IRS positions varies greatly across IRS-using pensions, and around 70% of pension disclosures do not provide sufficient information in their disclosures to assess the impact of IRS on duration risk. Pensions that are larger (as measured by liabilities) and hold larger notional IRS positions

are more likely to have informative disclosures. We find no relationship between the level of transparency and IRS positions consistent with duration hedging.

6. Empirical Determinants of IRS Usage

The results we report above suggest that public pension positions in IRS are not generally consistent with what we would expect to see if their IRS usage was predominantly driven by duration hedging strategies. However, we do observe IRS positions in many of these funds with significant cross-sectional variation in the direction and magnitudes of their positions. In this section, we investigate the cross-sectional determinants the pensions' propensity to use IRS and the variation in their positions. In addition to explanatory variables that we hypothesize are broadly related to derivative usage, we include several pension characteristics thought to be related to risk appetite. Risk appetite could affect IRS usage through multiple channels. Pensions with low risk appetites could use IRS as hedges, and pensions with high risk appetites could use IRS to speculate on interest rate forecasts or to free up capital that can be invested elsewhere. We describe our explanatory variables for this analysis, their motivations, and their use in prior literature in Appendix B.

In Section 6.1 below, we provide univariate tests of the relationship between the propensity of the pensions in our core sample to use IRS and these explanatory variables. In Section 6.2, we present multivariate regression models with various measures of the extent and direction of IRS usage as dependent variables.

6.1 Univariate Tests

Table 5 reports the results of univariate mean characteristic comparison tests of the determinants of public pension plan IRS usage. We divide our core sample into a group of

pensions that hold IRS positions on our sample date ("Users) and a group that does not ("Non-Users"). We then calculate the means of each characteristic described in Appendix B for both groups and test the null hypothesis of equality across groups. Our test statistics are two-sample t-tests.[32]

Our strongest result is for a pension's size. Users have mean LIABILITIES of $44.140 B, while Non-Users have mean LIABILITIES of $23.099 B. The difference of $22.040 B is statistically significant at the 1% level. IRS Users are almost twice as large as Non-Users. This is consistent with the hypothesis that smaller entities do not have sufficient resources to manage a derivatives program, and inconsistent with the hypothesis that larger pensions may be dissuaded from using derivatives because they face greater scrutiny.

IRS Users have lower investment portfolio allocations to fixed income securities than Non-Users. Users have FIXED_INCOME means of 21.17%, and Non-Users have means of 23.50%. This 2.33% difference is significant at the 10% level. This is consistent with IRS Users having higher risk appetites than Non-Users, and is also consistent with IRS serving as substitutes for fixed income securities.

Tests for all other pension characteristics are statistically insignificant.

6.2 Multivariate Regressions

Table 6 reports the results of regression analyses of the determinants of public pension plan IRS usage. Our dependent variables are various measures of pension IRS gross and directional positions. We use the same explanatory variables as in the univariate analysis, with the exception of FIXED_INCOME, which we drop due to excessive missing observations.

[32] Two-sample t-tests use the Satterthwaite procedure when the Folded F Test rejects the null of equal variances at the 5% level and the equal variance assumption otherwise.

Our regression models are variations of the following specification:

$$IRS\_usage\_measure_i = \beta_0 + \beta_1 LIABILITIES_i + \beta_2 FUND\_RATIO\_ACT_i + \beta_3 RETURN\_ASSUMPTION_i + \beta_4 CLOSED_i + \beta_5 RET\_1YR\_LAG1_i + \beta_6 RET\_5YR\_LAG1_i,$$

where explanatory variables are as defined above and i indexes pensions. For Model 1, the dependent variable is IRS gross notional. For Model 2, the dependent variable is IRS gross notional divided by the pension's LIABILITIES. For Model 3, the dependent variable is the pension's IRS 5-year swap equivalents, which is a net measure of its IRS duration exposure described in Section 3. For Model 4, the dependent variable is the pension's IRS 5-year swap equivalents divided by the pension's LIABILITIES. We estimate the models with OLS.

Model 1 tests the relationship between our explanatory variables and the gross size of pension IRS positions. The coefficient on LIABILITIES is positive and significant at the 10% level, indicating that larger pensions have larger gross IRS positions. This is consistent with the univariate results. The coefficient on CLOSED is also positive and is significant at the 1% level. This indicates that pensions that are closed to new participants hold larger gross IRS positions. The coefficient on RET_1YR_LAG1 is negative and significant at the 10% level, indicating that pensions with poor short-term investment portfolio returns tend to hold larger IRS positions. All other coefficients are insignificant.

Model 2 tests the relationship between our explanatory variables and the gross size of pension IRS positions normalized by the pensions LIABILITIES. This normalization measures the IRS position size as its fraction of the pension's size rather than a dollar value. The coefficient on CLOSED is positive and significant at the 5% level. This is consistent with the Model 1 result. All other coefficients are insignificant. The normalization process removes the effects for LIABILITIES and RET_1YR_LAG1 observed in Model 1. Note that the

insignificance of the coefficient on LIABILITIES after this normalization combined with the Model 1 result can be interpreted as a lack of non-linear effects of pension size on IRS gross notional positions.

Model 3 and Model 4 use net directional measures of IRS position durations as dependent variables. These variables are signed so that a net duration increasing (decreasing) position is positive (negative). In both models, the coefficients on all explanatory variables are statistically insignificant.

Overall, we interpret the results of this analysis as suggesting that public pensions use IRS for largely idiosyncratic or heterogenous reasons. While we document some relationships between pension IRS positions and our explanatory variables, their significance is often marginal, no patterns are observed in the models that take directionality into consideration, and the regression R-squareds are uniformly low.

7. Substitute Duration Hedges

IRS are arguably the most natural product for public pensions to use for duration hedging, but there are other financial instruments that could be used for this purpose. The low use of IRS by these funds prompted us to investigate their use of substitute hedging instruments. Two likely candidates are interest rate futures and swaptions. Interest rate futures are exchange-traded futures contracts that can be used to add duration to a portfolio. Treasury note and bond futures are likely the most useful futures for this application. A futures hedging program has the advantage of requiring less overhead than an IRS hedging program but the disadvantage that futures expire frequently and must be rolled. Swaptions are options on IRS. Adams and Smith (2009) describe how swaptions can be used to hedge pension duration risk. Swaptions have the

advantages of allowing the holder to benefit from favorable rate moves while avoiding large losses on adverse rate moves and simplifying margin issues. However, they require upfront premium payments and require a higher level of expertise to manage.

To assess whether these instruments are used as substitutes for IRS, we survey interest rate futures and swaption positions of public pensions on June 10, 2022 in an exercise similar to that described in Section 4. Unfortunately, duration data similar to the ENNs calculations are not available for the futures and swaptions in our sample, but the position size and direction data that are available provide useful insights.

Table 7 reports the results of this analysis. Panel A shows counts of pension plans holding positions in these instruments and breaks out counts for IRS Non-Users separately. 7 (8) of 153 (172) pensions in our core (extended) sample hold futures positions. 14 (25) of 153 (172) pensions in our core (extended) sample hold swaption positions. 4 (5) of the pensions in our core (extended) sample that hold futures positions also hold IRS positions, as do all of the swaption users. This suggests that few pensions that use interest rate futures do so because they are not able or willing to use IRS, and no pensions use swaptions for this reason. As we do not require pension characteristic data for the analyses in this section, we focus on the extended sample for the remainder of this discussion.

Panel B reports aggregate notional positions for both instruments. Aggregate gross notional futures positions for the extended sample are $30.093 B. These are predominately duration-extending positions, with $27.362 B being long. Aggregate gross notional swaption positions are much smaller, totaling $6.496 B. These are more evenly balanced, with $3.741 B long notional and $2.754 short notional.

Panels C and D report the distributions of the individual pension net notional positions in futures and swaptions respectively. For both instruments, mean net notional positions are small and medians are zero. For futures positions, no pensions are net short. The maximum net long position is less than $15 B.[33] For swaption positions, both net short and long positions are observed but no net positions are large. There are significant offsetting positions, and the aggregate net position across all pensions is $0.987 B.

Although we lack duration data for these instruments, we can make ballpark estimates of upper limits for their potential duration impacts for comparison with the pension duration hedging needs we estimated previously. The general approach we take is to assume the durations are all at the extreme long limits possible for these instruments. Starting with interest rate futures, these are generally futures on coupon-paying treasury bonds or notes. The longest duration actively-traded futures contracts is the CME's Ultra U.S. Treasury Bond contract, which has as a deliverable a U.S. Treasury bond with at least 25 years remaining to maturity. The underlying bond for this contract had a duration of 17.33 years on our sample date. After applying the conversion factor from the exchange and a forward delivery adjustment, this implies that each notional dollar of the futures contract gives approximately $5.75 of 5-year swap equivalents of duration.[34] Assume all interest rate futures positions in Table 7 are Ultra U.S. Treasury Bond contracts. Recall that the entire extended sample holds $30.093 B of gross futures notional, and the pension with the maximum net position holds less than $15 B net. Under these extreme assumptions, the duration of these futures positions in 5-year equivalents would be approximately $173.104 B for the extended sample and less than $86.284 B for the longest

[33] To ensure compliance with Section 8(a) of the CEA, we report inequalities rather than the exact minimums and maximums to represent bounds on positions in Table 7 and the related discussion. See FN (6).

[34] This calculation uses DV01 values from Bloomberg's HCTD screen for the September 2022 Ultra U.S. Treasury Bond contract traded on June 10, 2022 and from Bloomberg's Swap Manager screen for new 5-year IRS initiated on June 10, 2022.

individual pension. The estimate for the extended sample is very small compared to the duration hedging needs of the public pension universe estimated in Section 3. The estimate for the longest individual pension is on the order of magnitude of a typical pension's estimated hedging needs. While this is true for the maximum position size observed given the benefit of some extreme assumptions, this is not typical and the mean net pension futures position is less than $150 million.

Similarly, the most effective swaption to add duration to a portfolio would be a receiver swaption on a long maturity IRS with a delta of one, which is almost equivalent to a position in the swap itself. Assume all the swaption positions underlying Table 7 are high-delta positions in vanilla 30-year IRS, which is the longest duration vanilla IRS that is widely available (see the CFTC's "Swaps Made Available to Trade" or MAT list). Then each notional dollar of swaption would be approximately $4.37 of 5-year swap equivalents of duration.[35] Recall that the entire extended sample only holds $6.496 B of swaption notional, and the pension with the maximum net position holds less than $0.500 B. Under these extreme assumptions, the 5-year swap equivalents would be approximately $28.404 B and less than $2.186 B respectively. These are both very small compared to the public pension duration hedging needs estimated in Section 3.

While positions in both interest rate futures and swaptions are observed, they are used by a small portion of public pensions and their use is not concentrated in pensions that are unwilling or unable to use IRS. Further, in the cases where they are used, they are generally not of sufficient size to hedge a material part of a typical pension's duration risk.

[35] This calculation uses DV01 values from Bloomberg's Swap Manager screen for new 5-year and 30-year IRS initiated on June 10, 2022.

8. Conclusion

U.S public pension plans face interest rate risk due to their long duration liabilities and shorter duration assets and are widely believed to use IRS to hedge this risk. We estimate the magnitude of this duration risk and show that it is high. Using standard linear duration risk analysis techniques and characteristics of U.S. public pensions, we estimate that the universe would face economic losses of over $800 B for a 1% decrease in market interest rates. We describe our methodology in sufficient detail so that researchers with more granular data or preferring different assumptions can refine our estimates further. We also characterize the IRS positions that would be required to hedge this risk.

Next, we study regulatory data on pension IRS positions, and find that they are not being used to hedge a meaningful portion of pension duration risk. Most pension plans in our sample do not use IRS. Of those that do, position sizes are an order of magnitude smaller than their duration hedging needs, and many of their positions are in a direction that would increase their duration risk. We show that public pensions do not systematically use interest rate futures or swaptions as substitutes for IRS in duration hedging programs. We also analyze the determinants of public pension IRS usage and find no strong patterns, which is consistent with pensions using IRS for idiosyncratic reasons.

We analyze the public disclosures of the pensions identified as IRS Users in the regulatory data to assess the overall transparency of their IRS positions and the cross-sectional differences in transparency. We are particularly interested in whether stakeholders relying on public disclosures to understand their IRS positions and their use in duration hedging would be able to reach similar conclusions to those we reach using regulatory data. In most cases, the answer is no. Only 19 out of 64 identified IRS Users disclose sufficient information to roughly

estimate the impact of the IRS positions on their duration risk profiles, and 17 do not clearly disclose whether they hold IRS positions at all. We find that larger pensions and pensions with larger notional IRS positions are more likely to have higher IRS transparency. We find no relationship between the level of transparency and whether a pension's IRS positions are more consistent with duration hedging.

Assessing the positions of U.S. public pensions in the financial instruments that are most suitable to use to manage interest rate risk, we fail to find any evidence of systematic hedging programs. In the course of our extensive examination of U.S. public pension disclosure documents, we find no discussion of any systematic or structured interest rate risk management activities.[36] This is surprising given their large duration exposures, evidence reported elsewhere of extensive interest rate risk management conducted by other types of pensions, and models in the literature motivating their incentives to hedge.

The reasons for this apparent lack of hedging are not clear, but we note the following. Jansen et al. (2024) show that IRS hedging benefits Dutch pensions by reducing the volatility of their funding levels, and there are many arguments in the theoretical literature we cite motivating benefits of duration management or hedging. Greenwood and Vayanos (2010) and Jansen (2023) provide evidence that European pension funds alter their durations and IRS positions in response to changes in regulatory capital requirements and liability valuation policy. Boon, Brière, and Rigot (2018) document that U.S public pensions are less regulated in these dimensions compared to several peer corporate and foreign pension systems and find a strong association between the regulatory environment and pension risk appetite. Given this context, our evidence suggests that

[36] Many U.S. public pensions do disclose that they are permitted to use derivatives to hedge interest rate risk. However, we have not encountered claims that they materially or systematically do so in these documents.

the economic incentives for U.S. public pensions to hedge are not strong enough to overcome the lack of regulatory and accounting incentives to do so.

We review arguments in the literature regarding other factors that may reduce the incentives of pension funds to hedge or otherwise increase their risk appetite. While some of these factors constitute agency costs, others are inputs to optimal financial management decisions. We therefore refrain from making normative statements regarding the appropriate level of hedging. However, the lack of transparency around their derivatives positions hides these decisions from stakeholders and policymakers.

References

Adams, J. and Smith, D.J., 2009. Mind the gap: using derivatives overlays to hedge pension duration. *Financial Analysts Journal*, 65(4), pp.60-67.

Adams, J. and Smith, D.J., 2019. Fixed income analysis, 4th edn. CFA Institute investment series. John Wiley & Sons, Inc., Hoboken N.J.

Andonov, A., Bauer, R.M. and Cremers, K.M., 2017. Pension fund asset allocation and liability discount rates. *The Review of Financial Studies*, 30(8), pp.2555-2595.

Baker, L., Haynes, R., Roberts, J., Sharma, R. and Tuckman, B., 2021. Risk transfer with interest rate swaps. *Financial Markets, Institutions & Instruments*, 30(1), pp.3-28.

Benston, G.J. and Kaufman, G.G., 1997. FDICIA after five years. *Journal of Economic Perspectives*, 11(3), pp.139-158.

Bierwag, G.O. and Kaufman, G.G., 1985. Duration gap for financial institutions. *Financial Analysts Journal*, 41(2), pp.68-71.

Blackrock, 2004. Understanding Duration. Blackrock Industry Research Article. Available at: https://www.blackrock.com/fp/documents/understanding_duration.pdf

Bonsall IV, S.B., Comprix, J. and Muller III, K.A., 2019. State pension accounting estimates and strong public unions. *Contemporary Accounting Research*, 36(3), pp.1299-1336.

Boon, L.N., Brière, M. and Rigot, S., 2018. Regulation and pension fund risk-taking. *Journal of International Money and Finance* 84, 23-41.

Boubaker, S., Gounopoulos, D., Nguyen, D.K. and Paltalidis, N., 2018. Assessing the effects of unconventional monetary policy and low interest rates on pension fund risk incentives. *Journal of Banking & Finance*, 92, pp.340-357.

Brown, J.R. and Wilcox, D.W., 2009. Discounting state and local pension liabilities. *American Economic Review*, 99(2), pp.538-542.

Domanski, D., Shin, H.S. and Sushko, V., 2017. The hunt for duration: not waving but drowning? *IMF Economic Review*, 65, pp.113-153.

Earle, P.C., 2023. Silicon Valley Bank: Bespoke, Woke, and Restoked? American Institute for Economic Research Daily Economy News, March 13, 2023. Available at: https://www.aier.org/article/silicon-valley-bank-bespoke-woke-and-restoked/

Greenwood, R. and Vayanos, D., 2010. Price pressure in the government bond market. *American Economic Review* 100(2), 585-590.

Greenwood, R.M. and Vissing-Jorgensen, A., 2018. The impact of pensions and insurance on global yield curves. Harvard working paper.

Hanson, S.G., Malkhozov, A. and Venter, G., 2024. Demand-and-supply imbalance risk and long-term swap spreads. *Journal of Financial Economics*, 154, p.103814.

Jansen, K.A., 2023. Long-term investors, demand shifts, and yields. *The Review of Financial Studies*, forthcoming.

Jansen, K.A., Klingler, S., Ranaldo, A. and Duijm, P., 2024. Pension Liquidity Risk. Swiss Finance Institute Research Paper 24-16.

Kane, E.J. and Foster, C., 1986. Valuing conjectural government guarantees of FNMA liabilities. In *Proceedings: Conference on Bank Structure and Competition*.

Khetan, U., Neamțu, I., and Sen, I., 2023. The market for sharing interest rate risk: quantities behind prices. Bank of England Staff Working Paper No. 1,031.

Klingler, S. and Sundaresan, S., 2019. An explanation of negative swap spreads: Demand for duration from underfunded pension plans. *The Journal of Finance*, 74(2), pp.675-710.

Khumawala, S., Ranasinghe, T. and Yan, C.J., 2016. Why hedge? Extent, nature, and determinants of derivative usage in US municipalities. *Journal of Accounting and Public Policy*, 35(3), pp.303-325.

Lu, L., Pritsker, M., Zlate, A., Anadu, K. and Bohn, J., 2019. Reach for yield by US public pension funds. Federal Reserve working paper.

McPhail, L., Schnabl, P. and Tuckman, B., 2023. Do Banks Hedge Using Interest Rate Swaps? National Bureau of Economic Research Working Paper No. w31166.

Mohan, N. and Zhang, T., 2014. An analysis of risk-taking behavior for public defined benefit pension plans. *Journal of Banking & Finance*, 40, pp.403-419.

Novy-Marx, R. and Rauh, J.D., 2009. The liabilities and risks of state-sponsored pension plans. *Journal of Economic Perspectives*, 23(4), pp.191-210.

Novy-Marx, R. and Rauh, J., 2011. Public pension promises: how big are they and what are they worth? *The Journal of Finance*, 66(4), pp.1211-1249.

Palacios, S.I.S. and Patel, K.B., 2023. UK Pension Market Stress in 2022 -Why it happened and implications for the U.S. Chicago Fed Letter 480.

Pennacchi, G. and Rastad, M., 2011. Portfolio allocation for public pension funds. *Journal of Pension Economics & Finance*, 10(2), pp.221-245.

Public Plans Data. 2001-2018. Center for Retirement Research at Boston College, Center for State and Local Government Excellence, and National Association of State Retirement Administrators, https://publicplansdata.org.

Rauh, J.D., 2017. Hidden debt, hidden deficits: How pension promises are consuming state and local budgets. Hoover Institution Essay.

Seiler, R.S., 2003. Market Discipline of Fannie Mae and Freddie Mac. Federal Housing Finance Agency Working Paper No. 03-04.

Siokis, F., 2023. Silicon Valley Bank failure explained. The City University of New York Economic Studies Group Analysis Articles, March 28, 2023. Available at: https://esg.gc.cuny.edu/2023/03/28/silicon-valley-bank-failure-explained/.

Figure 1

Time Series of Public Pension IRS Gross Notional Positions. The graph below shows the gross notional interest rate swap positions of municipal pension funds available in the CFTC Part 45 swap data from January 2014 through June 2022. The entities in this graph include all those identified as municipal pensions during this time period. The chart shows gross notional for this market segment increased from $20 billion in 2014 to roughly $60 billion in 2018. Gross notional declined to approximately $50 billion in 2020 then remained approximately flat for the remainder of the sample period.

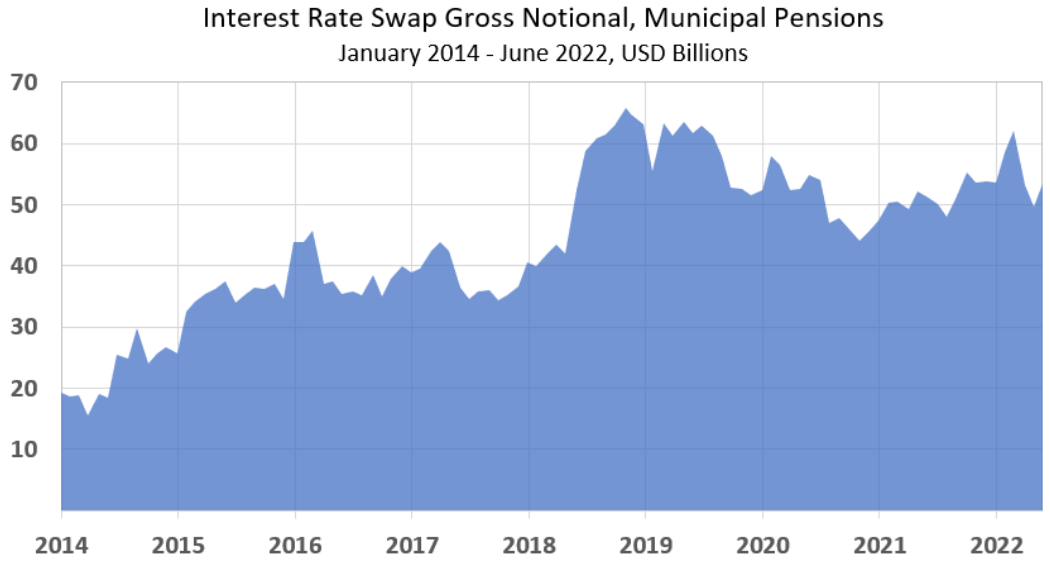

Figure 2

Examples of High and Low Transparency IRS Disclosures from Public Pensions. This figure provides excerpts from public pension disclosures categorized by level of transparency of IRS positions under the coding process discussed in Section 6. The coding criteria is whether the public disclosures are sufficient to determine whether the pension uses IRS and to estimate their effect on duration risk. The sources are the CAFR documents retrieved from the pensions' websites. Panel A provides a representative example of an IRS disclosure that coded as "High Transparency." Panel B provides a representative example of an IRS disclosure that coded as "Low Transparency."

Panel A. High Transparency IRS Disclosure Example

Investment derivatives disclosure

(dollars in thousands)

Derivative instruments	Net change in fair value for the fiscal year ended June 30, 2021	Fair value	Notional amount[1]
...			
Swaps			
Commodity forward swaps	119,544	13,289	(1,112,826) units
Credit default swaps bought	(13,439)	–	–
Credit default swaps written	10,535	24,103	680,109
Pay-fixed interest rate swaps	10,558	7,933	229,956
Receive-fixed interest rate swaps	(4,889)	(127)	330,732

Panel B. Low Transparency IRS Disclosure Example

		2021 Fair Value Measurements		
	6/30/2021	Quoted Prices in Active Markets (Level 1)	Significant Other Observable Inputs (Level 2)	Significant Unobservable Inputs (Level 3)
Investments by Fair Value Level				
...				
Investment Derivatives				
Futures	$ (17,816)	$ (17,816)	$ -	
Foreign Exchange Contracts	1,437,736	-	1,437,736	
Options	19,745	-	19,745	
Swaps	(238,140)	-	(238,140)	

Table 1

Public Pension Plan Summary Statistics. This table reports summary statistics for key characteristics of the core sample of public pension plans. The data source is the Center for Retirement Research at Boston College Public Plans Database (PPD). The sample includes all pension plans with a PPD record meeting the filtering requirements described in the text. Characteristics are measured from the latest available record before June 10, 2022. ASSETS and LIABILITIES are GASB actuarial values of plan assets and liabilities. FUND_RATIO_ACT is the plan actuarial funding ratio, where a value of 1 indicates full actuarial funding. BENEFICIARIES counts the total plan beneficiaries. RETURN_ASSUMPTION is the actuarial expected return on the pension's investment portfolio. ACTIVES_RATIO is the ratio of the plan's active members to total beneficiaries. CLOSED is an indicator variable that takes a value of 1 when the plan is closed to new employees of the sponsor and 0 otherwise. SINGLE_EMPLOYER is an indicator variable that takes a value of 1 when the plan sponsored by a single employer and 0 otherwise. FIXED_INCOME is the portion of the plan's investment portfolio allocated to fixed income investments. RET_1YR_LAG1 and RET_5YR_LAG1 are the 1-year and 5-year returns of the plan's investment portfolio lagged by one year.

	N	Sum	Mean	Std.	Min.	P25	Med.	P75	Max.
ASSETS ($M)	153	3,308,177	21,622	46,949	24	1,236	4,616	20,976	391,381
LIABILITIES ($M)	153	4,481,959	29,294	62,423	61	1,965	6,463	27,034	554,679
FUND_RATIO_ACT	153		0.7327	0.1808	0.1223	0.6410	0.7430	0.8378	1.1790
RETURN_ASSUMPTION	153		0.0706	0.0041	0.0425	0.0700	0.0700	0.0725	0.0825
BENEFICIARIES	150	7,786,831	51,912	96,362	183	3,986	10,537	57,465	732,529
ACTIVES_RATIO	149		1.1311	0.4935	0.1074	0.8724	1.0750	1.3004	5.4076
CLOSED	153	8	0.0523	0.2233	0	0	0	0	1
SINGLE_EMPLOYER	153	73	0.4771	0.5011	0	0	0	1	1
FIXED_INCOME	122		0.2275	0.0685	0.0290	0.1763	0.2271	0.2696	0.5272
RET_1YR_LAG1	153		0.0641	0.0628	-0.0390	0.0193	0.0450	0.0730	0.2100
RET_5YR_LAG1	153		0.0633	0.0125	0.0080	0.0561	0.0630	0.0706	0.1044

Table 2

Public Pension Plan Duration Risk Estimates. This table presents duration risk estimates for public pension plans in the core sample and for the universe of U.S. public pension plans. Panel A presents estimates for a hypothetical representative plan matching mean key characteristics from the core sample plans. Panel B presents estimates for total duration risk of the core sample plans. Panel C extrapolates similar estimates for the universe of U.S. public pension plans. Asset and Liability dollar values are retrieved/calculated from the Center for Retirement Research at Boston College Public Plans Database (PPD) and the Federal Reserve's State and Local Government Pension Funding Status table. Asset durations are estimated using PPD data, and liability durations are estimated using Fig. 5 from Novy-Marx and Rauh (2011). 5-year Eq. (five-year swap equivalents) is the notional amount of 5-year vanilla interest rate swaps with the same dollar duration as the estimated exposure of the Asset/Liability/Equity. 5-year Eq. is calculated using the DV01 from Bloomberg's Swap Manager screen for a new 5-year swap initiated on the sample date (June 10, 2022). The Equity 5-year Eq. is also the notional amount of a 5-year vanilla interest rate swap required to immunize the estimated duration risk for the plan or group of plans, and a negative value indicates a receive-fixed position in the offsetting swap. Further details on the estimation methodology are provided in the text.

	Value ($ millions)	Mean Duration (yrs)	Duration$ (millions)	5-year Eq. ($ millions)
Panel A: Hypothetical Representative Public Pension Plan				
Assets	21,622	1.27	27,546	6,001
Liabilities	29,510	12.50	368,875	80,365
Equity	-7,888	43.27	-341,329	-74,364
Panel B: Core Sample Public Pension Plan Totals				
Assets	3,308,177	1.27	4,214,617	918,217
Liabilities	4,515,049	12.50	56,438,115	12,295,886
Equity	-1,206,873	43.27	-52,223,498	-11,377,668
Panel C: U.S. Public Pension Plan Universe Totals				
Assets	5,137,800	1.27	6,545,557	1,426,047
Liabilities	7,012,147	12.50	87,651,836	19,096,260
Equity	-1,874,347	43.27	-81,106,278	-17,670,213

Table 3

Public Pension Plan Interest Rate Swap Positions. This table reports interest rate swap (IRS) positions for the core and extended samples of public pension plans. IRS positions are from CFTC ENNs data and are measured on June 10, 2022. Panel A reports counts of plans categorized by IRS positions. Plans holding IRS positions are categorized as IRS users, and subcategories are defined based on each plan's position size as measured by notional or five-year swap equivalents. Plans are categorized as Net Long (Net Short) if their net five-year swap equivalents positions are long (short) duration. Plans are categorized as Spreaders if they hold individual IRS positions with a mix of long and short durations. Panel B reports IRS gross, long, and short notional positions aggregated across plans. Panel C reports the distribution of plans' net IRS positions measured in five-year swap equivalents. Panel D reports the distribution of the ratios of plans' net IRS positions to their GASB actuarial liability values. Distributions in Panels C and D are conditional on using swaps. We report inequalities in place of exact minimum and maximum values and exclude percentile statistics to ensure compliance with Section 8(a) of the CEA (see FN (6)).

	Core Sample	Extended Sample
Panel A: Plan Counts		
All	153	172
IRS Users	43	62
IRS Gross Notional > $500M	11	15
Net Long	17	26
Net Long Spreaders	10	17
Net Short	26	36
Net Short Spreaders	18	25
Panel B: Aggregate IRS Notional Positions ($ millions)		
Gross	20,477	28,979
Long	10,701	14,398
Short	9,776	14,582
Panel C: IRS 5-year Eq. Positions ($ millions)		
Aggregate	-1,002	-1,156
Mean	-23	-19
Std.	160	137
Min.	>-500	>-500
Max.	<500	<500
Panel D: IRS 5-year Eq. Positions / Plan Liability		
Mean	0.0009	
Std.	0.0152	
Min.	>-0.05	
Max.	<0.10	

Table 4

Public Pension Plan IRS Transparency Analysis. This table reports counts, characteristics, and interest rate swap (IRS) positions for a sample of public pension plans holding positions in IRS and classified into High, Medium, and Low Transparency categories. Details on the classification procedure are provided in Section 5 and Appendix A. High Transparency pensions disclose IRS positions sufficient for estimating their impacts on the pension's interest rate risk profile. Medium Transparency pensions clearly disclose the existence of IRS positions but lack sufficient details to estimate interest rate exposure effects. Low Transparency pensions do not disclose sufficient information to determine whether IRS positions are held. Differences in means across High and Low Transparency pensions and t-statistics of tests of the null hypothesis that means are equal across categories are reported. T-statistics are in parenthesis and differences statistically significant at the 10% level or lower are bolded. IRS positions are from CFTC ENNs data and are measured on September 11, 2020. Transparency classification is based on hand-collected CAFRs for the reporting periods covering the sample date. Fund characteristics are from the Center for Retirement Research at Boston College Public Plans Database (PPD) for the reporting periods covering the sample date. Panel A reports results for the core sample. Panel B reports results for the extended sample.

	Disclosure Category			
	High	Medium	Low	High-Low
Panel A - Core Sample				
Plan Counts	13	17	14	
Aggregate Plan Liability ($M)	1,179,075	843,698	293,918	
Aggregate IRS Gross Not. ($M)	6,411	6,880	3,047	
Category Means:				
Plan Liability ($M)	90,698	49,629	20,994	**69,704**
				(2.65)
Funded Ratio	0.723	0.679	0.766	-0.0431
				(-0.65)
IRS Gross Not./Plan Liability	0.0072	0.0243	0.0217	-0.0145
				(-0.95)
IRS Net Not./Plan Liability	-0.0007	-0.0007	0.0023	-0.0030
				(-1.45)
IRS 5-year Eq. Positions/Plan Liability	-0.0005	0.0005	-0.0042	0.0036
				(0.42)
Panel B - Extended Sample				
Plan Counts	19	28	17	
Aggregate IRS Gross Not. ($M)	10,576	15,482	3,197	
Category Means:				
IRS Gross Not. ($M)	557	553	188	**369**
				(1.77)
Swap Net Not. ($M)	-106	-9	111	-216.7
				(-0.53)
IRS 5-year Eq. Positions ($M)	-95	-34	-19	-75.9
				(-1.24)

Table 5

Comparison of Characteristics of Public Pension Plans Between IRS Users and Non-Users. This table reports comparisons of key characteristics of public pension plans across IRS Users and Non-Users. IRS Users (Non-Users) are pensions holding (not holding) IRS positions as of the sample date of June 10, 2022. IRS positions are from CFTC ENNs data. Merged characteristics are from the Center for Retirement Research at Boston College Public Plans Database (PPD) as of the latest available record before the sample date. LIABILITIES are GASB actuarial values of plan liabilities. FUND_RATIO_ACT is the plan actuarial funding ratio, where a value of 1 indicates full actuarial funding. RETURN_ASSUMPTION is the actuarial expected return on the pension's investment portfolio. FIXED_INCOME is the portion of the plan's investment portfolio allocated to fixed income investments. CLOSED is an indicator value that takes a value of 1 when the plan is closed to new employees of the sponsor and 0 otherwise. SINGLE_EMPLOYER is an indicator value that takes a value of 1 when the plan sponsored by a single employer and 0 otherwise. ACTIVES_RATIO is the ratio of the plans active members to total beneficiaries. RET_1YR_LAG1 and RET_5YR_LAG1 are the 1-year and 5-year returns of the plan's investment portfolio lagged by one year. Differences in means across Users and Non-Users and t-statistics of tests of the null hypothesis that means are equal across categories are reported. T-statistics are in parenthesis and differences statistically significant at the 10% level or lower are bolded.

	Users	Non-Users	Diff	t(Diff)
N	43	110		
LIABILITIES ($M)	45,140	23,099	**22,040**	**1.98**
FUND_RATIO_ACT	0.7531	0.7248	0.0283	0.87
RETURN_ASSUMPTION	0.0704	0.0707	-0.0003	-0.51
FIXED_INCOME	0.2117	0.2350	**-0.0233**	**-1.77**
CLOSED	0.0233	0.0636	-0.0403	-1.22
SINGLE_EMPLOYER	0.4419	0.4909	-0.049	-0.54
ACTIVES_RATIO	1.0862	1.1493	-0.0631	-0.87
RET_1YR_LAG1	0.0558	0.0673	-0.0115	-1.02
RET_5YR_LAG1	0.0641	0.0629	0.0012	0.55

Table 6

Public Pension Plan IRS Usage Regressions. The regression models are variations of:

$$IRS\_Usage\_Measure_i = \beta_0 + \beta_1 LIABILITIES_i + \beta_2 FUND\_RATIO\_ACT_i + \beta_3 RETURN\_ASSUMPTION_i + \beta_4 CLOSED_i + \beta_5 RET\_1YR\_LAG1_i + \beta_6 RET\_5YR\_LAG1_i$$

where i indexes pensions. $IRS\_usage\_measure_i$ is one of the pension's IRS gross notional, IRS gross notional divided by the pension's LIABILITIES, the pension's IRS 5-year swap equivalents, or the pension's IRS 5-year swap equivalents divided by the pension's LIABILITIES. LIABILITIES are GASB actuarial values of plan liabilities. FUND_RATIO_ACT is the plan actuarial funding ratio, where a value of 1 indicates full actuarial funding. RETURN_ASSUMPTION is the actuarial expected return on the pension's investment portfolio. CLOSED is an indicator value that takes a value of 1 when the plan is closed to new employees of the sponsor and 0 otherwise. SINGLE_EMPLOYER is an indicator value that takes a value of 1 when the plan sponsored by a single employer and 0 otherwise. ACTIVES_RATIO is the ratio of the plans active members to total beneficiaries. RET_1YR_LAG1 and RET_5YR_LAG1 are the 1-year and 5-year returns of the plan's investment portfolio lagged by one year. We estimate the models with OLS. IRS positions are from CFTC ENNs data as of the sample date of June 10, 2022. Pension plan characteristics are from the Center for Retirement Research at Boston College Public Plans Database (PPD) as of the latest available record before the sample date. T-statistics are in parenthesis and are tests of the hypothesis that the true value of the coefficient is zero. Coefficients statistically significant at the 10% level or lower are bolded.

Model	1	2	3	4
Dependent Variable	IRS Gross Notional ($M)	IRS Gross Notional / LIABILITIES	IRS 5-year Eq. ($M)	IRS 5-year Eq./ LIABILITIES
Intercept	-1171.68	-0.07	-132.90	-0.01
	(-1.32)	(-1.36)	(-0.94)	(-0.49)
LIABILITIES (x 1M)	**1.46**	0.00	-0.20	0.00
	(1.92)	(0.18)	(-1.62)	(-0.05)
FUND_RATIO_ACT	29.53	0.02	33.11	0.00
	(0.11)	(1.44)	(0.79)	(0.59)
RETURN_ASSUMPTION	16775.00	0.83	1665.02	0.15
	(1.39)	(1.21)	(0.87)	(0.86)
CLOSED	**686.47**	**0.03**	22.61	0.00
	(2.72)	**(2.22)**	(0.56)	(0.58)
SINGLE_EMPLOYER	-26.41	0.01	10.52	0.00
	(-0.25)	(1.18)	(0.63)	(0.58)
ACTIVES_RATIO	-45.15	0.00	12.025	0.00
	(-0.45)	(-0.47)	(0.75)	(0.29)
RET_1YR_LAG1	**-1550.37**	-0.06	-6.81	-0.01
	(-1.82)	(-1.15)	(-0.05)	(-1.18)
RET_5YR_LAG1	2977.49	0.04	-454.71	-0.10
	(0.69)	(0.18)	(-0.67)	(-1.49)
N	149	149	149	149
R-Square	0.1078	0.0796	0.0477	0.0544
Adj. R-Square	0.0568	0.027	-0.0068	0.0003

Table 7

Public Pension Plan Interest Rate Futures and Swaptions Positions. This table reports interest rate futures and swaptions positions for the core and extended samples of public pension plans in. Both interest rate futures and swaptions positions are from CFTC data and are measured on June 10, 2022. Panel A reports counts of plans categorized by futures and swaptions positions and their relationship to interest rate swap usage. Panel B reports gross, long, and short notional positions aggregated across plans for interest rate futures and swaptions. Panel C reports the distribution of plans' net interest rate futures positions. Panel D reports the distribution of plans' net swaptions positions. We report inequalities in place of exact minimum and maximum values and exclude percentile statistics to ensure compliance with Section 8(a) of the CEA (see FN (6)).

	Core Sample	Extended Sample
Panel A: Plan Counts		
All	153	172
Futures Users	7	8
Futures Users with No Swaps	3	3
Swaptions Users	14	25
Swaptions With No Swaps	0	0
Panel B: Aggregate Notional Positions ($ millions)		
Futures Gross	28,130	30,093
Futures Long	25,399	27,362
Futures Short	2,731	2,731
Swaptions Gross	4,233	6,496
Swaptions Long	2,543	3,741
Swaptions Short	1,691	2,754
Panel C: Futures Net Notional Positions ($ millions)		
Aggregate	22,668	22,668
Mean	148	143
Std.	1,163	1,106
Min.	>= 0	>= 0
Max.	<15,000	<15,000
Panel D: Swaptions Net Notional Positions ($ millions)		
Aggregate	852	987
Mean	6	6
Std.	35	49
Min.	>-500	>-500
Max.	<500	<500

Appendix A: Pension IRS Disclosure Analysis Coding Procedure

[Note: An iterative version of this document was used by the research team in the data collection process and this version reflects the rules used for the final sample. Additional notes to the reader are added in italics.]

1) Start with list of public pension plans identified as IRS Users as of 9/11/2020 (the "data collection spreadsheet"). This has been prepopulated with links to pension websites and disclosure documents where possible. *[The data collection spreadsheet cannot be included in this manuscript, as it would reveal the list of IRS users from confidential regulatory data.]*

2) Retrieve the pensions disclosure document covering the sample date. The disclosure document is the pension's CAFR – preferably a document specific to the fund/plan but sometimes from the parent system or municipality.

    a. Choose CAFR with earliest date after 9/11/2020. If the pension has no CAFR after this date record as missing.

    b. Record the CAFR date in the data collection spreadsheet.

    c. Save the link to CAFR in spreadsheet.

    d. Most pensions in the IRS User sample already have links to the CAFR in the data collection spreadsheet. When these are missing, they can usually be found on the BCCRR PPD website. In a few cases they may require a web search for the plan sponsor or a parent entity.

3) Identify relevant material with keyword searches for "derivative", "swap", "hedg", and "interest rate risk" and review.

4) Identify transparency category classification and record data collection spreadsheet. Classification rules are:

    a. <u>High Transparency</u>- Disclosure of interest rate swap positions with sufficient detail to estimate the impact of the pensions interest rate swap positions on its interest rate risk profile. Disclosure at the individual swap level is common but not necessary – aggregated values are sufficient. Most disclosures seem to be in table format but this is not necessary, a pension still qualifies for this category if it reports aggregated positions in the text. The two criteria required for this determination are disclosure of IRS position sizes and directions. [*In principle, the highest level of disclosure would involve some form of durations or at least notionals in various maturity buckets. Based on an initial inspection of the data, this standard would only be met by a very small number of pensions so the less*

strict criteria is used here. Most of the pensions in this category require significant assumptions to estimate their IRS interest rate exposures, and it may only be possible to estimate fairly wide ranges of exposures.]

i. To be included in this category, there must be disclosure of the size of the pension's IRS positions. Size is generally expressed in notional dollar amounts. If any sample funds use other measures (i.e. duration dollars or 5-year swap equivalents) to convey equivalent or superior information, code them as providing size disclosures and add these measures to this paragraph. [*Note: this was not encountered*]. Fair values are not sufficient, as fair values do not provide information on interest rate exposure.
ii. To be included in this category, there must be directional disclosure. Directional disclosure is defined as designating positions (individually or aggregated) as "long" or "short", "pay-fixed" or "receive-fixed", or "payer" or "receiver". Dividing IRS positions into assets and liabilities does not convey this information without additional context. Directional fair values are not considered informative, only directional notional amounts. If any sample funds use other terminology or measures to convey this information, code them as directional disclosures and modify this paragraph. [*Note: this was not encountered*]

b. Medium Transparency - Disclosure of the existence of interest rate swaps but insufficient detail to estimate interest rate risk impact. Pensions clearly disclosing that they currently use interest rate swaps but not meeting criteria to be classified as High Transparency. The relevant information may be in text or tables. Disclosures too general to be informative are excluded from this category. These are generally cases where positions in a more general category of swaps or derivatives that may or may not include interest rate swaps are disclosed. Examples include "Swaps" and "Swaps-Domestic," as the positions could be interest rate swaps or could instead be total return swaps, CDS, commodity swaps, etc. Pensions disclosing that they or their subadvisors are permitted to use interest rate swaps but not whether they in fact have positions in the period covering 9/11/2020 are not classified in this category.

c. Low Transparency - All pensions that do not meet the criteria for High or Medium Transparency categories. It is not possible to determine whether these pensions hold IRS from their disclosures. This category includes pensions that do not specifically mention interest rate swaps in their disclosures. These may be cases where there is no swap usage disclosed or where disclosures are too general to be informative. This category also includes pensions disclosing that they or their subadvisors are permitted to use interest rate swaps but not whether they in fact have positions in the period covering 9/11/2020. Finally, pensions not releasing CAFRs covering this period as of our cutoff date 5/24/2022 will be

included in this category – check for updates through this date and then consider the classification final.

Appendix B: Explanatory Variables used in Analysis of the Empirical Determinants of Pension IRS Usage

The explanatory variables we use for the analysis in Section 6 and their motivations are as follows. First, we include the plan's liabilities (LIABILITIES) as a measure of the plan's size. Khumawala, Ranasinghe, and Yan (2016) argue that larger municipalities are more likely to use derivatives as perhaps smaller entities do not have sufficient resources to manage a derivatives program, and find empirical support for this hypothesis. Pennacchi and Rastad (2011), Mohan and Zhang (2014), and Adonov, Bauer and Cremers (2017) find that pension size is positively related to risk-taking. Bonsall, Comprix, and Muller (2019) argue that larger funds may receive greater scrutiny from the public.

Our second explanatory variable is the plan's actuarial funding ratio (FUND_RATIO_ACT). This is a ratio of the plan's assets to liabilities. The Klingler and Sundaresan (2019) model and empirical evidence suggest that pensions with lower funding ratios use more interest rate swaps as fixed-income substitutes due to their lower capital requirements. Mohan and Zhang (2014) present competing hypotheses that suggest a pension's propensity to take risk could be either positively (the "risk management hypothesis") or negatively related to funding status (the "risk transfer hypothesis"), and find empirical evidence of a negative relationship. Pennacchi and Rastad (2011), Adonov, Bauer and Cremers (2017) and Lu et al (2019) report similar results.

Our third explanatory variable is the plan's liability discount rate (RETURN_ASSUMPTION). Pennacchi and Rastad (2011), Mohan and Zhang (2014) and Adonov, Bauer and Cremers (2017) present hypotheses and supporting empirical evidence for a positive relationship between a pension's propensity to take risk and its liability discount rate. Bonsall, Comprix, and Muller (2019) find that discount rates are influenced by political

considerations, and we conjecture that these considerations could also influence risk taking or IRS usage.

Our fourth explanatory variable is the plan's investment portfolio's allocation to fixed income (FIXED_INCOME). Klingler and Sundaresan (2019) argue that pensions have a structural desire to add duration, and that fixed income securities or IRS are substitutes for this purpose. Fixed income allocations may also proxy for risk appetite. The logic is that pensions with higher risk appetites will have lower fixed income allocations to free up more capital to invest in risker asset classes with higher expected returns. Mohan and Zhang (2014), Boubaker et al. (2017), Adonov, Bauer and Cremers (2017), and Bonsall, Comprix, and Muller (2019) take this perspective.

Our fifth explanatory variable is an indicator variable that takes a value of 1 when a pension plan is closed to new employees of the sponsor and 0 otherwise (CLOSED). A plan that is closed to new participants is likely to have a shorter investment horizon, which presumably lowers its risk capacity. We are not aware of prior studies that use this variable.

Our sixth explanatory variable is an is an indicator variable that takes a value of 1 when the plan is sponsored by a single employer and 0 otherwise (SINGLE_EMPLOYER). A plan that serves multiple employers is likely to have higher coordination and monitoring costs when attempting to use IRS as part of a risky investment strategy. A plan that serves multiple employers may also find it more difficult to craft a hedging strategy that suits all stakeholders. We are not aware of prior studies that use this variable.

Our seventh explanatory variable is the ratio of a plans' active (working) members to total beneficiaries (ACTIVES_RATIO). Similar to the arguments for including CLOSED, a plan that servers more active workers is likely to have a longer investment horizon, which presumably

increases its risk capacity and appetite. Mohan and Zhang (2014), Adonov, Bauer and Cremers (2017), and Bonsall, Comprix, and Muller (2019) find empirical evidence that the opposite is true. Adonov, Bauer and Cremers (2017) attribute this effect to regulatory incentives.

Finally, we include measures of the plan's investment portfolios lagged returns over one and five years (RET_1YR_LAG1 and RET_5YR_LAG1). Following prior literature, we lag these returns by one additional year. Mohan and Zhang (2014) find that pensions increase risk after low returns, which they argue is evidence for a "risk transfer hypothesis" where pensions shift risks to future taxpayers as their funding status deteriorates. Boubaker et al. (2017) also find similar results for a subsample of pensions with poor funding status.