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Overperformance of The Underfunded: An Analysis of Pension Funds' Portfolio Choice

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ABSTRACT

Pensions are an attractive benefit most commonly offered to state and municipal employees that promise guaranteed income for life upon retirement. However, a troubling trend of reduced funding has left many public pension funds with future obligations that far exceed their accumulated assets, causing doubt amongst public workers that their promised retirement income is secure. Pension fund managers are tasked with deploying an investment strategy that preserves and increases the value of contributed assets. Using mean-variance optimization and the Sharpe ratio, my research suggests that through diversification and strategic changes in portfolio composition, underfunded pensions outperform their fully funded counterparts on a risk-adjusted return basis.

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Introduction

In 1911, Massachusetts was the first state to offer a pension plan to its state employees. By 1929, there were just six public pension funds available in the United States (Clark et al., 2003). In 2022, 4,632 defined benefit state and local pension plans were available to civil service employees (U.S. Census Bureau, 2022). With just over $5.3 trillion in assets, public pensions are the largest institutional investor and control the retirement compensation for 12 million current retirees and almost 25 million active workers in the public sector (Public Plans Data). In return for their dedicated service and loyalty to the state government, pension plans offer guaranteed income for life and financial security long after retirement. Recently, however, there has been a large downward shift in the number of plans and participants in both the private and public sector pensions. It is estimated by the end of the 2023 fiscal year, state pension funds will incur $1.3 trillion in unfunded liabilities (Christensen, 2023).

Public pensions are the livelihood of millions of American citizens, and their retirement benefits rely on the full contributions of their employer and the strong investment performance of the pension administrators to guarantee the solvency of their retirement savings. With the widespread depletion of contributions from employers, many current public employees are left to wonder if they will be receiving the defined benefits at their time of retirement. However, it is not just the future beneficiaries that need to worry about pension insolvency; it is also a concern for policy makers and the taxpayers. Bankrupt pension funds become a liability of the American taxpayer.

The goal of this research is to measure the performance of underfunded pension funds to discover if their change in investment behavior is different than that of fully funded pensions. Literature exists on pension funds' investment performance through different cycles of the stock market, with significant empirical research focused on the adverse impacts of the Great Recession on public pensions. Additionally, significant research is focused on how public pensions lose funding in general, mainly through changes in policy or budget cuts. However, a gap in literature exists that specifically analyzes the change in portfolio composition of underfunded pensions. A pension fund that has a greater amount of future liabilities than it does current assets is going to institute a different investment strategy than a pension that is financially stable. This paper aims to understand and analyze how pension fund's portfolio management style and behavior react to different levels of funding.

By using public pension asset allocation data and modern portfolio theory, I hope to find if there is a noticeable difference in the strategies deployed by the investment managers of these two distinct groups of pensions: funded and underfunded. Additionally, if a new investment strategy is implemented by a struggling pension, does it perform better, on average, than a fully funded pension? My hypothesis is that underfunded pension funds will improve their investment performance by making significant changes to their portfolio composition, while fully funded pensions will choose to stay committed to their long-term strategies.

Motivation

My mother, Lynne Eisel, has been a public-school teacher in the Altoona Area School District for 27 years. At the beginning of her career, public education was a highly respected profession in the local community and was heavily sought after for the pension that was available upon retirement. However, in the past 27 years, her pension, the Pennsylvania Public School Employees Retirement System, has become riddled with debt due to long periods of reduced employer contributions. The predictability of her retirement benefits in the short run is less worrisome, but to the nature of defined benefit pensions, her guaranteed income for life, paid from an underfunded source, raises some concern. Today, new hires of the Altoona Area School District are not even offered pensions for their service to the community.

My grandfather, Wayne Eisel Sr, although not a public service worker, was a loyal employee of Butterick in Altoona, PA. A printing company that specialized in the production of patterned fabrics. For his 35 years of service, he was offered a private pension fund upon retirement, but due to lack of funding and employer contributions, his once guaranteed monthly retirement income has dropped by more than 40% in value. Although private pensions are not the scope of this research, it is still alarming to see how impactful underfunded pensions can be on a retiree's life.

My passion for portfolio management and investment advisory molded well to the topic of pension funds. Tomorrow's benefit is created by today's decision-making, and the importance of how investment managers handle the nationwide reduction in funding for public pensions is crucial to the support and sustainability of these once-thriving retirement options.

Related Literature

3.1 Background

The focus of this paper surrounds pension fund managers' portfolio rebalancing choices during different states of funding. Asset allocation of a pension fund is a key determinant in the success of the pension fund during different market conditions (Government Finance Officers Association, 2009). In fact, Brinson et al. (1986) estimated that 95.3% of investment returns can be explained by just the composition of a portfolio. The return on these investments is also the leading contributor to the growth and solvency of pensions. "…between 1993 and 2018, about 25 percent of public pension fund receipts came from employer contributions, 11 percent from employee contributions, and about 64 percent from investment earnings" (Doonan and Kenneally, 2021, p. 4). This fact highlights the importance of pension fund managers' asset allocation choices and, even further, their response to a funding crisis.

3.2 The Nature of Underfunded Pensions

The absence of strict federal or state legislation that requires public employers to make whole on their annual required contributions to public pensions is one of the main reasons that state retirement accounts become underfunded in the first place. For example, when state policymakers are looking to make budget adjustments, pension funds are usually the first expense to be reduced, as very rarely are pensions with unfunded liabilities at risk of default in the short term (Thom and Randazzo, 2015). It is these same pension funds that represent the largest financial liability of state and municipal governments (Giesecke and Rauh, 2023).

Policymakers must trade long-term contributions for short-term budget corrections and deal with the issue of underfunding in the future. This reaction works much in the same way that consumers may choose to substitute savings for immediate consumption. Evidence reported by Thom and Randazzo (2015), suggested that fully paid annual contributions to pensions are more likely from states that have smaller long-term funding disparities. Since 2008 and in response to widespread depleting contributions, almost every state has passed reforms to their pension plans to increase funding, but today, most Americans feel they are not on the path to a financially stable retirement (Doonan and Kenneally, 2021) In 2021, states reported that only $0.82 cents had been set aside for every $1 of future benefit to be paid, netting the highest statewide average funding ratio since the Great Recession (The Pew Charitable Trusts, 2023).

3.3 Assessing Performance

Measuring the risk and return of an overall portfolio can be quite complicated but is paramount in understanding the success or failure of a pension fund's portfolio rebalancing choice. Pennacchi and Rastad (2011, p. 222) tracked the risk of a pension fund by measuring the volatility of the portfolio's tracking error. A term they define as "portfolio allocations that deviate from the benchmark portfolio." Lu, et al. (2019) analyzed pensions using a value-at-risk (VaR) model[1] to measure the minimum potential loss, which accounts for a comprehensive measurement of risk across time. However, this model has complications because the data is not time-synchronous and can lead to mismeasurements depending on when asset allocations were

[1] A VaR model, like the one used in this paper, is another way to empirically measure possible investment loss over a defined time

measured. Both papers' methodologies share a streamlined process of measuring expected returns. Expected return can be measured by averaging the historically observed values of the asset classes present in a pension fund's investment allocation. Then, one will be able to reasonably assume that a certain asset class will return to its historical average.

One can assess the performance of a pension fund's asset allocation choice by benchmarking the fund's performance against a portfolio that best reduces and hedges the risk of its liabilities (Pennacchi and Rastad, 2011). The liabilities of a pension fund are formal financial obligations, in the form of retirement annuities, that the fund must disperse to its beneficiaries, who are usually retirees of state and local municipalities. In practice, a pension fund must invest its contributions and earn a return that is large enough to cover, in the case of a defined benefit plan, its fixed payout to the retiree. In the 1950s, pension funds were mainly comprised of almost all fixed-income securities but have since largely shifted to a basket of diversified assets, including real estate, hedge funds, private equity, and equities (Pennacchi, Rastad, 2011). However, finding the optimal level of these securities that will be able to defend against market risk while providing a stable level of return great enough to cover the liabilities is an extremely difficult task. To highlight the complexities of finding the optimal portfolio asset allocation, we can examine two specific pension fund catastrophes. In the 1980s, The City of San Jose and the West Virginia Consolidated Investment Fund incurred disastrous collapses of their fund's financial health when public officials tried to position their portfolio's composition to take advantage of interest rate speculation (Stalebrink et al., 2010). While not focused on interest rate changes, historical public pension failures can be an important learning tool to further understand the portfolio choices of underfunded or failing pensions.

3.4 Optimal Pension Fund Allocations

(Peskin, 2001) found that the public sector pension fund's optimal equity exposure, according to its modeled efficient frontier, is 90%. An exposure to equity at this level would never be considered in practice, as equities are one of the riskier asset classes that an investor can hold. Pennacchi and Rastad (2011) estimated that to “immunize” the risk of pension funds liabilities, their model returned an impractical, 9% short exposure to U.S. Equities, a 160% allocation to fixed income, 24% allocation to private equity and a 67% short position to hedge funds. Although short positions are, for the most part, unused in pension funds, their research highlights the difficulty that can come with finding an optimal portfolio. According to Markowitz (1952), an investor should be able to diversify their portfolio while maximizing expected return at the same time. If an investor can achieve maximum diversification, thus creating minimum risk while maximizing expected return, then the optimal portfolio has been achieved. However, in practice, this is extremely difficult, as there are many confounding factors that can influence expected risk and return.

In 2017, the average United States pension fund portfolio had a 50% exposure to equities (Public Plans Data). State and local pension funds have substantially grown their equity exposure since then, rising from their 40% mark in 1990 and holding increasingly more equities than private sector pensions. (Munnell and Soto, 2007). This exposure may be suboptimal. Fleuriet and Lubochinsky (2005, p. 103) observed that pension funds with a large allocation towards equities struggle at an exponential rate as interest rates fall. In 2000, when interest rates decreased in response to the Dot-Com Bubble, high equity pension funds were faced with what the authors call the “scissor effect.” The “scissor effect” is a decline in the value of their equities due to struggling markets and an increase in the present value of their liabilities due to a reduction in interest rates. In related research on the optimal portfolio choice of pension funds, no correlation was found between the equity exposure of a pension fund and its assumed rate of return, leading to a high level of portfolio vulnerability (Lucas and Zeldes, 2009).

Although there is certainly not one prescription of asset allocations that can properly account for future market conditions and the unique liabilities of each pension fund, there is value in exploring the consequences of a poorly constructed investment vehicle. In practice, what most often occurs is a pension fund asset allocation is based solely on the performance of peer pension funds rather than on what choice of asset best minimizes the risk of its liabilities (Pennacchi and Rastad, 2011).

3.5 Investment Behavior During Policy Changes

There is importance in understanding the behavioral characteristics of policymakers and investors during deteriorating budget constraints and shifts in public policy, as pension fund managers are tasked with navigating through the economic and legislative turmoil. Monetary easing[2] can increase investors' risk appetite by improving the perceived economic and financial environment (Bauer et al., 2023). In 2016, Lu et al. (2019) observed that 12% to 32% of pension fund losses could be attributed to risk-taking behavior driven by underfunding and low risk-free rates. Although the authors identified the risk-taking behavior of underfunded pension funds, it was noted that these behaviors were pronounced during times of low-interest rate environments.

[2] Monetary policy aims to stimulate the economy through interest rate manipulation, changes to reserve requirements and open market operations

Additionally, Mohan and Zhang (2014) reported that a 1% decrease in funding leads to an increase of 1.4%-2.62% in equity allocation, an asset commonly assumed to have a higher beta than other asset classes[3]. However, Mohan and Zhang (2014) also reported, in congruence with this paper, that pension funds have been taking less risk after the recent financial crisis. The Great Recession led to a 25.3% decrease in the value of public pension assets, and again in 2009, with the largest pension funds losing over $165 billion in value.

3.6 Gap in Literature

Extensive literature is available on the decline in funding of public pensions, especially in the aftermath of the 2008-2009 financial crisis, when most of the mounting liabilities ballooned into generational deficits. Academics have reviewed and analyzed how, when, and the magnitude of these funding shortfalls, but few papers have chosen to study how investment managers of these underfunded pension funds react to the threat of insolvency. Additionally, does the behavior of underfunded pensions align with that of fully funded pensions, or do they make a drastic shift in strategy?

[3] Beta is a measurement of a securities volatility compared to the broader market

Theoretical Framework

4.1 Defined Benefit Pension Plan Fundamentals

A defined benefit pension plan (D.B.) is an employer-sponsored retirement account that has a predetermined payout at a future date that is mostly funded by the employer. Future benefits are computed by several factors, including salary, length of employment, and age. One commonly used formula to compute the defined benefit uses a multiplier[4], which is usually no more than 2% and chosen by the party offering the D.B., average earnings, and years of service.

$$Benefit = (Multiplier\ \%) * (Avg\ Annual\ Earnings\ over\ Career) * (Yrs\ of\ Service)$$

For example, if an employee averaged $55,000 a year in annual earnings, worked for 30 years, and the employer's multiplier was 1.5%, their lifetime annual payout at normal retirement would be $24,750. Pension plans are considered "qualified" accounts that grow tax deferred and are the responsibility of the employer to make investment decisions and cover any losses incurred in the account. In contrast to a defined contribution plan or typical 401k retirement account, D.B.'s payout is not linked to the performance of the underlying investment returns. Upon retirement, benefits can be received in a lump sum or annuitized into monthly payments for life.

A pension fund risk, due to its defined benefit nature, is solely on that of the employer or party offering the plan. Because of this risk, many employers will hire professional management to make strategic investment decisions for the assets in the account. If the return on investments of the contributed assets does not yield high enough to cover the liabilities of the fund, the

[4] The multiplier is a percentage used in the determination of the value of an employee's annual retirement annuity. This percentage can vary based on membership class and employer.

employer is legally obligated to make up the difference. To determine whether a pension fund is at risk of not covering its obligations, pension funds use a “funded ratio” to determine their financial health. In the public sector, this ratio is as follows:

$$Funded\ Ratio = \frac{Actuarial\ Assets}{Actuarial\ Accrued\ Liability}$$

Actuarial assets are generally just the current market value of the portfolio. Meanwhile, actuarial accrued liability is the present value of future benefits to be paid out to members of the plan. A healthy pension fund should have a funding ratio of 1 or 100%. As a general benchmark, a funded ratio of .8 or less may be a sign of an “at-risk” pension fund. It is the duty of the employer and the portfolio manager to make sound investment decisions to be able to fully fund the retirement of its beneficiaries. A pension fund portfolio manager’s goal is to devise an investment strategy that achieves a return high enough to cover future distributions.

4.2 Modern Portfolio Theory & Portfolio Optimization

One of the key theoretical assumptions used in this paper is Modern Portfolio Theory (MPT) (Markowitz, 1952). This theory defines a practical way to select investments to maximize return given any level of risk and stipulates that risk can be diversified away through investments made across unrelated securities. This methodology helps investors subjectively determine which combination of investable securities is considered “optimal” given a defined risk or return constraint. The optimal portfolio for an investor is the combination of assets that offers the highest level of expected return, given their prescribed level of risk. Meanwhile, the opposite is true for an investor with a prescribed level of return. The basket of assets that offers the lowest risk is optimal when a return constraint, or targeted return, is present. As many pension fund managers are given an expected return constraint, it is their duty to constantly be invested in the "optimal" basket of securities that offer the lowest amount of risk.

4.2a Measuring Risk

Determining the optimal portfolio is predicated on the assumption that an investor will be able to measure the risk of an asset. The risk of an asset can be measured using standard deviation, which computes the volatility of a securities price movement from its average. A high standard deviation signifies a risky investment, and a low standard deviation would result in low-risk security, otherwise known as price stability. Below is the population standard deviation formula that will be utilized in this paper, where x_i is the individual sample price, $\bar{x}$ is the average price of the sample set, and N is the number of samples.

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \bar{x})}{N}}$$

However, according to MPT, the individual risk of an asset is irrelevant; rather, it is the covariance among all individual assets that determines the overall risk of the portfolio. As Harry Markowitz presented, an individual investor can reduce the overall risk of their portfolio by allocating the available assets in such a way that produces the lowest covariance amongst them. An example of a three-asset covariance matrix below can be utilized to eventually determine the correlation between the three assets (x, y, z) where σ_p^2 is the variance of the entire portfolio, and w represents the weight of each asset.

$$\sigma_p^2 = \begin{bmatrix} w_x \; w_y \; w_z \end{bmatrix} \begin{bmatrix} \sigma_x^2 & \sigma_{xy} & \sigma_{xz} \\ \sigma_{yx} & \sigma_y^2 & \sigma_{yz} \\ \sigma_{zx} & \sigma_{zy} & \sigma_z^2 \end{bmatrix} \begin{bmatrix} w_x \\ w_y \\ w_z \end{bmatrix}$$

4.2b Measuring Return

The other factor that must be considered when searching for an optimal portfolio is the expected return of an individual asset, $E(R_i)$. To determine the expected return, this paper will use the mean, month-over-month price movement to determine an average price return. As an example, for a measurement of a portfolio's mean-variance optimization in 2008, historical prices from the previous five years (2003-2008) would be used as the sample. It is important to note that historical performance does not guarantee future results; however, it can help determine the average rate of return over the life of the investment. Additionally, the expected return of the portfolio $E(R_p)$, is each individual assets expected return, multiplied by the weight of its allocation in the total portfolio (w_i). An example of the expected return portfolio (x, y, z) is shown below.

$$E(R_p) = [E(R_x) \quad E(R_y) \quad E(R_z)] \begin{bmatrix} w_x \\ w_y \\ w_z \end{bmatrix}$$

4.2c The Efficient Frontier

A tool used to visualize and determine which portfolio of assets is "optimal" is the efficient frontier. The efficient frontier is mapped on a graph with risk on the x-axis and expected return on the y-axis. The curved line represents the threshold of optimal portfolios that maximize expected return for a defined level of risk. An example of an efficient frontier is shown below in Figure 1. Any point on the chart would represent a portfolio that has different combinations of the available assets. Portfolios that lie on the line are considered optimal, and portfolio combinations that are below the line are considered sub-optimal. Sub-optimal portfolio combinations either offer too low of an expected return for a defined amount of risk or embody too much risk for a defined level of return. As most pension funds know far into the future what obligations they are required to distribute, they can determine the required rate of return necessary to satisfy those liabilities. Using MPT and the efficient frontier, it can be easily identified if a portfolio manager's asset allocation choice carries too much or too little risk relative to the targeted return.

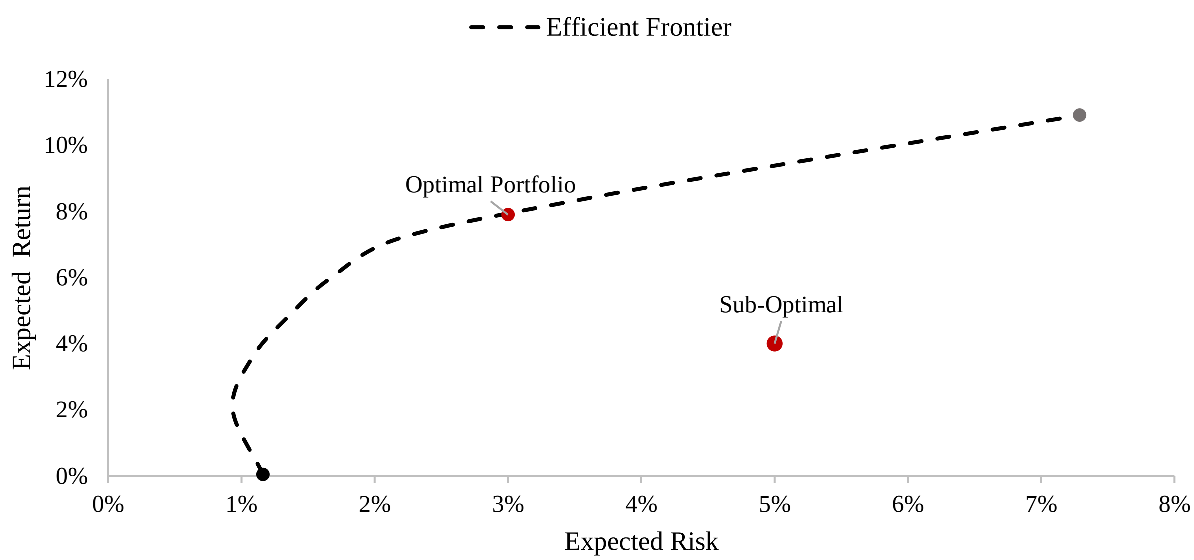

Figure 1: Basic Efficient Frontier

4.3 Application & Constraints

The theoretical framework above will be applied to the Public Plans Dataset, which includes pension fund's asset allocation data since 2001. Each pension fund's portfolio allocations are broken down into Equity, Fixed Income, Private Equity, Hedge Fund, Commodity, and Real Estate. MPT will be used to determine each pension fund's long-run efficient frontier. It is the goal of this paper to determine if in response to a change in a pension's funding evokes a change in pension fund managers' portfolio reallocation behavior. Additionally, this paper will be able to identify if defined benefit plans that are underfunded change their risk tolerance more than those that are fully funded.

As an example, by 2010, PA's contributions to the Pennsylvania State Employee's Retirement System (SERS) and the Pennsylvania School Employee Retirement System (PSERS) had been receiving less than half of their actuarial recommended contributions for the past decade and the state ranked 49th in fiscal discipline (Draine, et al, 2023). In response to this underfunding, portfolio managers would have been faced with the challenge of altering their investment strategy to be able to handle sustained periods of reduced cashflow, and a higher demand for safe, high-yield investments to cover their long-term liabilities.

Using the theoretical framework above and the Public Plans Data, the pension fund manager's real allocation choice will be measured against its long-run efficient frontier. If the real allocation of assets does not lie close to, or on the efficient frontier, it could lead to the conclusion that fund managers at the time were more risk-averse or more risk-tolerant than the model and market suggested and made a mistake in their response to underfunding.

It should be noted that MPT has its disadvantages, as the framework of this paper is built upon its methodology of portfolio optimization. The calculation of risk is heavily criticized as it is measured on the variance of price returns. In the scenario that security had relatively stable prices but, due to market circumstances, had one or two large price fluctuations, MPT would suggest that the risk of the security would be high because the variance would include those outliers. Alternative models have used downside risk[5] or future price expectations to measure the implied volatility or risk of a security.

Additionally, MPT is extremely reliant on historical prices. As previously mentioned, past returns do not guarantee future results, and MPT is no exception. Both return and risk are measured using historical data to project a future expected return, which in some instances could produce misleading results. Additionally, MPT does not account for commissions or trading fees, which are present in markets. These fees and commissions can cut into the expected return of an asset. However, this shortcoming may be dampened, as institutional investors like pension funds have commonly reduced trading costs due to the size and volume of their trades.

[5] Downside risk is a measurement of the potential price fall of an asset in response to a change in market conditions

Data Collection

5.1 Pension Fund Asset Allocation

Public pension data was collected using the Public Plans Data from the Center of Retirement Research at Boston College in conjunction with the Mission Square Research Institute, the National Association of State Retirement Administrators, and the Government Finance Officers Association. This data set included plan-level information on 229 state and local pension plans since 2001. For this analysis, the pension fund's individual asset allocation data and funded ratio were collected. Available data from 2002 to 2022 was collected from 17 different public pension funds spanning six states and the District of Columbia. Funds were strategically chosen to control for regional disparity between pensions and to control for the various beneficiaries that each pension fund has. For example, state employees, public school teachers, and police & fire-specific funds were collected, if available, for each of the seven chosen locations. Additionally, it is important to note that some sampled pension funds belong to a broader retirement system that administers sub-plans that share similar investment strategies and management. For example, the New York State and Local Retirement Systems administers the State and Local ERS pension and the State Local Fire and Police pension, while the New York State Teacher fund is independently managed. Table 3 shows the complete breakdown of collected pension abbreviations, total assets, total membership, and sampled years.

Asset allocation data is broken down into six categories: Equity, Fixed Income, Private Equity, Commodity, Hedge Fund, and Real Estate. Misc. alternatives, Cash, and Others were omitted from the sample, as their percentage allocation was not significant enough to impact the analysis.

5.2 Historical Price Returns

Historical price return data was collected from the Bloomberg terminal using a series of funds to proxy for the pension fund's general asset classes. Monthly index fund historical price data from 1997-2023 was collected to analyze the long-run performance and relationship between the assets. Table 1 displays the funds were chosen to proxy their respective asset class.

Asset Class	Proxy
Equities	Vanguard Total Stock Market Index
Fixed Income	Vanguard Total Bond Market Index
Private Equity	LPX50 Listed Private Equity Index
Commodity	Dow Jones Commodity Index
Hedge Fund	Morningstar Broad Hedge Fund TR Index
Real Estate	Wilshire U.S. REIT Index

Table 1: Asset Class Proxy List

Available index funds were chosen to mimic Pennacchi & Rastad's (2011) research, which conducted a similar analysis of the performance of pension funds' portfolios; however, not all proxies were an exact match. For this analysis, the adjusted closing price of the index fund was collected, or in the case of a mutual fund, the closing NAV[6].

Finally, the annualized Market Yield on U.S. Treasury Securities at 10-Year Constant Maturity from 2001-2022 was collected from the Board of Governors of the Federal Reserve System (U.S.) to compute a long-run average of the risk-free rate. In the calculation of the

[6] Net asset value (NAV) is a mutual funds total value of assets, less their liabilities. This net value is then divided by shares outstanding to determine a price per share.

Sharpe Ratio, it was assumed that the risk-free rate was constant, and portfolio managers used a projected long-run average risk-free rate in their asset allocation choice.

Methodology

To identify an observable change in the behavior of a portfolio manager's asset allocation in response to the deteriorating financial health of a pension fund, all sampled funds were divided into two groups. The control group consists of fully funded pension funds, and the treatment group was comprised of pension funds that, on average, did not meet the funding threshold. The assumed threshold was a funded ratio of 80%. A funded ratio of 80% is the benchmark used by credit rating agencies and the federal government, as mentioned in the Pension Protection Act of 2006 (Brainard & Zorn, 2012).

Following the measurement procedures as explained in the Theoretical Framework section of this paper, each pension fund’s risk and return were measured by year for all available data points. Using the long-run covariance of asset prices and real annualized asset allocations, the expected risk and return of a portfolio in a sampled year could be determined and plotted against its efficient frontier. The reward-to-variability ratio, defined in Sharpe (1966), was used to analyze the risk-adjusted return of each pension. This metric, commonly referred to as the Sharpe ratio, measures the annual expected return of a portfolio $E(R_p)$, minus the risk-free rate r_f, divided by the standard deviation of the portfolio σ_p. The fluctuation of this ratio overtime can help illustrate a change in the investment performance of a particular pension.

$$\text{Sharpe Ratio} = \frac{E(R_p) - r_f}{\sigma_p}$$

A larger Sharpe ratio would indicate that a portfolio manager has an investment strategy that has returned a higher risk-adjusted return. A lower Sharpe ratio implies that the portfolio has netted a less-than-desirable amount of return per unit of risk. Although the Sharpe ratio does not directly measure the aggressiveness of a portfolio, it can be used to judge the decision-making and performance of investment managers portfolio choice over time.

Many pension funds experienced unique changes in policy or funding across the sampled 20-year period. Therefore, all individual samples were pooled together, regardless of the year or individual pension, to control the variation and unobservable bias that may have led to a drop in funding. One consolidated data set was used to single out the interaction term without considering the case-by-case policy and changes in state funding for each pension. By doing this, the relationship between funding and portfolio choice could be analyzed without consideration of other variables.

Results

Empirical evidence suggests that underfunded pension funds, through a change in portfolio composition, pursue investment strategies that achieve higher risk-adjusted returns.

		Average Expected		*Funded Ratio*		*Sharpe Ratio*	
Financial Health	N	Return	Risk	Mean	SD	Mean	SD
Funded	169	5.74%	3.46%	0.96576	0.09328	0.78996	0.08446
Underfunded	151	5.66%	3.22%	0.64755	0.12087	0.81759	0.14804

Table 2: Summary Statistics for All Sampled Public Pension Funds

Table 2 displays the average annualized portfolio risk and return, mean funded ratio, and mean Sharpe ratio of both funded and underfunded public pensions from the sampled states chosen. In this measurement, regardless of which pension fund, if a sampled year had a funded ratio below .8, it was categorized as underfunded; the opposite is true for funded pensions. Almost all the sampled funds had time periods where they were financially strong but showed a deterioration in funding over time.

The differences in portfolio management between the Pennsylvania Public School Employees (PSERS) and the New York State Teachers (NYSTRS) pension illustrate the broader changes in investment behavior of these two distinct groups. Figure 5 shows that from 2009 to 2020, PSERS experienced a reduction in funding and congruently showed large year-over-year changes to their portfolio's composition of assets. In contrast, Figure 6 shows the NYSTRS remained above the fully funded threshold for the entirety of the available data set and showed no adjustment to their portfolio composition. However, PSERS' choice or mandated decision to alter their composition of assets reduced the overall risk of their portfolio while achieving the same expected return. Through diversification and strategic use of alternative investments, PSERS was able to increase its Sharpe ratio while simultaneously experiencing a decline in funding. NYSTRS, whose behavior is representative of most funded pension funds, did not pursue a change in portfolio composition, as there was no necessity. NYSTRS remained sufficiently funded during this period and did not need to capture a higher risk-adjusted return. Figure 7 also shows each pensions portfolio choices expected risk and return, per year, graphed against the efficient frontier. This graph further illustrates the conclusion that underfunded pensions perform better on a risk adjusted return basis, as their PSERS dots collectively lie closer to the frontier than NYSTRS. Additionally, NYSTRS is observed to have a tighter spread of individual portfolios, illustrating that their portfolio composition did not change very much in the

20-year sample. While PSERS, a historically underfunded pension, exhibits a wider spread of portfolio structures, illustrating their attempt to invest in a more optimal composition of assets.

An unequal variances t-test was conducted to compare an underfunded pension fund's expected annual return against funded pension funds. The two tailed, test showed that there was no significant difference in average returns between groups; $t(266) = -1.37\ , p = .1726$. However, a one-tailed, unequal variance t-test showed a statistically significant increase in the Sharpe ratios of underfunded pension funds when compared to funded pension’s $t(232), = 2.02, p = .0224$. This would imply that underfunded pension funds are successfully implementing new investment strategies to increase their risk-adjusted return, but not through the expected return channel. Pension fund managers are increasing their Sharpe ratio through a reduction in risk. Table 5 and Table 6 in the appendix show the expanded t-test results.

Pension funds that have more pending liabilities than current assets are prompted to reinvest into more optimal investment strategies to not only keep stable investment returns but to do so with less risk exposure. If, for any reason, the pension is not able to provide ample funding for its future beneficiaries, it is the responsibility of the investment manager to earn a return high enough to close the gap in funding. Figure 2 plots the Sharpe ratios of all underfunded and funded pensions in any given year. Most noticeably, underfunded retirement systems have a larger interquartile range, with a mean ratio that is above that of funded pensions. This difference can be explained by the fact that managers of financially inadequate funds are actively trying to reallocate assets into a more optimal portfolio to achieve a higher risk-adjusted return. This can be done by reallocating assets into more high-yield, low-risk alternatives such as private equity or real estate, using niche trading strategies, or simply building a more diversified portfolio.

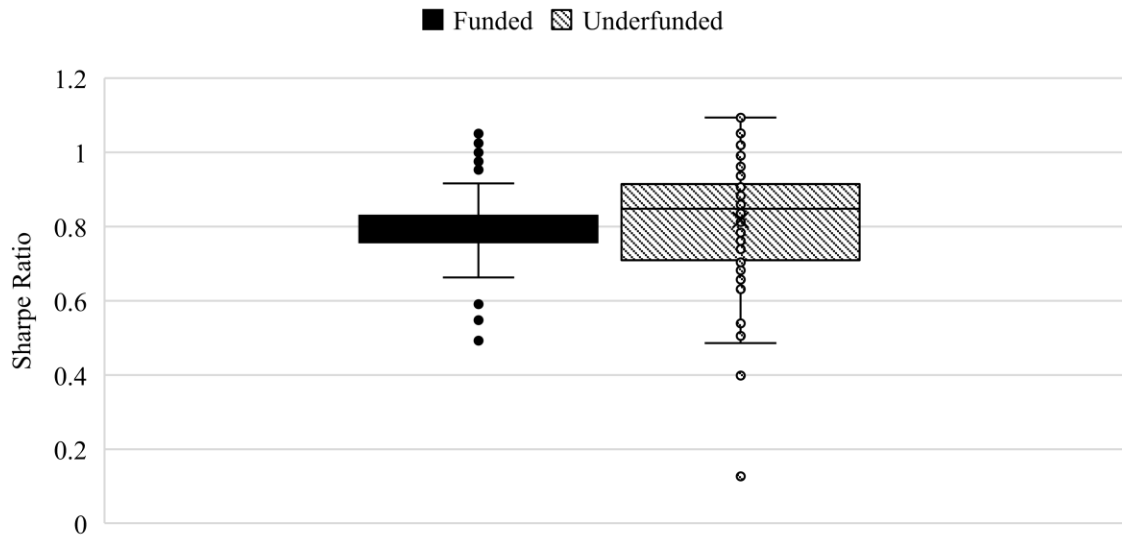

Figure 2: Box & Whisker Plot of Funded and Underfunded Pension's Sharpe Ratio

The tight box and whisker plot of funded pension funds may also suggest that managers of financially stable pensions do not deploy new investment strategies or reallocate assets. This intuitively makes sense, as in contrast to financially healthy retirement systems, underfunded pensions, and their managers must shift their goals towards both capital preservation and sufficient investment return. In contrast, funded pension managers are not pressured or incentivized to change their strategy since their goal remains only to return a sufficient yield on invested assets. Their original portfolio structure is "good enough" to maintain stability in its future funding. As previously mentioned, The New York State & Local Retirement Systems and the New York State Teachers' Pension Fund are perfect examples of this phenomenon. Since 2002, all have remained well above the funded ratio of 80% and observed almost no difference in their asset allocations or Sharpe ratio over the 20-year span. In the context of all funded pensions, this fact holds true. Descriptive statistics again build on the idea that funded pension funds have funded ratios that do not deviate greatly from their mean, and consequently, neither do their Sharpe ratios. Fully supported pensions had a funded ratio S.D. of .093 and a Sharpe ratio of S.D. of .084. Underfunded pension funds had higher S.D.'s of .121 and .148, respectively.

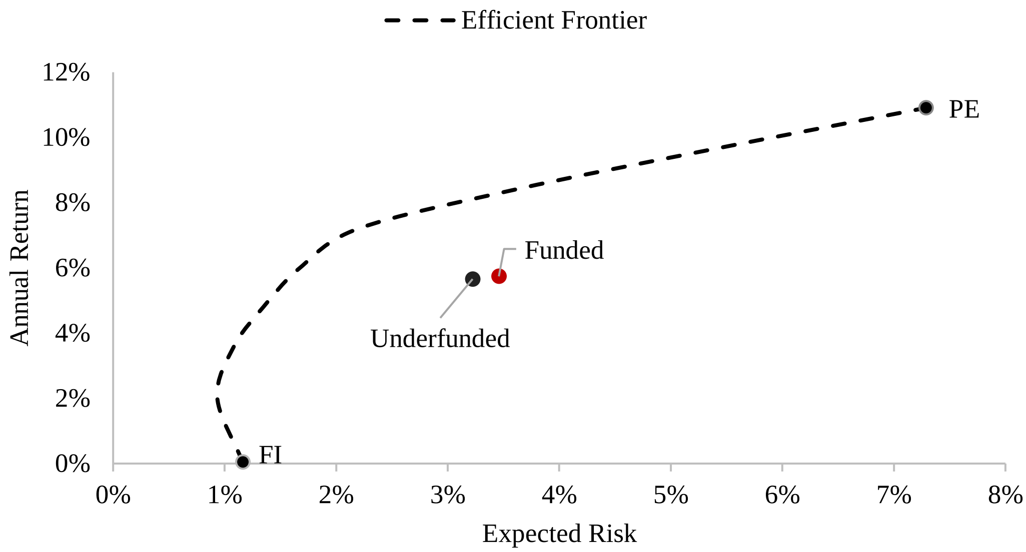

Figure 3: Average Underfunded Pension & Funded Pension Portfolio Choice

To further highlight the findings above, the efficient frontier, given the asset classes available to pension administrators, was constructed. The curve of the efficient frontier is all possible portfolio combinations that optimize the risk and return trade-off. Refer to Table 4 in the appendix for the asset correlation matrix. As shown in Figure 3, the model predicted that a portfolio of only private equity holds the highest optimal risk and return trade-off. Conversely, an investment strategy of only fixed-income securities is the optimal portfolio with the lowest expected return per unit of risk. Portfolios below and to the right of the curve are considered less optimal and continue to become more so the farther they move in that direction. For example, the least optimal portfolio on this figure would be a strategy that incurs an expected risk of 8%, with an expected return of 0%. Figure 3 that the illustrates the average portfolio structure of underfunded pension funds lies closer to the efficient frontier than that of funded portfolios. Each dot was calculated using the long run average expected risk and return of all underfunded and funded pension funds regardless of the sample date.

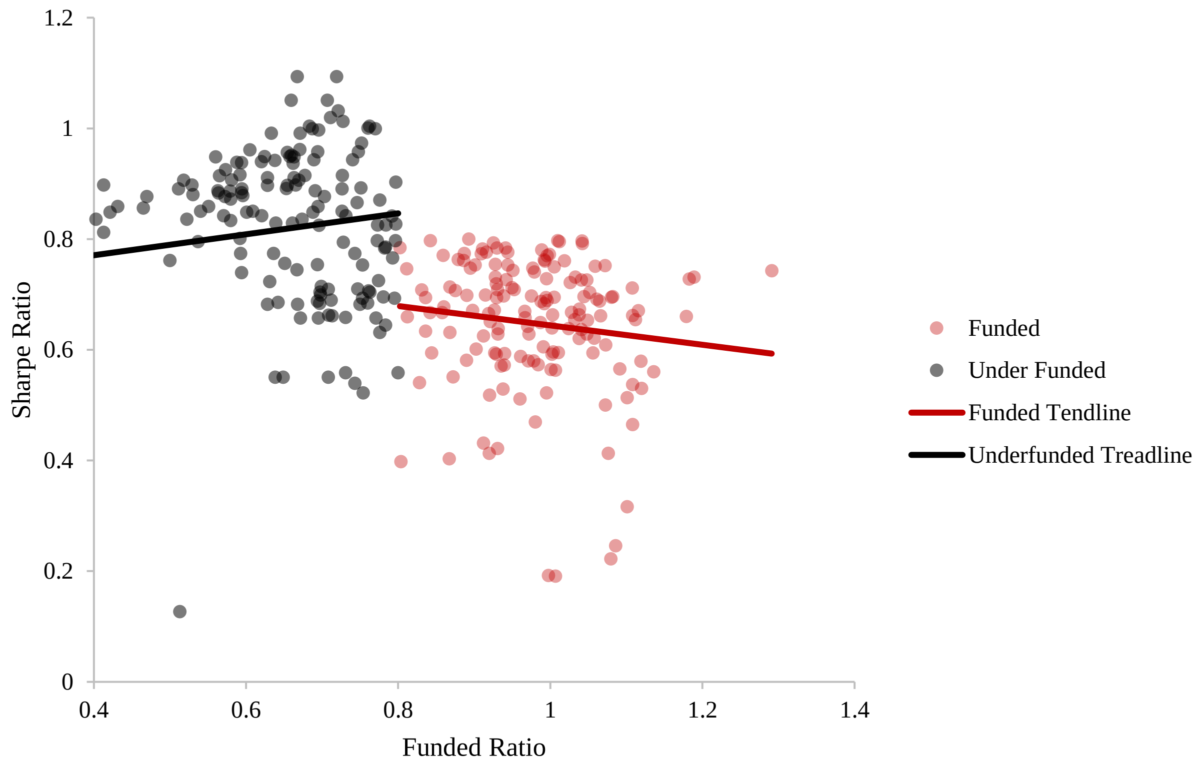

Figure 4: Pension Fund Trends

Finally, Figure 4 plots each pension's funded ratio against their Sharpe ratio. It can be observed that underfunded pensions in black, on average, have a much higher Sharpe ratio than the fully funded pensions in red. Trend lines were added to help illustrate the general direction that pensions shift towards as the funded ratio changes; however, it should be noted that both trendlines have an $R^2 < .1$, therefore, should not be used as a predictive model, but rather as an observable difference between the two groups.

Conclusion

In summary, the behavior of pension fund managers does change during financial burdens from lack of funding, poor market conditions, or adverse changes in public pension legislation. In fact, not only does their behavior change, but pension fund managers get better at their job. On average, pensions with a funded ratio below 80% earn a Sharpe ratio of .03 units higher than their fully funded counterparts. In response to a need to generate higher excess returns to close the gap between their diminishing assets and growing liabilities, pension fund managers must reallocate their assets into more optimal, diversified portfolios that generate a higher amount of risk-adjusted return. Fund managers are, on average, able to reallocate into investment strategies that offer marginally the same return as fully funded pensions but at a lower exposure of risk. This conclusion also draws on the aspect of asset preservation. Financially deficient pensions do not have the capacity to incur investment losses that would exacerbate their already poor financial health. Therefore, wealth managers try to reduce the risk of the pension funds' assets by rebalancing their portfolio and optimizing their investment strategy.

Although the funded ratio is not a trustworthy one-variable predictor of a pension's expected level of risk-adjusted return, there is a statistically significant increase in the average Sharpe ratio of underfunded pension funds compared to that of a fully funded pension. Financially healthy public pensions have no incentive to move on from "what works" and continue to stay invested in the portfolio structure that achieves stability. This result, however, is not surprising, as not only are world-class investment professionals at the helm of this decision-making process, but public pensions are routinely put through rigorous stress-testing exercises to predict future solvency and investment performance in various scenarios of adverse economic, legislative, and policy change. After all, public pensions are a liability of the American taxpayer if funds become insolvent.

Currently, this research has concluded that, although underfunded, public pensions are doing everything they can to get back to even and are surprisingly outperforming those that already are. Future research will be paramount in understanding if this success has continued or turned into greed and careless risk-taking behavior that puts not only the retirees' benefits at risk but also the financial stability of the American economy.

Appendix

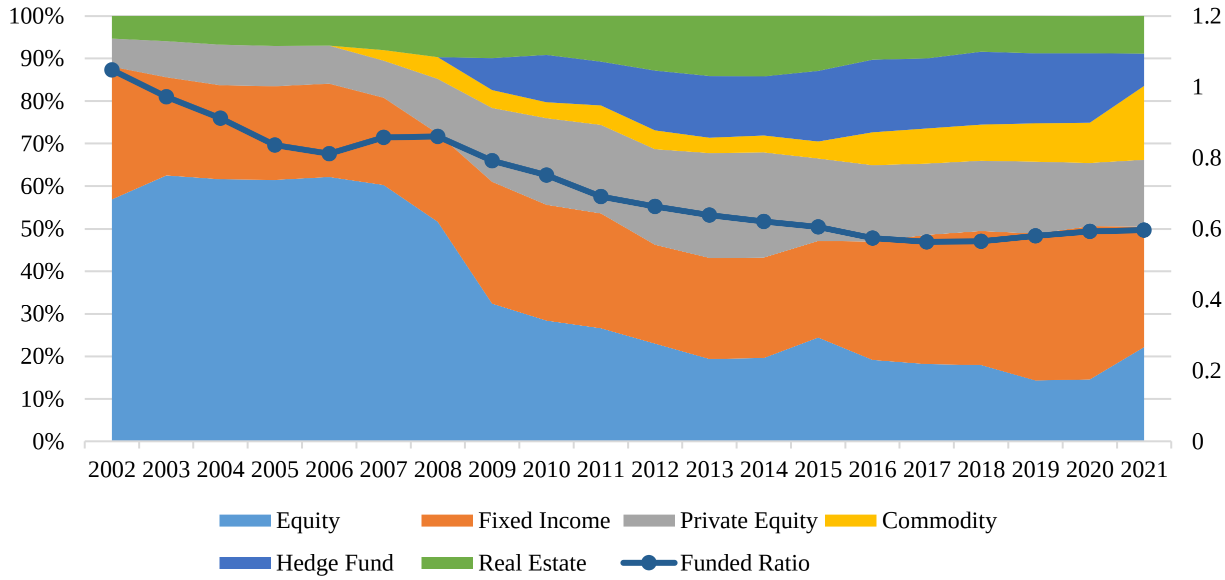

Figure 5: Pennsylvania School Employee Asset Allocation & Funded Ratio

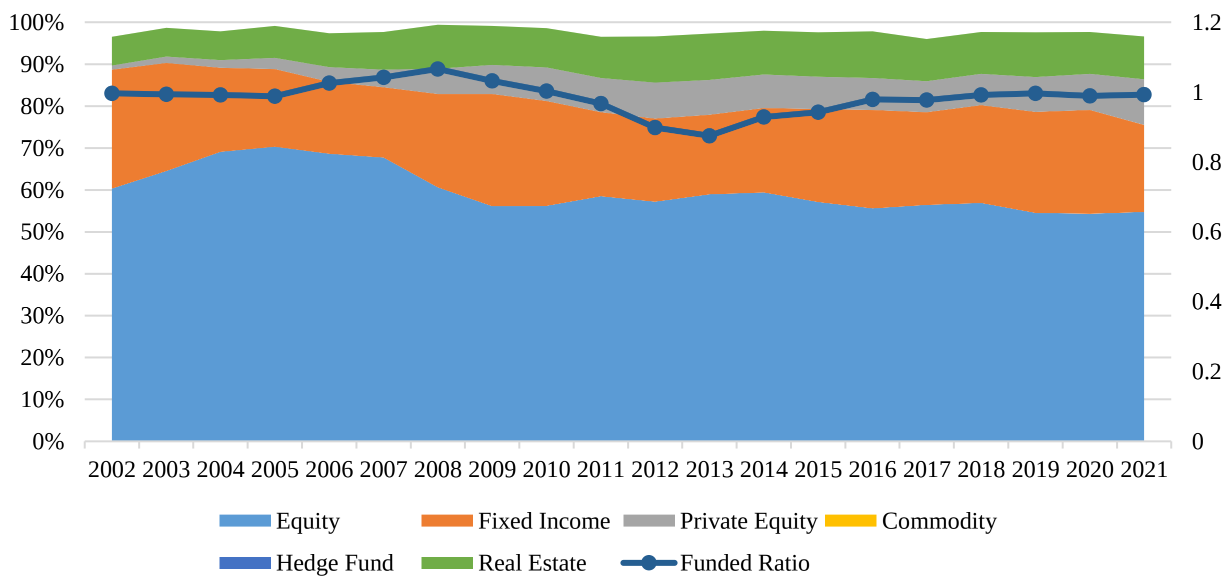

Figure 6: New York State Teachers Asset Allocation & Funded Ratio

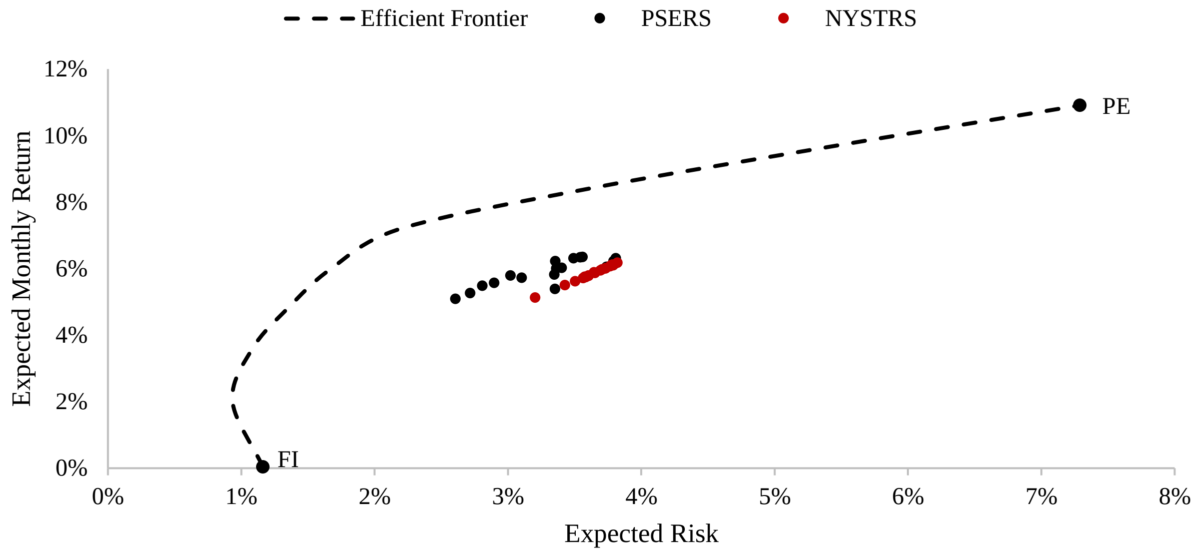

Figure 7: PSERS vs NYSTRS Asset Allocation & Efficient Frontier

Pension Fund Name	**Abbreviation**	**Assets* (Millions)**	**Total Memebers***	**Sampled Years**
Pennsylvania State Employee	PA - SERS	33,607	239,230	2002-2021
Pennsylvania Municipal	PMRS	3,529	16,315	2002-2021
Pennsylvania Public School Employee’s	PSERS	70,528	494,774	2002-2021
Ohio Public Employees Retirement System	OPERS	92,244	1,215,190	2002-2021
Ohio Police & Fire Pension Fund	OP&F	16,108	61,428	2002-2021
New York State Teachers	NYSTRS	131,965	442,044	2002-2021
New York State and Local Retirement Systems				
NY State and Local ERS	NY - ERS	232,050	991,250	2002-2021
NY State & Local Police & Fire	NY - PFRS	41,669	72,510	2002-2021
Maryland State Retirement and Pension System Basics				
Maryland PERS	MD - PERS	21,429	186,033	2002-2021
Maryland Teachers	MD - TRS	39,126	217,476	2002-2021
District of Columbia Retirement Board				
DC Police & Fire	DC - PFRS	6,900	9,862	2006 - 2021
DC Teachers	DC - TRS	2,573	11,871	2006 - 2021
New Jersey Division of Pension and Benefits				
New Jersey PERS	NJ - PERS	32,568	432,850	2006 - 2021
New Jersey Police & Fire	NJ - PFRS	30,709	90,632	2006 - 2021
New Jersey Teachers	NJ - TRS	24,641	269,892	2006 - 2021
West Virginia Consolidated Public Retirement Board				
West Virginia PERS	WV - PERS	8,007	69,489	2002-2021
West Virginia Teachers	WV - TRS	9,002	75,286	2002-2021

***As of 2022**

Table 3: All Sampled Public Pension Funds

	EQ	FI	PE	CM	HF	RE
EQ	0.22%					
FI	0.01%	0.01%				
PE	0.29%	0.01%	0.53%			
CM	0.09%	0.00%	0.17%	0.22%		
HF	0.04%	0.00%	0.06%	0.05%	0.04%	
RE	0.18%	0.02%	0.30%	0.09%	0.04%	0.37%

Table 4: Covariance Matrix Between Available Asset Classes

	Underfunded	Funded
Mean	0.818	0.790
Variance	0.02	0.01
Observations	151	169
Significance Level	0.05	
df	232	
t Stat	2.02*	
P(T<=t) one-tail	0.0224	
t Critical one-tail	1.65	
P(T<=t) two-tail	0.0447	
t Critical two-tail	1.97	

*Denotes statistical significance at the .05 level

Table 5: Assuming Unequal Variance's Two–Sample T-Test on Mean Sharpe Ratio

	Underfunded	**Funded**
Mean	5.66%	5.74%
Variance	2.7E-07	1.3E-07
Observations	151	169
Significance Level	0.05	
df	266	
t Stat	-1.37	
P(T<=t) one-tail	0.0863	
t Critical one-tail	1.65	
P(T<=t) two-tail	0.1726	
t Critical two-tail	1.96	

*Denotes statistical significance at the .05 level

Table 6: Assuming Unequal Variance’s Two–Sample T-Test on Mean E(r)

Bibliography

Bauer, M. D., Bernanke, B. S., & Milstein, E. (2023). Risk Appetite and the Risk-Taking Channel of Monetary Policy. *Journal of Economic Perspectives*, *37*(1), 77–100. https://doi.org/10.1257/jep.37.1.77

Brainard, K., & Zorn, P. (2012). The 80-Percent Threshold: Its Source as a Healthy or Minimum Funding Level for Public Pension Plans. National Association of State Retirement Administrators.

Brinson, G. P., Hood, L. R., & Beebower, G. L. (1986). *Determinants of Portfolio Performance*.

Board of Governors of the Federal Reserve System (U.S.), Market Yield on U.S. Treasury Securities at 10-Year Constant Maturity, Quoted on an Investment Basis [DGS10], retrieved from FRED, Federal Reserve Bank of St. Louis

Clark, R. L., Craig, L. A., & Wilson, J. W. (2003). A History of Public Sector Pensions in the United States. Robert L. Clark, Lee A. Craig and Jack W. Wilson. *University of Pennsylvania Press*. https://doi.org/10.15453/0191-5096.3061

Christensen, Z. (2023). *Pension reform news: $1.3 trillion in state pension debt, shortsighted calls for divesting, and more*. Reason Foundation. https://reason.org/pension-newsletter/trillion-in-state-pension-debt-calls-for-divesting/

Doonan, D., & Kenneally, K. (2021). AMERICANS' VIEWS OF STATE & LOCAL EMPLOYEE RETIREMENT PLANS. *National Institute on Retirement Security*.

Draine, D., Mennis, G., Silwa, K. (2023) Pennsylvania Makes Progress Toward Public Employee Pension Sustainability. Retrieved from https://www.pewtrusts.org/en/research-and-analysis/articles/2023/02/21/pennsylvania-makes-progress-toward-public-employee-pension-sustainability

Fleuriet, V., & Lubochinsky, C. (2005). *Interest rate risk management by life insurance companies and pension funds*. *6*.

Giesecke, O., & Rauh, J. (2023). Trends in State and Local Pension Funds. *Annual Review of Financial Economics*, *15*(1), 221–238. https://doi.org/10.1146/annurev-financial-110921-022054

Government Finance Officers Association 'GOFA' (2009), Asset Allocation for Defined Benefit Plans. Best *Practices*

Fleuriet, V., & Lubochinsky, C. (2005). *Interest rate risk management by life insurance companies and pension funds*. *6*.

Lu, L., Pritsker, M., Zlate, A., Anadu, K., & Bohn, J. (2019). Reach for Yield by U.S. Public Pension Funds. *Finance and Economics Discussion Series, 2019*. https://doi.org/10.17016/FEDS.2019.048

Lucas, D. J., & Zeldes, S. P. (2009). How Should Public Pension Plans Invest? *American Economic Review*, *99*(2), 527–532. https://doi.org/10.1257/aer.99.2.527

Markowitz, H. (1952). PORTFOLIO SELECTION*. *The Journal of Finance*, *7*(1), 77–91.

Mohan, N., & Zhang, T. (2014). An analysis of risk-taking behavior for public defined benefit pension plans. *Journal of Banking & Finance*, *40*, 403–419. https://doi.org/10.1016/j.jbankfin.2013.12.011

Munnell, Alicia H., and Mauricio Soto. 2007. "State and Local Pensions Are Different From Private Plans." Boston College Center

Pennacchi, G., & Rastad, M. (2011). Portfolio allocation for public pension funds. *Journal of Pension Economics and Finance*, *10*(2), 221–245. https://doi.org/10.1017/S1474747211000102

Peskin, M. (2001). *Pensions in the public sector* (O. S. Mitchell, E. C. Hustead, & Wharton School, Eds.). Univ. of Pennsylvania Press.

Public Plans Data. 2001-2022. Center for Retirement Research at Boston College, MissionSquare Research Institute, National Association of State Retirement Administrators, and the Government Finance Officers Association.

Sharpe, W. F. (1966). Mutual Fund Performance. *The Journal of Business*, *39*(1), 119–138. http://www.jstor.org/stable/2351741

Stalebrink, O. J., Kriz, K. A., & Guo, W. (2010). Prudent Public Sector Investing and Modern Portfolio Theory: An Examination of Public Sector Defined Benefit Pension Plans: Prudent Public Sector Investing and Modern Portfolio Theory. *Public Budgeting & Finance*, *30*(4), 28–46. https://doi.org/10.1111/j.1540-5850.2010.00967.x

Thom, M., & Randazzo, A. (2015). Underfunding Annual Pension Contributions: Examining the Factors Behind an Ongoing Fiscal Phenomenon. *State and Local Government Review*, *47*(1), 35–44. https://doi.org/10.1177/0160323X14568025

The Pew Charitable Trusts, (2023). "Public Retirement Systems Need Sustainable Policies to Navigate Volatile Financial Markets" Retrieved from, https://www.pewtrusts.org/en/research-and-analysis/issue-briefs/2023/11/public-retirement-systems-need-sustainable-policies-to-navigate-volatile-financial-markets

U.S. Census Bureau. (2022). Annual survey of public pensions (ASPP). 2022 Annual Survey of Public Pensions: State & Local Tables. Retrieved from, https://www.census.gov/data/tables/2022/econ/aspp/aspp-historical-tables.html