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Public Pensions in a World of Low Rates and Low Risk Premiums

By Andrew Ang, PhD, Calvin Yu, CFA®, Sarah Siwinski, and He Ren

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FEATURE

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ABSTRACT

During the 2010s, the assets of public pension plans generated significantly higher returns than their assumed, or actuarial, rates of return. In a sample of sixty-nine U.S. public plans with a total of $2.1 trillion of assets, the return outperformance of assets over the assumed returns was more than 200 basis points for the ten years ending June 30, 2019. The outperformance was driven by the asset allocations being mostly exposed to economic growth, which constituted nearly 75 percent of the total portfolio variance. Based on capital market assumptions with lower returns to growth-sensitive assets over the next decade, pension plans are less likely to outperform their assumed returns and also may experience significant downturns in scenarios where growth slows. In addition, the forecasted returns for fixed income over the next ten years are expected to be significantly lower than the historical experience over the past few decades due to much lower starting yields. Optimal pension allocations that are more likely to meet current return targets generally involve increasing allocations to alternatives and using leverage explicitly or through portable alpha strategies.

INTRODUCTION

The past decade has been very favorable to wealth accumulation for public pension plans. Over the ten years ending June 30, 2019, U.S. and international equities had annualized returns of 14.7 percent and 6.5 percent, respectively.[1] Over this period, the ten-year U.S. Treasury yield declined from 4.0 percent to 2.0 percent, with a U.S. Treasury bond portfolio experiencing an annualized return of 3.0 percent and a portfolio of global bonds had an annualized return of 2.9 percent.[2] The rise of growth-sensitive asset prices over the past decade generally has benefited large asset owners. In this paper, we examine sixty-nine large public pension plans in the United States with total assets under management (AUM) of US$2.1 trillion. We show that over the past decade, the average plan outperformed its assumed return by 2.2 percent.[3] Large allocations to growth-sensitive asset classes, such as public equities, hedge funds, and private equities, played a large role in this outperformance.

Today, however, the investment environment is not as supportive. The broad consensus is that forward-looking expected returns of risky assets are low, in contrast to the high risk premiums experienced over the previous ten years. As of November 30, 2020, approximately $17.1 trillion of developed sovereign bonds were priced at negative yields and the yield on ten-year U.S. Treasuries was 0.89 percent compared to an average of 3.08 percent over the previous decade.[4] Based on capital market assumptions from the BlackRock Investment Institute, a standard 60/40 equity/bond portfolio has an expected return of 5.2 percent over the next ten years.[5] Today's low capital market assumptions are driven both by low interest rates and relatively low risk premiums driven by high current valuations. We use the BlackRock capital market assumptions because they are available to institutional investors and complete, i.e., they cover all the major asset categories invested in by U.S. public pension plans. BlackRock is by no means unique among providers of capital market assumptions in advocating low forward-looking expected returns, and the ones we use in this paper are representative of those from the broad industry.

In our sample of large public pension plans, current asset allocations indicate that the average fund is forecasted to have a forward-looking expected return of 6.9 percent over the next ten years. This is 0.28-percent lower, on average, than the current assumed rates of return. The low expected returns on investments are even more important because, despite the high realized investment returns over the past decade, public pension plans are generally still significantly underfunded—and generating investment returns is an important way to close this gap between pension assets and liabilities.[6] Given that the asset allocation decision is the most important determinant of the returns earned by a plan (see Brinson et al. 1986; Brinson et al. 1991; Ang 2014, and many others), what should the strategic asset allocation of a public pension plan be in a world of low interest rates and low risk premiums?

We begin by tabulating the portfolios the public pension plans hold today. We aggregate and document statistics that describe the asset allocations, risk exposures, and realized performance of sixty-nine public pension plans in the United States. The plans range in size from US$1.2 billion to US$215 billion and have assumed rates of return from 5.25 percent to 8.00 percent on June 30, 2019. The average plan has a funded ratio of

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approximately 73 percent (with a range of 33 percent to 108 percent) and more than 200,000 participants. Public pension plan allocations are complex, with many allocating to approximately 125 managers across thirty-five different asset classes and strategies. The average plan holds approximately 46 percent in equities, 22 percent in fixed income, 30 percent in alternatives, and 2 percent in cash.

We use macro factors, such as economic growth, real rates, and inflation, to characterize the underlying economic drivers of risk and return of the pension universe.[7] We find that pension portfolios have very large exposures to economic growth, which accounts for nearly 75 percent of total portfolio volatility, and which has performed well over the past ten years. Thus, despite apparent diversification across asset classes, public pension plan portfolios have non-diversified risks because many asset classes, including alternatives, have exposures to this common factor.[8] These portfolios are exceedingly sensitive to global stress events that cause growth to slow and growth-sensitive assets to sell off, which we document by shocking the portfolios with historical and market-driven scenarios following Golub et al. (2018). These scenarios include the crash of 2008, the COVID-19 market drawdown in the first quarter of 2020, and a hypothetical stagflation scenario.

Expected returns are forecasts. How unusual are today's forecasted low-return expectations relative to history? How difficult would it have been historically to achieve the pension plans' assumed returns given today's return forecasts? "Very unlikely" is the short answer. Given public pension plans' current allocations, we consider the returns that would be required of equities, fixed income, and alternatives to achieve the average target portfolio return of 7.25 percent. We consider each asset class in isolation, allowing one asset class's return to change while the others are held constant. For equities, we find that the high equity returns required to hit the portfolio's return target correspond to approximately the top 10 percent of outcomes observed over the past few decades. In contrast, only modestly higher expected returns in alternatives relative to the historical data will enable plans to achieve 7.25-percent return targets, all else being equal. In fixed income, it would take unprecedented yields falling to significantly negative levels to generate the returns required to hit 7.25 percent at the portfolio level, holding constant the returns of other asset classes.

Finally, we use robust optimization techniques to suggest two ways that the average public pension portfolio can be changed to lessen dependence on growth, provide more downside resilience, and increase diversification. First, we allow all asset class positions to change, subject to a 35-percent limit on private markets, and impose a long-only constraint. Second, we allow the plan to take on leverage. This can be done explicitly at the plan level with direct borrowing or in indirect ways including portable alpha strategies. In the first case, we find that the optimized portfolios use lower equity allocations in favor of increased allocations to alternatives. Fixed income holdings actually increase, with especially larger positions held in government bonds, because fixed income holdings are diversifying for alternatives. Only when the use of leverage is permitted, however, does the public equity portion of the portfolio increase, back up to slightly less than the current average pension allocation. Both optimal portfolios, with or without leverage, show enhanced efficiency of enhanced expected returns with lower or similar levels of volatility.

DATA

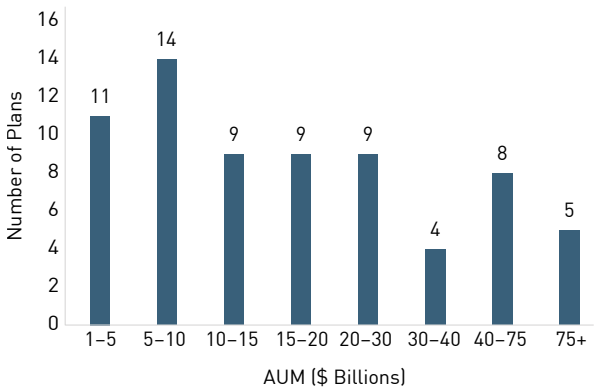
We collect fund-level asset data for sixty-nine U.S. public pension schemes as of June 30, 2019. These are collected by a portfolio consulting group of BlackRock Inc. using data from *Pensions & Investments*. We map each asset class of each fund to capital market assumptions as of May 2020 to estimate the risk and return characteristics of each plan.

Figure 1 shows some summary statistics of the sixty-nine public pension plans. Figure 1A states the AUM of the funds, which ranges from $1.2 billion for a municipal plan to

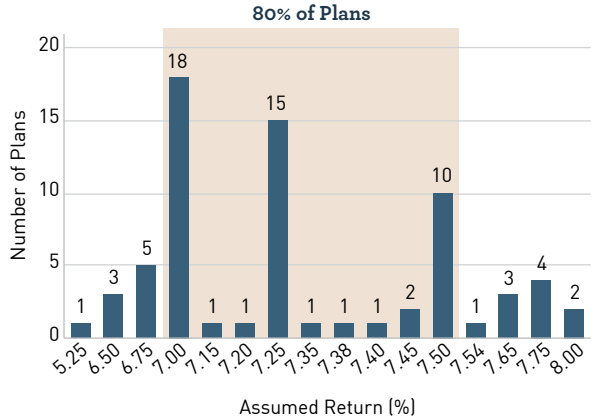
Figure 1

PUBLIC PENSION PLANS

(A): Coverage Universe with AUM



(B): Assumed Returns



Source: BlackRock and Pensions & Investments. *Plan level information is sourced from plans' annual and actuarial reports.*

$215 billion for a state-level plan. The average AUM is $30.3 billion, with twenty-five plans having assets less than $10 billion and five plans with more than $75 billion. The total AUM across all funds is $2.1 trillion. In figure 1B, we graph statistics describing the assumed returns of the plans in our sample. Assumed returns vary widely across the sixty-nine plans, ranging from 5.25 percent to 8.00 percent, with more than 72 percent having an assumed annual return of 7 percent to 7.50 percent.

PENSION PLAN PERFORMANCE AND ASSET ALLOCATIONS

We document pension plan performance over the past decade and find that pension plans did well during this time period and outperformed assumed returns by more than 200 basis points (bps). We break down the current asset allocations of public pension plans and decompose their asset allocations by macro drivers of return.

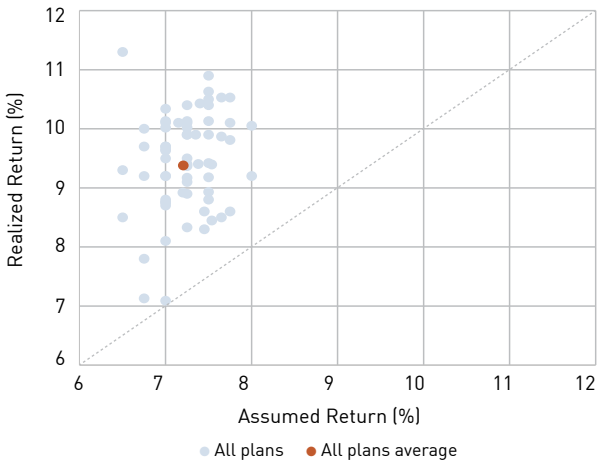
PERFORMANCE

Although asset returns exhibited sharp decreases during the financial crisis in 2008, which is well documented by numerous academic authors such as Mishkin (2011) and financial journalists such as Sorkin (2009), the 2010s saw strong economic growth and high returns for risky assets. This benefited many investors, including public pensions, which realized returns of more than 9 percent annually during the decade on average, exceeding assumed annual returns by more than 200 bps.

In figure 2, we plot realized returns over the decade July 1, 2009, to June 30, 2019, versus assumed returns as of June 30, 2019, for the public pension plans in our sample. The 45-degree dashed line indicates where realized returns equal assumed returns. In all cases, the plans plot above the 45-degree line, indicating that all plans outperformed their assumed return targets. The large orange dot represents the average. In the sample, the average plan has an assumed return of 7.2 percent and outperformed that target by 2.2 percent, with an average realized return of 9.4 percent. Although all plans have met or exceeded their assumed return targets over the past ten years, the next decade could be considerably more challenging.

Figure 2

2009–2019 REALIZED RETURNS VS. ASSUMED RETURNS



Past performance is not indicative of future results.

MACRO FACTOR DRIVERS

What enabled public pension plans to achieve such strong levels of outperformance over the past decade? Figure 3 reports the current asset allocation of the average public pension plan. The average allocation is 46 percent in equities, which can be further broken down into U.S., non-U.S., global, and emerging markets with allocations of 26 percent, 13 percent, 4 percent, and 4 percent, respectively. The average plan holds 22 percent in fixed income, which includes allocations of 15 percent to U.S., 2 percent to Treasury Inflation-Protected Securities, and 3 percent to high-yield and emerging-market debt. The remainder consists of fixed income assets such as bank loans, multi-strategy fixed income, and convertible debt. The typical public pension plan holds a large allocation to alternatives, at 30 percent. Across the plans, the smallest alternative allocation is 0 percent and the largest is 59 percent. The alternatives' allocations are roughly equally split across private equity (9 percent), real estate (9 percent), and hedge funds (7 percent). The other real assets allocation (3 percent) consists of investments in infrastructure, commodities, and energy. The remainder of the alternative assets, at 2 percent, are held in private credit strategies, which include direct lending, mezzanine, opportunistic, special situations, and distressed strategies.

All these asset classes have exposure to macro factors—broad and persistently rewarded macro drivers of return. Following the methodology in Bass et al. (2017), we can decompose the asset allocation of plans into macro factors: inflation, real rates, credit, economic growth, emerging markets, commodity, and foreign exchange (FX). In this taxonomy, each asset class is proxied by an underlying benchmark index, and then each asset at the holdings-level is mapped onto these macro factors. Aggregating the macro exposures from the holdings to the total portfolio level, we obtain the breakdown of average risk exposure reported in figure 3B.

The average asset allocation of the plans in figure 3A corresponds to an annualized standard deviation of 11.8 percent. The largest component of this, 75 percent, comes from economic growth. Even though the fixed income allocation of funds is relatively large, 22 percent, the proportion of the risk attributable to macro factors that predominate in fixed income—namely, real rates, inflation, and credit—is small; these three macro factors constitute only 2.0 percent of the total risk of 11.8 percent. This is driven by the relatively low volatility of fixed income investments and low correlation of fixed income

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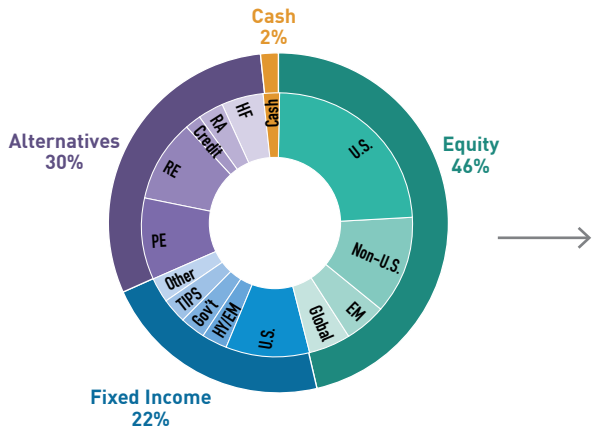
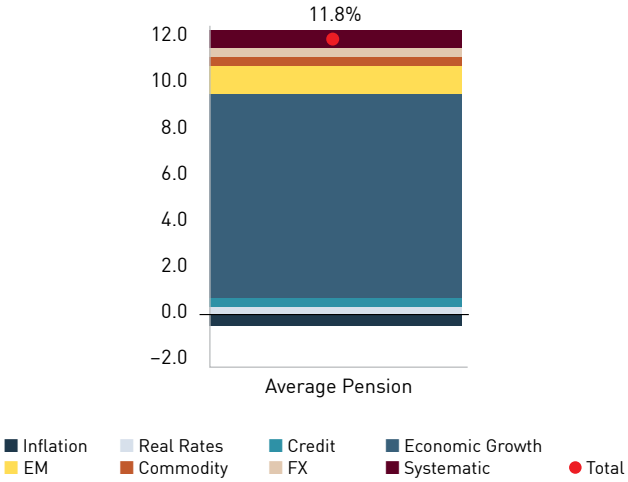
Figure 3

ASSET ALLOCATION AND FACTOR EXPOSURES

(A): Asset Allocation



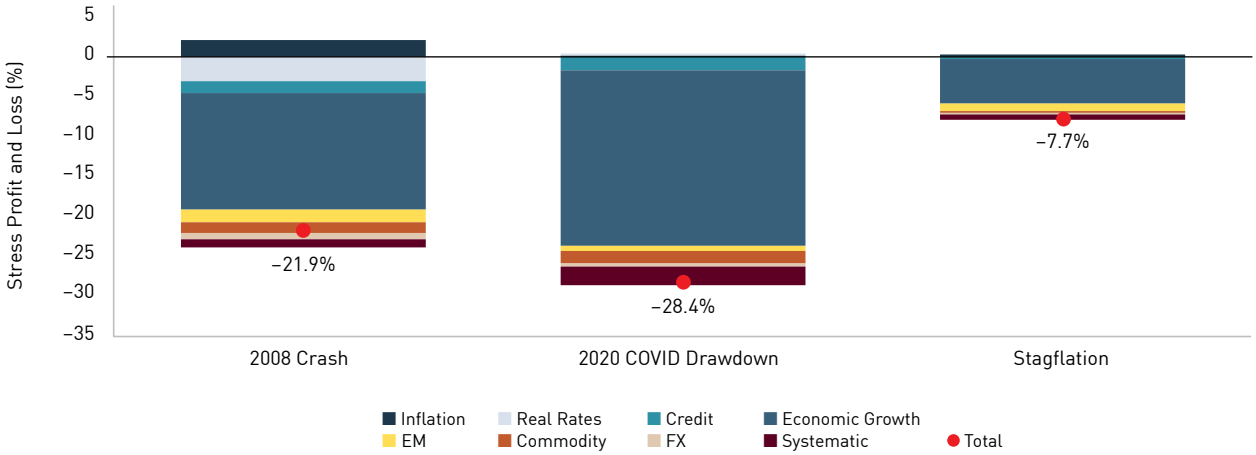
(B): Factor Exposures



Risk: 84-percent confidence interval, 234 constant weighted monthly observations, one-year horizon, as of May 2020; see table A1, "Capital Market and Modeling Assumptions," in the appendix for details regarding the indexes used to represent each asset class.

Figure 4

SCENARIO ANALYSIS



Risk: 84-percent confidence interval, 234 constant weighted monthly observations, one-year horizon, as of May 2020. Historical scenarios simulate each plan's current portfolio through historical time periods. Hypothetical scenarios simulate each plan's current portfolio through hypothetical large market shocks and geopolitical stresses, with implied shocks. The performance shown is hypothetical, does not represent the performance of any existing portfolio, and does not reflect fees and expenses; if fees and expenses were included, the performance would be lower. It is not possible to invest directly in an unmanaged index. There is no guarantee that any portfolio will perform in this manner under similar scenarios going forward. See table A2, "Stress Test Scenario Definitions," in the appendix for details.

with other asset classes. Whereas the proportion of alternative assets held by the average pension fund is high, 30 percent, alternatives have significant large exposure to idiosyncratic as well as macro factors; real estate prices, for example, tend to appreciate when the underlying economy is growing (see, e.g., Geltner and Goetzmann 2000, and Ang et al. 2013). A large literature, including Malkiel and Saha (2005) and Phalippou and Gottschalg (2009), documents that hedge funds and private equity have large and significant equity betas. Thus, although the typical asset allocation of public pension plans appears to be diversified in terms of asset classes, it is highly skewed toward economic growth.

In aggregate, we find a very large exposure of public pension plan portfolios to the economic growth factor. Given that assets sensitive to economic growth have experienced high returns during the past decade, this exposure has been responsible for the outperformance of these plans relative to their assumed returns.

SCENARIO ANALYSIS

One consequence of the large exposure to economic growth of public pension plans is that the aggregate portfolio performance is sensitive to shocks to economic growth. We illustrate this in figure 4, which shows three historical and hypothetical

scenarios. The first two scenarios show the estimated loss in value of the average public pension plan during two historical events. The first event is the Crash of 2008 from September 12, 2008, to November 3, 2008. The second scenario is the peak-to-trough market drop from February 21, 2020, to March 23, 2020, resulting from the COVID-19 outbreak. These historical time frames were two of the most significant market sell-offs since the Great Depression. Given the large exposure to economic growth in the average public pension portfolio, the estimated loss in value is significant in both the 2008 and 2020 scenarios, at -22 percent and -28 percent, respectively. Holding liabilities constant, this would result in approximately a 16-percent decline in funded status in the first scenario and a 21-percent decline in the second.

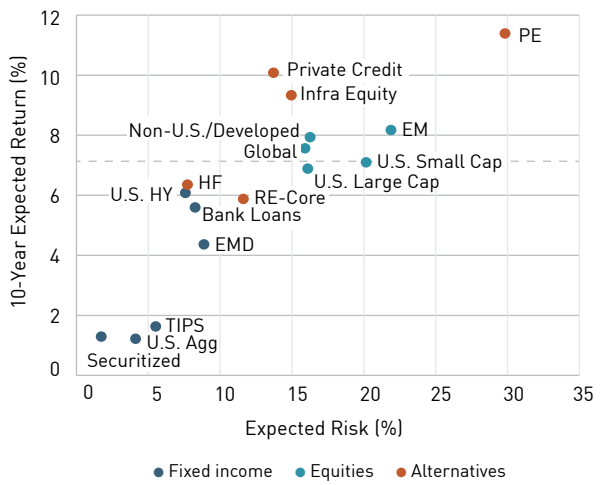
The increased exposure to economic growth makes the typical public pension plan exceedingly sensitive to sell-offs in growth-sensitive assets, and also to stress events where growth slows. The third stress scenario in figure 4 shows just that, a low-growth environment coupled with rising inflation. This stagflation scenario is generated using methods similar to Golub et al. (2018) and Bass et al. (2018). Similar to the prior scenarios, economic growth is the key driver of loss in value, making up 73 percent of the total 8-percent portfolio loss. Holding liabilities constant, this would result in approximately a 6-percent decline in the average plan's funded status.

EFFECT OF LOW RATES AND LOW RETURNS

It is unlikely that, over the next ten years, asset returns will outperform assumed returns by a large margin, as they did over the past ten. Here we investigate the effect of low expected returns over the next ten years. Next, we move beyond the point estimates of the low expected returns and consider forecasted public pension plan performance in the context of historical data distributions. We show that hitting the assumed return targets would be unlikely given the equity, fixed income, and alternative historical return distributions.

Figure 5

FORWARD-LOOKING TEN-YEAR RETURNS



There is no guarantee that the capital market assumptions will be achieved, and actual returns could be significantly higher or lower than those shown. See table A1, "Capital Market and Modeling Assumptions," in the appendix for details.

FORECASTED PENSION PLAN PERFORMANCE

Figure 5 shows the BlackRock Investment Institute's forecasted returns of various asset classes for the next ten years as of May 2020. The dashed horizontal line corresponds to the average assumed return of the public pension plans in this sample, 7.25 percent. Only six asset classes have expected returns that exceed this assumed return: three equity asset classes (non-U.S. developed markets, global equities, and emerging markets) and three private-market asset classes (private credit, infrastructure equity, and private equity). Private equity has an expected return assumption of 11.4 percent, but it has high volatility of 30 percent on a mark-to-market basis (see Chen and Greenberg 2017).

In figure 6A, we examine the implications of these capital market assumptions for our sample of public pension plans. To produce this figure, we take the current asset allocations of each plan as reported, on average, in figure 3 and multiply them by the capital market assumptions given in figure 5. This gives us expected returns for each pension fund. We follow a similar approach, taking into account the full covariance structure, to produce a risk estimate for each plan. We plot the forward-looking expected return of the plans in figure 6A. Although the BlackRock capital market assumptions are beta estimates that do not account for any fees or potential alpha that plans may capture, the results are much lower than the past realized returns versus risk over the previous decade shown in figure 2. With the expected returns shown in figure 6A, more than 70 percent of plans are expected to miss assumed target returns over the next ten years based on their current asset allocations.

Two apparent outliers in figure 6A are forecast to exceed their assumed returns. The first is a state public pension plan with $12.7 billion in AUM that has lowered its assumed return to 5.25 percent over time, making the likelihood of hitting this return more realistic under today's market conditions. This plan's asset allocation of 34 percent to fixed income, 38 percent to equity, and 24 percent to alternatives results in an expected return of 6.8 percent, exceeding the assumed return by 152 bps. The second outlier is a municipal plan with $9.6 billion in AUM, an expected return exceeding 9 percent, and an assumed return of 7.25 percent. This plan is able to generate a large excess expected return through an overweight allocation of 57 percent of the total portfolio to alternatives. Within this plan's alternatives portfolio is a 20-percent allocation to private equity and a 27-percent allocation to private credit, two of the higher-returning asset classes shown in figure 5.

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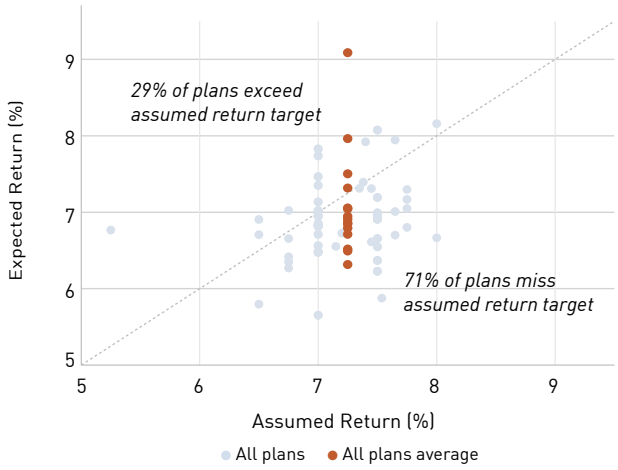
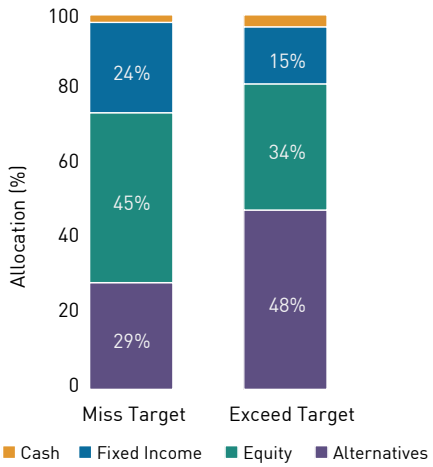
Figure 6

EFFECT OF FORECAST RETURNS

(A): Forecast Returns vs. Assumed Returns



(B): Asset Allocations of Plans with 7.25-percent Assumed Returns



There is no guarantee that the capital market assumptions will be achieved, and actual returns could be significantly higher or lower than those shown. See table A1, "Capital Market and Modeling Assumptions," in the appendix for details.

These two outliers demonstrate two potential responses to these low expected returns for public pension plans: Decrease the assumed return target or change the asset allocation in order to increase the expected return. In fact, public pension plans overall have reduced assumed returns. Ten years ago, the median assumed return was 8 percent, and it has decreased over the past decade.[9] As noted by many financial journalists as well as professionals in the government and nonprofit sectors, lowering the assumed return can lead to substantially higher valuations for liabilities. As Chaney et al. (2002) note, because many states and local governments operate with some form of balanced budget requirement, this can lead to large strains on state or municipal expenditures.

Given the large exposure to the economic growth factor described above, and that economic growth may not deliver, public pension plans are faced with changing their asset allocations to target higher returns. As an example, figure 6B breaks down the current asset allocations of plans with the median 7.25-percent assumed rates of return in our sample. We report the asset allocations of those plans missing or beating the 7.25-percent assumed return. Those plans that are more likely to achieve the target returns have significantly larger allocations to alternatives and lower allocations to fixed income. In particular, for those plans missing the assumed return, the alternatives and fixed income allocations are 29 percent and 24 percent, respectively, versus allocations of 48 percent and 15 percent, respectively, for those plans beating the assumed return target. Thus, by changing their asset allocations, public pension plans may partly position themselves for a low-rate and low-return environment.

DIFFICULTY OF MEETING TARGET RETURNS

We have examined the effect of point estimates for forward-looking expected returns. Now we extend the analysis to interpreting these point forecasts in the context of historical return distributions. Put another way, given the returns data since the 1970s, how likely would it be for the average public pension plan to hit a 7.25-percent return target with its current allocation?

To simplify, we aggregate the pension plan holdings into three broad asset classes: equity, fixed income, and alternatives, which have allocations of 49 percent, 22 percent, and 29 percent, respectively. We proxy the equity and fixed income allocations with U.S. equity and the U.S. Aggregate (Agg), respectively. This is reasonable given that within equities, our plans hold mostly U.S. equities and much smaller allocations to developed markets; and that within fixed income, exposure to Bloomberg Barclays U.S. Agg dominates. For the alternatives, we use an equal-weighted combination of hedge funds, private equity, and real estate.

We proceed as follows. Our starting point is the capital market assumptions for these three assets. With the current allocation, the expected portfolio return is 6 percent, which is 1.25 percent lower than the 7.25-percent target. To meet the target, one can ask for more returns from equities, fixed income, or alternatives. Given the portfolio weights, the mathematically derived required annual returns are 8.6 percent for equity, 6.26 percent for fixed income, or 13.5 percent for alternatives. We start by asking, all else being equal, how likely has it been for equity returns to push portfolio returns to exceed 7.25 percent? We repeat this exercise for fixed income and alternatives.

EQUITIES

To move the average plan's expected return from 6 percent to 7.25 percent by changing only the equity return requires increasing equity's expected return from the current 5.0 percent to 8.6 percent. At first glance, given that the volatility of equities is at 16 percent, this does not seem to be a very unlikely event. However, using a framework examining the different drivers of equity returns, we observe that the 8.6-percent required equity return corresponds to approximately the 90th percentile of historical experience.

Equity returns can come from three channels:[10] price to earning ratio (P/E) expansion (or repricing), earnings per share (EPS) growth, and dividend payout (see Arnott and Bernstein 2002; Grinold and Kroner 2002):

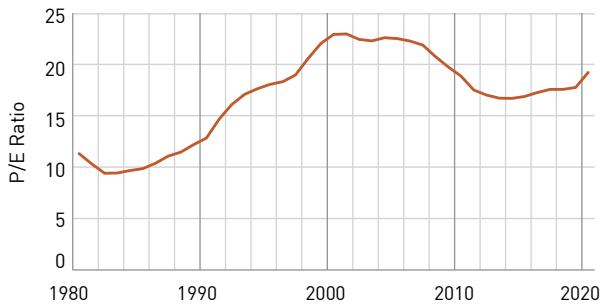
Equity return = % change P/E + % change EPS + dividend yield (1)

On December 30, 2020, the twelve-month trailing P/E for the S&P 500 is 30, which is the highest in history dating back to 1970, and also is one of the highest using extended datasets back to the late 1800s with Campbell and Shiller (1988)-adjusted earnings (see, e.g., Arnott et al. 2017). Figure 7A shows the ten-year rolling average P/E of the S&P 500, with the first ten-year period from 1970 to 1980 plotted at 1980. At the end of the sample on December 31, 2020, the S&P 500 has a P/E of 30 with a ten-year backward-looking average P/E of 19. Assuming that the current P/E of 30 converges to the maximum ten-year average P/E in historical data of 23, the first term in equation (1) is negative at -2.9 percent. The dividend yield traditionally has been fairly stable and is currently 1.5 percent. Thus, to generate an 8.6-percent equity return requires a 10-percent increase in EPS growth to offset the negative P/E impact in equation (1). In fact, holding constant the dividend yield, the required equity return is an implied assumption on both the change in P/E and EPS growth.

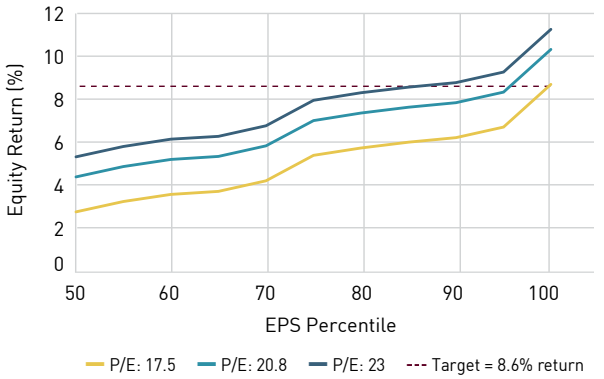
Figure 7

EXPECTED RETURNS IN HISTORICAL CONTEXT

(A): Ten-Year Rolling Average S&P 500 P/E



(B): Required EPS Growth Percentiles to Hit an 8.6-percent Equity Return



In equity valuation models, it is common to assume that long-run EPS growth converges to nominal gross domestic product (GDP) growth (see, e.g., Penman 2006; 2013). In December 2020, the long-run consensus economic GDP forecast is 2.0 percent and the Consumer Price Index inflation forecast is 2.3 percent, yielding a 4.3-percent nominal GDP growth as a long-run EPS growth anchor—much lower than the 10-percent EPS growth required to deliver the 8.6-percent equity return. Historically, EPS growth is more volatile and could deviate from GDP growth.

How likely is it for EPS to grow 5.7-percent faster than GDP? We use the spread between EPS growth and GDP growth as the historical context for different scenarios of equity returns. In figure 7B, we plot the equity return corresponding to different combinations of EPS growth and P/E levels. We show P/E levels of 17.5, 20.8, and 23, which correspond to the 50th, 75th, and 100th percentiles of the historical P/E distribution during 1970–2020. For a given P/E level, we plot the equity return corresponding to different percentiles of EPS growth in excess of nominal GDP. Our goal is to hit an 8.6-percent equity return, implying a 7.25-percent portfolio return, which is shown by the horizontal dashed line. At a P/E level of 23, we would need an 85th percentile of EPS growth over GDP to achieve the 8.6-percent return. If the P/E drops to 17.5, which is the 50th percentile, it would take a 100th percentile EPS growth spread to achieve an 8.6-percent return. Overall, this shows that a fairly extreme combination of both EPS and P/E levels over the next ten years would be required to achieve the target portfolio return of 7.25 percent through increasing equity return.

FIXED INCOME

We now consider the case of changing bond returns, holding constant equity and alternative returns and the current pension plan allocations.

Assuming no change in yields, expected returns for bonds can be expressed as the sum of current yield and expected rolldown (see Ilmanen 2011):

Bond return = Yield + Rolldown (2)

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At December 31, 2020, the U.S. Agg yields 1.12 percent with 34 bps of annual rolldown. This is unprecedentedly expensive. If we assume that the nominal U.S. yield goes to zero, this would generate a 2.1-percent annual return for the next ten years versus the current 0.8-percent assumption. Thus, it is not possible for the pension portfolio to reach 7.25-percent return through extraordinary fixed income returns alone, unless yields go extremely negative. Indeed, assuming the rolldown is held constant, the yield on U.S. Agg would need to decrease to -8.4 percent for the portfolio to yield a 7.25-percent return.

ALTERNATIVES

We group together private equity, real estate, and hedge funds as alternatives. In this analysis, we proxy alternatives as an equal-weighted combination of the three, which is in line with their roughly equal allocation in current pension portfolios. Using data from 2004–2020, the expected return for alternatives of approximately 9.3 percent corresponds to the 54th percentile—close to median.[11] Holding fixed the equity and fixed income expected returns, we can achieve a portfolio 7.25-percent target return on the average pension fund's portfolio if the alternative forecasted return moves from 9.3 percent to 13.5 percent. A 13.5-percent return corresponds to the 80th percentile in the historical data. This would not be unreasonable given the mark-to-market volatility of this asset class is 17.2 percent. A caveat is that long-run samples are unavailable for alternatives data, unlike equities and bonds.

SUMMARY

To summarize, all else being equal, achieving a 7.25-percent target return is possible with the current portfolio only if equity returns increase to approximately the 90th percentile, but with unlikely combinations of earnings growth and P/E changes. To match this return with fixed income returns alone would require unprecedented large moves into negative yields for bonds. For alternatives, the required return is also higher than the current return assumption, though it is more reasonable because it corresponds to the middle of the distribution in historical data. In these exercises, we have held fixed the other expected returns and the composition of the whole portfolio.

An important caveat is that we have considered comparative static exercises and changed only one variable. Thus, we have not considered the real-world case where asset returns are correlated. The advantage of this simplified framework is it highlights the returns required by each asset class and avoids correlation assumptions. The results would be directionally similar introducing correlation and our results are likely conservative. For example, higher equity returns would likely lead to higher returns in alternatives, following historical correlation and the positive exposure of both asset classes to economic growth, as described above. As a result, we would likely require a less-extreme equity return to achieve the 7.25-percent target because of a correlated higher return in alternatives. If equity, fixed income, and alternative returns are positively correlated, the overall difficulty in meeting the return target, in percentiles, would be a weighted average of the 90th, 100th (unprecedented), and 54th percentiles, respectively. Below, we consider a more optimal portfolio mix taking into account correlations.

DIVERSIFYING ROLE OF FIXED INCOME

Given that fixed income, which the current average public pension plan holds at 22 percent, is unlikely to generate high-enough returns to meet pensions' assumed returns, what potential role does it play in a portfolio? One important role is diversification. As noted by Jacobsen and Lee (2020), diversification may lead assets with negative Sharpe ratios to still have optimal non-zero holdings in a portfolio. We now examine the diversification properties of fixed income in public pension plans.

In an unconstrained optimization, the maximum Sharpe ratio portfolio holds weights h, which are proportional to

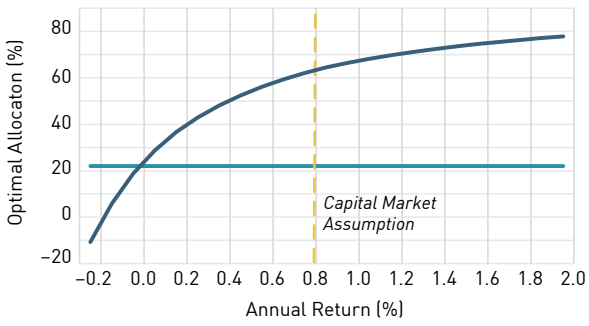
$$h \propto V^{-1}\mu, \tag{3}$$

where $V^{-1}\mu$ is the inverse asset covariance matrix and μ is the excess returns of each asset. Taking the empirical covariance matrix during 2010–2020 with our simplified framework using three asset classes (fixed income, equities, and alternatives), we graph the optimal fixed income allocation in figure 8 as a function of the expected return for fixed income. The average pension holding of fixed income is shown by the blue horizontal line at 22 percent. The vertical yellow dashed line is the baseline capital market assumption for fixed income, which is 0.8 percent.

Figure 8 shows that the optimal allocation to fixed income drops to zero only when the expected return for bonds is less than -0.1 percent. That is, even at a negative expected return, fixed income allocations are additive to the portfolio because they are diversifying. For the implied forward-looking return of 0.8 percent for fixed income in our baseline capital market

Figure 8

OPTIMAL BOND ALLOCATIONS VS. BOND EXPECTED RETURNS



assumptions (see figure 5), the optimal holdings of fixed income actually are much lower than in a mean-variance setting: The average public pension holds 22 percent compared with an optimal holding of 62 percent. There is large sensitivity, partly due to the low correlations of fixed income with equities and alternatives, which are -0.15 and -0.1, respectively. Increasing the expected correlation to zero decreases the optimal fixed income position to 55 percent.

Finally, the diversifying role of fixed income can be seen if we repeat the scenarios shown in figure 4, but we assume that there is zero fixed income, with the fixed income position reallocated pro rata to the other asset classes. Without fixed income, the estimated portfolio returns in the 2008, 2020, and stagflation scenarios would be -27.5 percent, -36.0 percent, and -9.5 percent, respectively, compared with the original estimated returns of -21.9 percent, -28.4 percent, and -7.7 percent, respectively, as reported in figure 4. Clearly, fixed income can be very valuable as a diversifier.

OPTIMAL PENSION PORTFOLIOS

In this section, we investigate some optimal allocations, under the forward-looking ten-year capital market assumptions shown in figure 5.

For this optimization exercise, we employ a robust optimization approach (see Garlappi et al. 2007), where we seek to find the portfolio that maximizes return for a given aversion to uncertainty and risk.[12] We perform two sets of optimizations to help improve the expected risk-adjusted return profile. The first optimization, which we refer to as the Optimal Long Only portfolio, reallocates across all asset classes in a fully funded construct, subject to a limit of 35 percent on private markets. We impose this limit on private markets because of the potential difficulties in accessing capital in illiquid assets during stress periods (see, e.g., Ang et al. 2014) as well as to account for plan liquidity requirements such as benefit payments, plan expenses, capital calls, and other considerations.

In the second optimization, which we call the Optimal With Leverage portfolio, we allow plans to take on leverage, which can be done by direct borrowing or indirectly through strategies employing leverage. (In the latter case, we have assumed no additional alpha by active management.) This can be accomplished directly through a credit line, prime broker arrangement, or direct issuance of debt.[13] Borrowing also can be done implicitly: Many underlying asset classes are levered, the fund can invest in strategies that employ leverage, or the fund could take long-short strategies to transfer risk from one asset class to another, which is also called portable alpha.

Borrowing also can be done implicitly: Many underlying asset classes are levered, the fund can invest in strategies that employ leverage, or the fund could take long-short strategies to transfer risk from one asset class to another, which is also called portable alpha.

OPTIMAL RISK-RETURN PROFILES

Figure 9 shows the risk-return profiles of the two optimizations, which helps improve the efficiency of the current average pension portfolio. For instance, the Optimal Long Only portfolio increases expected return from 6.9 per-cent to 7.3 percent and reduces risk from 11.8 percent to 10.1 percent. The Optimal With Leverage portfolio increases expected return further to 7.9 percent and slightly increases risk from 11.8 percent to 12.0 percent.

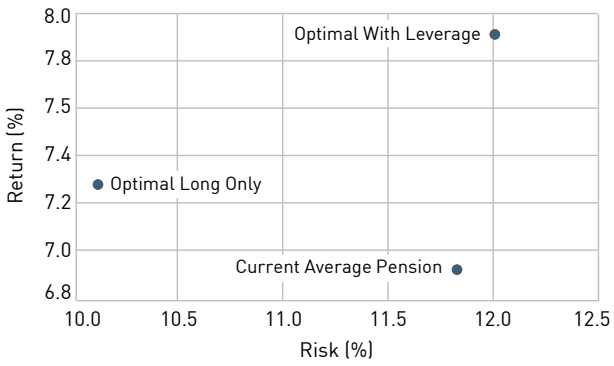
The Optimal Long Only allocation improves returns and reduces risk. The Optimal With Leverage portfolio uses leverage to bring risk back in line with the pension plans' original position, and thus the expected return further increases. Both the Optimal Long Only and Optimal With Leverage portfolios are expected to achieve higher returns than the 7.25-percent assumed return target. Using data since 1970, we estimate that approximately 49 percent of earnings growth outcomes observed over the past few decades would enable the plan to meet the 7.25-percent return target.

OPTIMAL HOLDINGS

What are the compositions of these two optimal portfolios? Table 1 reports the asset class weights of both the Optimal Long Only and the Optimal With Leverage portfolios compared with the original average pension plan portfolio. The Optimal Long Only portfolio reallocates out of equities into alternatives

Figure 9

RISK AND RETURN OF OPTIMAL PORTFOLIOS



There is no guarantee that the capital market assumptions will be achieved, and actual returns could be significantly higher or lower than those shown. See table A1, "Capital Market and Modeling Assumptions," in the appendix for details.

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Table 1

ASSET CLASS WEIGHTS OF OPTIMAL PORTFOLIOS

	Asset Class	Current Average Pension	Optimal Long Only	Optimal With Leverage
Equity	U.S. Equity	25.5%	12.4%	18.8%
	Dev ex-U.S.	7.8%	9.8%	13.2%
	ACWI ex-U.S.	5.4%	0.0%	0.0%
	EM Equity	3.9%	7.9%	9.2%
	Global Equity	3.8%	0.0%	0.0%
	Total Equity	**46.4%**	**30.2%**	**41.2%**
Fixed income	Government Bonds	1.8%	9.1%	9.5%
	IG Fixed Income	14.8%	11.8%	12.3%
	Sub IG Fixed Income	3.5%	1.9%	4.1%
	TIPS	1.9%	2.0%	2.3%
	Total Fixed Income	**22.0%**	**24.8%**	**28.3%**
Alternatives	Private Equity	9.3%	6.9%	8.0%
	Real Estate	9.0%	7.0%	6.8%
	Private Credit	1.9%	14.1%	13.5%
	Real Assets	3.1%	7.0%	6.8%
	Hedge Funds	6.8%	10.0%	10.0%
	Total Alternatives	**30.0%**	**45.0%**	**45.0%**
	Total Cash & Overlay Offset	**1.7%**	**0.0%**	**–14.5%**

and fixed income. In particular, the U.S. equity weight falls from 25.5 percent in the current portfolio to 12.4 percent in the Optimal Long Only portfolio. There are zero holdings of ACWI ex-U.S. and Global Equity in the Optimal Long Only portfolio. The allocation to government bonds increases from 1.8 percent in the current average pension allocation to 9.1 percent. There is a substantial increase in private equity from 1.9 percent to 14.1 percent moving from the current average pension portfolio to the Optimal Long Only portfolio.

The fact that optimal allocations to fixed income increase, given the low expected returns to fixed income, may seem counterintuitive. However, because fixed income tends to be negatively correlated with equities and alternatives, it still acts as a portfolio diversifier. As the optimal portfolios seek to generate greater expected returns by allocating more to alternatives and equities through leverage, the need for fixed income also is increasing due to its potential for protection during downside scenarios. This enables the portfolios to seek higher risk-adjusted returns.

The final column of table 1 reports the holdings of the Optimal With Leverage portfolio, which takes advantage of borrowing. This portfolio does not have the same allocations as the Optimal Long Only portfolio. The total fixed income allocations are similar, at 24.8 percent for the Optimal Long Only portfolio and 28.3 percent for the Optimal With Leverage portfolio; and the total alternative allocations are identical, at 45.0 percent, because of the upper bound on alternatives holdings. The main difference in allowing leverage is that risk is added back to the public equity allocation, which increases from 30.2 percent to 41.2 percent from the Optimal Long Only portfolio to the Optimal With Leverage portfolio. With fixed income playing the role of the diversifier, adding back risk to public equities allows the expected return to be approximately 100 bps higher than the current average pension portfolio (see table 1), even after taking into account the cost of leverage.[14]

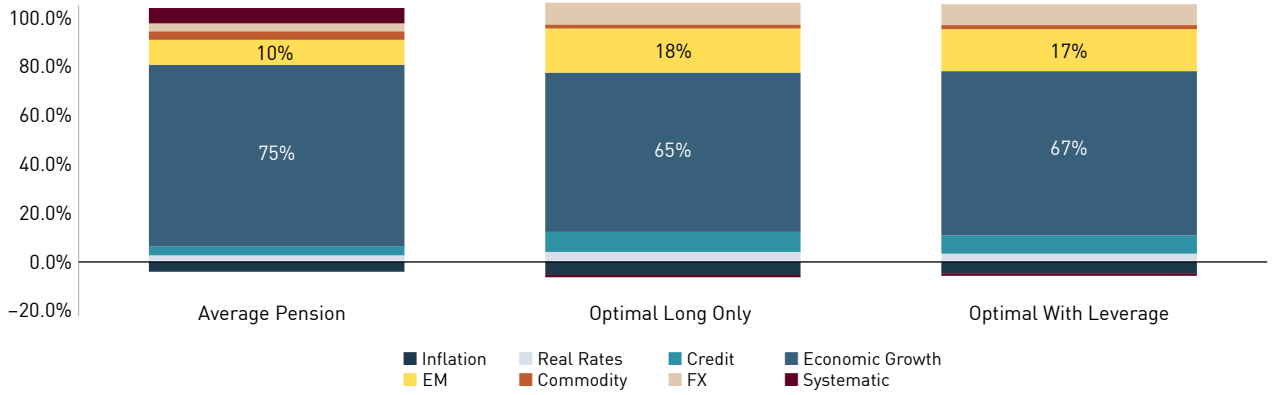
BEHAVIOR IN SCENARIOS

The typical asset allocation of public pension plans is dominated by risk to economic growth, making these portfolios exceedingly sensitive to global stress events where growth slows and growth-sensitive assets sell off. Figure 10 shows the economic exposure for the Optimal Long Only and Optimal With Leverage portfolios with the original pension plans' allocation. The amount of economic exposure has decreased from 75 percent in the current average pension portfolio to 65 percent for the Optimal Long Only and 67 percent for the Optimal With Leverage portfolios. There are also modestly larger exposures to some of the other macro factors. Further robustness and diversification potentially could be added by targeting further reductions to economic growth and increasing exposures to other macro factors.

The lower exposures to economic growth lead to differences in losses in the three stress scenarios as shown in figure 11, which shows conditional returns in the 2008, 2020, and stagflation scenarios. The first column in each scenario corresponds to the average pension fund portfolio and, for reference, is a repeat of figure 4. The second and third columns in each

Figure 10

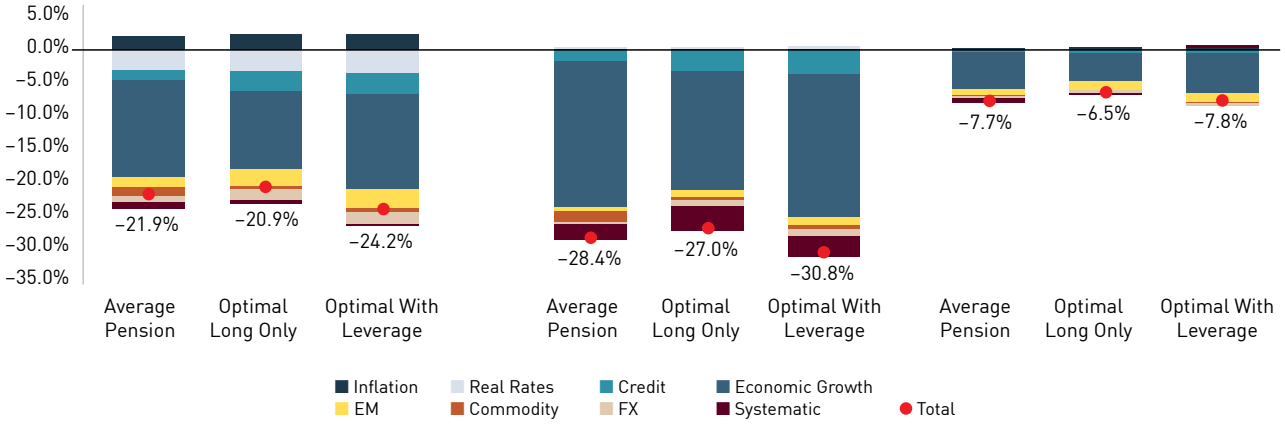
MACRO FACTOR RISK ALLOCATION



Risk: 84-percent confidence interval, 234 constant weighted monthly observations, one-year horizon, as of May 2020; see table A1, "Capital Market and Modeling Assumptions" in the appendix for details regarding the indexes used to represent each asset class.

Figure 11

SCENARIO ANALYSIS OF OPTIMAL PORTFOLIOS



Risk: 84-percent confidence interval, 234 constant weighted monthly observations, one-year horizon, as of May 2020. Historical scenarios simulate each plan's current portfolio through historical time periods. Hypothetical scenarios simulate each plan's current portfolio through hypothetical large market shocks and geopolitical stresses, with implied shocks. The performance shown is hypothetical, does not represent the performance of any existing portfolio, and does not reflect fees and expenses; if fees and expenses were included, the performance would be lower. It is not possible to invest directly in an unmanaged index. There is no guarantee that any portfolio will perform in this manner under similar scenarios going forward. See table A2, "Stress Test Scenario Definitions," in the appendix for details.

scenario illustrate the Optimal Long Only and Optimal With Leverage portfolios.

Figure 11 shows larger credit exposure from allocations to both public and private credit in the Optimal Long Only portfolio, resulting in a more diversified risk profile. Less exposure to economic growth helps the portfolio to perform better than the current average pension portfolio in each of the three scenarios. In the Optimal With Leverage portfolio, the allocation adds exposure to private markets and scales that exposure with leverage, resulting in a slightly higher portfolio risk than the average public pension. Typically, if a portfolio has higher risk, it will tend to perform worse in extreme-stress scenarios. The same is true for this portfolio. Although the portfolio still has an increased amount of credit exposure, economic growth exposure from public and private equity is responsible for the portfolio performing slightly worse than the average pension plan in the three growth-focused scenarios.

CONCLUSION

Over the ten years ending June 30, 2019, risky assets exposed to economic growth enjoyed high returns and bond yields decreased, making fixed income investments attractive. Over this period, a sample of sixty-nine public pension plans with a total of $2.1 trillion in assets outperformed their assumed, or actuarial, rates of return by more than 200 basis points. In fact, 100 percent of public pension plans in our sample beat their assumed returns. This outperformance was driven by these public pension plans' large holdings in growth-sensitive assets.

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There is broad consensus, however, that over the next ten years we will experience a world of low interest rates and low risk premiums on risky assets. Applying a set of forward-looking expected returns developed by the BlackRock Investment Institute to the public pension plans' current asset allocations, we see that more than 70 percent of these plans are expected to not meet their assumed returns. The large growth exposures also mean that these pension plans are sensitive to global stress events where growth-sensitive assets crash, e.g., the crash of 2008, the 2020 COVID market drawdown, and a hypothetical stagflation scenario.

Looking at the broader distribution of equity and fixed income returns since 1970, we find that it would be unlikely for pension plans to hit their assumed returns with their current allocations. This is because the required equity return lies in the top 10 percent of outcomes observed over the past few decades, and for bond returns to generate required capital gains to meet target returns, bond yields would have to decrease to extreme negative levels. Although large allocations to alternative investments with higher return forecasts may help to bridge the gap, outcomes are far from certain.

We also investigated two optimal portfolios, with and without leverage, that are expected to generate returns at or higher than assumed returns with lower or similar levels of volatility. Both portfolios shift some allocations from public equities to private markets. Interestingly, we find that fixed income still plays an important role as a diversifier in these portfolios despite low return expectations. In fact, because of fixed income's diversifying properties, average pension plans would hold positive allocations assuming annual returns as low as -0.2 percent.

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ENDNOTES

1. Represents Russell 3000 Index and MSCI ACWI ex-U.S. Index. Data from BlackRock and Bloomberg.
2. Data from BlackRock and Bloomberg.
3. We use the term "assumed return" to refer to the expected returns assumed in valuing liabilities. This is also known as the actuarial rate of return or the assumed investment return.
4. Data from BlackRock and Bloomberg.
5. All expected returns stated in this paper are annualized unless explicitly stated otherwise. See https://www.blackrock.com/institutions/en-us/insights/charts/capital-market-assumptions. These low forward-looking, long-horizon expected returns are broadly consistent across a range of asset managers and investment banks.
6. See, among other sources, https://www.pewtrusts.org/en/research-and-analysis/issue-briefs/2020/06/the-state-pension-funding-gap-2018. Academic studies include Novy-Marx and Rauh (2011, 2012) and Andonov et al. (2017). This is in contrast to corporate pension plans, which have seen significant improvements in funding status, as noted by Wadia et al. (2021).
7. See Greenberg et al. (2016) for a description of macro factors and how they can be used in strategic allocations. Ang (2014) is a literature summary on factor investing.
8. There is a large literature investigating systematic factor exposures of alternative investments. Early and important papers for real estate are Goetzmann (1993) and Goetzmann and Spiegel (1995), and more recently Sagi (2021), who estimate systematic and idiosyncratic components of real estate returns. For private equity, see Harris et al. (2014, 2016) and Ang et al. (2018). Among the many papers for hedge funds, see Kosowski et al. (2007) and more recently Bollen et al. (2020).
9. The Pew Charitable Trusts reports the median assumed return for the seventy-three state-level funds in its sample was 8 percent before 2010 and is now 7.4 percent (see https://www.pewtrusts.org/en/research-and-analysis/issue-briefs/2019/12/state-pension-funds-reduce-assumed-rates-of-return). This is higher than our sample, but our sample contains both state- and municipal-level funds. The finance literature advocates using low assumed rates of return, which reflects the low risk of public pension plan liabilities, as per theory of Modigliani and Miller (1958) and Sharpe (1964). Using low discount rates, often much lower than the assumed return, results in very large liability estimates as shown by Novy-Marx and Rauh (2011), among others. Kelley (2014) and Aggarwal and Goodell (2015) argue that there are political and cultural considerations in setting the assumed return, beyond economics.
10. One additional component impacting U.S. stock returns positively in the past decade is share repurchases. The seminal study by Ikenberry et al. (1995) shows that companies repurchasing stock tend to have high excess returns. Buybacks can affect the calculation of returns applying equation (1) per share. They do not, however, affect the decomposition in equation (1) for the aggregate market returns because their effects cancel out in both the numerator and denominator on the right-hand-side terms. Also, we have focused primarily on U.S. equities in this analysis. When dealing with international equities, currency yield is also a component of total equity returns.
11. Based on BlackRock's Aladdin dataset. Data for alternatives is admittedly less ideal than for public assets, because of alternatives' relatively short history and many underlying components that are hard to be directly investable. That said, this does not change our conclusions about the difficulty in meeting target returns from the perspective of public market assets.
12. The objective function is therefore to maximize the mean return at some horizon, with two penalties, one for the variability of returns through time (return volatilities) and the other for the dispersion of outcomes at the horizon (projection uncertainty). The inputs are the capital market assumptions developed by the BlackRock Investment Institute, which include the simulation path (a path-wise measure) and dispersion (measure of divergence or spread of simulations across paths, which is a cross-sectional measure) at a point in time in a range of currencies.
13. See https://www.ifre.com/story/1935373/pension-giants-add-leverage-as-30-year-old-canadian-model-flounders-v2gr57zw72.
14. The cost of leverage is 1.2 percent, which is in line with the expected return on cash.

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APPENDIX

Table A1

CAPITAL MARKET AND MODELING ASSUMPTIONS

Asset Class	Asset Description	Benchmark	Ten-year Annual Expected Return	Expected Risk
Cash	U.S. Cash	Citi 3-Month Treasury Bill	1.19%	0.00%
Equity	U.S. Large Cap	Russell 1000 Index	6.89%	16.11%
Equity	U.S. Mid Cap	Russell MidCap Index	6.87%	16.94%
Equity	U.S. Small/Mid Cap	Russell 2500 Index	7.09%	18.67%
Equity	U.S. Small Cap	Russell 2000 Index	7.09%	20.17%
Equity	U.S. All Cap	Russell 3000 Index	6.92%	16.30%
Equity	Non-U.S./Developed	MSCI World ex U.S. Index	7.93%	16.27%
Equity	Non-US	MSCI All Country World ex U.S. Index	8.16%	17.17%
Equity	EM	MSCI Emerging Markets Index	8.17%	21.90%
Equity	Frontier	MSCI Frontier Markets Index	6.13%	15.76%
Equity	Global	MSCI All Country World Index	7.56%	15.91%
Fixed Income	U.S. Aggregate	BBG Barclays U.S. Aggregate Index	1.22%	4.12%
Fixed Income	U.S. High Yield	BBG Barclays U.S. Corporate High Yield Index	6.08%	7.59%
Fixed Income	EM Debt	50% JPMGBIEGDV / 50% EMBIGLOBAL Index	4.36%	8.88%
Fixed Income	Long Duration	BBG Barclays Treasury 10+ Yr Index	–1.44%	15.09%
Fixed Income	TIPS	BBG Barclays U.S. TIPS Index	1.63%	5.52%
Fixed Income	Global Aggregate	BBG Barclays Global Aggregate Index	1.48%	5.56%
Fixed Income	Bank Loans	BlackRock Proxy	5.60%	8.26%
Fixed Income	Convertibles	ICE BofAML U.S. Convertible Excluding 144A Index	6.21%	14.05%
Fixed Income	Multi-Strat	BBG Barclays U.S. Universal Index	1.73%	4.05%
Fixed Income	Securitized	BBG Barclays Securitized Index	1.29%	1.73%
Alternatives	Hedge Funds	BlackRock Proxy: Hedge Funds (global fund weighted)	6.35%	7.73%
Alternatives	Private Equity	BlackRock Proxy: U.S. Buyout PE	11.39%	29.84%
Alternatives	Commodities	S&P GSCI Commodity Index	5.48%	18.67%
Alternatives	Energy	S&P GSCI Energy Index	5.88%	27.81%
Alternatives	Infrastructure Equity	BlackRock Proxy: Global Unquoted Infra Equity	9.33%	14.96%
Alternatives	Timber	S&P Global Timber and Forestry Index	8.94%	22.25%
Alternatives	Farmland	FTSE Nareit Equity Diversified	6.09%	16.79%
Alternatives	MLPs	Alerian MLP Index	3.91%	23.07%
Alternatives	RE – Core	BlackRock Proxy: U.S. Core Real Estate	5.88%	11.62%
Alternatives	RE - Value-Added	BlackRock Proxy: RE - Value-Added US	7.26%	17.76%
Alternatives	RE – Opportunistic	BlackRock Proxy: RE - Opportunistic US	7.63%	19.67%
Alternatives	REITs	FTSE EPRA Nareit United States Index	6.91%	15.53%
Alternatives	Private Credit	BlackRock Proxy: Direct Lending	10.08%	13.71%
Alternatives	Portable Alpha	BlackRock Proxy: Hedge Funds (global fund weighted)	6.35%	7.73%
Alternatives	Risk Parity	16.25% Long Duration, U.S. HY, TIPS, EMD | 20% MSCI ACWI | 15% Commodities	4.66%	7.28%

Risk Parity was constructed by blending six capital market assumptions; see above for more information on each component.

The analysis uses the BlackRock Investment Institute's Capital Market Assumption for U.S. Buyout Private Equity as a proxy for all Private Equity exposure within the public pension portfolios in our analysis. The U.S. Buyout Private Equity proxy uses an unsmoothed approach for its risk exposure when estimating the economic risks of a private equity fund within the context of a multi-asset portfolio. The risk proxy uses average observed fund exposures (based on capital deployed) spanning vintages 2000 to the latest available and takes into account geographic, industry, and capitalization attributes.

The representative indexes listed above may differ from those that are publicly available, but the underlying methodology and assumptions are consistent. BlackRock expected market return information is based on BlackRock's long-term capital market assumptions as of May 2020, which are subject to change. Capital market assumptions contain forward-looking information that is not purely historical in nature. They should not be construed as guarantees of future returns. The projections in table A1 are based on BlackRock's proprietary long-term capital markets assumptions (10+ years) for risk and geometric return and correlations between major asset classes. These asset class assumptions are passive only and do not consider the impact of active management. The assumptions are presented for illustrative purposes only and should not be used, or relied upon, to make investment decisions. The assumptions are not meant to be a representation of, nor should they be interpreted as BlackRock's investment recommendations. Allocations, assumptions, and expected returns are not meant to represent BlackRock performance. Long-term capital markets assumptions are subject to high levels of uncertainty regarding future economic and market factors that may affect actual future performance. Ultimately, the value of these assumptions is not in their accuracy as estimates of future returns but in their ability to capture relevant relationships and changes in those relationships as a function of economic and market influences. Note all information shown is based on assumptions, therefore exclusive reliance on these assumptions is incomplete and not advised. The individual asset class assumptions are not a promise of future performance. Indexes are unmanaged and used for illustrative purposes only and are not intended to be indicative of any fund's performance. It is not possible to invest directly in an index.

Table A2

STRESS TEST SCENARIO DEFINITIONS

Stress Test Scenario	Scenario Type	Historical Period	Implied Shock	Description, Catalysts, and Calibration of Event
2008 Crash	Historical Scenario	September 12, 2008–November 3, 2008	N/A	Credit and liquidity crisis and equity market crash set off by the Lehman Brothers bankruptcy; significant widening of credit spreads caused by massive deleveraging
2020 COVID Drawdown	Historical Scenario	February 21, 2020–March 23, 2020	N/A	Recent market volatility resulting from a more rapid spread of coronavirus than expected
Stagflation	Market-Driven Scenario (Hypothetical)	N/A	S&P 500 –10% S&P 500 Consumer Discretionary +5% U.S. High Yield Market +90bps U.S. 2-year Treasury –10bps U.S. 10-year Treasury +20bps U.S. 10-year CPI +20bps Catalysts: A policy change effectively increases wages; however, amid a backdrop of slowing growth, the increase in wages drives the economy into stagflation	Description: Income inequality is alarmingly high in the United States, with no meaningful changes over the past few decades; a change in policy to address wealth inequality has the potential to drive wages higher.

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