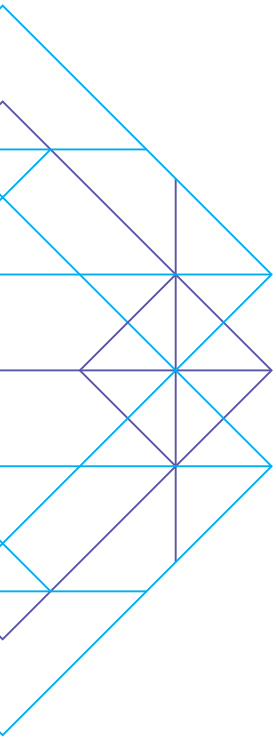
Alternative Thinking 2023 | Issue 2

Key Design Choices When Building a Risk-Mitigating Portfolio



Executive Summary

The year 2022 saw more real wealth destruction than 2008, the year of the Global Financial Crisis, as measured by a traditional stock/bond portfolio. As a result, many investors have recently begun to reconsider the role of risk-mitigating portfolios within their broader asset allocations, which are typically dominated by equity risk.

We believe trend following deserves a prominent place in any serious risk-mitigation portfolio given 1) its ability to deliver positive long-run returns and perform well in both growth- and inflation-driven bear markets and 2) its unmatched performance during the prolonged drawdowns that are most likely to impair investors' ability to achieve long-term goals.[1] The most effective trend-following programs diversify across signals, combining both short-/long-term price and economic trend signals, and across asset classes, including harder-to-access alternative markets.[2]

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1 Please refer to Exhibit 4 for empirical support.
2 Please refer to Exhibits 5, 6, and 7 for empirical support.

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About the Portfolio Solutions Group

The Portfolio Solutions Group (PSG) provides thought leadership to the broader investment community and custom analyses to help AQR clients achieve better portfolio outcomes.

We thank Jordan Brooks, Pete Hecht, Shreya Kakarla, Nick McQuinn, Yao Hua Ooi, and Erik Stamelos for their work on this paper. We also thank Dan Heffernan, Antti Ilmanen, Thomas Maloney, and Dan Villalon for helpful comments.

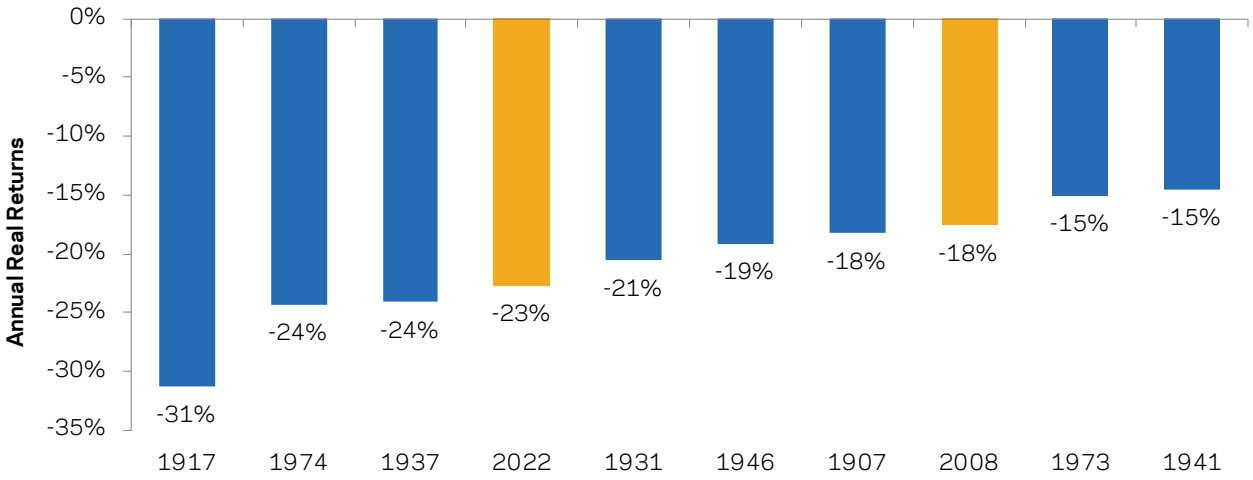
Introduction and Framework

After the Global Financial Crisis ("GFC"), many investors looked for ways to protect their equity risk-dominated portfolios. Liquid and illiquid alternatives—so-called diversifiers—grew in popularity. A subset of liquid strategies that offered both long-term positive expected returns and protective properties during market selloffs, such as trend following,[3] received special attention.[4] These strategies became the basis of new risk-mitigating portfolios that were adopted by asset allocators on the recommendation of their investment consultants.

The adoption of risk-mitigating portfolios slowed down as traditional stock/bond portfolios experienced unusually high returns during the 2010s. Many investors forgot about the wealth destruction resulting from the equity market drawdown during the GFC until an ugly wake-up call in 2022. Upside inflation surprises, and an associated re-pricing of monetary policy expectations, crushed both stocks and bonds, leading to worse real returns on 60/40 portfolios than those seen in 2008, around the GFC (**Exhibit 1**).

Exhibit 1: 2022's Inflation Shock Led to Worse Real Returns for 60/40 than the GFC

Ten Worst Calendar Years for U.S. 60/40 Real Returns, January 1, 1900 – December 31, 2022



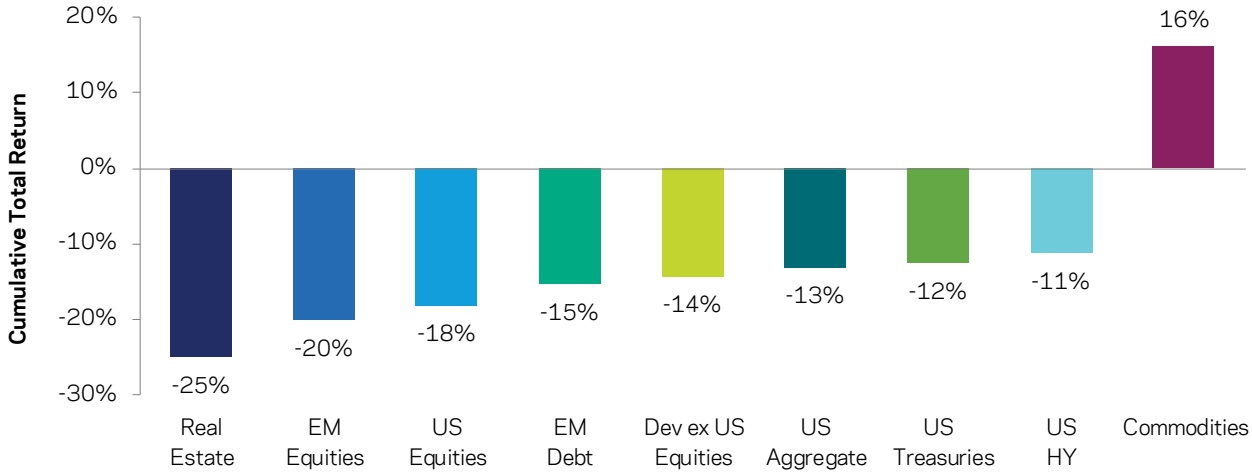
Source: AQR, Global Financial Data, Bloomberg. U.S. 60/40 is 60% U.S. stocks and 40% U.S. bonds using monthly data from Global Financial Data's S&P 500 Total Return Index (with GFD extension) and USA 10-year Government Bond Total Return Index, respectively. Returns are calculated over calendar years. Past performance is not a reliable indicator of future performance. Gross performance results do not reflect the deduction of investment advisory fees and other expenses, which would reduce an investor's actual return.

The pain was not limited to 60/40: **Exhibit 2** highlights the ubiquity of the underperformance in 2022. As a result, many investors have begun to reconsider the role of risk-mitigating portfolios within a larger asset allocation.

3 Please refer to Hurst et al. (2017) for a century of evidence on trend following across a variety of asset classes.
4 Please refer to footnote 5.

Exhibit 2: Most Traditional Asset Classes Suffered in 2022

Cumulative Total Returns of Major Asset Classes, January 1, 2022 – December 31, 2022



Source: AQR, Bloomberg. Real Estate is the FTSE EPRA/NAREIT Equity REITs Index. EM Equities is the MSCI Emerging Markets Index. US Equities is the S&P 500 Index. Dev ex US Equities is the MSCI World ex US Index. US Aggregate is the Barclays US Aggregate Index. US Treasuries is the Barclays US Treasury Index. US HY is the Barclays US High Yield Corporate Bond Index. Commodities is the Bloomberg Commodity Index. All returns are gross of fees. Please see the Appendix for index definitions. Past performance is not a reliable indicator of future performance. Gross performance results do not reflect the deduction of investment advisory fees and other expenses, which would reduce an investor's actual return.

Given the renewed interest in risk-mitigating portfolios, this paper discusses some of the key (but sometimes overlooked) design choices required for a successful implementation. In the process of doing so, we re-underwrite the "conventional wisdom" associated with these design choices. In particular, we address the following questions:

1. Which asset classes and strategies are best suited for a risk-mitigating portfolio? What are popular diversifying and/or defensive strategies that don't belong in a risk-mitigating portfolio? *Conventional wisdom says Treasuries, tail risk strategies (e.g. put buying), trend following, and other general diversifiers (e.g., global macro, alternative risk premia [ARP], equity market neutral [EMN]) are the best candidate risk-mitigating strategies.*[5]

2. Given trend-following strategies should be a core component of any risk-mitigating portfolio (validated in the next section), what separates a good implementation from a great implementation? For example, should trend-following strategies focus on short-term price trends in order to be more "responsive" to market selloffs? *Conventional wisdom says yes.*[6] Additionally, if the goal is to protect against equity drawdowns, should trend-following strategies focus on those traditional markets most closely linked to equities? *Again, conventional wisdom says yes.*

5 Meketa Investment Group's 2023 whitepaper "Risk Mitigating Strategies (RMS) Framework" provides a detailed framework for selecting the components of and constructing a risk-mitigation portfolio, in which they include long Treasuries, options-buying, trend following, and other so-called diversifiers such as EMN and global macro hedge funds. Meketa's earlier 2012 whitepaper "Tail Risk Management" also includes this set of strategies and considers a few other assets such as long-dated TIPS and gold.

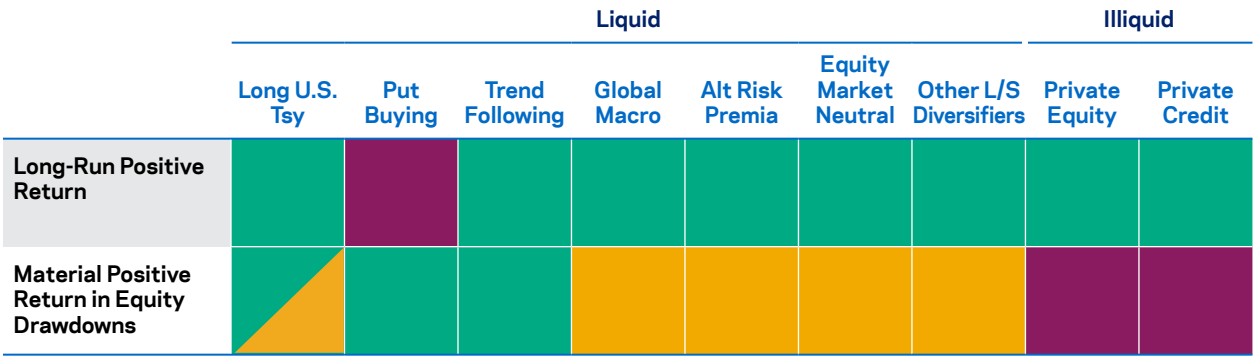
6 For example, see Mackic (2023) which argues that faster (i.e., shorter-term) trend signals provide better protective properties than slower (i.e., longer-term) signals.

Which Asset Classes and Strategies Deserve Attention as Risk Mitigators?

Our criteria for selecting risk-mitigating strategies are straightforward. First, the strategy should deliver a long-run positive expected return—mandate number one.[7] Secondly, the strategy should earn a material, positive expected return during both growth- and inflation-driven equity drawdowns—mandate number two.

Using the above criteria, **Exhibit 3** scores various asset classes and strategies. Green represents a passing mark, red a fail, and orange an ambiguous grade. **Exhibit 4**, which looks at performance in the five worst equity drawdowns since 1990, provides empirical evidence supporting the "protective property" grade reported in **Exhibit 3**. The 2022 equity drawdown plays an important role as the only genuine inflation-driven market selloff since 1990. While the worst five drawdowns include both fast (e.g., the 2020 Covid crash) and slow market selloffs, it's important to remember that the slow/long drawdowns are associated with a greater destruction of wealth and, thus, deserve more attention from investors.[8]

Exhibit 3: Scoring Out the Various Asset Classes and Strategies
Green for Passing, Orange for Mixed Results, and Red for Failing



Source: AQR, Global Financial Data, Bloomberg. Long U.S. Treasuries is the Barclays U.S. Treasury Long Index. Put Buying is the CBOE PutWrite Index in excess of the S&P 500 Index. Trend Following is the SG Trend Index. Global Macro is the CS Global Macro Index. Alternative Risk Premia (Alt Risk Premia for short) is a combination of two indices: the EurekaHedge Multi-factor Risk Premia Index from August 1, 2010 to December 31, 2015 and then the SG Multi-asset Alternative Risk Premia Index from January 1, 2016 onward. Equity Market Neutral is the HFRI Equity Market Neutral Index. Other L/S Diversifiers, Private Equity, and Private Credit scores are based on qualitative economic arguments discussed in the text. Past performance is not a reliable indicator of future performance.

How do the "conventional" risk-mitigating strategies perform? It's a mixed bag. Trend following is the only strategy with a full pass for both mandates, providing meaningful protection in both growth- (e.g., GFC) and inflation-driven (e.g., 2022) equity drawdowns. Long Treasuries earns only a orange/green score for protective properties given its inability to protect in inflation-driven equity drawdowns. Systematic put buying provides

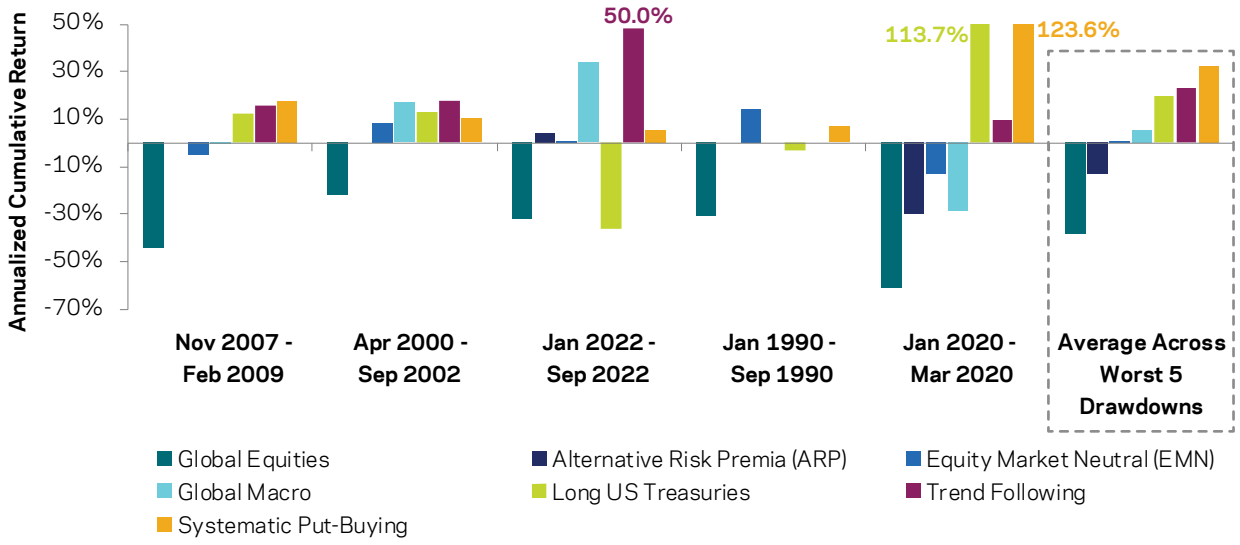
7 Technically, in an unconstrained optimization, an alpha-oriented negative expected return strategy, such as an active tail risk strategy, could be helpful to the overall portfolio. However, leverage constraints and alpha estimation error make this difficult to implement in practice. Furthermore, organizational constraints could make it difficult to hold onto a negative expected return strategy.

8 We have written extensively on the importance of slow, long drawdowns relative to quick, short drawdowns in McQuinn et al. (2021) and the Q4 2022 AQR Alternative Thinking.

protection, but its long-run expected return is negative.[9] Other long/short diversifiers, such as global macro, alternative risk premia, and equity market neutral strategies, don't provide reliable enough positive expected returns during equity drawdowns to be considered risk mitigators, validating their orange status for mandate number two. Global macro shows some signs of protective properties in **Exhibit 4**, but because the category is highly heterogeneous, the degree of protective properties will depend on the manager.[10]

Exhibit 4: Performance during the Five Worst Equity Drawdowns

Annualized Cumulative Returns in 5 Worst Equity Drawdowns, January 1, 1990 – March 31, 2023



	Long US Treasuries	Put Buying	Trend Following	Global Macro	Alt Risk Premia	Equity Market Neutral
Full Period Sharpe Ratio	0.39	-0.51	0.35	0.78	0.51	0.98
Hit Rate (% of Times Positive Return in Drawdown)	60%	100%	100%	50%	50%	60%

Note: We truncated the y-axis range to achieve a reasonable scale. The three data labels in the chart refer to returns that are greater than or equal to the max y-axis value of 50%.

Source: AQR, Global Financial Data, Bloomberg. Long U.S. Treasuries is the Barclays U.S. Treasury Long Index. Systematic Put Buying (Put Buying, for short) is the CBOE PutWrite Index in excess of the S&P 500 Index. Trend Following is the SG Trend Index. Global Macro is the CS Global Macro Index. Alternative Risk Premia (Alt Risk Premia or ARP, for short) is a combination of two indices: the EurekaHedge Multi-factor Risk Premia Index from August 1, 2010 to December 31, 2015 and then the SG Multi-asset Alternative Risk Premia Index from January 1, 2016 onward. Equity Market Neutral (EMN, for short) is the HFRI Equity Market Neutral Index. Global Equities is the MSCI World Index. The chart above only shows a bar for an asset class if it has a continuous history of returns over the period of the drawdown. Full Period Sharpe Ratio is from January 1, 1990 except for the indices which start later. Trend Following starts January 1, 2000. Global Macro starts January 1, 1994. Alt Risk Premia starts August 1, 2010. Cash used for Sharpe ratio calculations is the U.S. 3-Month Treasury Bill return. The Hit Rate in the table above is calculated as the % of the 5 Worst Equity Drawdowns over which each asset had a positive return (this is calculated only over the period for which each asset had returns). Past performance is not a reliable indicator of future performance. Gross performance results do not reflect the deduction of investment advisory fees and other expenses, which would reduce an investor's actual return.

9 We have written extensively on the downsides, no pun intended, of put-buying. For further reading on the topic, please refer to Israelov (2017), Israelov and Tummala (2018), and Israelov et al. (2017). Ilmanen et al. (2021) and the Q4 2022 AQR Alternative Thinking directly contrast put and trend strategies.

10 For example, systematic directional macro strategies might offer more protective properties than relative value.

Given the popularity of long-only illiquid alternatives among investors, **Exhibit 3** also includes a few examples of private assets. While many investors believe there are more opportunities for alpha in illiquids, private equity and private credit inherit the first-order risk and return characteristics of their public counterparts, justifying their failing grade for mandate number two. From a purely accounting perspective, illiquids can benefit from price smoothing over the short run. However, this does not change their true economic market value; i.e., the cash proceeds you would receive if you had to sell the asset in an orderly manner during times of market stress. Furthermore, in slow/long drawdowns, illiquids could underperform from an accounting perspective as well, as general partners eventually have to incorporate bad economic outcomes into prices.

Based on the report card in **Exhibit 3**, trend following, with its unequivocally-positive score across both mandates, should be the anchor strategy for any risk-mitigating portfolio. It also has the desirable property of performing the best during slower drawdowns; i.e., the types of drawdowns that most impair investors' ability to achieve long-run return objectives. There is a significant body of evidence pointing to these properties, including the live performance of the industry over more than two decades, as well as voluminous academic research.[11] The case for trend following is even stronger for portfolios with large allocations to private assets (whose reported losses become more evident in slow/long market drawdowns).

Given their ability to provide protection during disinflationary recessions, we believe long-duration Treasuries deserve an allocation in the portfolio if properly sized.[12] We wouldn't include tail risk strategies, such as put buying, given their unattractive long-run return profile. While we spend significant resources researching and implementing long-short diversifiers, such as global macro, ARP, and EMN, we believe most of these strategies belong in a diversifying bucket and not a risk-mitigating portfolio. Governance and oversight committees are likely to find them harder to defend because they may not deliver on both risk-mitigation mandates, or at least not as consistently as strategies like trend following. Certain types of global macro managers could be considered for the risk-mitigating portfolio if they have an investment approach that tends to benefit from large market dislocations, and can show a proven track record of providing protective properties. Within EMN, long/short quality has delivered outsized returns during market selloffs and, thus, could also be considered for a risk-mitigating program.[13]

11 Exhibits 5 and 6 of Hurst et al. (2017) highlight trend following's convexity properties over 100+ years of data.

12 Some may wonder why commodities aren't included in the analysis given they outperform in inflation-driven equity drawdowns, though underperform in growth-driven equity drawdowns. This is in some sense analogous to Treasuries which benefit from growth-driven equity drawdowns, but underperform in inflation-driven equity drawdowns. We plan to explore the role of commodities within a risk-mitigating portfolio in future research. Until then, we believe both Treasuries and commodities improve the diversification properties of the overall portfolio and, thus, should be included in the strategic asset allocation.

13 Asness et al. (2019) provides evidence that high quality stocks may act as a hedge during periods of market distress (Table 6).

Trend Following as a Risk Mitigator

Should Trend Following Focus on "Responsive," Short-Term Price Signals?

As the anchor strategy within a risk-mitigating portfolio, it's important that trend following "max out" on both the positive return and protective property mandates. Some might believe that focusing on short-term price signals provides better protective properties because they outperformed longer-term signal horizons in the few years prior to 2022. Does the empirical evidence back this up? In short, no.

While short-term price signals play a role in a prudent trend-following program, they are more susceptible to market choppiness and disappointing performance in environments like 2022, when despite large losses on the year, equity markets staged several reversals. Short-term price trends may outperform in a fast/short drawdown (e.g., Covid crash), but fast/short drawdowns are not the only way markets behave in stress scenarios, and these drawdowns are less odious in terms of impairing the ability to achieve long-run return objectives. Diversifying across various lookbacks, including longer horizons (e.g., one year), may provide more robust average returns and drawdown protection.

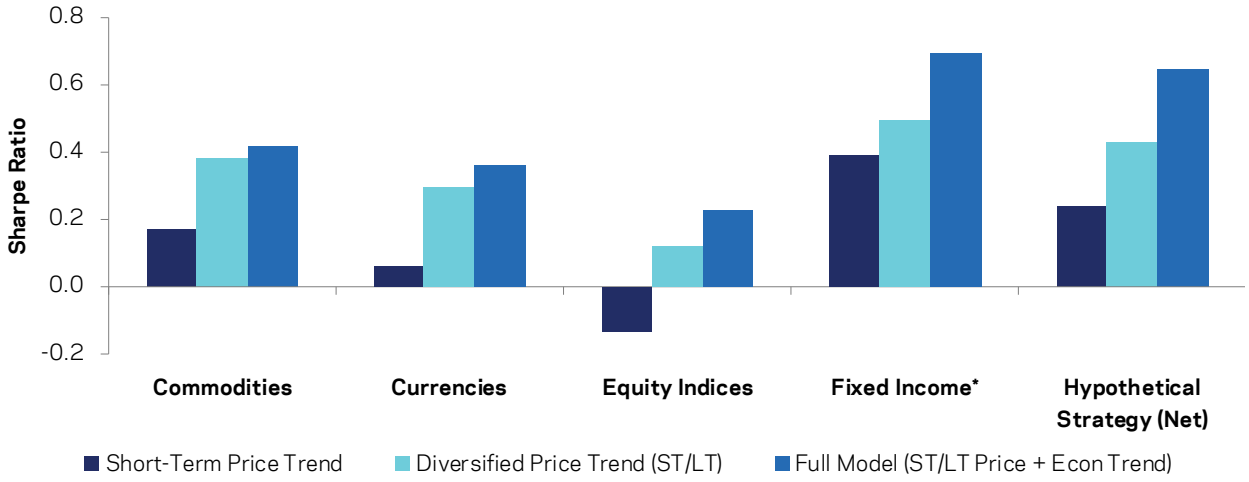
Both average returns and drawdown protection can be improved by moving beyond price-based trend signals. *Economic trend* signals, which take positions on the basis of trends in economic fundamentals, aim to capitalize on the same behavioral biases as price trend, particularly the tendency for markets to underreact to new information.[14] As changes in economic fundamentals often precede or coincide with asset price changes, economic trend signals tend to be profitable on average. And since many crisis scenarios and large market drawdowns are often preceeded by deteriorating fundamentals, economic trend signals have tended to provide excellent drawdown protection. Economic trend signals are complementary to price-based trend measures. While price-based trend measures must wait for a reversal in prices before adjusting positions, economic trend measures may anticipate inflection points and more speedily capture drawdowns and recoveries (e.g., as inflation expectations increased and monetary policy trends turned hawkish in late 2021, economic trend signals began positioning for bearish equity markets, moderating the bullish price trend). Economic trend signals may also help "stay the course" when prices whipsaw but fundamental trends are steadfast (e.g., spring into summer 2022).[15] **Exhibit 5** shows that a combination of short-term (ST) price, long-term (LT) price, and economic trend indicators produces stronger average returns and drawdown performance than ST price signals alone.

14 Often referred to as economic trend following, this strategy goes long assets for which fundamental macroeconomic trends are improving and short assets for which fundamental macroeconomic trends are deteriorating. Example macroeconomic variables include changes in GDP growth and inflation forecasts, changes in yields, and FX depreciation. For more information, please refer to Brooks (2017) and Brooks et al. (2023).

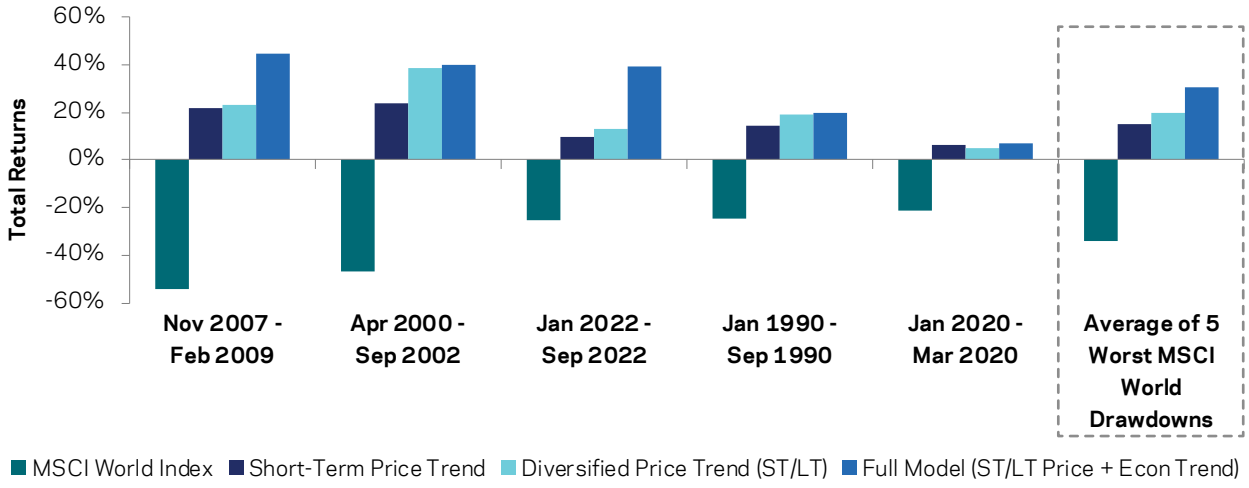
15 We provide more detail and empirical evidence for this approach in our 2023 whitepaper "Fast, Slow & Fundamental: Building Better Trends."

Exhibit 5: A Blend of Trend Signals May Provide Better Long-Run Returns and Protection

Hypothetical Risk-Adjusted Returns of Trend Portfolios
January 1, 1990 – March 31, 2023



Hypothetical Performance of Trend Portfolios in Equity Drawdowns
January 1, 1990 – March 31, 2023



* Fixed Income was by far the best trending asset class over most of this period, but that doesn't mean that it will continue to outperform other asset classes going forward. We are confident a multi-asset class approach to trend following will outperform a single asset class implementation on an ex-ante basis. Also note that the asset class bars are gross of fees while the strategy bars are net of fees.
Source: AQR, Bloomberg. Short-Term Price, Diversified Price Trend (ST/LT), and Full Model (ST/LT Price + Econ Trend) are hypothetical backtests of simple trend-following strategies. Diversified Price Trend (ST/LT) allocates 2/3 of the overall risk to ST signals, and the remaining 1/3 to LT signals. Full Model (ST/LT Price + Econ Trend) is an equal-weighted combination of Price Trend and Economic Trend. All aggregate strategy (i.e., multi-asset class portfolio) returns (far right bars on the top chart, all of the Trend bars in the second chart) are net of transaction costs and net of 1.25%/20% management/performance fees per annum. The asset class component returns in the top chart are gross of fees but net of transaction costs. All hypothetical return series are scaled to target a 10% annualized volatility level. Please read performance disclosures in the Appendix for a description of the investment universe and the allocation methodology used to construct the hypothetical Price-Based Trend-Following and Economic Trend-Following backtests. Hypothetical data has inherent limitations, some of which are disclosed in the Appendix. Past performance is not a reliable indicator of future results. Diversification does not eliminate the risk of experiencing investment losses.

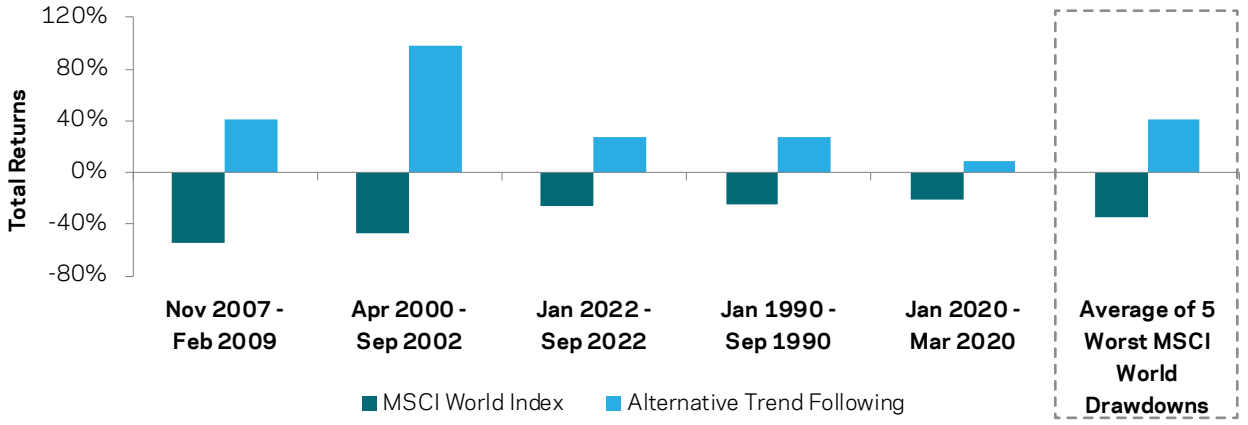
Should Trend Following Focus on Traditional Markets More Closely Linked to Equities?

Beyond signal diversification, there is another way to materially improve a trend-following implementation from the perspective of a risk-mitigating portfolio's dual mandate: extending the application of trend-following techniques to harder-to-access and/or lower-capacity *alternative markets*.[16] Example alternative markets can include equity portfolios (e.g., industries, long-short factors, etc.), non-index commodities (e.g., European energy contracts), emerging market currencies and interest rate swaps, credit default swaps, and volatility instruments, among others. Trend following strategies, like many systematic alternatives, may benefit from breadth. Adding alternative markets, many of which are lowly correlated to traditional markets, vastly increases the investable universe, leading to greater expected risk-adjusted returns. Trend following in alternative markets has historically provided strong drawdown protection. This may seem puzzling—after all, an alternative market trend strategy may not directly take directional equity market exposure, and, as a result, can't be explicitly short equity markets to profit in a drawdown. But persistent bear markets typically arise from a fundamental catalyst, which has an impact on markets beyond just equities. As a result, in equity bear markets we tend to observe trending behavior across several asset classes. As seen in **Exhibit 6**, in addition to attractive returns, trend following in alternative markets provides protective properties against equity drawdowns.

Exhibit 6: Trend in Alternative Markets Delivers on the Dual Mandate

Hypothetical Long-Run Returns (table) and Returns during Equity Drawdowns (chart)
January 1, 1990 – March 31, 2023

	Net of Fee Returns (Annualized)	Realized Volatility (Annualized)	Sharpe Ratio	MSCI World Correlation	Barclays Global Agg Correlation
Jan 1, 1990 – Mar 31, 2023	13.5%	10.1%	1.1	(0.2)	0.0



Source: Bloomberg, AQR. The Hypothetical Alternative Trend-Following Strategy performance is a backtest that targets 10% volatility, and is net of estimated transaction costs and net of 1.25/20 fees. The Alternative Trend-Following Strategy applies price-based trend signals to alternative asset classes. The 3-Month T-Bill is the risk-free rate used to derive the Sharpe ratio. Please read performance disclosures in the Appendix for a description of the investment universe and the allocation methodology used to construct the Hypothetical Alternative Trend-Following Strategy. Markets considered only where data existed during the time period. Chart is provided for illustrative purposes only and is not based on an actual portfolio AQR manages. Hypothetical data has inherent limitations, some of which are disclosed in the Appendix.

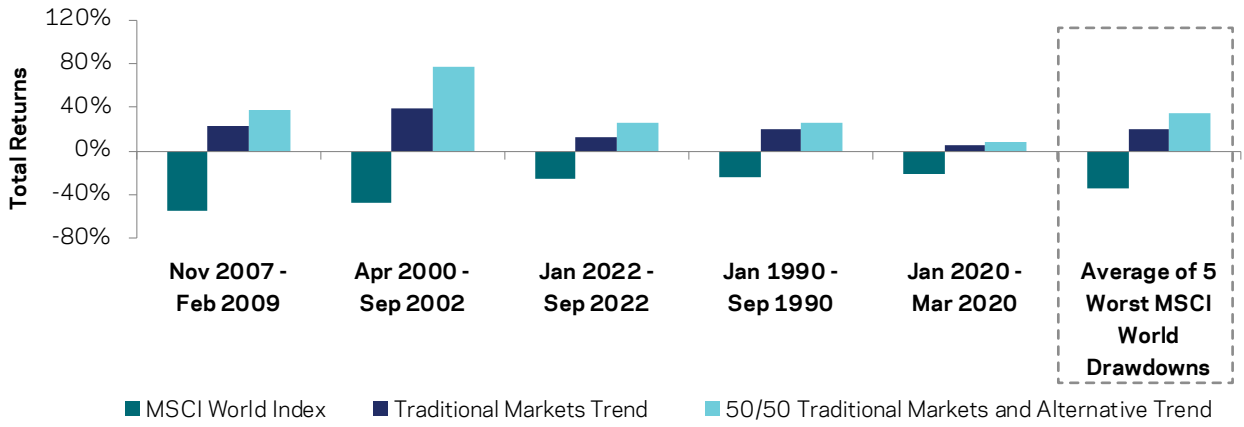
16 For more information on trend-following strategies applied in alternative asset classes, please refer to Babu et al. (2020).

The conventional wisdom that including alternative markets "waters down" the equity-related protective properties of a trend-following program is contradicted by the empirical evidence. Including alternative markets alongside traditional markets provides diversification benefits, leading to enhanced equity protective properties as seen in **Exhibit 7**. The addition of alternative markets to a traditional trend-following program delivered stronger returns in each of the five worst equity market drawdowns.

Exhibit 7: Blending Alternative and Traditional Markets Trend Enhances Long-Run Performance and Protection

Hypothetical Long-Run Returns (table) and Returns during Equity Drawdowns (chart)
January 1, 1990 – March 31, 2023

Jan 1, 1990 – Mar 31, 2023	Net of Fee Returns (Annualized)	Realized Volatility (Annualized)	Sharpe Ratio	MSCI World Correlation	Barclays Global Agg Correlation
Traditional Markets Trend Following	6.8%	9.8%	0.4	(0.2)	0.1
50/50 Traditional Markets and Alternative Trend	**11.6%**	**10.3%**	**0.9**	**(0.2)**	**0.1**



Source: Bloomberg, AQR. The Hypothetical 50/50 Traditional Markets and Alternative Trend-Following Strategy performance is a backtest that is 50% Traditonal Markets Trend Following and 50% Alternative Trend Following. The returns are net of estimated transaction costs and net of 1.25/20 fees. Traditional Markets Trend Following refers to the Price-Based Trend Following backtest in the Appendix. The 3-Month T-Bill is the risk-free rate used to derive the Sharpe ratio. Please read performance disclosures in the Appendix for a description of the investment universe and the allocation methodology used to construct the Price-Based and Alternative Trend-Following Strategies. Markets considered only where data existed during the time period. Chart is provided for illustrative purposes only and is not based on an actual portfolio AQR manages. Hypothetical data has inherent limitations, some of which are disclosed in the Appendix. Diversification does not eliminate the risk of experiencing investment losses.

Final Thoughts

Investors' desire for high returns, combined with their aversion to leverage, suggests that pro-growth/equity-centric portfolios are here to stay. Given that the timing and duration of future financial market crises are very hard to forecast, we recommend including a risk-mitigating portfolio in strategic, not tactical, asset allocation. This program should be complemented with other diversifiers. From a governance perspective, it may be helpful to keep "generic" diversifiers separate from risk-mitigating strategies given their different return profiles in large market selloffs.

When it comes to implementing a risk-mitigating portfolio, we believe trend-following strategies deserve significant attention given their ability to deliver positive long-run returns *and* outperform in both growth- and inflation-driven equity drawdowns. They also outperform other risk mitigators during slow/long drawdowns—the very types of drawdowns that most impair an investor's ability to achieve long-run return objectives. Not all trend-following strategy implementations are created equal, however. In contrast to conventional wisdom, signal diversification across short-term price, long-term price, and economic trends, and the inclusion of niche alternative markets provides the most robust return and equity protective property profile.

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Index Definitions:

The **GFD USA 10-year Government Bond Total Return Index** measures the performance of U.S. 10-year government bonds.

The **S&P 500 Index** is the Standard & Poor's composite index of 500 stocks, a widely recognized, unmanaged index of common stock prices.

The **Barclays U.S. Corporate High Yield Index** measures the USD-denominated, high yield, fixed-rate corporate bond market. Securities are classified as high yield if the middle rating of Moody's, Fitch and S&P is Ba1/BB+/BB+ or below.

The **FTSE EPRA/NAREIT Equity REITs Index** measures the performance of real estate investment trusts listed on the U.S. stock exchange.

The **MSCI Emerging Markets Index** is a market capital weighted index designed to track the large- and mid-cap equity market performance of 23 emerging market countries.

The **Barclays EM USD Aggregate Index** is a flagship hard currency Emerging Markets debt benchmark that includes fixed and floating-rate U.S. dollar-denominated debt issued from sovereign, quasi-sovereign, and corporate EM issuers.

The **Barclays U.S. Aggregate Index** is a broad measure of the U.S. investment-grade fixed-income securities market.

The **Barclays U.S. Treasury Index** is a market-capitalization weighted index that measures the performance of public obligations of the U.S. Treasury that have a remaining maturity of one year or more.

The **Bloomberg Commodity Index** is a broadly diversified commodity price index designed to reflect commodity futures price movements.

The **Barclays U.S. Treasury Long Index** is a market-capitalization weighted index that measures the performance of public obligations of the U.S. Treasury that have a remaining maturity of ten years or more.

The **CBOE PutWrite Index** tracks the value of a hypothetical portfolio of securities (PUT portfolio) that yields a buffered exposure to S&P 500 stock returns. The PUT portfolio is composed of one- and three-month Treasury bills and of a short position in at-the-money put options on the S&P 500 index (SPX puts).

The **SG Trend Index** is an equal weighted index which measures the daily rate of return for a pool of 10 CTAs selected from the largest managers that are open to new investment.

The **Credit Suisse (CS) Global Macro Index** is a subset of the Credit Suisse Hedge Fund Index that measures the aggregate performance of global macro funds.

The **EurekaHedge Multi-factor Risk Premia Index** is designed to provide a broad measure of the performance of a diversified portfolio of systematic drivers of risk and return across asset classes and is comprised of multiple strategies managed by large global banks.

The **SG Multi-asset Alternative Risk Premia Index** is an equal weighted index designed to measure the performance of risk premia managers who employ investment programs diversified across multiple asset classes while utilizing multiple risk premia factors.

The **HFRI Equity Market Neutral Index** is an equal weighted index designed to measure the performance of equity hedge fund strategies which are characterized by low exposure to the equity market and the use of leverage, shorting and other quantitative investing techniques.

HYPOTHETICAL PERFORMANCE RESULTS HAVE MANY INHERENT LIMITATIONS, SOME OF WHICH, BUT NOT ALL, ARE DESCRIBED HEREIN. NO REPRESENTATION IS BEING MADE THAT ANY FUND OR ACCOUNT WILL OR IS LIKELY TO ACHIEVE PROFITS OR LOSSES SIMILAR TO THOSE SHOWN HEREIN. IN FACT, THERE ARE FREQUENTLY SHARP DIFFERENCES BETWEEN HYPOTHETICAL PERFORMANCE RESULTS AND THE ACTUAL RESULTS SUBSEQUENTLY REALIZED BY ANY PARTICULAR TRADING PROGRAM. ONE OF THE LIMITATIONS OF HYPOTHETICAL PERFORMANCE RESULTS IS THAT THEY ARE GENERALLY PREPARED WITH THE BENEFIT OF HINDSIGHT. IN ADDITION, HYPOTHETICAL TRADING DOES NOT INVOLVE FINANCIAL RISK, AND NO HYPOTHETICAL TRADING RECORD CAN COMPLETELY ACCOUNT FOR THE IMPACT OF FINANCIAL RISK IN ACTUAL TRADING. FOR EXAMPLE, THE ABILITY TO WITHSTAND LOSSES OR TO ADHERE TO A PARTICULAR TRADING PROGRAM IN SPITE OF TRADING LOSSES ARE MATERIAL POINTS THAT CAN ADVERSELY AFFECT ACTUAL TRADING RESULTS. THERE ARE NUMEROUS OTHER FACTORS RELATED TO THE MARKETS IN GENERAL OR TO THE IMPLEMENTATION OF ANY SPECIFIC TRADING PROGRAM, WHICH CANNOT BE FULLY ACCOUNTED FOR IN THE PREPARATION OF HYPOTHETICAL PERFORMANCE RESULTS, ALL OF WHICH CAN ADVERSELY AFFECT ACTUAL TRADING RESULTS. The hypothetical performance results contained herein represent the application of the quantitative models as currently in effect on the date first written above, and there can be no assurance that the models will remain the same in the future or that an application of the current models in the future will produce similar results because the relevant market and economic conditions that prevailed during the hypothetical performance period will not necessarily recur. Discounting factors may be applied to reduce suspected anomalies. This backtest's return, for this period, may vary depending on the date it is run. Hypothetical performance results are presented for illustrative purposes only. In addition, our transaction cost assumptions utilized in backtests, where noted, are based on AQR Capital Management LLC's, ("AQR's") historical realized transaction costs and market data. Certain of the 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 achieving the returns have been stated or fully considered. Changes in the assumptions may have a material impact on the hypothetical returns presented. Actual advisory fees for products offering this strategy may vary.

Hypothetical Price-Based Trend-Following Strategy

The Hypothetical Price-Based Trend-Following Strategy model uses data from January 1880 onward. The investment strategy is based on trend-following investing which involves going long markets that have been rising and going short markets that have been falling, betting that those trends over the examined look-back periods will continue. The strategy was constructed with an equal-weighted combination of 1-month, 3-month, and 12-month trend-following strategies for 67 markets across 4 major asset classes: 29 commodities, 11 equity indices, 15 bond markets, and 12 currency pairs. Since not all markets have return data going back to 1880, we construct the strategies using the largest number of assets for which return data exist at each point in time. We use futures returns when they are available. Prior to the availability of futures data, we rely on cash index returns financed at local short rates for each country. Please see Figure 2 for additional details. The strategy targets a long-term volatility target of 10% but does not limit volatility during periods where realized volatility may be higher or lower than this number.

Hypothetical performance is gross of advisory fees and net of transaction costs, unless stated otherwise. In order to calculate net-of-fee returns, we subtracted a 1.25% annual management fee and a 20% performance fee from the gross-of-fee, net-of-transaction-cost returns to the strategy. The transactions costs used in the strategy are based on proprietary estimates of average transaction costs for each of the four asset classes, including market impact and commissions. The transaction costs are assumed to be twice as high from 1993 to 2002 and six times as high from 1880–1992. The transaction costs used are shown in Figure 1.

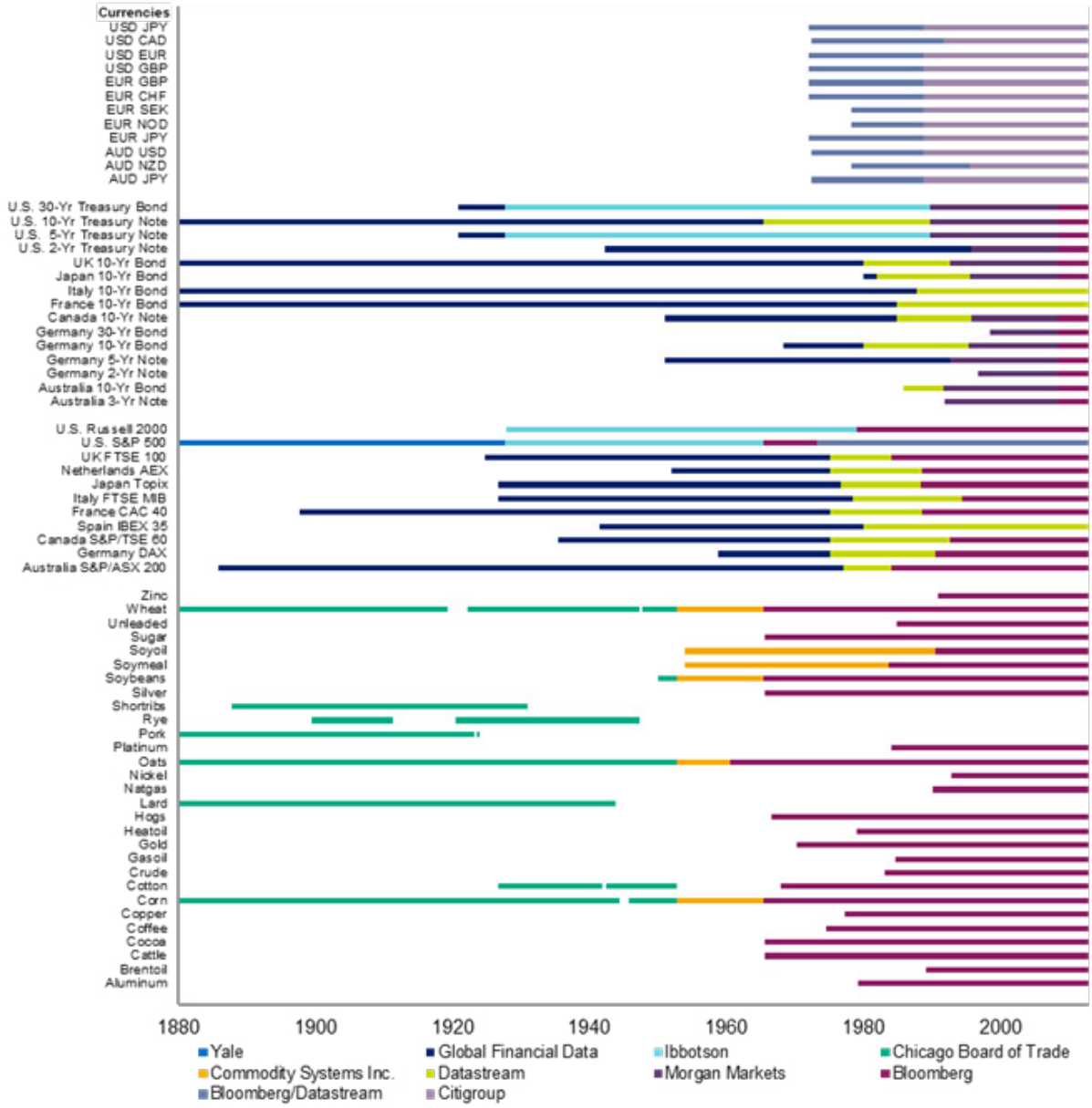
This model is not based on an actual portfolio AQR manages.

The benchmark and relevant cash rate is assumed to be ICE BofA 3-Month T-Bill. Prior to 1929 when 3-month Treasury bills became available, the benchmark and relevant cash rate is assumed to be the NYSE call money rates (the rates for collateralized loans) through 1920 and returns on short-term government debt (certificates of indebtedness) from 1920 until 1929.

Figure 1

Asset Class	Time Period	One-Way Transaction Costs (as a % of notional traded)
Equities	1880 – 1992	0.34%
	1993 – 2002	0.11%
	2003 – Present	0.06%
Fixed Income	1880 – 1992	0.06%
	1993 – 2002	0.02%
	2003 – Present	0.01%
Currencies	1880 – 1992	0.18%
	1993 – 2002	0.06%
	2003 – Present	0.03%
Commodities	1880 – 1992	0.58%
	1993 – 2002	0.19%
	2003 – Present	0.10%

Figure 2



Hypothetical Economic Trend-Following Strategy Backtest Construction

The Hypothetical Economic Trend-Following Strategy uses data from February 1970 onward. The investment strategy is based on trend following which for each theme (Growth, Inflation, International Trade, Monetary Policy, Risk Aversion) and within each asset class, takes a long position in assets in which economic trends are improving and a short position in assets in which economic trends are deteriorating. Each individual position is sized to target the same amount of volatility, both to provide diversification and to limit the portfolio risk from any individual market. The theme portfolio across all assets is scaled to target 10% forecasted annual volatility.

Not all markets and assets have returns going back to 1970; details outlined on the following page.

Growth: Growth trends are captured using one-year changes in forecasts of real GDP growth. From 1990 onward forecast data is from Consensus Economics. Prior to 1990, we use one-year changes in realized year-on-year real GDP growth, lagged one quarter (this definition is equivalent to changes in forecasts assuming that real GDP growth follows a random walk). The series is from the OECD. Increasing growth is assumed to be bullish for equities (cash-flow impact), commodities (increasing demand), and currencies (Balassa-Samuelson hypothesis), and bearish for fixed income (both government bonds and interest rates) via both inflationary pressures and upward pressure on real interest rates.

Inflation: Inflation trends are captured using one-year changes in forecasts of CPI inflation. From 1990 onward forecast data is from Consensus Economics. Prior to 1990, we use one-year changes in realized year-on-year CPI inflation, lagged one quarter (this definition is equivalent to changes in forecasts assuming that CPI inflation follows a random walk). The series is from the OECD. Increasing inflation is assumed to be bearish for equities (see Katz and Lustig (2017)), bullish for currencies (see Clarida and Waldman (2008)), and bearish for fixed income.

International Trade: International trade trends are captured using one-year changes in spot exchange rates against an export-weighted basket. Data is from DataStream. A depreciating currency is bullish for equities (exports become more competitive), bearish for currencies (very similar to price momentum), bearish for fixed income (other things equal, a depreciating currency reduces the pressure on a central bank to reduce interest rates), and bearish for commodities (depreciation of the currencies of commodity consumers means commodities, which are generally priced in USD, are effectively more expensive).

Monetary Policy: Monetary policy trends are captured using one-year changes in the front end of the yield curve. From 1992 onwards, I use two-year yields, while prior to 1992 I use Libor and its international equivalents. Both data series are from Bloomberg. Expansionary monetary policy is bullish for equities (see Bernanke and Kuttner (2005)), bullish for currencies (see Eichenbaum and Evans (1995)), bullish for commodities, and bearish for fixed income.

Risk Sentiment: Changes in risk sentiment are captured using one-year equity market excess returns. Data is from DataStream. Increasing risk sentiment — i.e., strong equity market returns — is bullish for equities, commodities, and currencies, and bearish for fixed income.

The model employs relatively simple measures as they afford long data availability and are less susceptible to concerns about data mining. The strategy is therefore intended as a proof of concept, and can potentially be enhanced by employing additional and improved measures of economic trends.

Backtest returns are hypothetical gross of transaction costs and fees. Even after adjusting for transaction costs and fees, backtest returns are likely overstated, despite best effort to employ simple and transparent signals, due to unavoidable hindsight bias. Hypothetical data has inherent limitations, some of which are disclosed herein.

As the backtest is constructed to take a long position in assets in which economic trends are improving and a short position in assets in which economic trends are deteriorating, the strategy would likely underperform in a period of sharp reversals across asset classes and investment themes or in an environment in which price trends and economic trends diverge. However, due in part to the diversification benefits of the four asset classes and four investment themes, the performance of the backtest has been consistent over a wide variety of macroeconomic and financial environments over the last 50 years.

Hypothetical Economic Trend-Following Strategy Universe:

Equity index return data is from Bloomberg. Start dates are the earliest available date of the series:

- 1970: Australia, Germany, Canada, Spain, France, Italy, Japan, Netherlands, U.K., U.S.
- 1975: Switzerland
- 1980: Denmark, Hong Kong, Sweden
- 1988: New Zealand

Government bond return data is from Bloomberg and DataStream. Start dates are

- 1970: Germany, Canada, U.K., U.S.
- 1980: Japan
- 1981: Switzerland
- 1985: Denmark
- 1986: Australia
- 1987: Sweden

Currency return data is from Citi and Reuters. Start dates are

- 1971: Germany, Japan, Switzerland, U.K.
- 1972: Australia, Canada
- 1978: New Zealand, Sweden

Interest rate futures return data is from IFS. Start dates are

- 1987: U.S.
- 1988: U.K.
- 1989: Australia, Europe (Euribor)
- 1991: Canada, New Zealand, Switzerland

Commodity futures return data is from Bloomberg. Start dates are

- 1970: Cattle, Corm Cotton, Hogs, Soybeans, Soymeal, Soyoil, Sugar, Wheat
- 1974: Coffee
- 1979: Heat Oil
- 1983: Crude Oil
- 1984: Gas Oil
- 1985: Unleaded
- 1989: Brent Oil
- 1990: Natural Gas
- 1991: Zinc
- 1993: Nickel

Hypothetical Alternative Trend-Following Strategy

The Hypothetical Alternative Trend-Following Strategy was constructed with an equal-weighted combination of 1-month, 3-month, and 12-month trend-following strategies for markets across 6 major asset groups – equity factor portfolios, credit indices, interest rate swaps, emerging currencies, alternative commodities, and volatility futures – from January 1990 onward. Since not all markets have the same length of historic return data available, we construct the strategies using the largest number of assets for which return data exist at each point in time. We use futures returns when they are available. The strategy targets long-term volatility target of 10% but does not limit volatility during periods where realized volatility may be higher or lower than this number.

In order to calculate net-of-fee returns for the time series momentum strategy, we subtracted a 1.25% annual management fee and a 20% performance fee per annum from the gross-of-fee returns to the strategy. The performance fee is calculated and accrued on a monthly basis, but is subject to an annual high-water mark. In other words, a performance fee is subtracted from the gross returns in a given year only if the returns in the fund are large enough that the fund's NAV at the end of the year exceeds every previous end of year NAV. The transactions costs used in the strategy are based on proprietary estimates of transaction costs for each market traded, including market impact and commissions.

This model is not based on an actual portfolio AQR manages.

The benchmark and relevant cash rate is assumed to be 3-month Treasury bills

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