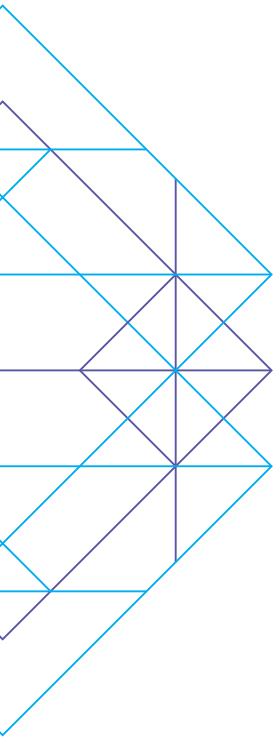
Alternative Thinking | 3Q18

It Was the Worst of Times: Diversification During a Century of Drawdowns



Executive Summary

Big equity drawdowns happen time and again and tend to drag down typical investor portfolios with them. Unfortunately, attempting to tactically avoid the next equity sell-off is likely to disappoint investors.

In this article we use nearly 100 years of data to evaluate the effectiveness of diversifying investments during the worst of times for most portfolios. We also analyze the potential benefits and costs of shifting away from equities, including into investments that are diversifying (i.e., lowly correlated) and investments that are defensive (i.e., expected to outperform in bad times). With regard to the latter, we observe an intuitive trade-off: investments with better hedging characteristics tend to do worse on average. Investors should evaluate this trade-off in deciding how—and how much—to diversify their exposure to equity drawdowns.[1]

1 This topic isn't a new one for us. For more on strategies that diversify and/or hedge during bad periods for equities, see Berger, Nielsen and Villalon (2011); Asvanunt, Nielsen and Villalon (2015); and AQR Alternative Thinking 3Q2015, "Good Strategies for Tough Times.."

Contents

It's Happened Before, It Will Happen Again (and No, We Can't Tell You When)

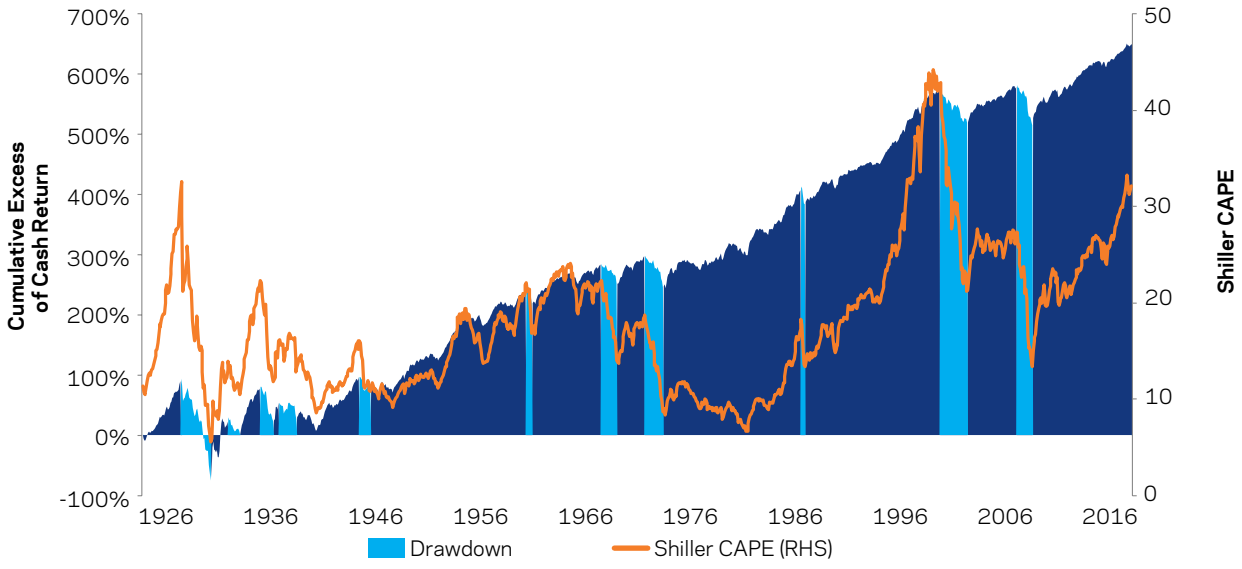
Most investor portfolios are dominated by equity risk.[2] This is not without reason — equities have had high average returns historically — but when equities have major drawdowns, the overall portfolio will likely suffer, too.

There's some subjectivity in determining what qualifies as a "major drawdown" for equities, but here we use -20 percent cumulative returns as the threshold.[3] Losses of this magnitude wipe out several years of typical performance, and we believe have also forced many investors to make reactive (and generally suboptimal) changes to their portfolios. While recent examples such as the Global Financial Crisis and Tech Bust are fresh in the memory of many investors, we use a data set spanning almost a century to see what would have helped over the *truly* long term.

Exhibit 1 shows that drawdowns worse than -20 percent have happened 11 times since 1926 — a little over once per decade on average. The average peak-to-trough has been -33 percent, and on average it took

Exhibit 1

S&P 500 Drawdowns Worse than -20 Percent and Market Valuations
Feb 1, 1926 – Dec 31, 2017



Source: Robert Shiller data library. Past performance is not an indication of future performance. Please see appendix for important disclosures.

2 Even a seemingly diversified 50 percent stock/50 percent bond portfolio is dominated by equity risk due to the fact that equities tend to be a (much) higher-risk asset class. For more on equity risk exposure, see Hurst, Johnson and Ooi (2010). Additionally, many private and illiquid assets, such as Private Equity, may have more equity risk than commonly presumed, due to reported returns that are "too smooth."

3 Note: All returns in this article are excess of cash (here the US 3-month Treasury bill, unless stated otherwise).

27 months to get back to pre-drawdown levels (assuming investors stayed invested throughout![4]). Clearly, tactically avoiding these large drawdowns would be valuable, so we start by evaluating that option.

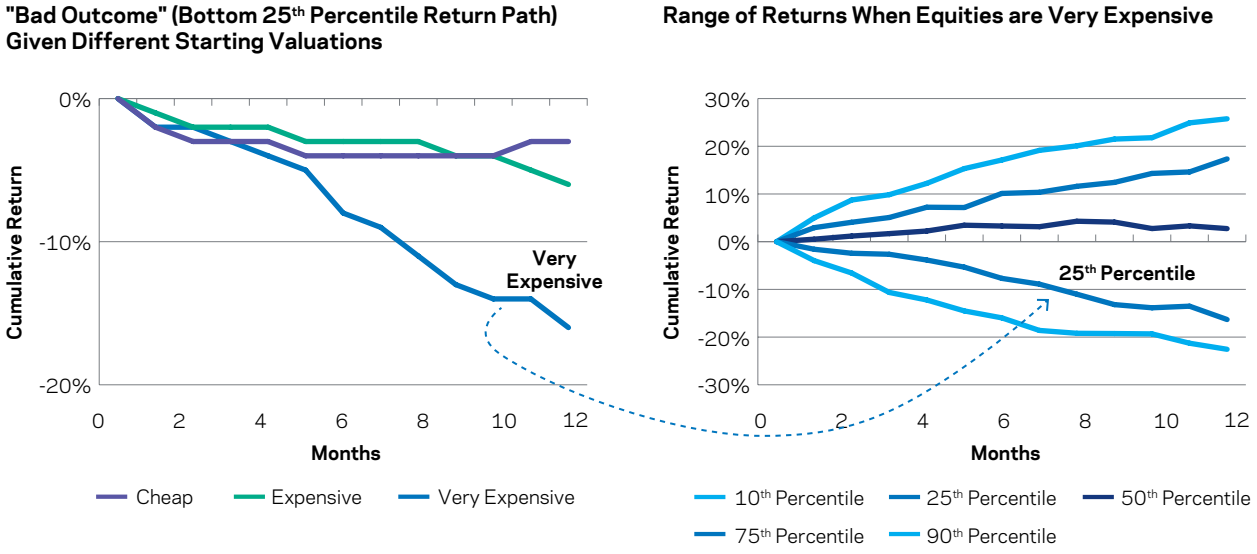
Focusing on equity market valuations (the timing indicator we hear about most often), we see in Exhibit 1 that over the long history, there is no consistent pattern between when drawdowns happen and the level of the Shiller CAPE.[5] Although investors might have expected big sell-offs to be precipitated by off-the-charts valuations — as in the case of the Tech Bubble — it doesn't always play out that way.

Would-be-timers might counter that even if high valuations didn't consistently predict major drawdowns, they could still predict a higher *likelihood* of drawdowns — and therefore stretched valuations may still be a useful tactical indicator. **Exhibit 2** evaluates this empirically. On the left side we split our sample into periods of "cheap" (below median), "expensive" (above median), and "very

Exhibit 2

Failure to Crash: Bad outcomes have been worse when markets were very expensive (left), but markets have tended to go up on average, *even when expensive* (right)

Feb 1, 1926 – Dec 31, 2017



Source: Shiller data library. All returns are excess of cash and gross of fees. "Cheap" is when the Shiller CAPE is below its full-period median; "Expensive" is when the Shiller CAPE is above its median; "Very Expensive" (both for left and right charts) is when the Shiller CAPE is in the 90th percentile of expensiveness or higher. This exhibit uses the full Feb 1926 – Dec 2017 history to determine market expensiveness; the results are similar if we used an expanding window. Past performance is not an indication of future performance. Please see appendix for important disclosures.

4 Numerous studies have shown that poorly timed decisions lead, on average, to lower returns for investors than for the investments themselves. See, for example, Dichev (2007). For a summary of some of the most common inefficient decisions investors make, see AQR Alternative Thinking 3Q2014, "Bad Practices and Good Habits."

5 For more on the evidence and underappreciated challenges in market timing (both value-based and momentum-based), see Asness et al. (2017a). Also see Asness et al. (2017b) for related findings for factor timing. As with many quantitative signals, value and momentum may represent "small edges" and are thus best implemented in a diversified process using multiple signals and many securities.

expensive" (top 10th percentile) valuations and measure the path of a typical bad outcome associated with each.[6] Indeed, the left side of the exhibit shows that bad outcomes looked considerably worse when equity markets were very rich to start — a glimmer of hope for tactically avoiding drawdowns!

However, the right side of Exhibit 2 shows that when we look at the *full* distribution of outcomes starting from when markets are very expensive, we find that more than half of the time, equities still show *positive* returns. In other words, despite there being a greater chance of a big drawdown, more often than not, equities still make money; an investor getting out of equities every time they observed rich valuations could miss out on a great deal of the long-term equity risk premium.[7] Consider recent experience as one example: the Shiller CAPE crossed its 90th percentile in August 2016, yet the equity market has experienced meaningful gains since then.

While we present illustrative evidence here, we have elsewhere (and more thoroughly) evaluated contrarian timing strategies and found their performance to be positive but weak, particularly given the real-world restriction of using only known (i.e., trailing) data to determine the percentile of market valuation. In other words, we are not against the concept of small tactical tilts based on value or other signals such as momentum (if market timing is a sin, we have advocated to "sin a little"[8]), but they are far from a panacea for the reality of occasional, large equity market drawdowns.

6 Specifically, here a "bad outcome" is defined as the 25th percentile of all return paths starting from times in which equity valuations started within a given valuation bucket.

7 In addition, this approach would not be implementable in practice as identifying the full-sample percentile of Shiller CAPE is not possible in real time. See Asness et al. (2017a) for the difference between the apparent viability of valuation-based timing using in-sample data (i.e., with a look-ahead bias) versus using a more realistic, out-of-sample approach.

8 See "Cliff's Perspectives" (Nov 2015) and references therein.

Getting by with a Little Help from Our Friend, Diversification

A better solution to mitigate the pain of bad times may be diversification. Specifically, to incorporate return sources that are expected to make money on average but have a low correlation to equities. Importantly, to actually help mitigate drawdowns, diversification should be true both in normal times and when most needed: during tough periods for equities.

Our analysis includes two traditional asset classes (Bonds and Commodities[9]); two long-only portfolios of assets (the classic 60/40 stock/bond portfolio and a hypothetical Risk Parity[10] portfolio of stocks, bonds and commodities); and two hypothetical long/short alternative strategies (a relative-value "Styles" strategy[11] and a Trend-following strategy[12]). The Risk Parity, Styles, and Trend strategies in this analysis each target approximately 10 percent volatility, given many investors tend to invest in these strategies at that volatility level.[13]

Exhibit 3 summarizes the average returns and correlation to equities for each (the table), as well as the more subtle question of whether this diversification held up during drawdowns (the chart). Starting with the former, we see that over 90-plus years, each of these candidates had positive returns on average (albeit less so than equities for the most part[14]), and in most cases they acted as a diversifier to equity risk. In particular, Bonds and Commodities have had lowly positive correlations, while hypothetical Styles and Trend have been uncorrelated. The portfolios that include equities have not surprisingly seen a positive correlation, though much less so for the hypothetical Risk Parity portfolio as compared to 60/40.

We next shift our focus to the box-and-whisker chart to assess performance during major equity drawdowns. Starting with traditional asset classes, Bonds and Commodities have both been solid diversifiers over these periods

9 Bonds here are US 10-year government bonds; Commodities are the return to an equal dollar-weighted portfolio that takes equal notional weights of all commodities in the commodity basket at each point in time (see appendix for list of commodities and when each is added to the basket); and Equities are the S&P 500. See appendix for more details. Diversification does not eliminate the risk of experiencing investment losses.

10 Risk Parity here uses the same three asset class series also used in this analysis (US stocks and bonds, and commodities), and targets 10 percent volatility (using trailing 36-month volatility to scale position sizes).

11 A hypothetical long/short strategy that combines style premia across multiple asset classes, based on Ilmanen, et al. (2018). For stock selection, we use value, momentum and defensive styles; and in asset allocation we add a fourth style, carry. The implementation of each style necessarily varies by asset class, but in general, value means cheap versus expensive, momentum is recent outperformers versus recent underperformers, defensive is safe/high-quality versus risky/low-quality, and carry is high-yielding versus low-yielding. The combination of stock selection and asset allocation portfolios is equal-weighted. Returns are discounted to a Sharpe ratio of 0.8. See appendix for more details.

12 Based on Hurst, Ooi and Pedersen (2017). Returns are discounted to a Sharpe ratio of 0.6. See appendix for more details.

13 This is not a trivial assumption, as the choice of volatility for alternative strategies directly affects their level of average returns. We (among others) offer strategies with different target volatilities, meaning investors with primary objectives of reducing risk for the same expected return, or other investors with the objective of increasing expected return for the same level of risk may choose different volatility-versions of the same strategy (and update the analysis presented in this paper accordingly). We feel that the 10 percent volatility level used in this paper is a realistic and representative level for our analysis.

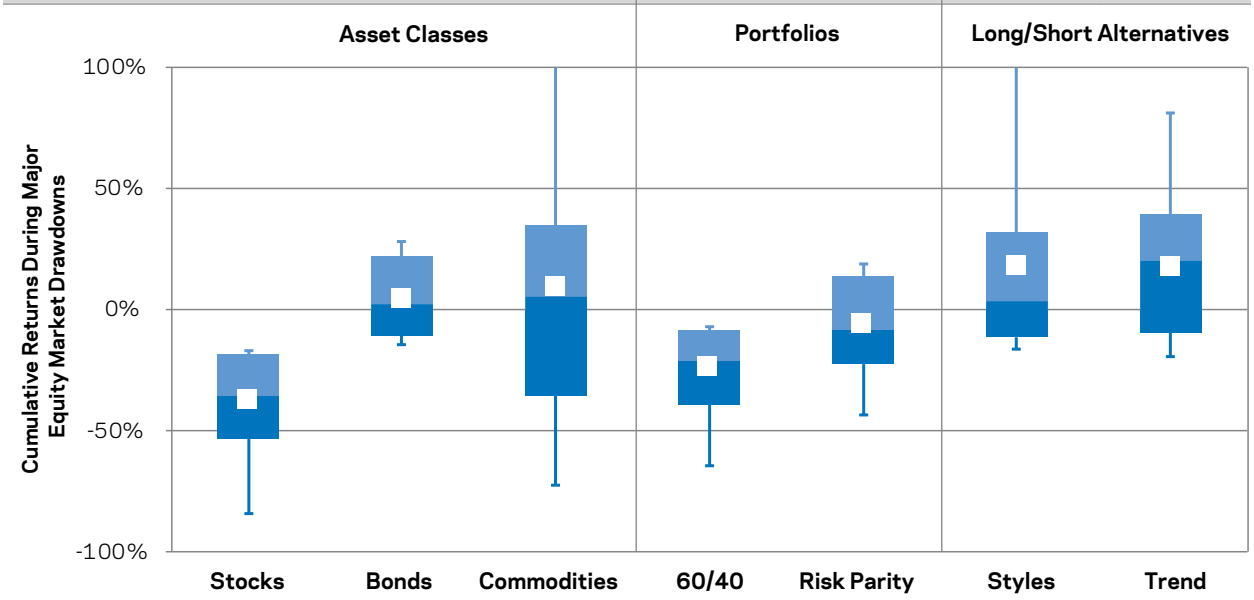
14 Again, contingent on the volatility target used for the alternatives.

Exhibit 3

Performance on Average (Table) and Performance in Equity Drawdowns (Chart)

Feb 1, 1926 – Dec 31, 2017

	Stocks	Bonds	Commodities	60/40	Hypothetical Risk Parity	Hypothetical Styles	Hypothetical Trend
Average Return	7.5%	1.9%	4.7%	5.3%	6.5%	8.0%	6.5%
Correl. to Stocks	1.00	0.08	0.28	0.98	0.63	-0.09	-0.01



Source: Robert Shiller data library and AQR. All returns are excess of cash. "Stocks" are the S&P 500. "Stock Market Drawdowns" are defined here as times when the S&P 500 loses at least 20 percent, peak-to-trough. Over this period, there are eleven such observations. The white squares are the average cumulative returns. Within the box-and-whisker plots, the whiskers show the 0-10th and 90-100th percentile results (given eleven observations, this corresponds to the single worst and single best observations). Within the "boxes" (the 10th through 90th percentile observations), the median return is where the colors change. The highest result for Styles was 156%, which was during the Tech Bust. The highest result for Commodities was 144 percent, which was during the mid-1970s recession. "Risk Parity," "Styles" and "Trend" are hypothetical returns as defined in footnotes 10 through 13. Hypothetical data has inherent limitations, some of which are disclosed in the Appendix. Please see Appendix for data and strategy descriptions.

— their average returns (white squares) were positive, meaning they did not *on average* lose when equities sold off. For many investors, strategically increasing exposure to these asset classes may be a step in the right direction.[15]

Moving on to the portfolios, clearly for the 60/40 portfolio, the 40 percent allocation to bonds wasn't much of a diversifier — the box-and-whisker chart for 60/40 returns looks pretty much the same as that for the S&P 500, only a little closer to zero. In contrast, the hypothetical Risk Parity portfolio held up better — and in some equity drawdowns, returns were *above* zero. This result is intuitive: with its meaningful exposure to equities, Risk Parity is still affected by equity sell-offs, but compared to 60/40, it gives enough weight to bonds and commodities to actually make a difference at the portfolio level. Finally, we find that for the long/short alternative strategies, their behavior

15 The large difference in ranges is driven by the different volatilities between bonds and commodities.

matches what we would expect of a truly diversifying source of returns: a distribution that appears to be largely unaffected by tough times for equity markets.[16]

Note that *diversification is not the same thing as a hedge*. Although uncorrelated assets can be tremendously valuable additions to a portfolio, "uncorrelated" simply means returns that aren't influenced by the other risks in the portfolio. To that end, each one of the diversifying strategies lost money in some of the individual equity sell-offs, and in some cases a fair amount. Importantly, observing this behavior in individual instances does not mean they are not diversifiers! The key is that these other strategies and asset classes did not suffer *on average* when equities did (unlike the 60/40 portfolio, for example). In contrast, a hedge is something you would expect to do better than average exactly when other parts of the portfolio are suffering (and while a hedge might sound more desirable than "uncorrelated," we argue in the next section there's a cost).

It is also worth noting that adding diversifying strategies to any portfolio means adding new risks. The diversifiers will have their *own* (hopefully different) periods of underperformance, which can be hard to stick with. This is one reason diversification can be harder in practice than in theory and should be assessed and understood ahead of any potential allocation and incorporated in any sizing decision.

In **Exhibit 4,** we study the portfolio impact of making an allocation from a 60/40 portfolio to these other strategies. We consider two approaches: 1) funding purely from equities (top two rows), and 2) funding from a combination of equities and fixed income (at a 60/40 ratio, bottom two rows). In both cases, we evaluate a 10 percent allocation from the funding source to the new investment and consider both the impact on returns during equity drawdowns as well as the impact on returns on average over the entire 1926–2017 period. Finally, in addition to the asset classes and alternative strategies considered so far, we add cash as a "benchmark" for reducing drawdowns, as it presents the simplest way to reduce equity risk. (In this exhibit we focus on the impact on returns rather than on Sharpe ratio, in keeping with the adage that investors "can't eat risk-adjusted returns."[17])

16 We find this behavior holds up well even for the underlying individual risk premia.

17 As mentioned earlier, the choice of volatility target of the three alternative portfolios matters. Investors may see better results in average returns and "drawdown returns" (on average) from higher-volatility implementations if they have the ability to access them.

Exhibit 4

Impact of a 10 Percent Allocation to a New Investment from a 60/40 Starting Portfolio

Feb 1, 1926 – Dec 31, 2017

		Cash	Bonds	Commodities	60/40	Hypothetical Risk Parity	Hypothetical Styles	Hypothetical Trend
Funded from Stocks	Change in Drawdown Return	+2.8%	+3.1%	+2.8%	+1.2%	+2.4%	+3.6%	+3.6%
	Change in Average Return	-0.8%	-0.6%	-0.3%	-0.2%	-0.1%	+0.0%	-0.1%
Funded 60/40 from Stocks /Bonds	Change in Drawdown Return	+1.5%	+1.9%	+1.5%	n/a	+1.2%	+2.3%	+2.4%
	Change in Average Return	-0.5%	-0.3%	-0.1%	n/a	+0.1%	+0.3%	+0.1%

Source: Robert Shiller data library and AQR. All returns are compared to a 60/40 US stock/bond portfolio. All returns are excess of cash. "Drawdowns" are defined here as times when the S&P 500 loses at least 20 percent, peak-to-trough. "Risk Parity," "Styles" and "Trend" are hypothetical returns as defined in footnotes 10 through 13. See AQR Alternative Thinking 1Q2018 for considerations when building expected return assumptions for alternatives, and AQR Alternative Thinking 2Q2014 for other considerations in incorporating alternatives into a portfolio. Hypothetical data has inherent limitations, some of which are disclosed in the Appendix. Please see Appendix for data and strategy descriptions.

Exhibit 4 shows that the funding source can matter just as much as the new diversifying investment: funding from equities means a much greater offset to drawdown losses, but the trade-off is a bigger hit to long-term average returns (compared to funding from 60/40). Not surprisingly, Exhibit 4 shows that portfolio drawdowns are mitigated when allocating toward *any* diversifier (including cash, the simplest way to reduce equity risk). But when allocating to other traditional assets, a clear trade-off emerges: the "cost" of smaller drawdowns is slightly lower returns on average (albeit this "cost" is always smaller than simply de-risking to cash). In contrast, the alternatives appear to have kept up with equities on average, though they have their own potential drawbacks of higher complexity and fees.[18] In determining how to and how much to allocate to diversifiers, investors should evaluate the trade-off between offsets to losses in bad times versus performance on average.[19]

18 See AQR Alternative Thinking 2Q2014 "Strategic Risk Allocation" for considerations beyond expected returns in incorporating alternatives into a portfolio including: conviction, constraints, conventionality and capacity.

19 It should be noted that the portfolios with the "new" 10 percent allocations are also slightly less volatile than the starting portfolio; thus, investors focused on *boosting* their average returns might consider higher-volatility versions of their diversifiers.

If Diversifying Is Good, Is Hedging Great?

Given the recent advent and interest in "defensive" investments, we evaluate if these can deliver on the promise of doing more than just diversify, and consistently deliver positive returns during equity market drawdowns. These investments are described in **Exhibit 5,** and include Gold,[20] Global Macro Momentum, Defensive Equities, Defensive Trend and a "passive" Put Option buying strategy.[21] We restrict this broader analysis to 1986–2017 due to data availability for the additional strategies, and recognizing fewer major drawdowns over this shorter window, we relax the threshold for a drawdown to -10 percent.[22]

Exhibit 6 shows the results for both our original and "new" (defensively oriented) strategies. Over the past 30 years, the five candidate "defensive" strategies provided positive returns on average

Exhibit 5
Defensively Oriented Strategies Used in the 1986–2017 Sample

	Description	Intuition as a Diversifier/Hedge
Gold	Constant notional exposure to gold futures	Commonly considered a "safe haven," may benefit in risk-off environments
Global Macro Momentum	Follows trends in macroeconomic fundamentals across multiple asset classes	Large equity market downturns are often precipitated by worsening fundamentals
Defensive Equities	Long/short (dollar-neutral) strategy that takes long positions in high-quality, low-risk assets and short positions in the overall market[23]	Defensive stocks may be expected to outperform the aggregate markets during flights to quality or risk-off environments
Defensive Trend	Trend-following strategy, customized to 1) not be net long equities, and 2) take larger short positions	The constraints imposed on a traditional trend-following strategy are designed to generate better returns in down-equity markets
Puts	Buys front-quarter, 5 percent out-of-the-money put options and holds until expiry	An "explicit" hedge, often used as portfolio insurance

Source: AQR. Please see Appendix for data and strategy descriptions.

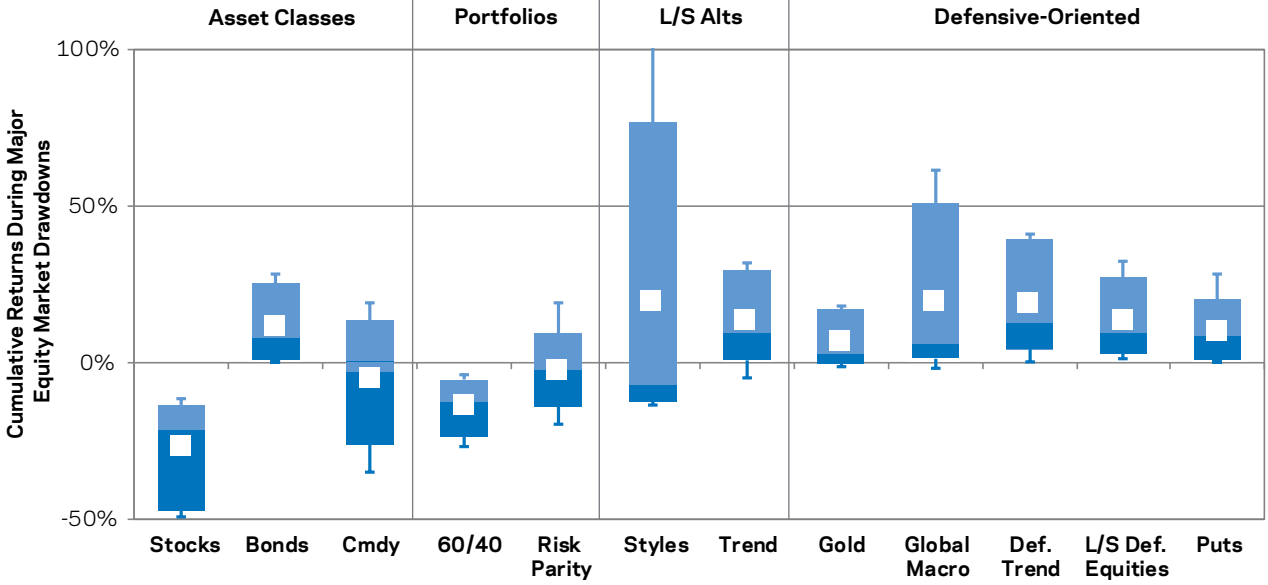
20 Gold is one of many examples of assets that tend to display safe-haven characteristics. Others include the US dollar, Japanese yen and Swiss franc.
21 As before, risk-targeted strategies (Global Macro and Defensive Trend) target a 10 percent volatility level. Defensive Equity and Puts are not risk targeted, and each realized approximately 6 percent annualized volatility over this period. Global Macro and Defensive Trend are discounted to Sharpe ratios of 0.5.
22 This gives us six bad periods to look at, as opposed to only three if we had stuck with drawdowns in excess of -20 percent.
23 The dollar-neutral construction used here results in a strategy that will mechanically tend to have a negative correlation to equities. There are other ways to build long/short defensive strategies (including beta-neutral), but we focus on the more straightforward implementation here for simplicity.

during equity drawdowns, and almost no periods with meaningful negative performance. For an investor focused purely on mitigating bad times, the evidence suggests they are attractive choices.

Revisiting the traditional asset classes over this shorter time period is also interesting. While both Bonds and Commodities appeared uncorrelated to equities over the long term, Bonds more recently have shown a tendency to *hedge*, posting positive returns in each of the equity drawdown periods (and higher than their 30-year average return),[24] while Commodities in aggregate seem to have gone the other way. The reason for this change may relate to the economic causes of recent drawdowns, with adverse demand shocks in periods like 2008 causing commodities to sell off alongside equities, with an opposite effect

Exhibit 6
Average Performance (Table) and Performance During Equity Drawdowns (Chart)
Jan 1, 1986–Dec 31, 2017

					Hypothetical				Hypothetical				
	Stocks	Bonds	Commo-dities	60/40	Risk Parity	Styles	Trend	Gold	Global Macro	Def. Trend	L/S Def. Equity	Puts
Average Return	7.5%	3.8%	3.0%	6.0%	7.6%	9.2%	6.3%	1.8%	5.4%	5.0%	0.4%	-4.2%
Correl. to Stocks	1.0	-0.03	0.24	0.96	0.63	-0.05	-0.08	-0.08	-0.18	-0.30	-0.67	-0.76



Source: Robert Shiller data library and AQR. "Stocks" are the S&P 500. All returns are excess of cash. "Stock Market Drawdowns" are defined here as times when the S&P 500 loses at least 10 percent, peak-to-trough. Over this period, there are six such observations. The squares are the average cumulative returns. Within the box-and-whisker plots, the whiskers show the 0 to 10th and 90th to 100th percentile results (given only six drawdowns, this corresponds to the min and max observations). Within the "boxes" (the 10th to 90th percentile observations), the median return is where the colors change. "Risk Parity," "Styles," "Trend," "Global Macro," "Def. Trend," and "L/S Def. Equity" are hypothetical strategies defined in footnotes 10 through 13, 21 and Exhibit 5. See AQR Alternative Thinking 1Q2018 "Capital Market Assumptions for Major Asset Classes" for considerations in forming expected return assumptions for alternatives. The passive put strategy buys front quarter 5 percent out-of-the-money put options and holds till expiry. The highest result for "Styles" was 143 percent, which was during the Tech Bust. Hypothetical data has inherent limitations, some of which are disclosed in the Appendix. Please see Appendix for data and strategy descriptions.

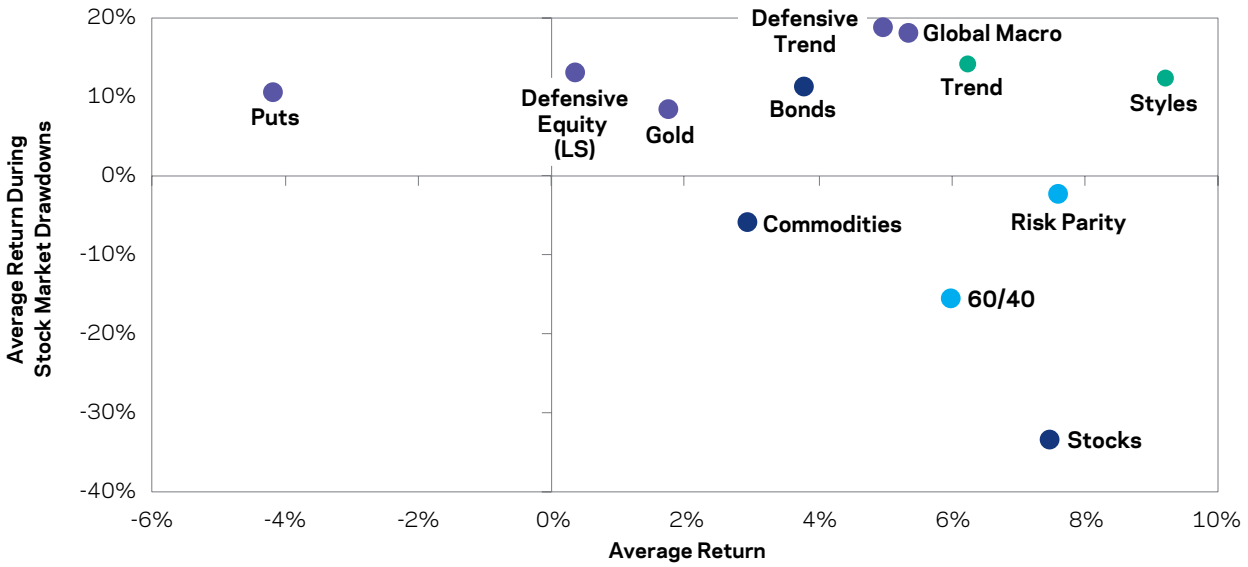
24 This may be one reason investors think of bonds today as a hedge and not "just" a diversifier. The long-term evidence cautions us against making such heroic assumptions going forward.

on bonds. However, investors should note that the closer-to-zero longer-term correlations to equities suggest that the post-1986 experience will not necessarily hold in the future.

Finally, in **Exhibit 7** we evaluate how hedging characteristics compare to average returns. In particular we plot each investment's average return during equity drawdowns against its full-sample average return. An intuitive trade-off emerges: the strategies that are more defensively oriented tend to have lower average returns. The comparison between standard Trend and Defensive Trend may be the clearest example of this, as the constraints in the latter that are targeted at improving tail performance prevent the strategy from implementing trades that are profitable on average, leading to worse average performance.

The trade-off is at its most extreme when considering the most explicit hedging strategy, Puts, which have meaningfully *negative* returns over the long term. It is also important to recognize that even though put options are an explicit hedge, they are not a silver bullet — their returns vary by drawdown, and the protection that they provide is far from guaranteed.[25] In contrast, the "indirect hedges" — such as Defensive Equity, Defensive Trend and Global Macro — appear to have delivered better performance on average and when most needed.

Exhibit 7
A "Hedging Frontier"
Jan 1, 1986 - Dec 31, 2017



Source: Robert Shiller data library and AQR. "Stocks" are the S&P 500. All returns are excess of cash. "Stock Market Drawdowns" are defined here as times when the S&P 500 loses at least 10 percent, peak-to-trough. Over this period, there are six such observations (the picture looks similar had we chosen -20 percent drawdowns). "Risk Parity," "Styles," "Trend," "Global Macro," "Def. Trend," and "L/S Def. Equity" are hypothetical strategies defined in footnotes 10 through 13, 21 and Exhibit 5. See AQR Alternative Thinking 1Q2018 "Capital Market Assumptions for Major Asset Classes" for considerations in forming expected return assumptions for alternatives. The passive put strategy buys front-quarter 5 percent out-of-the-money put options and holds till expiry. Hypothetical data has inherent limitations, some of which are disclosed in the Appendix. Please see Appendix for data and strategy descriptions.

25 Even seemingly small mismatches in timing between the put option's maturity (and the need to roll over to new options) and the length of the drawdown can lead to much weaker hedging efficacy. For more on this, see Israelov (2017).

Conclusion

Bad times for investors are a sure thing, but ways to address them are not. The data does not support the conventional wisdom that expensive markets can help to time crashes. Buying put options has fared worse than many investors might suspect, too. As with everything in investing, there is no perfect solution to addressing the risk of large equity market drawdowns. However, we find using nearly a century of data that diversification is probably (still) investors' best bet. This is not to say that diversification is easy. Investors should analyze the return and correlation profiles of their diversifying investments to prepare themselves for the range of outcomes that they should expect during drawdowns and also over the long term.

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Disclosures

Data Sources:

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

Stocks: AQR, Yale, Ibbotson, Bloomberg. Stocks are the return of the S&P 500.

Bonds: Global Financial Data, Datastream, Morgan Markets. Bonds are the return of 10-Year U.S. Treasury Notes.

Commodities: AQR, Chicago Board of Trade. Commodity contract prices are from Chicago Board of Trade for the period before 1951, Commodity Systems Inc. for 1951–2012, and Bloomberg for 2012–2015. Rolled return series for platinum, aluminum, copper, lead, nickel, tin, and zinc are from S&P, Goldman Sachs, Bloomberg, and DataStream. The risk-free rate is New York call money rates until 1889, the *New York Times* money rates until 1918, secondary market rates on the shortest-term US bonds available until 1931 and T-bills thereafter. A rolling one-year average of the short-term rate is used. Commodities are the return to an equal dollar-weighted portfolio, which takes equal notional weights of all commodities in the commodity basket at each point in time. See chart below for data sources and components of the commodities basket.

Risk Parity: Using the stocks, bonds, and commodities returns above, this strategy allocates equal risk to each of the three asset classes using rolling, trailing 36-month volatility. The strategy is rebalanced monthly and is gross of transaction costs and of fees.

Trend: AQR, etc. The Trend strategy is constructed with an equal-weighted combination of one-month, three-month, and 12-month trend-following strategies for 67 markets across four 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. The strategy targets a long-term volatility target of 10 percent but does not limit volatility during periods where realized volatility may be higher or lower than this number. The strategy is gross fees, net of transaction costs, and is discounted to a full-period Sharpe ratio of 0.6. See chart below for data sources and components of the hypothetical trend-following strategy.

Gold: Bloomberg.

Global Macro Momentum: AQR. The Global Macro Momentum strategy backtest used in this analysis is based on the paper "A Half Century of Macro Momentum" (Brooks, 2017). The strategy invests in global equity indices, global currencies, global government bonds (ten-year maturity), and global interest rates (three-month maturity) and focuses on four macroeconomic state variables that affect each of the asset classes considered: 1) business cycle, 2) international trade, 3) monetary policy and 4) risk sentiment. The strategy is gross of fees and transaction costs and is discounted to a full-period Sharpe ratio of 0.5.

Defensive Equities: AQR, Barra. Defensive Equities is a long-only backtest of a strategy that overweights low-beta and high-quality stocks and underweights the opposite. The universe is roughly the Russell 1000. The backtest is rebalanced quarterly and uses the Barra USE3L risk model. The strategy is net of transaction costs and undiscounted.

Styles: The implementation of each style necessarily varies by asset class (and described below), but in general, value means (long) cheap versus (short) expensive; momentum is recent outperformers versus recent underperformers; defensive is safe/high-quality versus risky/low-quality; and carry is high yielding versus low yielding. Styles:

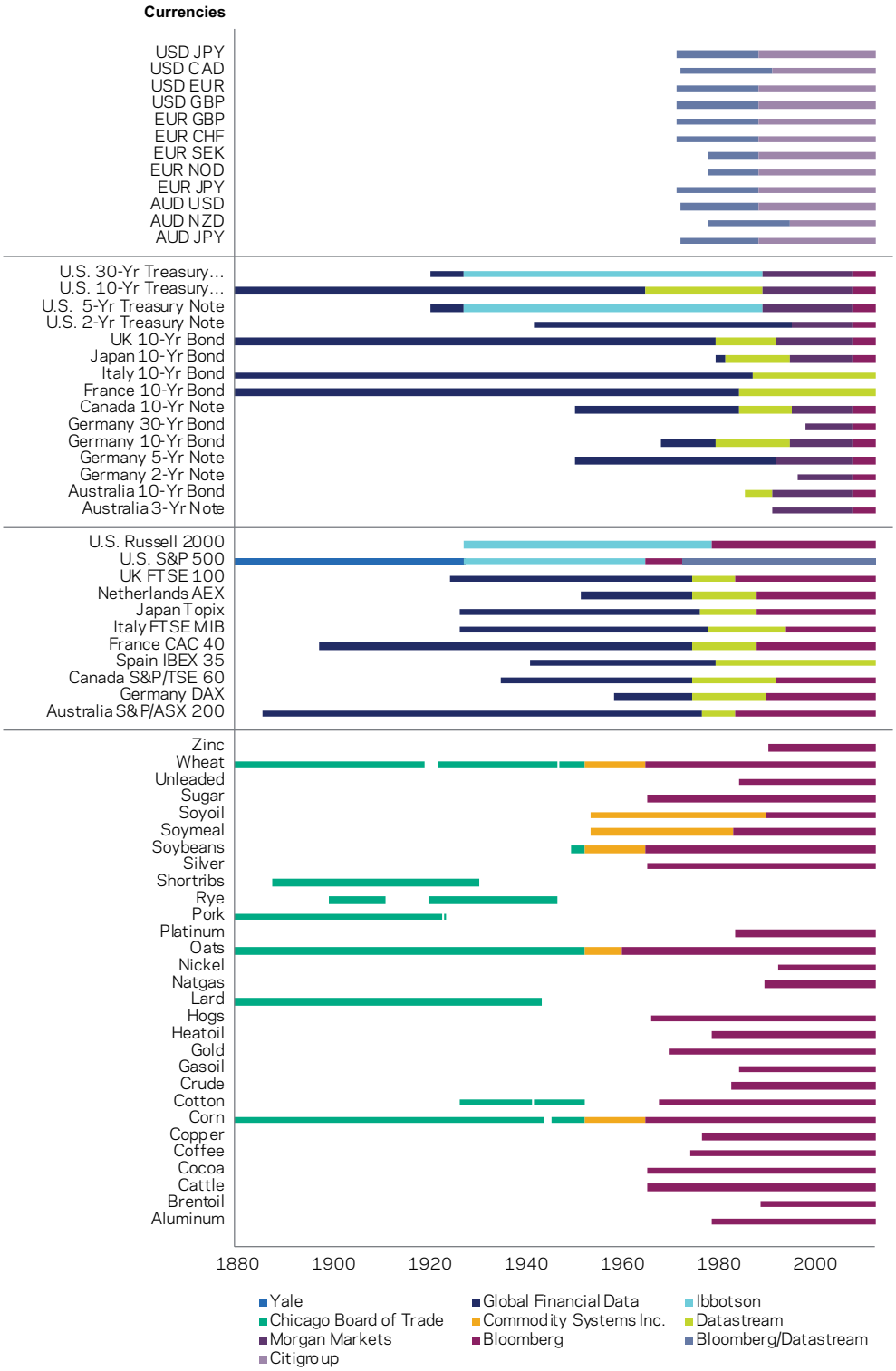
This series is scaled to 10 percent volatility and discounted to a Sharpe Ratio of 0.8. Descriptions of style premia used in each asset class: US Stocks Value: Book-to-Price Ratio, Momentum: Past 12-Month Return, Excluding Last Month, Defensive: Beta; International Stocks Value: Book-to-Price Ratio, Momentum: Past 12 Month Return, Excluding Last Month, Defensive: Beta; Equity Indices Value: Cyclically Adjusted Earnings-to-Price Ratio, Momentum: Past 12-Month Return, Excluding Last Month, Carry: Dividend Yield, Defensive: Beta; Fixed Income Value: Real Bond Yield, Momentum: Past 12-Month Return, Excluding Last Month, Carry: Term Premium, Defensive: Beta; Commodities, Value: 5-Year Reversal, Momentum: Past 12-Month Return, Excluding Last Month, Carry: Futures Curve Rolldown, Defensive: Beta; Currencies, Value: Purchasing Power Parity, Momentum: Past 12-Month Return, Excluding Last Month, Carry: Short-Term Interest Rate.

Asset class descriptions for style premia used: US Stocks: Individual stock-level data from the CRSP database from July 1926 for Value, July 1927 for Momentum, and July 1931 for Defensive strategies. Compustat/XpressFeed Global is used for accounting data post-1950 and pricing data post-1998. Accounting data pre-1950 is from Moody; International Stocks: Individual stock-level data from Compustat/XpressFeed Global from July 1984 for Value, January 1985 for Momentum, and February 1987 for Defensive strategies; Equity Indices: Returns on equity indices from 23 equity markets international, which include all countries in the MSCI World Index as of 10/31/2016. Since most countries have multiple equity indices, we use the index that is investable, has the most coverage of the total stock market of that country, and has the longest history. We source monthly total returns from Global Financial Data and futures returns from Bloomberg and Datastream; Fixed Income: Nominal yield and total returns data of 10-year local currency government bonds as well as three-month interest rates for 13 countries covering North America, Northern Europe, Japan, and Australia/New Zealand, sourced from Global Financial Data, Bloomberg, and Datastream; Commodities: Monthly futures prices of 40 commodities starting in 1877, sourced from the Annual Report of the Trade and Commerce of the Chicago Board of Trade, Commodity Systems Inc., and Bloomberg. For base metals and platinum, rolled return series from the S&P, Goldman Sachs, and Bloomberg are used; Currencies: Spot and one-, two-, three-, and six-month forward exchange rates from AQR's production database and interpolate the forward exchange rate for the next quarterly IMM date. This simulates a strategy of buying and holding the forward contract maturing at the near IMM date and rolling to the far contract five days before the maturity date. Before 1990, we use changes in spot exchange rates plus the carry of the currency for the total return. This includes data from 20 developed market currencies (Australia, Eurozone, Canada, Japan, Norway, New Zealand, Sweden, Switzerland, United Kingdom, the US, Belgium, Spain, Finland, France, Germany, Ireland, Italy, Netherlands, Austria, and Portugal).

Defensive Trend: Defensive Trend represents the Trend strategy described earlier with a series of adjustments. First, we form an equity-hedged trend strategy that looks at the previous month-end's net equity position, and if it was positive, removes the equity performance for the following month (effectively hedging out any return from equities). Next, we form an asymmetric equity trend strategy that applies an asymmetric timing curve (i.e., double short) to the equity portion of the trend strategy. That is, when the strategy goes short equities, it

levers that short position 2x. Our Defensive Trend strategy combines the equity-hedged and asymmetric trend strategies, and so is long-term slightly negatively correlated to equities and doubly short equities in periods of negative equity trend. The strategy is net of transaction costs, gross of fees, and discounted to a full-period Sharpe ratio of 0.5.

Puts: AQR, OptionMetrics. Puts represents a backtested strategy that goes long Third Month puts 95 percent of spot strike. Options are sized such that the total option notional bought is 100 percent of NAV. Options are held to expiration and are not delta-hedged. Option returns from October 1984 through January 1996 are constructed from S&P 100 options data, and returns from January 1996 through present are constructed from S&P 500 options data. Returns are gross of transaction costs and of fees.



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