A Diversified Approach to Tail-Risk Mitigation

We suggest a mix of strategies with strong theoretical support.

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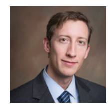

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KEY INSIGHTS

- Investors often seek to manage exposure to tail risk using options and other financial products. However, the costs can overwhelm the potential benefits.
- T. Rowe Price offers a diversified risk-mitigation strategy that seeks to balance effective hedging against tail risk with durable long-term performance.
- Our framework incorporates a number of complementary strategies, each with their own performance characteristics inside and outside of left-tail outcomes.

Tail-risk hedging, tail-risk mitigation, downside protection, and drawdown protection are common terms that relate to the objective of limiting the "left tail" of a portfolio return distribution. Investors who fear left-tail events often turn to specific financial products as remedies. These may include options, structured products, constant proportion portfolio insurance (CPPI), or customized protection from insurers and/or investment banks.

While these products may make sense for specific investors, in many other situations the costs (both direct and indirect) may overwhelm the potential hedging benefits, leading to poor investment results and investor disappointment.

As an alternative to these products, T. Rowe Price has developed a diversified tail-risk mitigation framework that potentially can deliver the desired outcome of protecting against left-tail events while simultaneously limiting the drag on portfolio performance in more normal investment environments. Our approach incorporates a number of complementary strategies, each with their own attributes and behaviors inside and outside of the left tail.

We begin this paper by categorizing tail-risk mitigation strategies. After describing the components of our tail-risk mitigation framework and our portfolio construction process, we present a case study that demonstrates how investors can align a tail-risk mitigation strategy with their own specific risk tolerance and long-run return objectives.

Categorizing Tail-Risk Mitigation Strategies

We generally think of tail-risk mitigation strategies as falling into one or more of four[1] broad categories:

[1] There is a fifth category, which we call "explicit" hedging, where an investor would partner with an investment bank or insurance company to provide a customized explicit guarantee or floor on a custom portfolio. We do not consider these approaches in our framework.

1. Structural: Structural strategies seek to reduce risk to the underlying assets with minimal basis risk—for example, by hedging an equity portfolio with a short equity futures position.

2. Proxy: Proxy strategies seek to reduce effective risk to the underlying assets by constructing long or short positions that are expected to be negatively correlated to the underlying assets (e.g., an equity portfolio hedged with a short emerging markets currency position).

3. Dynamic: Dynamic strategies seek to create empirical convexity to the underlying assets via dynamic trading (e.g., constant proportion portfolio insurance, managed volatility strategies).

4. Non-Linear: Non-linear strategies seek to provide ex-ante convexity to the underlying assets via use of options or other non-linear instruments.

It is important to note that these categories are not mutually exclusive. For instance, a simple put option could fit the characteristics of categories 1, 2, and 4, all in one instrument.

T. Rowe Price's tail-risk mitigation framework incorporates six strategies that have both theoretical and empirical properties that align with at least one of the categories above. Figure 1 provides a categorization of these six components, along with brief descriptions and the rationales for their inclusion in our framework.

Components of T. Rowe Price's Tail-Risk Mitigation Framework

(Fig. 1) Descriptions and categorization

Strategy	Category	Description	Implementation	Rationale
S&P 500 Futures **(ES)**	Structural	Structural hedge for equity risk	Short S&P 500 futures (rolled quarterly)	Structurally reducing equity exposure reduces tail risk
Defensive Style Premia[1] **(DSP)**	Structural/ Proxy	Proxy hedge focused on carry/ value/momentum factors	Long T. Rowe Price style premia strategy; short 100% S&P 500 Index	Cross-asset strategies designed to harvest risk premia have exhibited low correlation with equity markets and positive excess return
10-Year U.S. Treasury Futures **(TY)**	Structural/ Proxy	Proxy hedge for equity risk (dependent on varying stock/bond correlation)	Long 10-Year U.S. Treasury futures	In the modern monetary policy era, long U.S. duration has typically exhibited negative correlation to equity markets in severe equity drawdowns while having positive long-term return
Low Volatility Equity **(MSCILV)**	Proxy	Proxy hedge focused on low volatility factor	Long 100% MSCI USA Minimum Volatility (USD) Index; short 100% S&P 500 Index	Low and/or minimum volatility equity strategies have delivered excess performance relative to the cap-weighted benchmarks with lower realized volatility
Managed Volatility[1] **(MVOL)**	Dynamic	Strategy that adjusts exposure to achieve a volatility target	T. Rowe Price managed volatility strategy on S&P 500 futures with a volatility target of 14% and maximum 150% notional cap minus 100% S&P 500 Index	Dynamically adjusted equity exposure in response to changes in equity risk has helped mitigate drawdowns
Delta-Hedged Put Options[2] **(DHP)**	Non-Linear/ Proxy	Non-linear/proxy pure exposure to downside volatility	Buy 20-delta SPX put options that are rolled quarterly and delta hedged on daily basis[2]	Explicit downside volatility exposure can provide highly useful convexity in tail events even when assuming negative expected returns

Source: T. Rowe Price.

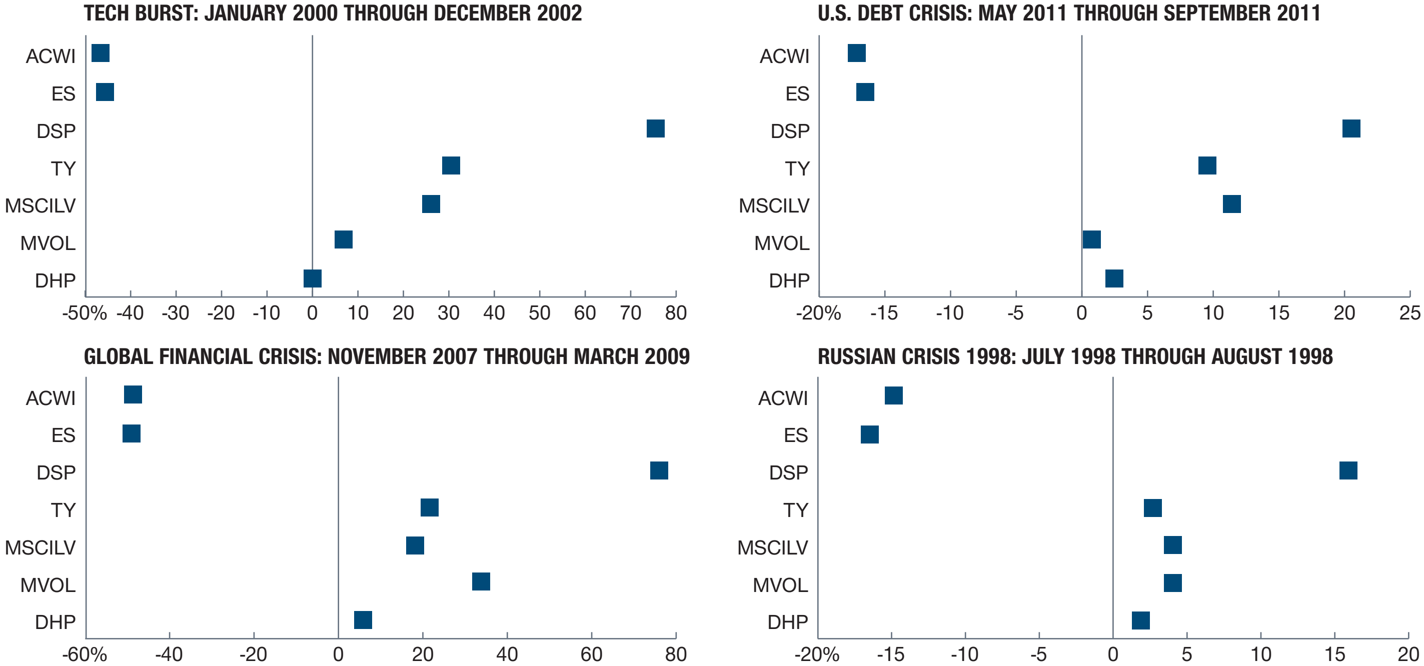
[1] Return series for DSP and MVOL are back test results of independent strategies managed by T. Rowe Price. See the important information on hypothetical portfolios at the end of this paper.

[2] A 20-delta SPX put option would be expected to fall $0.20 for every dollar the S&P 500 Index rises and vice versa.

Tail-Risk Mitigation Model Strategies

(Fig. 2) Hypothetical Performances in Historical Tail-Risk Scenarios

Cumulative Returns for Periods Shown[1]



This chart contains hypothetical analysis, which is shown for illustrative purposes only and is not indicative of realized past or future performance. See the important information on hypothetical portfolios at the end of this paper.

Sources: Citi, Standard & Poor's, MSCI (see Additional Disclosures), and T. Rowe Price; data analysis by T. Rowe Price.

Source for Bloomberg Barclays index data: Bloomberg Index Services, Ltd (see Additional Disclosures).

[1] Figures are calculated in U.S. dollars.

Historical Performance in Tail-Risk Scenarios

We examined potential hypothetical performance by each of the six strategies in our tail-risk mitigation framework across a range of historical left-tail regimes, including the 1998 Russian debt default, the bursting of the technology bubble of the late 1990s, the 2007–2009 global financial crisis, and 2011 concerns about the U.S. federal debt limit.

The performance results shown in Figure 2 might lead an investor to conclude that any one of the component strategies in our framework would be sufficient to mitigate tail-risk. But what is not shown in Figure 2 are the return profiles of the component strategies in periods "outside the tail."

Investing is a multi-period problem, not a one-period problem. In the case of option-based strategies (a common approach to tail-risk hedging), repeated net purchases of options can result in a significant negative return drag even when left-tail events are encountered.

For example, suppose an investor seeking left-tail mitigation pursued a simple long option strategy that purchased 3½ month 20-delta S&P 500

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put options and rolled those positions on the last day of the month before expiration. Over a period beginning January 1, 1998, and ending February 29, 2020, the hypothetical annualized return on that strategy would have been -2.5%.[2] About 125 basis points (bps) of the performance drag would have been due to the structural 20% short equity position associated with a 20-delta put option, but the remainder reflected a combination of the variance risk premium and the horizon, roll, and strike choices associated with the option.[3]

Buy-and-hold option positions require an investor to make specific choices on time horizon, roll, and strike, which all lead to path dependency in the investment process. Because drawdowns and tail-events unfold over a wide variety of time horizons, we believe that effective tail-risk mitigation should not rely on good timing—or luck.

Constructing a Tail-Risk Mitigation Model

Our tail-risk mitigation framework uses a multi-step portfolio construction process that emphasizes the potential risk-and-return characteristics of each component strategy during tail events. While we consider performance behavior during historical tail events, our portfolio construction process relies on forward-looking assumptions for each strategy component.[4]

For example, the annualized return over cash of 10-year U.S. Treasury futures from January 1, 1998, through May 31, 2019, was 3.61%. However, as of January 31, 2020, the 10-year U.S. Treasury note was yielding just 1.51%. This means that designing a tail-risk mitigation portfolio based on historical 10-year U.S. Treasury futures performance would result in a materially different allocation than an approach that used what we believe is a more reasonable forward-looking return assumption—which, in the case of our model, is a 1.00% annual return over cash.

There are five steps in our portfolio construction process:

- **Step 1:** Determine the unconditional equilibrium return, risk, and Sharpe ratio assumptions for the initial portfolio and tail-risk mitigation strategies for an investor with no specific tail-risk preferences;
- **Step 2:** Estimate a new covariance matrix that better captures risk and correlations in tail scenarios (note that we deliberately avoid estimating skewness, kurtosis, etc. or directly optimizing on historical returns);[5]
- **Step 3:** Based on the Sharpe ratios from Step 1 and the "tail" covariance matrix from Step 2, determine the equilibrium "tail" return assumptions;
- **Step 4:** Using an implementation of the Black-Litterman model, blend forward-looking views on the underlying and tail-risk mitigation strategies with the "tail" equilibrium assumptions;[6] and
- **Step 5:** Using the "tail" covariance matrix from Step 2 and blended return assumptions from Step 4, calculate the mean variance optimal (MVO) portfolio after applying an additional penalty to account for client tracking-error preferences.

Our portfolio construction framework is designed to be flexible and can accommodate a wide range of portfolio

[2] Note that we did not include the performance of the underlying position in our analysis, only the returns on the options strategy.
[3] The variance risk premium is the tendency for option-implied volatility to trade above subsequent realized volatility.
[4] Forward-looking return assumptions (all excess of cash and per annum) are as follows: for the underlying strategy: 100 bps outperformance of the benchmark, the Morgan Stanley Capital International All Country World Index (MSCI ACWI); for DSP, outperforming a short S&P 500 position by 100 bps; for TY, 100 bps; for MVOL, -50 bps; for MSCLIV, equal to return of the MSCI Minimum Volatility (USD) Index; for DHP, -75 bps; for ES, equal to the return of the S&P 500 Index.
[5] Sébastien Page and Robert A. Panariello, When Diversification Fails, *Financial Analysts Journal*, Vol. 74, Issue 3, Third Quarter 2018.
[6] The Black-Litterman asset allocation optimization model is described in Litterman, Robert B. Modern Investment Management: An Equilibrium Approach. Hoboken, N.J.: John Wiley, 2003.

designs and targeted tracking error profiles. To demonstrate this flexibility, we offer a case study for a hypothetical global equity portfolio.

Case Study: MSCI ACWI

We assume that the hypothetical investor in our case study is interested in a tail-risk mitigation solution for an U.S. dollar-denominated global equity (GE) allocation, which is represented

Customizing Tail-Risk Mitigation Strategies to Investor Requirements

(Fig. 3) Global Equity Hedged Allocations (%) by Tracking Error Preference

	Model Allocations by Tracking Error Preference						
	Higher ←						→ Lower
	1	2	3	4	5	6	7
GE	89	92	94	96	97	99	100
ES	-12	-9	-6	-4	-3	-2	0
DSP	8	6	4	3	2	1	0
TY	16	12	8	6	4	2	0
MSCILV	24	18	12	9	5	3	0
MVOL	18	14	9	7	4	2	0
DHP	11	8	5	4	2	1	0
Total Exposure[1]	**176**	**157**	**138**	**129**	**118**	**110**	**100**

Model Allocation Tracking Errors		
Model Allocation	Long-Term TE	Tail TE
1	6.88	9.61
2	5.16	7.21
3	3.44	4.80
4	2.58	3.60
5	1.59	2.22
6	0.90	1.25
7	0.00	0.00

January 1, 1998, through May 31, 2019.

This chart contains hypothetical analysis, which is shown for illustrative purposes only and is not indicative of realized past or future performance. See the important information on hypothetical portfolios at the end of this paper.

Sources: Standard & Poor's, MSCI (see Additional Disclosures), and T. Rowe Price; data analysis by T. Rowe Price.

[1]Total exposure does not include potential netting.

Tail-Risk Mitigation Potentially Reduced Volatility Without Sacrificing Returns

(Fig. 4) Hypothetical Performance Statistics for Global Equity Model Allocations

	Model Allocations by Tracking Error Preference						
	Higher ←						→ Lower
	1	2	3	4	5	6	7
Return (%) (Annualized)[1]	4.10	4.15	4.17	4.16	4.15	4.13	4.10
Volatility (%) (Annualized)	7.85	9.34	10.88	11.67	12.59	13.24	14.08
Return/Risk (Annualized)	0.52	0.44	0.38	0.36	0.33	0.31	0.29
Equity Beta	0.54	0.65	0.77	0.83	0.89	0.94	1.00
Probability (Return < 0) (%)	37.59	37.59	39.10	39.10	38.72	39.47	39.10
CVAR 5% (%)	-5.35	-6.40	-7.48	-8.02	-8.67	-9.12	-9.72
Max Drawdown From Peak Equity (%)	-29.73	-35.58	-41.45	-44.20	-47.25	-49.28	-51.82

January 1, 1998, through February 29, 2020.

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Sources: Standard & Poor's, MSCI (see Additional Disclosures), and T. Rowe Price; data analysis by T. Rowe Price.

[1] Returns calculated excess of cash.

by the MSCI ACWI. Using our portfolio construction model, we designed seven model allocations across a range of tracking error targets. Model seven is a simple unhedged global equity portfolio, represented by the MSCI ACWI.

Figure 3 presents the range of model allocations for the six component strategies in our tail-risk mitigation framework and the unhedged global equity portfolio, sorted by their forecasted tracking error. Allocation one has the highest exposure and tracking error, while allocation seven, which does not include any tail-risk strategy exposure, has no expected tracking error. Our framework is designed to customize the tracking error (and accompanying notional exposure) to investor preferences.

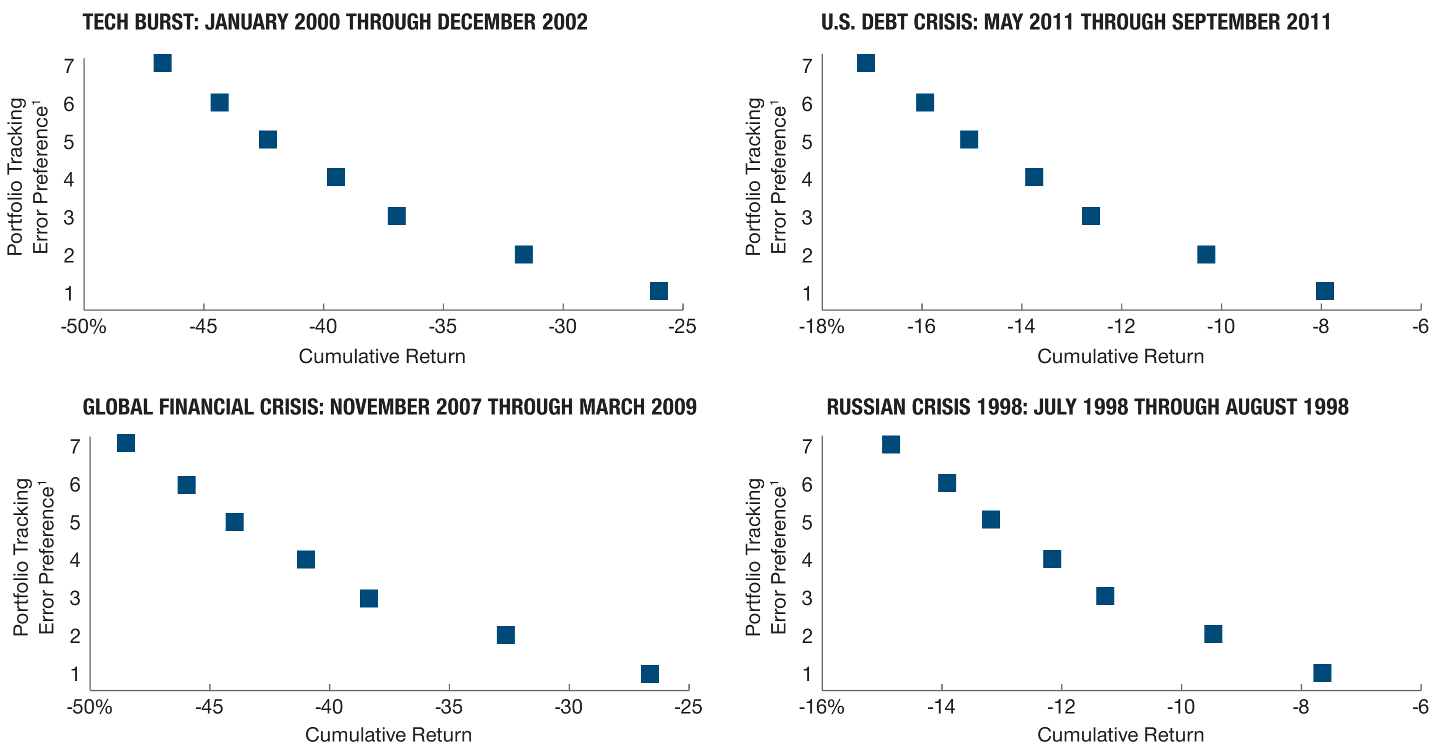
Figure 4 summarizes the results of a historical back test of the allocations shown in Figure 3. The annualized return on the underlying global equity allocation could have been only modestly impacted by the tail-risk mitigation allocations, but the volatility of those allocations and the associated performance statistics—such as the maximum drawdown and the conditional value at risk (CVAR)—could have materially improved as notional exposure to the strategies increased. Cumulative returns in the four historical tail-risk scenarios we examined also could have been improved significantly (Figure 5).

As previously discussed, our portfolio construction methodology incorporates forward-looking assumptions for the component tail-mitigation strategies in

Higher Tolerance for Tracking Error Could Have Improved Results

(Fig. 5) Potential Cumulative Returns for Model Allocations in Historical Tail-Risk Scenarios

Cumulative Returns for Periods Shown[1]



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[1] Figures are calculated in U.S. dollars.

Sensitivity Analysis Finds More Intuitive Risk/Reward Trade-Off

(Fig. 6) Hypothetical Results Based on Historical and Forward-Looking Assumptions

	Model Allocations						
	1	2	3	4	5	6	7
Scenario 1 Annualized Return (%)[1]	2.89	3.24	3.56	3.71	3.87	3.97	4.10
Scenario 2 Annualized Return (%)[1]	2.30	2.63	2.93	3.07	3.22	3.31	3.43
Annualized Volatility (%)	7.87	9.35	10.89	11.68	12.60	13.24	14.08

January 1, 1998, through February 29, 2020.

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Sources: Citi, Standard & Poor's, MSCI (see Additional Disclosures), and T. Rowe Price; data analysis by T. Rowe Price.

Source for Bloomberg Barclays index data: Bloomberg Index Services Limited.

[1] Returns calculated excess of cash. The indexes used for the 5-year capital market assumptions are global equity (the MSCI ACWI), 5.0%; global investment grade (BBgBarc Global Aggregate Bond Index), 1.9%; and cash (USD), 1.6%. See the Important Information about our capital market assumptions at the end of this paper.

our framework given what we believe is the inappropriateness of optimizing based on historical returns. In anticipation of investor curiosity regarding the performance of the tail-risk mitigation strategies based on forward-looking return assumptions, Figure 6 offers two additional scenario analyses:

- **Scenario 1** blends historical returns for the MSCI ACWI with our forward-looking return assumptions for the tail-risk mitigation strategies.
- **Scenario 2** combines our capital market assumption for global equity (as represented by the MSCI ACWI) with our forward-looking return assumptions for the tail-risk mitigation strategies.

Because our return assumptions are more modest than the historic averages, the results shown in Figure 6 present a more "intuitive" risk/return trade-off (in the sense that return is not fully preserved) as notional exposure to the tail-risk strategies increases. Yet, we see demonstrable potential improvement in risk-adjusted returns using the tail-risk mitigation framework.

Conclusions

Equity market returns are inherently difficult to predict. Tail-risk hedging programs that rely on a single approach, such as option-based strategies, are inherently inefficient given the inability of most investors to time the tail event. We believe the use of a multi-strategy tail-risk mitigation framework potentially can provide the tail-risk management investors desire without sacrificing too much performance "outside the tail."

Important Information—Capital Market Assumptions

T. Rowe Price Capital Market Assumptions: The information presented herein is shown for illustrative, informational purposes only. Forecasts are based on subjective estimates about market environments that may never occur. This material does not reflect the actual returns of any portfolio/strategy and does not guarantee future results. The historical returns used as a basis for this analysis are based on information gathered by T. Rowe Price and from third-party sources and have not been independently verified. The asset classes referenced in our capital market assumptions are represented by broad-based indices, which have been selected because they are well known and are easily recognizable by investors. Indices have limitations due to materially different characteristics from an actual investment portfolio in terms of security holdings, sector weightings, volatility, and asset allocation. Therefore, returns and volatility of a portfolio may differ from those of the index. Management fees, transaction costs, taxes, and potential expenses are not considered and would reduce returns. Expected returns for each asset class can be conditional on economic scenarios; in the event that a particular scenario comes to pass, actual returns could be significantly higher or lower than forecast.

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The information presented herein is hypothetical in nature and is shown for illustrative, informational purposes only. This material is not intended to forecast or predict future events, but rather to demonstrate T. Rowe Price's capability to manage assets in this style. It does not reflect the actual returns of any portfolio/strategy and does not guarantee future results. Certain assumptions have been made for modeling purposes and are unlikely to be realized. No representation or warranty is made as to the reasonableness of the assumptions made or that all assumptions used in modeling analysis presented have been stated or fully considered. Changes in the assumptions may have a material impact on the information presented. Data shown for the sample portfolios are as of the dates shown and represent the manager's analysis of sample portfolios as of that date and are subject to change over time. The sample portfolios do not reflect the impact that material economic, market, or other factors may have on weighting decisions. If the weightings change, results would be different. Management fees, transaction costs, taxes, potential expenses, and the effects of inflation are not considered and would reduce returns. Actual results experienced by clients may vary significantly from the hypothetical illustrations shown. The information is not intended as a recommendation to buy or sell any particular security, and there is no guarantee that results shown will be achieved.

The gross model performance results do not reflect the deduction of investment advisory fees. Returns shown would be lower when reduced by the advisory fees and any other expenses incurred in the management of an investment advisory account. For example, an account with an assumed growth rate of 10% would realize a net of fees annualized return of 8.91% after three years, assuming a 1% management fee.

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