Morgan Stanley

INVESTMENT MANAGEMENT

Managing Inflation Risk through Improved Portfolio Optimization

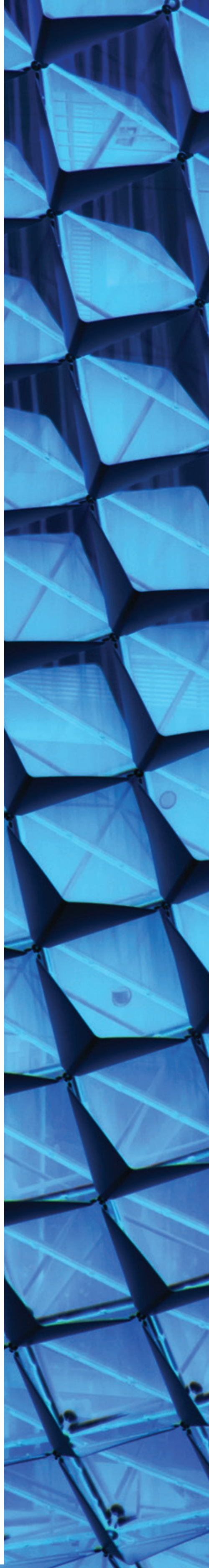
PORTFOLIO SOLUTIONS GROUP | INVESTMENT INSIGHT | DECEMBER 2022

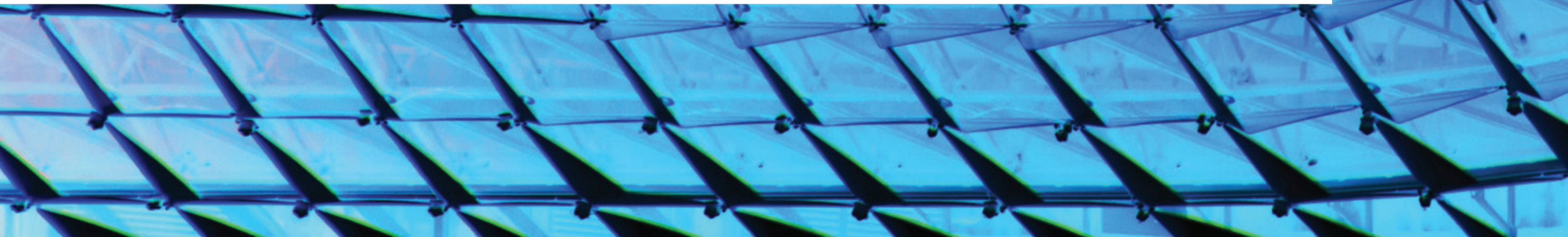
- In a global economy driven by an unprecedented combination of forces, sophisticated investors need improved tools to cope with inflation and growth surprises.
- With inflation lingering around levels that have never been seen in the past four decades, the right tail risk of surprises is still very relevant. At the same time, various GDP tracking tools indicated below-trend or negative levels.
- As of November 2022, the latest median forecast of Survey of Professional Forecasters expected 1-year-ahead inflation to be 3.5% and growth to be 0.8%.
- Investors have generally either not incorporated inflation hedging into their portfolios or have taken a single-asset approach for their hedge (typically TIPS or real estate). New research by Morgan Stanley Investment Management offers a portfolio construction framework that fully optimizes inflation hedging and incorporates investor preferences and expectations. Our approach explicitly factors in the assumptions that investors may very well consider implicitly and uses a variety of assets vs. a single asset.
- This paper offers an improved method for optimizing portfolios in a range of inflationary and growth scenarios, and then suggests appropriate allocations for a range of institutions:
- First, we characterize how assets perform under different market environments, across inflation and growth surprises, based on their sensitivity to those surprises, also taking into account the reliability of those characteristics. This framework is included in a more traditional optimization model that incorporates the risk/return profile of each asset class, as well as investor risk preference.
- Second, we outline portfolios that may be suitable for pension plans, life insurers, and endowments and foundations for a range of target tracking errors.

AUTHORS

PORTFOLIO SOLUTIONS GROUP

Specialists in designing and managing custom multi-asset, multi-manager investment solutions that span from broadly diversified to focused portfolios. The team's expertise lies in partnering with institutional and high net worth investors to understand their unique needs and crafting solutions to help them achieve their overall investment objectives.





Broad Findings

Our broad findings show that asset classes can be categorized by their typical responses to inflation and growth surprises: 1) ones that are mainly driven by growth surprises, like public and private equities; 2) ones that are driven by inflation, such as commodities; and 3) ones that are driven by both inflation and growth.

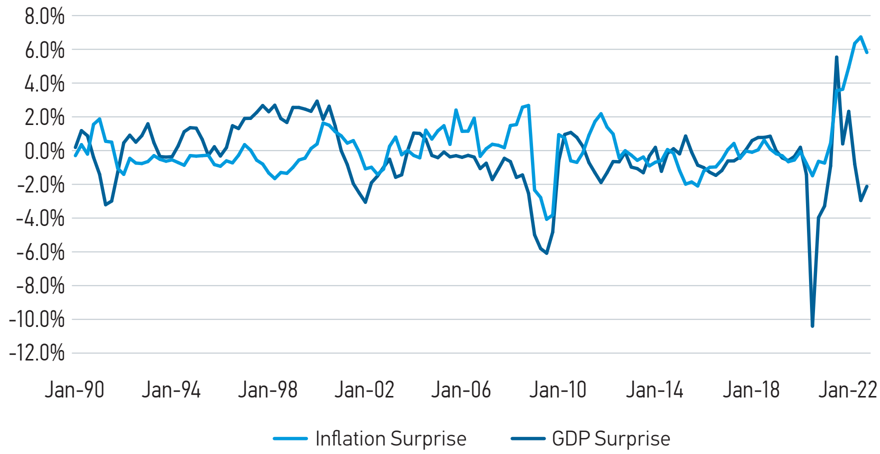
Because assets span this spectrum, how one hedges inflation, and the funding source, depend on the intersection of both types of surprises.

The paper suggests a number of perhaps non-obvious implications for asset allocators including:

- As a baseline scenario, (e.g., when growth surprises are modest), equity allocations should not vary significantly with inflation. Related, reducing the fixed income allocation is a dominant funding source for more inflation-oriented portfolios.
- When stagflation prevails, TIPS will likely be a more attractive hedge, while in an overheating environment, commodities will be more attractive.
- Similarly, the role equity plays also varies highly—when stagflation prevails, reducing the equity allocation will be a dominant source for funding hedging assets, but in an overheating environment, only modest equity reductions are called for.
- Finally, within equities, high inflation has historically made private equity even more attractive relative to public equity. This can also remain true going forward due to the concentration of private equity in secular growth areas such as technology, and healthcare which may increase prices easily.

DISPLAY 1

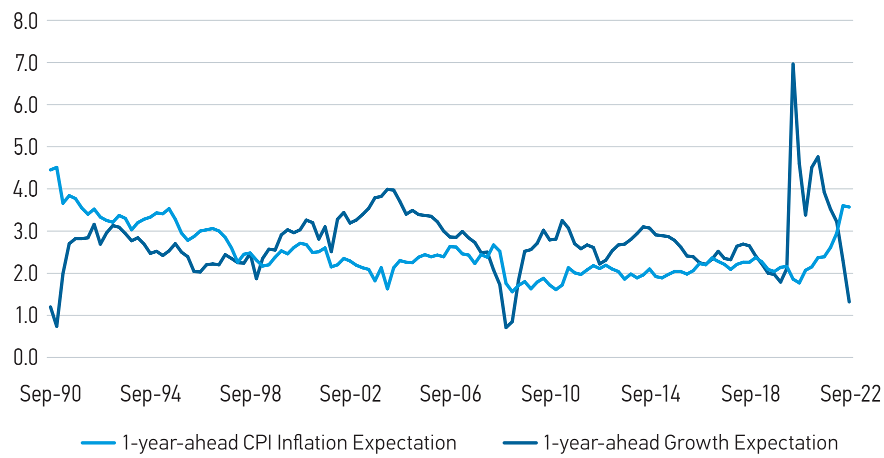
Inflation and growth surprises have surged recently...



Source: Bloomberg LLC, Survey of Professional Forecasters, September 2022

DISPLAY 2

... boosting expectations for higher inflation and lower growth.



Source: Survey of Professional Forecasters, September 2022

For the past two years, inflation growth has repeatedly surprised to the upside. This is shown on the right side of *Display 1*, along with highly volatile growth surprises, both to the upside and downside. This trend is boosting expectations for higher inflation and weaker growth (*Display 2*), while *Display 3* illustrates the toll this took on both equity and fixed-income markets in the first half of 2022.

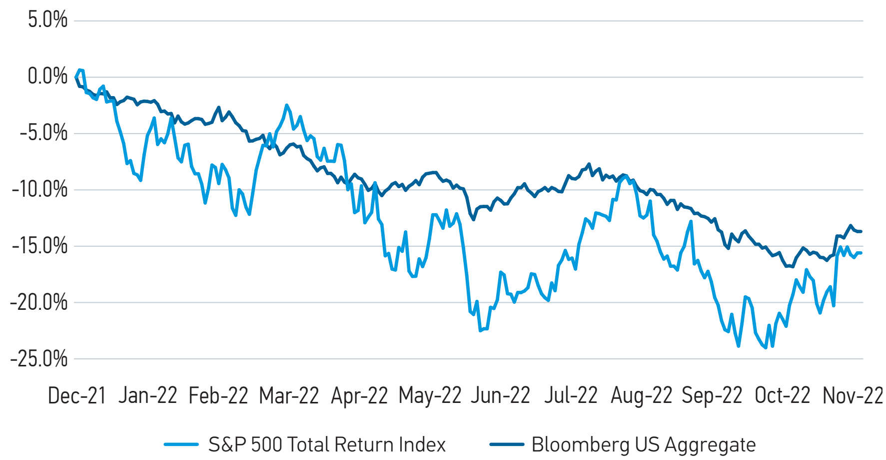
The largest inflationary surge in four decades stems from a significant imbalance in supply and demand, as the global economy has been buffeted by an unprecedented combination of factors. A global health crisis, followed by massive monetary and fiscal stimulus, and the war in Ukraine have led to huge shifts in consumer demand and sustained disruptions to global supply chains.

CPI subcomponents suggested that inflation pressures were broad based and inclusive of stickier categories (e.g. rent and owners-equivalent-rent). Slower growth was shown by PMI indexes maintaining a downward trend, economic surprise indexes that remained in negative territory, and various GDP tracking tools indicating below-trend or negative levels.

The U.S. Federal Reserve responded aggressively in 2022, hiking rates rapidly to bring the target fed funds rate back to neutral. After the Fed's July meeting, Chair Jerome Powell held out the hope that "at some point it will be appropriate to slow down."

DISPLAY 3

Inflation and growth trends weighed on equity and bond markets in 2022



Source: Bloomberg LLC, November 2022.

A PORTFOLIO FRAMEWORK ATTUNED TO INFLATION RISK

Our framework starts with the investor's benchmark portfolio, which we assume implies original return expectations. Our factor model, combined with inflation and growth surprises, forecasts how returns may differ from the original expectations. We combine the confidence level of the forecasts with the two sets of return expectations, with help from the classic Black-Litterman approach. The final return output is fed into a mean-variance optimization to generate the optimal portfolio. Please see appendix for further details.

The inflation hedging challenge

In this uniquely challenging environment, investors are moving quickly to devise strategies for hedging inflation exposure.

However, most inflation hedging strategies pursued by investors typically involve no more than adding allocations to TIPS, commodities and real estate. Some go a little further by overweighting assets expected to be the most sensitive to inflation. We believe that such strategies fall short because they lack a comprehensive approach that is suitable for the objectives and constraints of sophisticated investors and do not account for economic growth scenarios.

Thus, we believe that investors would be well served with an approach that fully integrates inflation hedging, and incorporates investor preferences and expectations. New research by Morgan Stanley Investment Management refines the classic portfolio construction framework with that goal in mind. This paper outlines our approach (see callout), which examines the value of inflation hedges based on criteria that include:

- Sensitivity and stability with regard to inflation surprises in a range of different magnitudes.
- Performance in periods of positive or negative growth surprises.
- How the portfolio is likely to conform to investor preference for risk tolerance and return expectations.

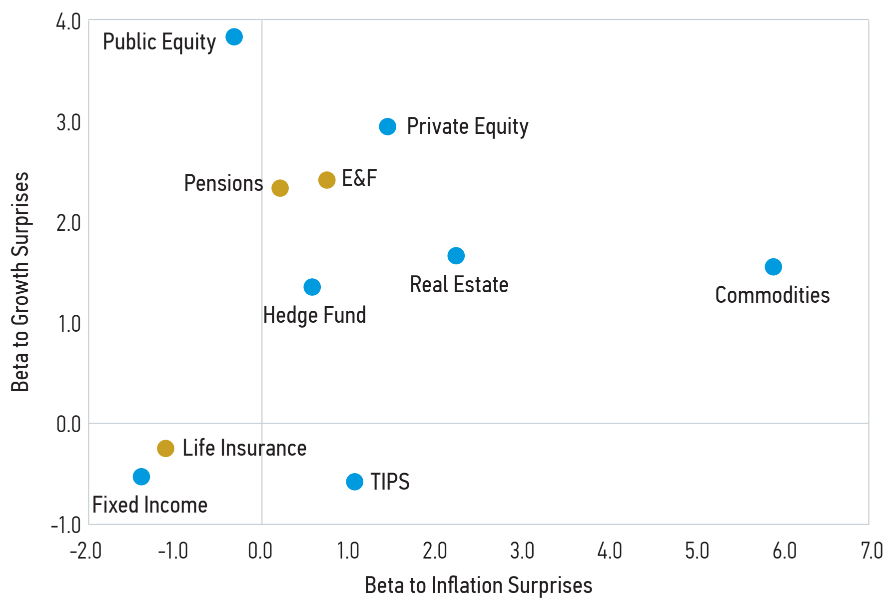
Asset sensitivity to inflation and growth

One of the fundamental concepts in our analysis involves how different asset sectors respond to both inflation and growth surprises. We define inflation surprises as the difference between realized inflation and inflation expectations, and similarly for growth surprises. We believe asset prices should reflect aggregate inflation and growth expectations, but surprises will drive returns that vary from what the market had predicted.

For example, *Display 4* shows that commodities, with a beta of over 6 to inflation surprises, are the most highly sensitive to that risk. Many commodities are important inputs to production, and all else being equal, their rising prices will eventually be passed through to consumer goods. In addition, their prices are very sensitive to supply/demand balance, typically rising when demand exceeds supply, either due to surging demand or supply disruptions.

DISPLAY 4

Most institutional portfolios have modest or negative betas to inflation surprises



9/30/81 – 3/31/22. Sources: Morgan Stanley Investment Management, Bloomberg, Cambridge Associates, NCREIF, Haver, Survey of Professional forecasters. Date range reflects earliest availability of data. Please see appendix for details about actual index data and calculation.

In contrast, public equity has a negative beta to inflation surprises, but the largest positive beta to growth surprises. The relationship between equity and inflation is less clear, as inflation can increase both the future earnings and discount rate at the same time. Earnings growth depends on two factors: the company's exposure to rising input costs, and whether it is in a position to pass those price increases through to customers.

Display 4 also shows the sensitivity of typical portfolios of life insurers, endowments and foundations, and pension funds. All of those portfolios have either negative or modest positive beta. This suggests that some rebalancing to adjust for an inflationary environment would be desirable for all three.

Examining asset shifts

The model provides guidance for how portfolio weights to various asset classes should change as a function of growth and inflation surprises. This provides insights to the role of each asset class in various regimes. *Displays 5-7* shows the magnitude of asset shifts in optimally hedged portfolios, under different scenarios of inflation and growth, with surprises that range from -4% to 4%. The color coding, from red to yellow to green, illustrates the progression from reducing allocations to increasing them.

To illustrate the principle and streamline this presentation, these displays just represent allocation shifts within typical pension fund portfolios with a maximum 4% tracking error;[1] life insurers and endowment and foundation (E&F) will be included later.

[1] We fixed the confidence level (tau) in the Black-Litterman model to reflect to the impact of different surprise magnitudes. Across scenarios, tracking error can be as high as 3.6%.

Display 5 shows that equities (including both public and private) are mainly driven by growth surprises, regardless of inflation. For example, assuming a growth surprise of 0%, the variation of expected allocation shift to equities is small, while fixed income varies widely with very large shifts as a funding source for inflation hedges. Commodities again are very sensitive to changes. Assuming a high inflation surprise of 4%, recommended allocation shifts range from 9%, when growth is negative 4%, to 14% when growth is positive 4%.

TIPS and real estate make another interesting contrast. *Display 6* reveals an important, and counterintuitive, aspect of TIPS in an optimal portfolio—as growth surprises transition from negative to positive, the allocation to TIPS gets smaller. That is because TIPS are negatively impacted by real yields which, on average, are positively correlated with growth and tend to rise when monetary policy turns more hawkish. In contrast, commodities and real estate provide more "bang for the buck" as inflation hedges in a strong growth economy. As *Display 6* shows, in contrast, real estate progresses from a poor inflation hedge to a good one as growth surprises go from negative to positive, when inflation surprise is moderate.

Our analysis also found that TIPS weightings do not increase linearly to the inflation surprise upper bound of 4%. Rather, the TIPS weighting increases when inflation surprise magnitude is moderate and then decreases when inflation surprises further increase. The precise "peak" for the TIPS allocation depends on growth surprise magnitude and investor confidence level in the model's return forecasts—for higher confidence levels, the transition away from TIPS to commodities and real estate would start sooner. This is because investors are likely to allow more concentration in commodities and real estate when they are more confident about the model's return forecasts, which expects outperformance in those two asset sectors.

DISPLAY 5

Equities are driven mainly by growth surprises, commodities by inflation

INFLATION SURPRISE

GROWTH SURPRISE

EQUITIES	-4%	-3%	-2%	-1%	0%	1%	2%	3%	4%
4%	8%	8%	8%	8%	8%	8%	9%	10%	9%
3%	6%	6%	6%	6%	6%	6%	6%	7%	8%
2%	4%	4%	4%	4%	4%	4%	4%	4%	5%
1%	2%	2%	2%	2%	2%	2%	2%	2%	2%
0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
-1%	-3%	-2%	-2%	-2%	-2%	-2%	-2%	-2%	-2%
-2%	-6%	-5%	-4%	-4%	-4%	-4%	-4%	-4%	-4%
-3%	-9%	-8%	-7%	-6%	-6%	-6%	-6%	-6%	-6%
-4%	-12%	-10%	-9%	-8%	-8%	-8%	-8%	-8%	-8%

INFLATION SURPRISE

GROWTH SURPRISE

COMMODITIES	-4%	-3%	-2%	-1%	0%	1%	2%	3%	4%
4%	-5%	-5%	-4%	-1%	2%	5%	9%	12%	14%
3%	-5%	-5%	-4%	-1%	2%	5%	8%	11%	14%
2%	-5%	-5%	-5%	-2%	1%	4%	7%	10%	13%
1%	-5%	-5%	-5%	-2%	1%	4%	7%	10%	13%
0%	-5%	-5%	-5%	-3%	0%	3%	6%	9%	12%
-1%	-5%	-5%	-5%	-4%	-1%	2%	5%	8%	11%
-2%	-5%	-5%	-5%	-4%	-1%	2%	4%	7%	10%
-3%	-5%	-5%	-5%	-5%	-2%	1%	4%	7%	10%
-4%	-5%	-5%	-5%	-5%	-3%	0%	3%	6%	9%

Sources: Morgan Stanley Investment Management, Bloomberg, Cambridge Associates, NCREIF, Haver, Survey of Professional forecasters. Please see appendix for details about actual index data and calculation.

DISPLAY 6

TIPS are favored when growth surprises are negative —real estate, the opposite

INFLATION SURPRISE

GROWTH SURPRISE

TIPS	-4%	-3%	-2%	-1%	0%	1%	2%	3%	4%
4%	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-1%
3%	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-1%
2%	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-1%
1%	-1%	-1%	-1%	-1%	-1%	0%	1%	0%	-1%
0%	-1%	-1%	-1%	-1%	0%	1%	2%	3%	1%
-1%	-1%	-1%	-1%	0%	1%	2%	4%	5%	5%
-2%	-1%	-1%	-1%	2%	3%	4%	5%	6%	7%
-3%	-1%	-1%	-1%	3%	4%	5%	6%	7%	9%
-4%	-1%	-1%	-1%	4%	6%	7%	8%	9%	10%

INFLATION SURPRISE

GROWTH SURPRISE

REAL ESTATE	-4%	-3%	-2%	-1%	0%	1%	2%	3%	4%
4%	-4%	-2%	0%	2%	3%	4%	5%	5%	5%
3%	-5%	-3%	-1%	1%	2%	4%	5%	6%	6%
2%	-6%	-4%	-2%	0%	2%	3%	5%	6%	6%
1%	-7%	-5%	-2%	-1%	1%	2%	4%	6%	7%
0%	-8%	-6%	-3%	-2%	0%	2%	3%	5%	6%
-1%	-8%	-6%	-4%	-2%	-1%	1%	2%	4%	5%
-2%	-8%	-7%	-5%	-3%	-2%	0%	1%	3%	4%
-3%	-8%	-8%	-6%	-4%	-3%	-1%	0%	2%	4%
-4%	-8%	-8%	-7%	-5%	-4%	-2%	0%	1%	3%

Sources: Morgan Stanley Investment Management, Bloomberg, Cambridge Associates, NCREIF, Haver, Survey of Professional forecasters. Please see appendix for details about actual index data and calculation.

The final pair comprises fixed income and hedge funds (*Display 7*). Fixed income is the main underweight in high-inflation scenarios, and it requires changes in much larger dollar amounts versus the other asset classes. This is not surprising, as fixed income generally is hurt the worst by inflation. Coupons and principal payments are fixed, providing no offsets when yields rise along with inflation. Hedge funds might be considered the "plug" position in the portfolio. With its moderate beta to both inflation and growth surprises, the hedge fund allocation serves as a diversifier driven by the shifts in other asset classes in the portfolio.

DISPLAY 7

Fixed income is the main underweight as inflation grows

FIXED INCOME (GROWTH SURPRISE \ INFLATION SURPRISE)	-4%	-3%	-2%	-1%	0%	1%	2%	3%	4%
4%	2%	-4%	-10%	-15%	-20%	-21%	-21%	-21%	-21%
3%	7%	1%	-4%	-10%	-15%	-20%	-21%	-21%	-21%
2%	12%	7%	1%	-4%	-10%	-15%	-21%	-21%	-21%
1%	17%	12%	6%	1%	-4%	-10%	-17%	-21%	-21%
0%	21%	17%	12%	6%	0%	-6%	-13%	-19%	-21%
-1%	24%	22%	17%	10%	4%	-2%	-9%	-15%	-21%
-2%	27%	25%	22%	14%	8%	1%	-5%	-11%	-18%
-3%	30%	29%	26%	18%	12%	5%	-1%	-7%	-14%
-4%	33%	31%	29%	22%	16%	9%	3%	-3%	-10%

HEDGE FUND (GROWTH SURPRISE \ INFLATION SURPRISE)	-4%	-3%	-2%	-1%	0%	1%	2%	3%	4%
4%	0%	4%	6%	7%	8%	4%	0%	-5%	-7%
3%	-2%	1%	4%	5%	6%	6%	3%	-2%	-6%
2%	-5%	-1%	2%	3%	4%	4%	5%	2%	-3%
1%	-7%	-4%	0%	1%	2%	3%	3%	4%	0%
0%	-7%	-6%	-2%	-1%	0%	1%	2%	3%	2%
-1%	-7%	-7%	-5%	-3%	-2%	-1%	0%	1%	2%
-2%	-7%	-7%	-7%	-4%	-4%	-3%	-2%	-1%	0%
-3%	-7%	-7%	-7%	-6%	-5%	-4%	-4%	-3%	-2%
-4%	-7%	-7%	-7%	-7%	-7%	-6%	-5%	-4%	-4%

Sources: Morgan Stanley Investment Management, Bloomberg, Cambridge Associates, NCREIF, Haver, Survey of Professional forecasters. Please see appendix for details about actual index data and calculation.

Portfolio implications

Display 8 shows how these concepts apply in a typical pension plans portfolio in three inflation scenarios: high inflation/high growth, high inflation/low growth, and high inflation growth in the 90th percentile. The high and low scenarios are defined as whether the inflation or growth surprises are positive or negative. We add two new dimensions to the analysis: A range of tracking errors that reflect risk preference, and the corresponding expected changes to the portfolio's betas to inflation and growth surprises.

Both of the first two tables in *Display 8* are high inflation scenarios, but one is low growth and the other, high growth. Their differences and commonalities further illustrate how hedging assets are best positioned in optimal portfolios.

In the high inflation and high growth scenarios, commodities and real estate allocations are increased. As the portfolio's desired tracking error is increased, commodities gain larger positions to boost growth potential. The equities allocation is also increased. This is not surprising, as higher equity exposure is preferred when experiencing positive growth surprises. Private equity is favored against its public counterpart, as it has slightly better inflation hedging characteristics. The allocation is largely funded by nominal fixed income and hedge funds.

In the high-inflation and low-growth scenarios, commodities and real estate allocations are increased, as in the prior scenario. Similarly, nominal fixed income and hedge fund positions are reduced as tracking error increases. The equities position is also reduced.

The biggest difference between the high- and low-growth scenarios is the positioning of TIPS. As noted above, TIPS are negatively correlated to real yields. When growth surprises are high, TIPS only merit a small allocation, across all tracking error preferences, in favor of hedging assets with larger betas to growth. In contrast, with a stagflation economy—high inflation, low growth—TIPS play a larger role, which grows as tracking error increases.

The last table in looks at a special case scenario of very high inflation surprises, when inflation exceeds the 90th percentile. It is comparable to high inflation/high growth scenario, but allocations to real estate and commodities are even greater.

The goal of these allocations is to manage inflation exposure, within the investor's risk profile, and that is achieved by increasing the portfolio's beta to inflation, as shown in the last line of the three displays. For the high inflation/high growth scenario, the base case inflation surprise beta is 0.21. That increases gradually from 0.39 to 1.55, as tracking error preferences increase.

For the stagflation scenario base case inflation surprise beta is the same 0.21. That increases from 0.45 to 2.07, corresponding to larger tracking errors. The inflation betas grow the most in the inflation-90th percentile scenario, ranging from 0.45 to 2.01.

DISPLAY 8

Optimal portfolios shift under different inflation and growth scenarios.

High inflation/high growth

ASSET CLASS / TRACKING ERROR	0.0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%
	CHANGE IN ALLOCATION								
US Equity		0.7%	1.4%	2.1%	2.8%	2.9%	2.5%	1.7%	-2.5%
US Fixed Income		-4.6%	-9.2%	-14.0%	-18.9%	-21.0%	-21.0%	-21.0%	-21.0%
TIPS		-0.4%	-0.7%	-0.9%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%
Hedge Fund		1.3%	2.7%	4.1%	5.5%	2.8%	-2.5%	-7.0%	-7.0%
Private Equity		0.5%	0.9%	1.3%	1.7%	3.8%	6.9%	10.0%	14.5%
Real Estate		1.1%	2.1%	3.2%	4.3%	4.9%	5.1%	5.2%	3.1%
Commodity		1.4%	2.8%	4.2%	5.6%	7.7%	10.0%	12.2%	13.9%
infl beta	0.21	0.39	0.57	0.75	0.94	1.11	1.27	1.42	1.55
gdp beta	2.33	2.45	2.58	2.70	2.82	2.90	2.95	2.98	2.95

High inflation/low growth

ASSET CLASS / TRACKING ERROR	0.0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%
	CHANGE IN ALLOCATION								
US Equity		-1.8%	-3.7%	-5.5%	-7.4%	-9.3%	-11.3%	-13.6%	-16.1%
US Fixed Income		-3.4%	-6.8%	-10.2%	-13.8%	-17.4%	-20.9%	-21.0%	-21.0%
TIPS		2.5%	5.0%	7.7%	10.5%	13.4%	16.3%	16.4%	16.0%
Hedge Fund		-0.7%	-1.3%	-2.0%	-2.7%	-3.4%	-4.1%	-6.0%	-7.0%
Private Equity		0.0%	-0.1%	-0.1%	-0.1%	-0.1%	0.0%	0.4%	0.7%
Real Estate		0.9%	1.7%	2.6%	3.4%	4.2%	4.9%	5.8%	6.7%
Commodity		2.6%	5.1%	7.6%	10.1%	12.6%	15.1%	18.0%	20.8%
infl beta	0.21	0.45	0.70	0.94	1.19	1.44	1.69	1.88	2.07
gdp beta	2.33	2.31	2.28	2.26	2.23	2.20	2.17	2.13	2.09

Inflation > 90%ile

ASSET CLASS / TRACKING ERROR	0.0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%
	CHANGE IN ALLOCATION								
US Equity		-0.3%	-0.7%	-1.1%	-1.5%	-2.2%	-3.4%	-5.0%	-7.7%
US Fixed Income		-4.9%	-9.8%	-14.7%	-19.5%	-21.0%	-21.0%	-21.0%	-21.0%
TIPS		0.9%	1.7%	2.5%	3.4%	1.3%	-1.0%	-1.0%	-1.0%
Hedge Fund		0.7%	1.3%	2.0%	2.6%	2.1%	0.1%	-4.2%	-7.0%
Private Equity		0.3%	0.6%	0.9%	1.2%	1.9%	3.1%	5.1%	7.3%
Real Estate		1.2%	2.4%	3.6%	4.8%	6.2%	7.4%	8.1%	8.3%
Commodity		2.2%	4.5%	6.7%	9.0%	11.7%	14.8%	18.0%	21.1%
infl beta	0.21	0.45	0.70	0.94	1.19	1.39	1.58	1.80	2.01
gdp beta	2.33	2.41	2.49	2.57	2.65	2.71	2.76	2.76	2.73

Sources: Morgan Stanley Investment Management, Bloomberg, Cambridge Associates, NCREIF, Haver, Survey of Professional forecasters. Please see appendix for details about actual index data and calculation.

DISPLAY 9

Portfolios can be optimized for pension plans, life insurers and E&Fs.

Pension Plans

ASSET CLASS	BASE CASE	HIGH INFLATION HIGH GROWTH	HIGH INFLATION LOW GROWTH	LOW INFLATION HIGH GROWTH	LOW INFLATION LOW GROWTH	INFLATION > 90%ILE
US Equity	49.0%	51.1%	47.1%	51.3%	47.0%	47.8%
US Fixed Income	21.0%	7.3%	17.4%	19.9%	35.9%	4.6%
TIPS	1.0%	0.1%	3.6%	0.0%	2.2%	3.8%
Hedge Fund	7.0%	11.0%	6.3%	8.7%	2.8%	9.2%
Private Equity	9.0%	10.3%	9.0%	9.2%	7.6%	10.0%
Real Estate	8.0%	11.1%	8.9%	7.7%	4.5%	12.0%
Commodity	5.0%	9.1%	7.7%	3.2%	0.2%	12.6%
Tracking Error	0.0%	1.5%	0.5%	0.5%	1.6%	1.7%
CHANGE IN ALLOCATION						
US Equity		2.1%	-1.9%	2.3%	-2.0%	-1.2%
US Fixed Income		-13.7%	-3.6%	-1.1%	14.9%	-16.4%
TIPS		-0.9%	2.6%	-1.0%	1.2%	2.8%
Hedge Fund		4.0%	-0.7%	1.7%	-4.2%	2.2%
Private Equity		1.3%	0.0%	0.2%	-1.4%	1.0%
Real Estate		3.1%	0.9%	-0.3%	-3.5%	4.0%
Commodity		4.1%	2.7%	-1.8%	-4.8%	7.6%
infl beta	0.21	0.74	0.47	0.11	-0.39	1.03
gdp beta	2.33	2.69	2.30	2.42	1.93	2.60

Endowment and foundations and life insurers

We believe our approach is robust enough to accommodate a range of investor objectives and constraints, and here we offer additional examples that include E&F and life insurers, in addition to pension plans portfolios *(Display 9)*. To keep the examples comparable, we assume the same confidence level in the forecasted return due to inflation and growth surprises.

Life insurers are inherently less vulnerable to inflation, because the bulk of their liabilities are fixed in nominal terms. This is evident in their base 90% allocation to fixed income, which barely changes, regardless of the different growth and inflation scenarios.

E&F base portfolios are characterized by large positions in alternatives. In the case where the fixed income allocation is depleted, alternatives can provide another source to fund inflation hedges. On the other hand, pension funds have large positions in fixed income—21% in the base case—which gives them a lot of flexibility in reallocating to inflation hedges.

As with the pension plans example in *Display 8*, the "inflation beta" line near the bottom of *Display 9* shows how the betas of the optimized portfolios are improved over the base case. But *Display 8* only illustrated how betas increase as inflation grows. *Display 9* further shows how inflation betas are successfully reduced below the base portfolios in low-inflation scenarios.

Tools for coping with surprise challenges

The combination of forces driving the global economy today has little precedent. We believe that our approach to optimizing portfolios is worth considering by institutional investors, as they seek a new level of sophisticated hedging tools for the surprises that growth and inflation may have in store.

Endowment and Foundations

ASSET CLASS	BASE CASE	HIGH INFLATION HIGH GROWTH	HIGH INFLATION LOW GROWTH	LOW INFLATION HIGH GROWTH	LOW INFLATION LOW GROWTH	INFLATION > 90%ILE
US Equity	29.5%	30.7%	27.3%	32.0%	27.2%	28.9%
US Fixed Income	9.8%	0.0%	5.9%	8.0%	26.9%	0.4%
TIPS	0.5%	0.0%	3.4%	0.0%	1.2%	2.1%
Hedge Fund	18.6%	17.3%	17.8%	20.5%	13.6%	19.9%
Private Equity	30.8%	34.1%	30.8%	31.0%	29.2%	31.4%
Real Estate	5.8%	8.1%	6.8%	5.4%	1.9%	8.1%
Commodity	5.0%	9.7%	8.0%	3.0%	0.0%	9.3%
Tracking Error	0.0%	1.4%	0.6%	0.5%	1.8%	1.0%
CHANGE IN ALLOCATION						
US Equity		1.2%	-2.2%	2.5%	-2.3%	-0.6%
US Fixed Income		-9.8%	-3.9%	-1.8%	17.1%	-9.4%
TIPS		-0.5%	2.9%	-0.5%	0.7%	1.6%
Hedge Fund		-1.3%	-0.8%	1.9%	-5.0%	1.3%
Private Equity		3.3%	0.0%	0.2%	-1.6%	0.6%
Real Estate		2.3%	1.0%	-0.4%	-3.9%	2.3%
Commodity		4.7%	3.0%	-2.0%	-5.0%	4.3%
infl beta	0.75	1.25	1.04	0.65	0.10	1.22
gdp beta	2.41	2.70	2.38	2.51	1.97	2.56

Life Insurance

ASSET CLASS	BASE CASE	HIGH INFLATION HIGH GROWTH	HIGH INFLATION LOW GROWTH	LOW INFLATION HIGH GROWTH	LOW INFLATION LOW GROWTH	INFLATION > 90%ILE
US Equity	2.3%	2.5%	2.1%	2.5%	2.1%	2.2%
US Fixed Income	90.8%	89.6%	90.4%	90.8%	91.8%	90.0%
TIPS	1.0%	0.9%	1.3%	0.8%	1.2%	1.1%
Hedge Fund	0.0%	0.4%	0.0%	0.1%	0.0%	0.1%
Private Equity	4.0%	4.1%	4.0%	4.0%	3.8%	4.0%
Real Estate	0.6%	0.9%	0.7%	0.6%	0.3%	0.8%
Commodity	1.3%	1.7%	1.5%	1.2%	0.8%	1.6%
Tracking Error	0.0%	0.1%	0.0%	0.0%	0.1%	0.1%
CHANGE IN ALLOCATION						
US Equity		0.2%	-0.2%	0.2%	-0.2%	-0.1%
US Fixed Income		-1.2%	-0.4%	0.0%	1.0%	-0.8%
TIPS		-0.1%	0.3%	-0.2%	0.2%	0.1%
Hedge Fund		0.4%	0.0%	0.1%	0.0%	0.1%
Private Equity		0.1%	0.0%	0.0%	-0.2%	0.0%
Real Estate		0.3%	0.1%	0.0%	-0.3%	0.2%
Commodity		0.4%	0.2%	-0.1%	-0.5%	0.3%
infl beta	-1.11	-1.06	-1.08	-1.12	-1.16	-1.07
gdp beta	-0.25	-0.22	-0.25	-0.24	-0.28	-0.24

Source: Morgan Stanley Investment Management, 2021 NACUBO-TIAA Study of Endowments, Society of Actuaries, Federal Reserve Bank of Chicago.

Appendix

Following are metrics and parameters used in our research.

MEASURING ASSET SENSITIVITY AND STABILITY: We measure inflation sensitivity as the beta in a regression model (see below) and the adjusted R square from the regression indicates the stability of the model.

$$\text{asset return} = \alpha + \beta_1 \times \text{inflation surprises} + \beta_2 \times \text{GDP growth surprises} + \varepsilon$$

As mentioned earlier, inflation and growth surprises are defined as the difference between realized numbers and expectation. Both asset returns and surprises are measured over a year horizon. We use quarterly frequency data and adjust standard error for serial correlation due to overlapping observation windows. Private asset data is unsmoothed to mitigate the impact from lagging marks. Lastly, we winsorized asset return data to reduce the impact of extreme values.

DEFINING INFLATION SCENARIOS: We take the average of historical inflation and growth surprises in five different scenarios: high or low inflation/growth surprises and extreme high inflation. The high and low scenarios are defined as whether the inflation or growth surprises are positive or negative. And then we use historical average for each scenarios as our inputs. We also vary the magnitude of inflation/growth surprises from -4% to positive 4% in hypothetical scenarios.

PORTFOLIO CONSTRUCTION: We utilize the traditional Black-Litterman model to combine regression results and investor asset return/risk expectations, implied by the investor's original portfolio allocation.

We derive the original return assumptions (implied return, $\prod$) from the base case portfolio.

$$\prod = \lambda \Sigma w + \theta \cdot I$$

Where,

- Σ is the n×n covariance matrix
- w is the portfolio weights
- I is n×1 vector, n is the number of asset classes, each entry of the vector is 1
- λ,θ are the Lagrange multipliers which can be calibrated with the condition:
  - Equity has a Sharpe ratio of 0.3
  - Equity risk premium (public equity over public fixed income) is 4%.

Then, we can estimate conditional return based on inflation and growth scenarios

$$Q = \alpha + \beta_1 \times x_1 + \beta_2 \times x_2$$

Where,

- α is the implied return, equals $\prod$, derived from the above
- x_1 and x_2 are the inflation and growth surprises

Derive the ex-post return based on Black Litterman model

$$E(R) = [(\tau\Sigma)^{-1} + \Omega^{-1}]^{-1} [(\tau\Sigma)^{-1} \prod + \Omega^{-1} Q]$$

Where:

$$\Omega = \text{diag}(\text{diag}(\Sigma) \times (1 - R^2_{adj}))$$

τ is the parameter that describes investor's confidence in the factor model. If τ is small, more emphasis will be put on the original return vector and vice versa. It can be determined based on the preferred tracking error target.

Lastly, the new return vector E(R) is used as the input for mean variance optimization to derive the optimal portfolio allocation.

$$\max_{w} \left(w' E(R) - \frac{1}{2} \lambda w' \Sigma w\right), \text{ such that } I'w = 1$$

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