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The Best of Strategies for the Worst of Times: *Can Portfolios Be Crisis Proofed?*

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The Best of Strategies for the Worst of Times: *Can Portfolios Be Crisis Proofed?*

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ABSTRACT: *In the late stages of long bull markets, a popular question arises: What steps can an investor take to mitigate the impact of the inevitable large equity correction? Hedging equity portfolios is notoriously difficult and expensive. In this article, the authors analyze the performance of different tools that investors could deploy. For example, continuously holding short-dated S&P 500 put options is the most reliable defensive method but also the most costly strategy. Holding safe-haven US Treasury bonds produces a positive carry but may be an unreliable crisis-hedge strategy because the post-2000 negative bond–equity correlation is a historical rarity. Long gold and long credit protection portfolios sit between puts and bonds in terms of both cost and reliability. Dynamic strategies that performed well during past drawdowns include futures time-series momentum (which benefits from extended equity sell-offs) and a quality strategy that takes long (short) positions in the highest (lowest) quality company stocks (which benefits from a flight-to-quality effect during crises). The authors examine both large equity drawdowns and recessions. They also provide some out-of-sample evidence of the defensive performance of these strategies relative to an earlier, related article.*

TOPICS: ***Equity portfolio management, options, risk management, performance measurement****

The typical investment portfolio is highly concentrated in equities, leaving investors vulnerable to large drawdowns. We examine the performance of a number of candidate defensive strategies, both active and passive, between 1985 and 2018, with a particular emphasis on the eight worst drawdowns (instances in which the S&P 500 fell by more than 15%) and three US recessions. To guard against overfitting, we provide out-of-sample evidence of the performance of these strategies in the 2018Q4 drawdown that occurred after we wrote an earlier, related article.[1]

We begin with two passive strategies, both of which benefit directly from a falling equity market. A strategy that buys, and then rolls, one-month S&P 500 put options performs well in each of the eight equity drawdown periods. However, it is very costly during the normal times that constitute 86% of our sample and during expansionary (non-recession) times, which constitute 93% of our observations. As such, passive option protection seems too expensive to be a viable crisis hedge. A strategy that is long credit protection (short credit risk) also benefits during each of the eight equity drawdown periods, but in a more uneven manner, doing particularly well during the 2007–2009 Financial Crisis,

[1] See Cook et al. (2017).

which was a credit crisis. Nevertheless, the credit protection strategy is less costly during normal times and non-recessions than the put buying strategy.

Next, we consider so-called *safe-haven* investments. A strategy that holds long positions in 10-year US Treasuries performed well in the post-2000 equity drawdowns, but it was less effective during previous equity sell-offs. This is consistent with the negative bond–equity correlation witnessed post-2000, which is atypical from the longer historical perspective. As we move beyond the extreme monetary easing that has characterized the post-Financial Crisis period, it is possible that the bond–equity correlation may revert to the previous norm, rendering a long bond strategy a potentially unreliable crisis hedge. A long gold strategy generally performs better during crisis periods than at normal times, consistent with its reputation as a safe-haven security. However, its appeal as a crisis hedge is diminished by the fact that its long-run return, measured over the 1985–2018 period, is close to zero and that it carries substantial idiosyncratic risk unrelated to equity markets. In addition, extended historical evidence presented by Erb and Harvey (2013) suggests that gold is an unreliable equity and business cycle hedge.

We then turn our attention to dynamic strategies. Certain active strategies—such as shorting currency carry or taking long positions in on-the-run Treasury bonds against short positions in off-the-run bonds—may perform well during crisis periods, but they are expensive in the long term. Given the costs of managing active strategies, we choose to focus only on those that are, at the least, positive in expectation before costs: time-series momentum and a long–short quality strategy.

Time-series momentum strategies add to winning positions (ride winners) and reduce losing positions (cut losers), much like a dynamic replication of an option straddle strategy (see Hamill, Rattray, and Van Hemert 2016).[2] We show that such strategies performed well over the eight equity drawdowns and three recessions. We also explore limitations on the equity exposure (no long positions allowed), which we find enhances the crisis performance.

Next, we consider long–short US equity strategies. A review of the factors proposed in the academic literature suggests that those that take long positions in high-quality and short positions in low-quality companies are most promising as crisis hedges because they benefit from flights to quality when panic hits markets. The definition of a quality business is, of course, open to debate. However, broadly speaking, such companies will be profitable, be growing, have safer balance sheets, and run investor-friendly policies in areas such as payout ratios. We examine a host of quality metrics and illustrate the importance of a beta-neutral (common in practice) rather than a dollar-neutral (common in academic studies) portfolio construction.

Finally, we show that futures time-series momentum strategies and quality long–short equity strategies are not only conceptually different but also have historically uncorrelated returns, meaning that they can act as complementary crisis-hedge components within a portfolio. We demonstrate the efficacy of the dynamic hedges through some portfolio simulations.

CRISIS PERFORMANCE OF PASSIVE INVESTMENTS

We begin by identifying the eight worst equity drawdowns and three recessions for the United States in the 34-year period from 1985 to 2018. Next, we consider a number of passive, buy-and-hold strategies, including ones that hold futures contracts that are rolled according to some predefined schedule. We first analyze strategies that should logically benefit from falling firm valuations, such as a long put option and a short credit investment, and explore how they perform during these crises. This investigation is followed by a discussion of how a long safe-haven (bond or gold) position fares during equity crises, including an analysis of the bond–equity correlation since 1900 and the gold–equity correlation post–Bretton Woods.[3]

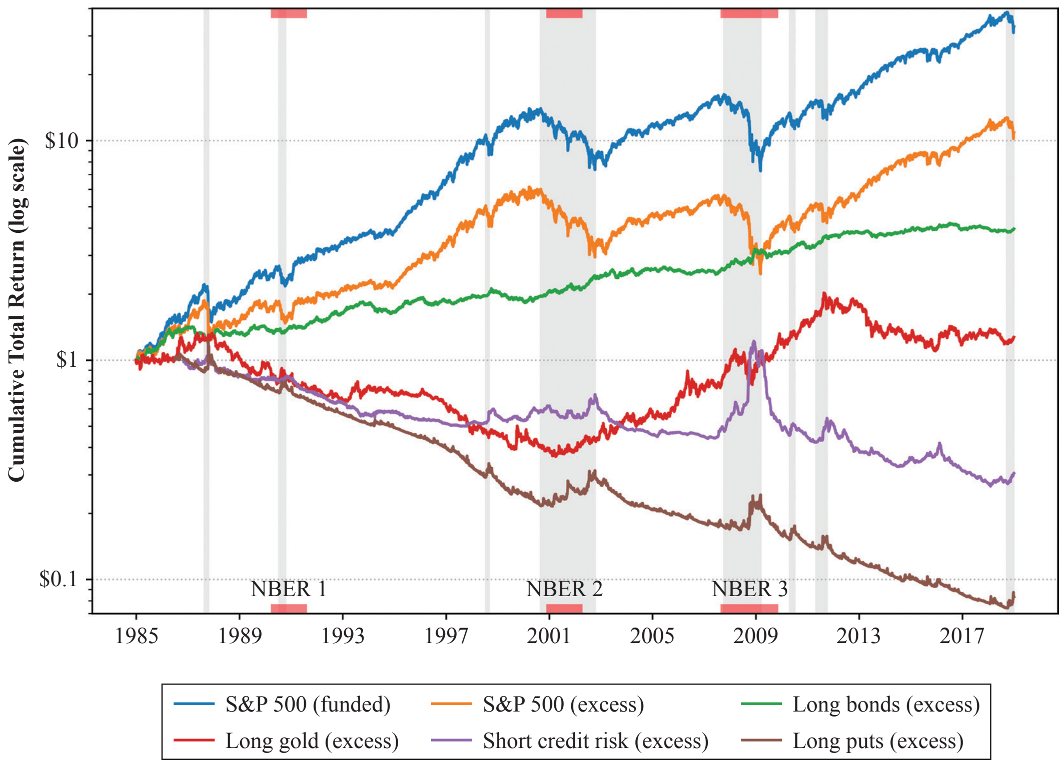
We do not include transaction costs or fees in the exhibits in the initial sections, but we do comment on the approximate cost of implementation. We explicitly account for transaction costs in the later section, where we evaluate the effectiveness of the two most promising dynamic strategies together.

[2] Also see, for example, Kaminski (2011).

[3] Arnott et al. (2019) examined equity factor returns in equity up and down months and in recessions/expansions. An AQR white paper (2015) reported the average performance of various strategies over the worst quarters for equities markets.

Exhibit 1

Passive Investment Total Return over Time



Notes: The authors show the cumulative return of the S&P 500 (funded and in excess of cash) and the excess return of long puts (one-month, at-the-money S&P 500 puts), short credit risk (duration-matched US Treasuries over US investment-grade corporate bonds), long bonds (US 10-year Treasuries), and long gold (futures). The authors highlight in gray the eight worst drawdowns for the S&P 500. NBER recessions are indicated on both the top and bottom of the exhibit. The data are from 1985 to 2018.

Crisis Definitions

Exhibit 1 shows the cumulative total return of the S&P 500 (top line) using daily data from 1985 to 2018.[4] A log scale is used, so a straight line corresponds to a constant rate of return, aiding the comparison of the severity of drawdown periods at different points in time. In this article, we focus on the eight periods in which the S&P 500 lost more than 15% from its peak, with the corresponding peak-to-trough periods shown in gray in Exhibit 1. We also label the last three US recessions as defined by the National Bureau of Economic Research (NBER).

Exhibit 2 provides a more detailed analysis, which includes returns, peak and trough dates, lengths of the drawdowns, and whether the peak was an all-time high or a local high. The bursting of the tech bubble and the Financial Crisis are the most severe equity crises, with the S&P 500 losing about half of its value. The drawdown around 1987's Black Monday was also severe, with a –32.9% return in less than two months. The remaining equity sell-offs are associated with the first Gulf War, the Asian financial crisis (and the ruble devaluation and Long-Term Capital Management collapse), two episodes of the euro area sovereign debt crisis, and the 2018Q4 sell-off.[5]

[4] For the 1988–2018 period, daily total returns are available from Bloomberg. Prior to 1988, we use data on daily index percent changes (excluding dividends) and monthly total returns (including dividends), and we proxy the daily total return as the daily index percentage change plus the monthly dividend return spread equally over the days of the month.

[5] The S&P 500 had recovered from the 2018Q4 drawdown by April 2019, after our sample period ends. The trough date remained December 24, 2018.

Exhibit 2
Performance over Drawdown Periods

	Black Monday	Gulf War	Asian Crisis	Tech Burst	Financial Crisis	Euro Crisis I	Euro Crisis II	2018Q4	Drawdown (14%)	Normal (86%)	All (100%)	Hit Rate
Peak Day	Aug 25, 1987	Jul 16, 1990	Jul 17, 1998	Sep 1, 2000	Oct 9, 2007	Apr 23, 2010	Apr 29, 2011	Sep 20, 2018				
Trough Day	Oct 19, 1987	Oct 11, 1990	Aug 31, 1998	Oct 9, 2002	Mar 9, 2009	Jul 2, 2010	Oct 3, 2011	Dec 24, 2018				
Weekdays Count	39	63	31	548	369	50	111	67				
Peak = HWM?	Yes	Yes	Yes	Yes	Yes	No	No	Yes				
Strategy	**Total Return**								**Annualized Return**			
S&P 500 (funded)	–32.9%	–19.2%	–19.2%	–47.4%	–55.2%	–15.6%	–18.6%	–19.4%	–44.3%	24.4%	10.8%	n.a.
S&P 500 (excess)	–33.5%	–20.7%	–19.7%	–51.0%	–56.3%	–15.7%	–18.6%	–19.8%	–45.8%	20.3%	7.3%	n.a.
Long Puts (excess)	38.0%	12.4%	15.5%	44.7%	40.5%	15.8%	13.4%	18.0%	42.4%	–14.2%	–7.4%	100%
Short Credit Risk (excess)	7.6%	3.3%	12.1%	17.0%	127.7%	11.7%	26.1%	9.5%	39.6%	–9.8%	–3.6%	100%
Long bonds (excess)	–8.3%	–2.7%	3.0%	24.2%	20.4%	5.7%	10.1%	2.5%	10.6%	3.1%	4.1%	75%
Long gold (excess)	4.4%	5.5%	–6.9%	7.5%	18.9%	4.6%	6.3%	4.5%	9.0%	–0.6%	0.7%	88%
1m MOM unconstrained	5.6%	19.3%	9.0%	31.3%	28.6%	2.7%	4.9%	8.1%	22.5%	6.2%	8.4%	100%
1m MOM EQ position cap	9.5%	22.8%	12.5%	37.4%	34.3%	4.8%	8.4%	9.7%	29.0%	3.1%	6.5%	100%
3m MOM unconstrained	10.3%	10.5%	9.3%	50.7%	32.6%	0.5%	10.9%	0.8%	25.1%	6.2%	8.7%	100%
3m MOM EQ position cap	15.4%	18.7%	14.4%	61.3%	41.4%	4.7%	13.7%	2.7%	35.1%	3.5%	7.6%	100%
12m MOM unconstrained	0.4%	12.2%	7.7%	52.3%	17.3%	–4.0%	–4.1%	–2.8%	14.5%	11.2%	11.6%	63%
12m MOM EQ position cap	8.3%	18.7%	16.2%	71.7%	23.7%	2.1%	0.2%	–0.9%	27.0%	8.2%	10.7%	88%
Profitability, dollar-neutral	–1.6%	–2.1%	3.0%	161.9%	33.9%	10.5%	10.9%	4.5%	35.7%	1.2%	5.5%	75%
Profitability, beta-neutral	2.3%	2.9%	9.1%	160.7%	21.2%	2.4%	3.3%	1.7%	32.1%	1.7%	5.6%	100%
Payout, dollar-neutral	0.1%	6.3%	9.1%	178.6%	20.5%	7.0%	5.0%	7.6%	37.3%	0.3%	4.9%	100%
Payout, beta-neutral	–2.8%	8.0%	11.9%	196.1%	13.1%	1.2%	1.2%	5.1%	34.3%	3.2%	7.2%	88%
Growth, dollar-neutral		–6.6%	–9.6%	–8.6%	9.0%	10.8%	9.8%	–1.3%	0.2%	1.2%	1.0%	43%
Growth, beta-neutral		–3.0%	–5.7%	–16.2%	12.4%	3.1%	2.8%	1.4%	–1.6%	–0.1%	–0.3%	57%
Safety, dollar-neutral	5.0%	9.5%	9.1%	90.7%	12.2%	7.9%	13.6%	9.9%	30.0%	–4.3%	0.0%	100%
Safety, beta-neutral	–3.5%	4.8%	0.8%	96.9%	–9.1%	1.8%	4.2%	1.9%	14.9%	4.5%	5.9%	75%
Quality All, dollar-neutral	4.3%	7.3%	8.2%	142.9%	26.3%	10.2%	15.2%	4.5%	38.5%	–1.5%	3.5%	100%
Quality All, beta-neutral	–3.3%	7.0%	6.6%	164.9%	9.6%	2.4%	4.6%	1.7%	29.1%	5.0%	8.2%	88%

Notes: The authors report the total return of the S&P 500 and various strategies during the eight worst drawdowns for the S&P 500; the annualized (geometric) return during drawdown, normal, and all periods; and the hit rate (percentage of drawdowns with positive return). The annualized standard deviation ranges between 6.4% for bonds to 16.5% for the S&P 500, with dynamic strategies all scaled to 10%. The row Peak = HWM indicates whether the index was at an all-time high before the drawdown began. The data are from 1985 to 2018.

EXHIBIT 3
Performance over Recession Periods

	Gulf War Recession	Tech Burst Recession	Financial Crisis Recession	Recession (8%)	Expansion (92%)	All (100%)	Hit Rate
Peak Day	Aug 1, 1990	Apr 1, 2001	Jan 1, 2008				
Trough Day	Mar 31, 1991	Nov 30, 2001	Jun 30, 2009				
Weekdays Count	172	174	390				
Strategy		**Total Return**			**Annualized Return**		
S&P 500 (funded)	7.9%	–0.9%	–35.0%	–12.1%	13.2%	10.8%	n.a.
S&P 500 (excess)	3.2%	–3.1%	–36.1%	–14.6%	9.5%	7.3%	n.a.
Long puts (excess)	–3.7%	9.1%	9.7%	5.2%	–8.5%	–7.4%	67%
Short credit risk (excess)	–3.6%	–3.7%	26.0%	5.7%	–4.5%	–3.6%	33%
Long bonds (excess)	2.2%	3.5%	11.1%	5.8%	4.0%	4.1%	100%
Long gold (excess)	–7.6%	4.3%	7.0%	1.1%	0.7%	0.7%	67%
1m MOM unconstrained	20.4%	2.7%	26.3%	17.0%	7.7%	8.4%	100%
1m MOM EQ position cap	18.9%	2.6%	28.4%	17.2%	5.5%	6.5%	100%
3m MOM unconstrained	9.4%	2.1%	26.8%	13.1%	8.4%	8.7%	100%
3m MOM EQ position cap	10.5%	3.2%	31.9%	15.5%	6.9%	7.6%	100%
12m MOM unconstrained	–2.5%	11.0%	3.0%	3.9%	12.4%	11.6%	67%
12m MOM EQ position cap	–1.6%	13.1%	4.7%	5.6%	11.2%	10.7%	67%
Profitability, dollar-neutral	8.3%	12.7%	6.9%	9.8%	5.2%	5.5%	100%
Profitability, beta-neutral	11.9%	13.2%	6.9%	11.3%	5.1%	5.6%	100%
Payout, dollar-neutral	–3.4%	7.9%	6.9%	3.9%	5.0%	4.9%	67%
Payout, beta-neutral	–3.5%	12.7%	5.5%	5.0%	7.4%	7.2%	67%
Growth, dollar-neutral	10.2%	0.1%	–8.4%	0.4%	1.1%	1.0%	67%
Growth, beta-neutral	13.4%	–3.5%	–2.4%	2.4%	–0.6%	–0.3%	33%
Safety, dollar-neutral	–4.6%	1.5%	–3.1%	–2.2%	0.2%	0.0%	33%
Safety, beta-neutral	–3.6%	6.7%	–9.1%	–2.4%	6.7%	5.9%	33%
Quality All, dollar-neutral	1.2%	6.6%	3.0%	3.8%	3.5%	3.5%	100%
Quality All, beta-neutral	5.0%	11.4%	0.1%	5.7%	8.4%	8.2%	100%

Notes: The authors report the total return of the S&P 500 and various strategies during the three NBER recession periods; the annualized (geometric) return during recession, expansion, and all periods; and the hit rate (percentage of recessions with positive return). The annualized standard deviation of the various strategies ranges from 6.4% for bonds to 16.5% for the S&P 500, with dynamic strategies all scaled to 10%. The data run from 1985 to 2018.

Based on this drawdown definition, 14% of days since 1985 are equity drawdown days and 86% are normal days. The annualized S&P 500 return during equity crises and normal periods is −44.3% and 24.4%, respectively, and it is 10.8% overall. Both the total return and annualized returns take into account the effect of compounding.[6] The second row in Panel A reports the S&P 500 return above that of one-month Treasury bills, which provides an apples-to-apples comparison to the defensive strategies.

In Exhibit 3, we report results for recessions, which do not exactly overlap with S&P 500 drawdown periods. For the Gulf War period, the recession includes the stock market rebound, and the S&P 500 is actually up over the full recession period. For the tech bubble burst, the recession period just covers a small part of the lengthy S&P 500 drawdown period. Only for the Financial Crisis do the recession and stock market drawdown periods mostly overlap.

Using the NBER definitions, only 8% of the sample is in recession. The annualized S&P 500 return

[6] This means that we take into account that a +10% return followed by a −10% return actually means a loss of −1% (computed as $1.1 \times 0.9 - 1$). The annualized return is computed as $(1 + \text{Geometric mean})^{\text{days per year}} - 1$.

is −12.1% during recessions and 13.2% during expansions. Not surprisingly, the return difference between recessions and expansions is much smaller than the difference segregated by large drawdowns. Does this mean that hedging recessions is less important than protecting against drawdowns? Probably not. Both are important. Although the drawdowns during recessions are less severe, recessions are often accompanied by painful negative shocks to investors' incomes.[7]

Hedging with Passive Short Firm-Value Strategies: Long Puts and Short Credit Risk

In this subsection, we consider passive hedging strategies that directly benefit when equity value decreases: a long put option strategy and a short credit risk strategy.

A rolling long put option strategy is perhaps the most direct hedge against equity drawdowns because it explicitly protects against the risk of a sudden, severe equity market sell-off. Various other equity derivatives may also be usefully considered for crisis hedges, most notably variance and volatility swaps, owing to the inverse relationship between equity returns and equity volatility. Although only traded over the counter, these swaps can be liquid and can be entered on a forward-starting basis (see, for example, Demeterfi et al. 1999). However, because these are all somewhat related, we have focused only on the most straightforward option-based strategy for this analysis.

To evaluate how a long put investment performs during the eight identified drawdowns and in normal times, we look at the Chicago Board Options Exchange (CBOE) S&P 500 PutWrite Index, for which we have daily returns starting in 1986. The index tracks the performance of selling one-month at-the-money S&P 500 put options each month and holding them until expiry, at which point new options are sold. Positions are sized such that the options are fully collateralized at all times. Then, even if the S&P 500 goes to zero, the obligation toward the put option buyer can be honored. Because we are interested in the returns of buying puts, rather than selling puts, we use the negative of the index's excess returns.[8] We also examine (in the appendix) the performance of out-of-the money puts in a shorter sample.

Exhibits 1 and 2 show that the long put strategy performs well in all eight large equity drawdowns (100% hit rate). However, the performance is not evenly spread over these episodes but rather appears to be earned in short periods of time, such as October 2008, when the equity sell-off suddenly accelerated. Once a drawdown has begun, the subsequent rolls of the options become more expensive as implied volatility rises, increasing the cost of the hedge. This effect then requires accelerated price decreases to produce the same hedge return.

Exhibit 3 details the performance of the long put strategy during the three recessions in our sample. The recession period returns for this strategy are lower mainly because equity returns in the Gulf War recession were positive.

The main concern with this strategy is its long-term overall cost. During the whole sample (equity crisis and normal), the long put strategy's annualized excess return is −7.4%. An equal-weighted combination of a long S&P 500 investment and the long put strategy has a negative excess return in each of the eight crises and a negative overall excess return. Including the transaction costs of trading options (which are relatively expensive to trade) would make the return of this strategy even more negative, underlining our observation that it is an expensive strategy.[9]

As a robustness check, we show in the Appendix that using monthly data since 1996 from a leading broker for over-the-counter S&P 500 puts leads to similar results. These additional data also allow us to study 5% and 10% out-of-the-money put options. Although out-of-the-money puts are cheaper than

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[7] An investor's portfolio includes her human capital. A drawdown of X in a recession might be worse than a drawdown of $2X$ in a non-recession if, for example, the investor potentially loses her job during the recession or is faced with lower income.

[8] Asvanunt, Nielsen, and Villalon (2015) considered various ways to hedge the equity tails of a 60/40 portfolio, including option (collar) strategies.

[9] Various approaches could be taken to mitigate the strategy's costs, but their benefits need to be carefully weighed against any loss of hedge efficacy, an examination that is beyond the scope of this article. First, one can generate income by selling out-of-the-money options, such as through put spreads or collars. Second, one can purchase protection where it is cheapest by analyzing the cost across strikes, across tenors, or across markets. Third, one could employ a timing approach: buying more protection at times of stress and buying less when conditions are loose. This might involve measuring market conditions (e.g., along the lines of the Chicago Fed's National Financial Conditions Index). Alternatively, one could forecast realized volatility directly using a statistical model (e.g., Shepherd and Sheppard 2010) and then increase protection ahead of expected volatility spikes and the associated increased probability of market falls.

at-the-money puts on a per-unit basis, they provide a worse cost–benefit trade-off if one factors in that they do not provide much of a payoff during more gradual, prolonged drawdowns.

Long credit protection strategies have generally benefited during drawdowns as the spreads between corporate and Treasury bond yields widen. It is generally more difficult, in the case of credit strategies, to accurately simulate historical returns going back to 1985 because many reliable indexes were introduced later in our sample. We use the BofA Merrill Lynch US Corp Master Total Return index, which tracks the performance of US investment-grade corporate bonds. Index returns in excess of duration-matched Treasury bonds are available from 1997. Our passive investment uses the negative of these returns. For earlier years, using a rolling one-year window, we measured the beta of the index to US 10-year Treasury futures. The excess returns of this strategy are the beta-adjusted returns of the Treasury futures minus the excess returns of the credit index. As a final step, we scaled the returns ex post to achieve a volatility of 10% across the whole sample. This is based on what we feel is the reasonable assumption that leverage can be applied, without capital borrowing requirements.[10]

From a practical point of view, although it may be hard to short a large amount of corporate bonds (particularly during a crisis), one may instead obtain a short credit risk exposure using credit default swaps, like with the synthetic CDX index.[11] One consideration, which we do not attempt to address here, is that during a major crisis there may be other risks that affect any credit strategy, such as the reliability of mark-to-market pricing and heightened counterparty risk.

Similar to the put strategy, the credit strategy appears to have had negative returns on average outside of equity market drawdown periods. Drawdown period returns in Exhibit 2 are similar in scale to those of the put strategy. The 2007–2009 Financial Crisis—which was primarily a credit crisis—was a particularly profitable episode for the strategy (128% return). Unfortunately, the subsequent drawdown was equally large and swift. Over the whole sample, the credit strategy has an annualized return of −3.6%, consistent with the interpretation that it is short a risk premium (see Luu and Yu 2011). It is noted, however, that Exhibit 1 shows the strategy has been on a pronounced downward drift since 2000. Based on our trading experience, we expect the transaction costs of implementing a short credit risk strategy through synthetic indexes such as CDX to be less than 0.1% per year.

Exhibit 3 shows that the credit strategy produced a large positive return in the 2007–2009 recession and small negative returns in the other two recessions. Comparing the long put option and short credit risk strategies, long puts should intuitively be more reliable because they are more directly linked to the equity value they aim to hedge. However, the long put strategy appears to come at a higher cost in terms of negative long-term returns. In other words, investors face a trade-off between reliability and cost of the hedge.

Hedging with Safe-Haven Assets: Long Bonds and Long Gold

Government bonds and gold are often described as safe-haven assets.[12] A long bond position is sometimes viewed as a crisis hedge, possibly based on the perception that the government bonds of advanced economies are safe-haven securities. We show the performance of a long 10-year US Treasury investment in Exhibits 1, 2, and 3. Returns are based on 10-year Treasury futures contracts.[13]

In the 1985–2018 period, bonds performed well, helped by the compression in 10-year yields, from double-digit levels in the mid-1980s to around 2% in recent years. The annualized return over cash for equity drawdown periods is 10.6% in Exhibit 2, which exceeds the still positive value of 3.1% for normal periods. However, it is only during the drawdowns after 2000 that bonds performed well. During the earlier drawdowns, the performance of bonds was mixed, and over the Black Monday period, the bond return was −8.3%. The bond performance is consistently positive during the three recessions detailed in Exhibit 3.

The recent shift in bond–equity return correlations is consistent with the fact that the recent performance of

[10] Before scaling, the volatility of the strategy is 2.7%.

[11] Because historical data are limited, we did not use credit default swaps or CDX for our empirical analysis.

[12] We focus on bonds issued by the US federal government, which are believed to bear little to no credit risk. Bonds from other countries may have substantial credit risk and thus different return dynamics.

[13] Throughout this article, a futures return is based on the near contract, rolled into the next contract shortly before the expiration date. The rolled futures returns data come from Man-AHL.

bonds during equity drawdown periods exceeds that of earlier times. That is to say, since 2000, when stock prices have fallen, Treasuries have rallied. To explore further the long-term evidence, we looked at monthly returns extending our sample using returns from Global Financial Data. for the US equity index and Treasury bond returns. Exhibit 4 (Panel A) shows the rolling five-year bond–equity correlation. We see that, although the correlation was negative after 2000, it was positive for most of the preceding 100 years. This finding is in line with studies that argue that common fundamental factors would typically imply a positive bond–equity correlation (see, for example, Baele, Bekaert, and Inghelbrecht 2010). Funnell (2017) provided a similar long-term perspective of the bond–equity relationship for the United Kingdom.

Another approach to analyzing this effect is to take three subsamples of the 1960–2018 period, each around 20 years long, and then sort the three-month bond returns into quintiles based on the equity return.[14] Quintile one represents the periods with the worst equity returns; quintile five denotes the periods with the best equity returns. Exhibit 4 (Panel B) plots the annualized average bond return for the five quintiles. Consistent with the positive bond–equity correlation before 2000, a long bond position does not provide a drawdown hedge before 2000. In fact, bond returns are negative in quintile one (the worst periods for equities) for both the 1960–1979 and 1980–1999 periods. Given the economic reasons why stocks and bonds should be positively correlated and the empirical evidence, investors should pause. It is not clear whether bonds in the future will deliver the type of hedge they provided in the Financial Crisis.

Gold has long been viewed as the original safe-haven asset, a source of absolute value in an uncertain world, whose price rises with increased risk aversion in markets. Gold does not provide a dividend, but, as a real asset, it can help offer protection against certain sources of long-term inflation. Gold is typically priced in US dollars (and all subsequent analyses follow this convention), and so its price is partly driven by fluctuations in foreign exchange rates. This then links gold to US monetary policy. For example, a hawkish shift in policy may lead to a rise in the dollar (on a trade-weighted basis) and a subsequent fall in the gold price. A related scenario under which gold may benefit is a significant loss of confidence in fiat currencies, a tail risk in the true sense of the expression. However, gold is also subject to significant idiosyncratic risk (e.g., miners' strikes and political instability in mining regions), which may make it an unreliable hedge in many circumstances.

We use gold futures for the excess returns shown in Exhibits 2 and 3. Gold has positive returns in seven of the eight equity drawdowns, with an annualized return of 9.0% during equity market drawdowns. Outside of equity drawdown periods, gold returns were negative on average, leading to a full-sample performance that is marginally better than flat. Gold's hedging ability is less clear for recessions; positive returns are recorded for only two of the three recessions in Exhibit 3. Based on our trading experience, we expect the annual transaction costs for maintaining a bond or gold exposure through futures to be below 0.1% per year.

In the online supplement, we take a longer view of gold, as we did with bonds in Exhibit 4, and find that from 1972 (after Bretton Woods) to 1984 the gold–equity correlation is slightly positive. From 1985, gold has performed well during the worst equity market environments. Indeed, during this period, there is a strong correlation between gold and bonds. Erb and Harvey (2013) extended the analysis back by hundreds of years. Their evidence suggests that gold is an unreliable crisis hedge and an unreliable unexpected inflation hedge. Although gold has kept its buying power over millennia (the real return is zero), the large amount of idiosyncratic noise means that holding periods need to be measured not in years but in centuries.

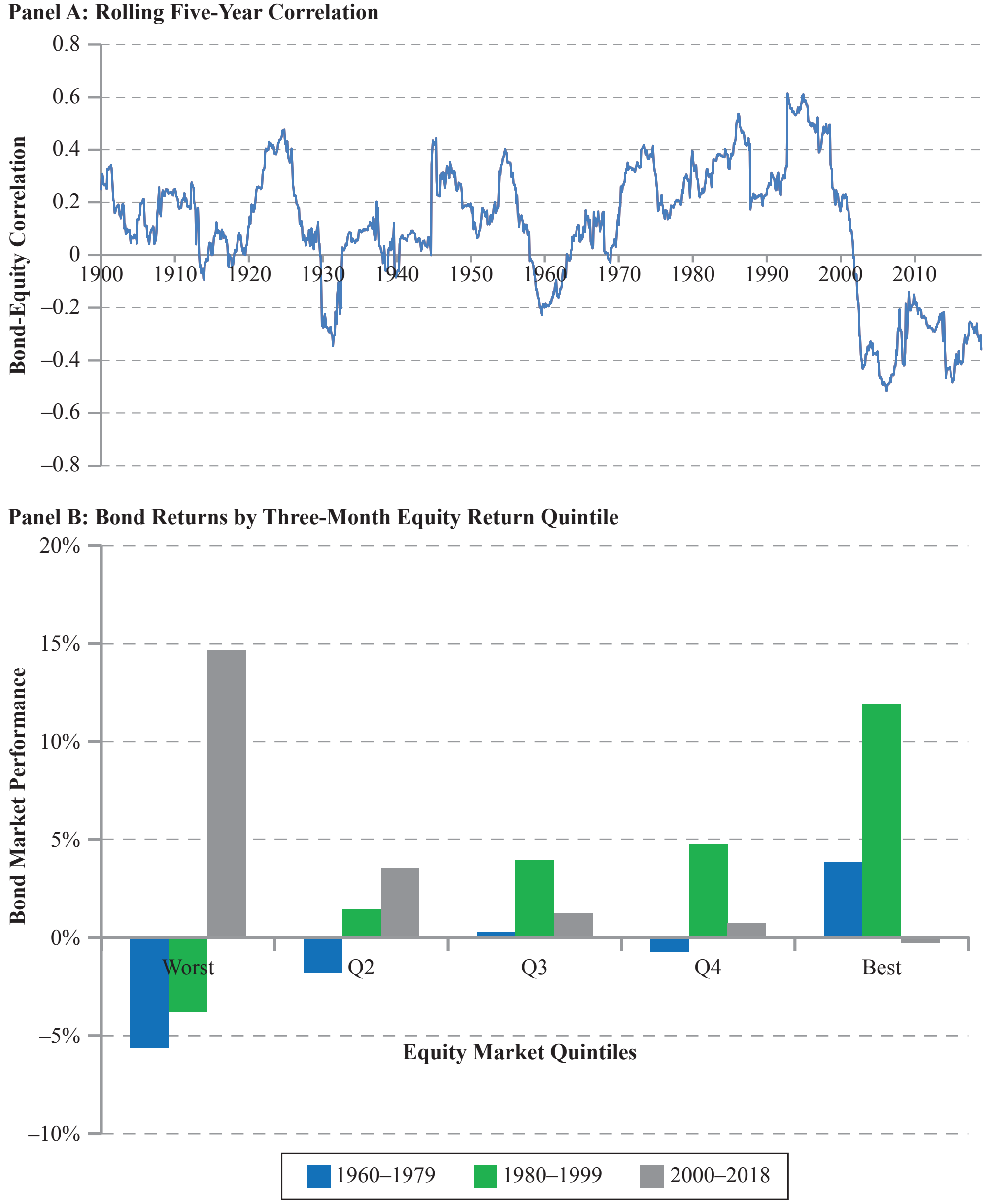
ACTIVE HEDGING STRATEGIES: TIMES-SERIES MOMENTUM

We now examine the performance of an active strategy, time-series momentum, applied to 50 futures and forward markets, during equity market drawdown and recession periods.[15] We explore both an unconstrained strategy and one in which equity exposures are capped at zero (no long equity positions), given that a long equity position will not be a useful hedge in an equity drawdown. As before, the performance is reported gross of transaction costs. We estimate the combined transaction

[14] Harvey et al. (2018) argue that bond markets had very different return dynamics before the 1960s, so we start the quintile analysis in 1960.

[15] Although commodity trading advisors may often use moving-average crossovers, Levine and Pedersen (2015) showed that these are very similar to the time-series momentum strategies that we use in this article.

EXHIBIT 4
Time Varying Co-Movement between Equity and Bond Returns



Notes: In Panel A, the authors plot the rolling five-year correlation between monthly US equities and US Treasury bond excess returns from 1900 to 2018. In Panel B, the authors plot the annualized bond returns by three-month equity quintiles and for different subperiods. The data are from Global Financial Data, Bloomberg, and Man-AHL.

and slippage costs of implementing a three-month momentum strategy to be 0.6%–0.8% per annum.[16]

[16]Based on execution analysis of live trades at Man Group over a 25-year history.

A Simple Time-Series Momentum Strategy

We define a simple futures time-series momentum signal as the compound return over the past N days, scaled by volatility:

$$\text{mom}_{t-1}^{k}(N) = \frac{\prod_{i=1}^{N}(1+R_{t-i}^{k})-1}{\sigma_{t-1}^{k}\sqrt{N}} \tag{1}$$

where R_{t-i}^{k} is the daily return of security k at time $t-1$ and σ_{t-1}^{k} is the standard deviation of the past 100 daily returns for security k observed at time $t-1$, which is multiplied by $\sqrt{N}$ to achieve an approximate unit standard deviation for the signal.[17]

For the purpose of our analysis, we consider 1-, 3-, and 12-month momentum strategies to capture short-, medium-, and long-term momentum trading. That is, N in [1] is set to 22, 65, and 261 days, respectively.

We divide the momentum score by the standard deviation of security returns to calculate a risk-adjusted market target allocation. The strategy performance is then given by multiplying the market target allocations by a gearing factor and the next period's return and then summing across securities:

$$\text{Performance}_t(N) = \sum_k \text{Gearing}_{t-1}^{k} \frac{\text{mom}_{t-1}^{k}}{\sigma_{t-1}^{k}} R_t^k \tag{2}$$

The gearing factor is chosen such that we target an annualized volatility of 10% and allocate risk to six groups as follows: 25% currencies, 25% equity indexes, 25% fixed income, and 8.3% to each of agricultural products, energies, and metals. Within each group, markets are allocated equal risk. Gearing factors are calculated at the group-level using an expanding window.

To prevent the strategy from increasing overall portfolio equity beta, we follow Hamill, Rattray, and Van Hemert (2016; henceforth HRV) and consider an extension of the strategy, whereby positions in each equity market are capped at zero (only zero or short equity positions are acceptable). Like HRV, we rescale the position-capped strategy return series to achieve the same realized volatility as the unconstrained strategy and, as such, effectively redistribute some of the equity risk allocation to the other asset classes. That is, we consider the following:

- **Unconstrained:** as defined in Equation 1 with no further limits to the equity exposure.
- **EQ position cap:** positions in equities are capped at zero.

We scale the returns of each strategy (ex post) to 10% annualized volatility to allow for fair comparison.[18]

We study the empirical performance of the different strategies using the 50 liquid futures and forwards from Cook et al. (2017). This dataset covers commodities (six agricultural, six energy, and seven metal contracts), 9 currencies (all against the US dollar), 10 equities, 9 bonds, and 3 interest rate contracts.

Performance of Futures Time-Series Momentum Strategies

We report the total return of the time-series strategies for equity drawdowns in Exhibit 2 and for recessions in Exhibit 3. The one- and three-month unconstrained strategies have tended to perform well during equity crises, consistent with HRV, who argued that faster trend strategies are particularly good at providing potential crisis alpha and during recessions.

On the other hand, the 12-month unconstrained strategy has negative returns during the three most recent equity drawdowns (where the 2018Q4 sell-off can be considered out of sample, per our previous discussion) and performs notably less well during recessions.

The EQ position cap strategy performs better during equity drawdowns. In the cases of 3- and 12-month momentum, this comes at the cost of a 1.1% and 0.9% lower overall performance (per annum), respectively, compared to the unconstrained strategy.

In Exhibit 5, we report the average 5-, 22-, 65-, and 261-day return (not annualized) of three-month momentum strategies for different equity quintiles based on 5-, 22-, 65-, and 261-day windows. These statistics were derived without reference to our equity drawdown periods and so offer additional insight into the strategies' performance when equity markets fall. Unsurprisingly, the EQ position cap strategy outperforms the unconstrained strategy in the worst equity market quintile and underperforms in the best equity market quintile.

Summarizing, medium-term time-series momentum strategies have performed well during recent crisis periods (including 2018Q4) and over our full sample.

[17] We also follow industry practice and restrict the signal value to between –2 and 2 to prevent putting too much weight on outliers. We omit this step from the formula for ease of exposition.

[18] We also considered restrictions based on the beta of the equity or overall portfolio to the S&P 500 and found similar results.

EXHIBIT 5

Average Return Three-Month Futures Times-Series Momentum for Equity Quintiles

		5-Day Equity Quintiles					
		Worst	**Q2**	**Q3**	**Q4**	**Best**	**ALL**
S&P 500 (excess)		–3.00%	–0.67%	0.30%	1.17%	3.01%	0.16%
3m MOM	Unconstrained	0.30%	0.00%	0.16%	0.27%	0.13%	0.17%
3m MOM	EQ position cap	0.79%	0.17%	0.09%	0.00%	–0.29%	0.15%
		22-Day Equity Quintiles					
		Worst	**Q2**	**Q3**	**Q4**	**Best**	**ALL**
S&P 500 (excess)		–5.64%	–0.92%	1.10%	2.83%	6.12%	0.70%
3m MOM	Unconstrained	1.25%	0.13%	0.63%	0.72%	0.98%	0.74%
3m MOM	EQ position cap	2.28%	0.50%	0.41%	0.12%	–0.05%	0.65%
		65-Day Equity Quintiles					
		Worst	**Q2**	**Q3**	**Q4**	**Best**	**ALL**
S&P 500 (excess)		–8.73%	–0.36%	2.77%	5.63%	11.08%	2.08%
3m MOM	Unconstrained	3.73%	0.59%	1.26%	1.84%	3.64%	2.21%
3m MOM	EQ position cap	5.61%	0.93%	0.82%	0.87%	1.49%	1.94%
		261-Day Equity Quintiles					
		Worst	**Q2**	**Q3**	**Q4**	**Best**	**ALL**
S&P 500 (excess)		–16.22%	4.11%	10.83%	17.55%	27.64%	8.78%
3m MOM	Unconstrained	14.39%	6.27%	7.49%	7.92%	10.29%	9.27%
3m MOM	EQ position cap	18.18%	5.60%	6.57%	5.21%	4.89%	8.09%

Notes: The authors report the average 5-, 22-, 65-, and 261-day return of the S&P 500 and unconstrained and EQ position cap futures times-series momentum strategies by S&P 500 return quintiles. The momentum strategies are scaled to 10% annualized volatility (ex post). The data are from 1985 to 2018.

Restricting the long equity exposures seems to increase the crisis performance potential of these strategies but comes at a cost in terms of overall performance.

ACTIVE HEDGING STRATEGIES: QUALITY STOCKS

We now turn to a second active strategy: long–short US equity strategies that use quality metrics. Performance is reported gross of transaction costs. Based on our live experience, we estimate that the combined transaction, slippage, and financing costs of implementing the composite quality strategies amounts to around 1.0%–2.0% per annum.

Motivation to Look at Quality Stocks

Asness, Frazzini, and Pedersen (2019; henceforth AFP) argued that, although quality stocks logically deserve a higher price-to-book ratio, in reality they do not always exhibit such a premium. In particular, toward the end of equity bull markets, quality stocks have often looked underpriced. Then, when the market has a drawdown, these stocks have outperformed, benefitting from the so-called flight-to-quality effect.

Using the Gordon growth model, AFP derived the following formula for the price-to-book (P/B) ratio[19]:

$$\frac{P}{B} = \frac{\text{Profitability} \times \text{Payout ratio}}{\text{Required return} - \text{Growth}} \tag{3}$$

Each of the four components on the right-hand side of Equation 3 is a quality metric that can be measured in several ways, such as

[19] In the Gordon growth model, *Price* = *Dividend*/(*Required return* – *Growth*). Using *Profitability* = *Profit*/*B* and *Payout ratio* = *Dividend*/*Profit* and then rearranging terms yields Equation 3.

1. **Profitability:** profits (gross profits, earnings, cash flows) scaled by an accounting value (book equity, book assets, sales)
2. **Growth:** trailing five-year growth of a profitability measure
3. **Safety (required return):** safer companies command lower required returns; return-based measures include market beta and volatility, and fundamental-based measures include low leverage, low volatility of profitability, and low credit risk
4. **Payout:** the fraction of profits paid out to shareholders, which can be seen as a measure of the shareholder friendliness of management

The literature finds that many of these metrics have some ability to predict cross-sectional stock returns.

Evidence from Other Popular Factors

We start our analysis by using publicly available daily returns to evaluate the performance of factors documented in the literature. In Exhibit 6, we present results for the Fama and French (2015) five-factor model (the first five factors) and factor returns based on AFP and other researchers (the last three factors).[20] Only US stocks are considered in each case.

Quality and profitability (in itself a component of quality) stand out in terms of their performance over equity market drawdown periods (Panel A) and recessions (Panel B). It is important to note that these factors are constructed in a dollar-neutral way, which is common practice in the literature. In the case of the quality factor, however, this leads to a negative correlation of −0.48 to the S&P 500, based on five-day overlapping returns. This raises the question of whether the positive drawdown-period performance is simply explained by the negative equity exposure.[21] The subsequent subsections present evidence that suggests this is not the case.

Also noteworthy for its return during equity drawdowns is the stock momentum factor, which in this case is traded at the stock level and in a cross-sectional (dollar-neutral) fashion and so differs from the futures time-series momentum discussed previously. However, some of the intuition behind futures trend-following providing crisis alpha (see HRV) may carry over to stock momentum. For example, stock momentum may pick up sector trends that reflect the broader macro movements, which are also picked up by futures trend-following. The investment factor, which goes long the stock of conservative companies with low growth in book assets while shorting aggressive, high-asset-growth companies, performs about as well as the stock momentum factor during equity drawdowns.

In contrast, the value factor has been much less effective as an equity market drawdown hedge than the quality and profitability factors. In general, a profitability factor is the ratio of two accounting values (e.g., the ratio of net income to the book value of equity), and as such the positioning is unaffected by the short-term gyrations of the equity market. A value factor is the ratio of an accounting value and a market value (e.g., the ratio of net income to the market value of equity). Hence, a value metric will change more favorably for stocks that underperform the market, causing the factor to increase its exposure to such stocks.

Individual Quality Factor Performance

In this subsection, we evaluate various quality metrics. Exhibit 7 lists all the signals we consider, which form a subset of AFP's signals; we omit Ohlson's O and Altman's Z (which are more highly parameterized than the others) and instead focus on return- and leverage-based safety measures.[22]

At each date, the raw signal value, s, is ranked cross sectionally, $r(s) = \text{rank } s$; then a cross-sectional z-score is determined, $z(r) = (r - \mu_r)/\sigma_r$, where μ_r is the cross-sectional mean and σ_r is the cross-sectional standard deviation. The key purpose of this ranking step is to reduce the impact of outliers. This robustness step can be a relevant precaution when working with accounting data. Denoting the signal arising from this first step time at t

[20] Daily returns are available from http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html and https://www.aqr.com/library/data-sets.

[21] Liang, Tang, and Xu (2019) also found that profitability strategies perform better in months with negative equity returns.

[22] In addition, AFP used CRSP/XpressFeed Global data, whereas we use their Worldscope analogues. The accounting data are extracted from the Worldscope fundamental dataset, where we use annual, semiannual, and quarterly data when available. We generate comparable numbers by constructing trailing 12-month averages for each frequency, per variable.

EXHIBIT 6
Equity Factor Performance over Drawdown and Recession Periods

Panel A: Drawdowns

Factor	Total Return								Annualized Return			Correl. to S&P 500
	Black Monday	Gulf War	Asian Crisis	Tech Burst	Financial Crisis	Euro Crisis I	Euro Crisis II	2018Q4	Drawdown (14%)	Normal (86%)	All (100%)	
Market (NYSE, AMEX, NASDAQ)	–30.1%	–22.2%	–21.3%	–51.8%	–55.8%	–16.1%	–20.3%	–21.0%	–46.2%	20.4%	7.2%	0.99
Size	9.5%	–11.0%	–8.6%	29.4%	–5.5%	–3.8%	–10.1%	–9.0%	–3.1%	0.3%	–0.2%	–0.02
Value	4.4%	7.3%	5.6%	72.0%	–23.2%	–8.9%	–7.7%	0.8%	5.9%	1.4%	2.0%	–0.11
Profitability (robust – weak)	–2.3%	–1.0%	5.2%	123.4%	31.5%	2.2%	13.3%	0.7%	29.1%	0.5%	4.2%	–0.27
Investment (conservative – aggressive)	4.0%	12.3%	9.8%	61.2%	0.2%	–1.9%	–4.7%	5.4%	15.7%	0.7%	2.8%	–0.35
Cross-Sectional Momentum	–7.9%	10.0%	2.3%	39.3%	35.7%	–5.4%	1.3%	0.7%	13.9%	5.0%	6.2%	–0.13
Quality (quality – junk)	1.5%	7.7%	9.1%	101.9%	67.3%	7.6%	24.1%	8.3%	43.3%	0.1%	5.4%	–0.48
Low Risk (bet-against-beta)	3.1%	–1.3%	–0.1%	115.3%	–32.0%	3.8%	5.3%	0.8%	10.7%	8.5%	8.8%	–0.36

Panel B: Recessions

Factor	Total Return			Annualized Return			Correl. to S&P 500
	Gulf War Recession	Tech Burst Recession	Financial Crisis Recession	Recession (8%)	Expansion (92%)	All (100%)	
Market (NYSE, AMEX, NASDAQ)	3.9%	–2.3%	–34.7%	–13.5%	9.4%	7.2%	0.99
Size	–2.6%	7.6%	9.0%	4.8%	–0.6%	–0.2%	–0.02
Value	–5.6%	0.5%	–7.4%	–4.5%	2.7%	2.0%	–0.11
Profitability (robust – weak)	7.5%	9.7%	21.5%	13.5%	3.3%	4.2%	–0.27
Investment (conservative – aggressive)	–5.2%	2.9%	–1.7%	–1.5%	3.1%	2.8%	–0.35
Cross-Sectional Momentum	2.5%	–0.4%	–39.9%	–15.8%	8.5%	6.2%	–0.13
Quality (quality – junk)	9.4%	10.3%	29.6%	17.1%	4.4%	5.4%	–0.48
Low Risk (bet-against-beta)	–16.3%	12.1%	–23.9%	–11.2%	10.8%	8.8%	–0.36

Notes: The authors report the total return of various long–short US equity strategies with publicly available return data. In Panel A, the authors report the total return over the eight worst drawdowns for the S&P 500; the annualized (geometric) return during equity market drawdown, normal, and all periods; and the correlation to the S&P 500. In Panel B, the authors report the same statistics for recessions and expansions. Strategies are scaled to a dollar long–short. The data are from 1985 to 2018.

EXHIBIT 7
Quality Factor Definitions

Category	Name	Description
Profitability	Cash flow over assets	(Net income + Depreciation – Change working capital – Capital expenditures)/Total assets
Profitability	Gross margin	(Revenue – Cost of goods sold)/Net sales
Profitability	Gross profits over assets	(Revenue – Cost of goods sold)/Total assets
Profitability	Low accruals	(Depreciation – Change working capital)/Total assets
Profitability	Return on assets	Net income/Total assets
Profitability	Return on equity	Net income/Book equity
Payout	Net debt issuance	–log(Total debt current/Total debt one year ago)
Payout	Net equity issuance	–log(Outstanding number of shares current/ Outstanding number of shares one year ago)
Payout	Total net payouts over profits	Total net payouts/Profits
Growth	Cash flow over assets (five-year change)	Five-year change corresponding profitability metric; that is $(\text{CashFlow}_t – \text{CashFlow}_{t–5})/\text{TotalAssets}_{t–5}$
Growth	Gross margin (five-year change)	Five-year change corresponding profitability metric
Growth	Gross profits over assets (five-year change)	Five-year change corresponding profitability metric
Growth	Low accruals (five-year change)	Five-year change corresponding profitability metric
Growth	Return on assets (five-year change)	Five-year change corresponding profitability metric
Growth	Return on equity (five-year change)	Five-year change corresponding profitability metric
Safety	Low beta	Minus realized beta to S&P 500 Index based on weekly returns over a rolling three-year window
Safety	Low Idiosyncratic volatility	Minus standard deviation of the daily market-adjusted returns over the past year
Safety	Low leverage	Total debt/Total assets

Notes: The authors list the various quality factors used in our strategies. All fundamental data are from Worldscope.

for stock i as $\text{Signal}_{t,i}$, we form a beta-neutral portfolio by defining a neutral signal as

$$\text{Signal}^{\text{Neutral}}_{t,i} = \begin{cases} \dfrac{\text{Signal}_{t,i}}{\text{BetaLong}}, \text{ if Signal}_{t,i} \geq 0, \\ \dfrac{\text{Signal}_{t,i}}{\text{BetaShort}}, \text{ if Signal}_{t,i} < 0 \end{cases} \quad (4)$$

where

$$\text{BetaLong} = \sum_j \mathbb{I}\{\text{Signal}_{t,j} > 0\}\ \text{Signal}_{t,j}\beta_{t,j},$$

$$\text{BetaShort} = \sum_j \mathbb{I}\{\text{Signal}_{t,j} < 0\}\ \text{Signal}_{t,j}\beta_{t,j}$$

The beta is computed with respect to the S&P 500 using five-day overlapping returns over the past three years. Strategy returns are obtained by multiplying the final signal values, lagged by a day, with stock returns:

$$\text{Performance}_t = \sum_k \text{Signal}^{\text{Neutral}}_{t-1,k} R_{t,k} \quad (5)$$

In a final step, we scale strategy returns (ex post) such that the full-sample realized volatility is 10%, merely to aid comparison across various definitions of quality and with the futures time-series momentum strategies.

We evaluate the performance of the quality factors in a universe of mid- and large-cap US stocks. Each month, we define a market cap threshold: Those stocks that exceed it are defined as large-cap and those that do not are mid-cap. This threshold is set equal to $2 billion at the end of 2016 (and onward), and for earlier dates it is suitably deflated.[23] As an example, the threshold in 1986 was about $200 million. This results in a sample with lower turnover, with the number of constituents ranging between 951 and 1,611 over our analysis.

Exhibit 8, Panel A, reports the drawdown- and normal-period performance for the different quality factors. As a result of data availability, some factors have returns missing for the first one or two equity drawdowns. For most factors, the annualized drawdown-period return is higher than the return during normal periods, suggesting a crisis-hedge property. A first notable exception, however, is the set of growth factors, for which the drawdown-period performance is worse than the normal performance in three of six cases; moreover, the overall performance is around zero for all six growth factors.

A second exception is the low beta factor. A beta-neutral implementation of the low beta factor in effect means leveraging the long positions in low beta stocks. This tends to lead to better overall performance but worse drawdown-period performance because strategies with embedded leverage underperform when funding constraints tighten (Frazzini and Pedersen 2014), which often occurs at times of market stress (as in the Financial Crisis). In contrast, a beta-neutral, low-idiosyncratic-volatility strategy does not involve as much leveraging of the long positions and, indeed, still historically performs well during crises.

During recession periods, reported in Exhibit 8, Panel B, results are a bit more mixed, but some profitability and payout factors show a notably stronger performance during recessions compared to expansionary periods.

In the online supplement, we report results for dollar-neutral versions of the strategies, which can be constructed by setting all beta estimates to unity in Equation 4. Constructing the strategies in this way can lead to negative correlations with the S&P 500. The low beta factor provides an extreme example with a correlation of −0.73. Dollar-neutral implementations are commonplace in many published papers (e.g., see AFP) but leave open the possibility that a good performance over equity drawdown periods can be attributed to negative equity exposure, rather than being a positive convex function of the equity market return. We are mostly interested in positive convexity, with a factor performing well during equity bear markets and not performing badly during equity bull markets.

Composite Quality Factor Performance

Exhibits 2 and 3 present the performance of composite factors for both dollar-neutral and beta-neutral portfolios. Composites are determined at each point in time by averaging the (ranked and z-scored) score of a stock across multiple factors and then re-ranking and z-scoring these averages across stocks.

In Exhibit 2, we see that profitability, payout, safety, and a grand composite of the four quality composites, denoted *quality all*, performed well during equity market drawdowns and for the full sample. Only the growth composite stands out as performing poorly during both equity market drawdown and normal periods. In Exhibit 3, we see that the annualized performance during recessions is strong for profitability but not for safety.

In the online supplement, we report the output of a regression of the different quality composites on the market, size, value, and momentum factors. The main result is that quality composites capture anomalies beyond these control factors. Also noteworthy is that, except for growth, all composites have a negative beta to the size factor.[24] Profitability and growth have a negative beta to the value factor, whereas payout and safety have a positive beta to value. The exposure to the cross-sectional equity momentum factor is small in all cases.

In Exhibit 9, we report the return (not annualized) of quality composites for different equity quintiles based on 5-, 22-, 65-, and 261-day windows, as we did in the previous section for the futures time-series momentum strategies. The quintile analysis does not depend on our choice of equity drawdown periods and, as such, provides an alternative view of the defensive property. Profitability, payout, safety, and quality all perform best in the worst equity quintile for each of the four horizons.

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In Exhibit 10, we present correlations between a selected subset of the strategies considered earlier. The

[23] The deflation factor is proportional to the total return index of the S&P 500 (see Exhibit 1).

[24] The relation between quality and different size metrics is discussed by Asness et al. (2018).

Exhibit 8
Quality Factor Performance, Beta-Neutral

Panel A: Drawdowns

		Total Return								Annualized Return			Correlation
Category	Name	Black Monday	Gulf War	Asian Crisis	Tech Burst	Financial Crisis	Euro Crisis I	Euro Crisis II	2018Q4	Drawdown (14%)	Normal (86%)	All (100%)	Correl. to S&P 500
Profitability	Cash Flow/Assets		11.7%	6.5%	113.5%	8.9%	1.1%	2.8%	1.6%	25.4%	3.0%	6.3%	–0.14
Profitability	Gross Margin	4.7%	2.4%	8.1%	–25.9%	12.8%	4.6%	4.7%	3.5%	1.9%	3.0%	2.8%	0.03
Profitability	Gross Profits/Assets	0.5%	–3.7%	5.6%	132.5%	13.8%	–0.8%	2.9%	3.1%	23.8%	1.9%	4.8%	–0.18
Profitability	Low Accruals		–5.3%	4.0%	68.4%	0.7%	0.0%	–1.9%	–3.1%	10.3%	1.1%	2.5%	–0.11
Profitability	Return on Assets	0.1%	7.4%	5.7%	122.8%	21.3%	2.3%	2.9%	2.1%	27.6%	–0.3%	3.3%	–0.16
Profitability	Return on Equity	1.5%	1.3%	6.1%	138.0%	8.4%	2.0%	3.1%	0.1%	24.9%	1.1%	4.2%	–0.14
Payout	Net Debt Issuance	0.2%	6.5%	15.5%	130.7%	22.8%	–1.3%	2.9%	5.3%	30.9%	5.3%	8.7%	–0.18
Payout	Net Equity Issuance	–2.9%	3.5%	7.4%	159.7%	5.5%	0.2%	2.5%	3.8%	26.5%	2.2%	5.4%	–0.18
Payout	Total Net Payouts/Profits		11.7%	9.8%	56.2%	8.7%	3.9%	–2.6%	2.1%	17.5%	0.0%	2.6%	0.01
Growth	Cash Flow/Assets (5-yr chg)			0.1%	37.6%	5.3%	1.4%	2.3%	–0.1%	9.5%	–0.6%	1.2%	–0.03
Growth	Gross Margin (5-yr chg)		–4.7%	–5.4%	–39.9%	4.7%	3.0%	2.1%	3.2%	–9.7%	1.4%	–0.4%	0.12
Growth	Gross Profits/Assets (5-yr chg)		–4.6%	–4.9%	–32.8%	9.6%	1.5%	1.1%	3.3%	–7.0%	0.2%	–0.9%	0.07
Growth	Low Accruals (5-yr chg)			–2.7%	–32.8%	1.9%	0.6%	–0.1%	0.9%	–8.3%	–0.1%	–1.7%	0.06
Growth	Return on Assets (5-yr chg)		2.7%	–3.0%	12.9%	13.7%	3.5%	2.2%	–0.1%	6.5%	–1.1%	0.0%	0.00
Growth	Return on Equity (5-yr chg)		–4.7%	–4.5%	21.4%	12.9%	3.9%	4.5%	–1.1%	6.4%	–0.7%	0.3%	0.01
Safety	Low Beta	–6.5%	–4.7%	–7.1%	77.7%	–16.6%	1.0%	3.1%	–0.5%	5.0%	9.5%	8.8%	0.24
Safety	Low Idiosyncratic Volatility	–0.2%	10.1%	8.2%	99.1%	3.6%	1.3%	4.5%	3.4%	22.3%	1.4%	4.3%	–0.19
Safety	Low Leverage	–2.4%	4.9%	–2.4%	49.1%	–13.4%	1.6%	0.6%	–0.1%	5.8%	–0.3%	0.6%	–0.04

Panel B: Recessions

Category	Name	Total Return: Gulf War Recession	Total Return: Tech Burst Recession	Total Return: Financial Crisis Recession	Annualized Return: Recession (8%)	Annualized Return: Expansion (92%)	Annualized Return: All (100%)
Profitability	Cash Flow Over Assets	16.3%	12.1%	1.0%	10.2%	5.9%	6.3%
Profitability	Gross Margin	8.0%	–3.7%	13.3%	6.0%	2.5%	2.8%
Profitability	Gross Profits Over Assets	18.3%	12.9%	10.9%	14.9%	3.9%	4.8%
Profitability	Low Accruals	–14.4%	0.3%	4.8%	–3.7%	3.2%	2.5%
Profitability	Return on Assets	8.1%	13.0%	1.0%	7.7%	2.9%	3.3%
Profitability	Return on Equity	3.8%	6.2%	–4.2%	2.0%	4.4%	4.2%
Payout	Net Debt Issuance	–3.2%	26.8%	14.3%	12.7%	8.3%	8.7%
Payout	Net Equity Issuance	–3.4%	9.0%	6.3%	4.1%	5.5%	5.4%
Payout	Total Net Payouts Over Profits	0.0%	–3.0%	–9.6%	–4.5%	3.3%	2.6%
Growth	Cash Flow Over Assets (5-yr chg)		7.9%	0.7%	3.9%	0.9%	1.2%
Growth	Gross Margin (5-yr chg)	12.4%	–7.6%	0.4%	1.5%	–0.6%	–0.4%
Growth	Gross Profits Over Assets (5-yr chg)	17.8%	–3.2%	4.0%	6.2%	–1.6%	–0.9%
Growth	Low Accruals (5-yr chg)		–6.1%	1.9%	–2.0%	–1.6%	–1.7%
Growth	Return on Assets (5-yr chg)	10.8%	2.6%	–6.8%	2.1%	–0.2%	0.0%
Growth	Return on Equity (5-yr chg)	9.5%	0.5%	–6.2%	1.1%	0.3%	0.3%
Safety	Low Beta	–3.8%	9.3%	–16.8%	–4.6%	10.2%	8.8%
Safety	Low Idiosyncratic Volatility	–0.4%	5.6%	–1.0%	1.4%	4.5%	4.3%
Safety	Low Leverage	–7.7%	–2.3%	–5.5%	–5.5%	1.2%	0.6%

Notes: The authors report the total return of various quality factors, where portfolios are constructed to be beta neutral. In Panel A, the authors report the total return over the eight worst drawdowns for the S&P 500; the annualized (geometric) return during equity market drawdown, normal, and all periods; and the correlation to the S&P 500. In Panel B, the authors report the same statistics for recessions and expansions. Strategies are scaled to a dollar long–short. All strategies are scaled to 10% annualized volatility (ex post). The data are from 1985 to 2018.

EXHIBIT 9
Average Return Beta-Neutral Quality Composites for Equity Quintiles

	5-Day Equity Quintiles					
	Worst	Q2	Q3	Q4	Best	ALL
S&P 500 (excess)	–3.00%	–0.67%	0.30%	1.17%	3.01%	0.16%
Profitability	0.62%	0.11%	0.06%	0.00%	–0.10%	0.14%
Payout	0.70%	0.24%	0.12%	–0.07%	–0.12%	0.17%
Growth	–0.14%	–0.04%	0.02%	0.10%	0.08%	0.00%
Safety	0.26%	0.20%	0.15%	0.03%	0.08%	0.14%
Quality All	0.56%	0.22%	0.18%	0.03%	0.01%	0.20%
	22-Day Equity Quintiles					
	Worst	**Q2**	**Q3**	**Q4**	**Best**	**ALL**
S&P 500 (excess)	–5.64%	–0.92%	1.10%	2.83%	6.12%	0.70%
Profitability	2.18%	0.40%	0.22%	0.30%	0.03%	0.63%
Payout	2.36%	0.80%	0.35%	0.14%	0.22%	0.77%
Growth	–0.07%	–0.14%	–0.05%	0.29%	0.05%	0.01%
Safety	0.97%	0.69%	0.70%	0.42%	0.46%	0.65%
Quality All	2.09%	0.79%	0.62%	0.51%	0.48%	0.90%
	65-Day Equity Quintiles					
	Worst	**Q2**	**Q3**	**Q4**	**Best**	**ALL**
S&P 500 (excess)	–8.73%	–0.36%	2.77%	5.63%	11.08%	2.08%
Profitability	6.01%	1.79%	0.88%	0.86%	–0.17%	1.87%
Payout	6.26%	2.60%	1.30%	0.95%	0.41%	2.30%
Growth	–0.25%	0.02%	0.12%	0.41%	–0.03%	0.06%
Safety	2.91%	2.35%	1.60%	1.54%	1.40%	1.96%
Quality All	5.67%	3.00%	1.84%	1.78%	1.16%	2.69%
	261-Day Equity Quintiles					
	Worst	**Q2**	**Q3**	**Q4**	**Best**	**ALL**
S&P 500 (excess)	–16.22%	4.11%	10.83%	17.55%	27.64%	8.78%
Profitability	27.97%	5.92%	1.93%	3.89%	0.94%	8.13%
Payout	31.03%	4.19%	3.97%	5.51%	6.57%	10.25%
Growth	–0.81%	3.70%	0.11%	0.78%	–2.18%	0.43%
Safety	15.76%	4.43%	7.32%	5.33%	9.36%	8.44%
Quality All	28.91%	6.75%	6.23%	7.28%	9.18%	11.67%

Notes: The authors report the average 5-, 22-, 65-, and 261-day return of the S&P 500 and various beta-neutral quality composites by S&P 500 return quintiles. All strategies are scaled to 10% annualized volatility (ex post). The data are from 1985 to 2018.

EXHIBIT 10

Correlation between Strategies Considered in Previous Sections

	S&P 500	Long Puts	Short Credit Risk	Long Bonds	Long Gold	1 m MOM: EQ pos. cap	3 m MOM: EQ pos. cap	12 m MOM: EQ pos. cap	Profitability, Beta-Neutral	Payout, Beta-Neutral	Growth, Beta-Neutral	Safety, Beta-Neutral	Quality All, Beta-Neutral
S&P 500		–0.86	–0.35	–0.05	–0.03	–0.36	–0.36	–0.23	–0.18	–0.18	0.05	–0.01	–0.12
Long puts	–0.86		0.35	0.11	0.05	0.42	0.39	0.22	0.18	0.15	–0.04	–0.01	0.10
Short credit risk	–0.35	0.35		0.17	0.05	0.24	0.24	0.17	0.16	0.11	0.03	0.00	0.09
Long bonds	–0.05	0.11	0.17		0.04	0.13	0.20	0.29	0.08	0.05	–0.01	0.16	0.14
Long gold	–0.03	0.05	0.05	0.04		0.04	0.09	0.12	–0.08	–0.05	0.08	–0.03	–0.04
1 m MOM: EQ pos. cap	–0.36	0.42	0.24	0.13	0.04		0.73	0.45	0.06	0.10	–0.06	0.01	0.04
3 m MOM: EQ pos. cap	–0.36	0.39	0.24	0.20	0.09	0.73		0.68	0.07	0.11	–0.05	0.03	0.07
12 m MOM: EQ pos. cap	–0.23	0.22	0.17	0.29	0.12	0.45	0.68		0.04	0.07	0.02	0.06	0.07
Profitability, Beta-neutral	–0.18	0.18	0.16	0.08	–0.08	0.06	0.07	0.04		0.66	0.20	0.39	0.79
Payout, beta neutral	–0.18	0.15	0.11	0.05	–0.05	0.10	0.11	0.07	0.66		–0.38	0.74	0.88
Growth, beta-neutral	0.05	–0.04	0.03	–0.01	0.08	–0.06	–0.05	0.02	0.20	–0.38		–0.54	–0.17
Safety, beta-neutral	–0.01	–0.01	0.00	0.16	–0.03	0.01	0.03	0.06	0.39	0.74	–0.54		0.83
Quality All, beta-neutral	–0.12	0.10	0.09	0.14	–0.04	0.04	0.07	0.07	0.79	0.88	–0.17	0.83	

Notes: The authors report the correlations between the five-day overlapping returns of various strategies considered. Passive strategies: S&P 500 (excess), long puts (one-month, at-the-money S&P 500 puts), short credit risk (duration-matched US Treasuries over US investment-grade corporate bonds), long bonds (US 10-year Treasuries), and long gold (futures). Dynamic strategies: 1-, 3-, and 12-month futures time-series momentum with equity positions capped at zero and the different beta-neutral quality stock composites. The data are from 1985 to 2018.

futures time-series momentum strategies (1-, 3-, and 12-month momentum with equity positions capped at zero) demonstrate negligible correlation with any of the quality stock strategies (profitability, payout, growth, safety, and the grand quality composite). Hence, time-series momentum and quality stocks are complementary defensive strategies.[25]

To investigate the effectiveness of dynamic strategies in providing returns during equity market drawdown periods and recessions, we simulated portfolios with varying allocations to the S&P 500, three-month momentum with no long equity positions, and the quality composite factor strategy. In a first step, we deduct transaction costs from the momentum and quality strategies. We assumed the midpoints of our earlier estimates, so 0.7% per annum for momentum and 1.5% per annum for quality. Second, we scale up returns (after costs) of the hedge strategies so that they achieve 15% volatility when combined. This higher volatility is closer to the long-run historical volatility of equities. Based on the authors' experience, the combined hedge portfolio can be implemented at this leverage without any additional funding.

The simulated portfolios allocate some proportion of capital to the combined hedge portfolio and the remaining capital to the S&P 500. Hence, a hedge proportion of 30% implies a 70% allocation to the S&P 500 and a 30% allocation to the hedge portfolio. Statistics for these portfolios are shown in Exhibit 11 (Panel A for equity drawdowns and Panel B for recessions). Although a 50% allocation to the hedge strategy is required to achieve a positive return over the equity market drawdown periods in our simulations, a 10% allocation improves the return

[25] The low correlation between futures time-series momentum and quality stocks also is obtained when considering only equity market drawdown periods or only normal periods.

Exhibit 11

Effectiveness of Dynamic Hedges

Panel A: Drawdowns

Portfolio	Total Return								Annualized Return		
Hedge Proportion	Black Monday	Gulf War	Asian Crisis	Tech Burst	Financial Crisis	Euro Crisis I	Euro Crisis II	2018Q4	Drawdown (14%)	Normal (86%)	All (100%)
0%	–32.9%	–19.2%	–19.2%	–47.4%	–55.2%	–15.6%	–18.6%	–19.4%	–44.3%	24.4%	10.8%
10%	–29.1%	–15.1%	–15.7%	–33.0%	–48.6%	–13.5%	–15.4%	–17.1%	–36.8%	23.5%	12.2%
20%	–25.1%	–10.9%	–12.0%	–14.9%	–41.1%	–11.4%	–12.0%	–14.9%	–28.4%	22.6%	13.5%
30%	–21.0%	–6.4%	–8.2%	7.7%	–32.8%	–9.2%	–8.6%	–12.6%	–19.0%	21.6%	14.7%
40%	–16.8%	–1.8%	–4.2%	–35.9%	–23.6%	–7.0%	–5.1%	–10.2%	–8.6%	20.6%	15.9%
50%	–12.4%	3.0%	–0.1%	70.9%	–13.3%	–4.8%	–1.5%	–7.8%	2.9%	19.6%	17.0%

Panel B: Recessions

Portfolio	Total Return			Annualized Return		
Hedge Proportion	Gulf War Recession	Tech Burst Recession	Financial Crisis Recession	Recession (8%)	Expansion (92%)	All (100%)
0%	7.9%	–0.9%	–35.0%	–12.1%	13.2%	10.8%
10%	9.7%	1.3%	–29.3%	–8.2%	14.2%	12.2%
20%	11.4%	3.5%	–23.4%	–4.2%	15.2%	13.5%
30%	13.2%	5.7%	–17.2%	–0.3%	16.2%	14.7%
40%	14.9%	7.8%	–10.8%	3.6%	17.1%	15.9%
50%	16.5%	9.9%	–4.3%	7.4%	17.9%	17.0%

Notes: The authors simulated portfolios with varying allocations to the S&P 500, three-month momentum with no long equity positions, and the quality composite factor strategy. Transaction costs for the dynamic strategies are included. A hedge proportion of 30% implies a 70% allocation to the S&P 500 and a 30% allocation to the hedge portfolio. In Panel A, we report the total return during the eight worst drawdowns for the S&P 500 and the annualized (geometric) return during equity market drawdown, normal, and all periods. In Panel B, we report the same statistics for recessions and expansions. The data are from 1985 to 2018.

in each of the eight historical equity market drawdown periods, resulting in more than a seven percentage point improvement in the annualized drawdown-period return (from −44.3% to −36.8%).

CONCLUDING REMARKS

Can a portfolio be crisis proofed? Possibly yes, but at a very high cost. We show that a passive strategy that continually holds put options on the S&P 500 is prohibitively expensive, leading to a return drag of more than 7% per year. A strategy that passively holds US 10-year Treasuries is an unreliable crisis hedge, given that the post-2000 negative bond–equity correlation is historically atypical. Long gold and short credit risk sit between puts and bonds in terms of both cost and reliability, according to our research.

To reduce the cost of crisis protection, we evaluated a number of dynamic strategies for their potential to perform well during the worst equity market drawdowns as well as recessions.

Two conceptually different classes of strategies emerge as credible candidates in our view. First, futures time-series momentum strategies, which resemble a dynamic replication of long straddle positions, performed well during both severe equity market drawdowns and recessions. Restricting these strategies from taking long equity positions further enhances their protective properties but comes at the cost of lower overall performance.

Second, strategies that take long and short positions in single stocks, using quality metrics to rank companies cross sectionally, have also historically performed well when equity markets have sold off and during recessions, likely a result of a flight-to-quality effect. We analyzed

EXHIBIT A1
Long Puts

	Asian Crisis	Tech Burst	Financial Crisis	Euro Crisis I	Euro Crisis II	2018Q4	Drawdown (14%)	Normal (86%)	All (100%)	Hit Rate
Starting month	Jul 1998	Sep 2000	Oct 2007	Apr 2010	Apr 2011	Sep 2018				
Ending month	Aug 1998	Oct 2002	Mar 2009	Jul 2010	Oct 2011	Dec 2018				
Strategy							**Annualized Return**			
S&P 500 (funded)	–15.4%	–39.9%	–45.8%	–5.2%	–7.1%	–13.0%	–26.7%	20.6%	8.2%	n.a.
S&P 500 (excess)	–16.1%	–44.1%	–47.1%	–5.3%	–7.1%	–13.6%	–28.4%	18.1%	5.9%	n.a.
ATM puts (index, as before)	14.9%	32.8%	19.5%	3.7%	1.4%	12.2%	16.6%	–12.7%	–7.0%	100%
ATM puts (OTC), 1 unit	11.6%	17.3%	20.2%	2.6%	2.8%	10.2%	12.8%	–13.0%	–7.9%	100%
5% OTM puts (OTC), 1 unit	7.8%	–3.1%	2.4%	–1.6%	–4.0%	4.3%	1.1%	–7.3%	–5.5%	50%
10% OTM puts (OTC), 1 unit	3.8%	–11.2%	–7.5%	–2.6%	–3.4%	–0.7%	–4.4%	–3.1%	–3.4%	17%
ATM puts (OTC), 1% pm	5.0%	10.8%	7.8%	1.4%	1.6%	8.2%	7.0%	–6.9%	–4.1%	100%
5% OTM puts (OTC), 1% pm	7.0%	1.2%	3.8%	–0.1%	–4.1%	11.8%	3.8%	–10.9%	–7.9%	67%
10% OTM puts (OTC), 1% pm	6.7%	–22.3%	–11.3%	–3.9%	–5.9%	–3.9%	–8.6%	–11.4%	–10.8%	17%

Notes: The authors report the total return of the S&P 500 and various long put strategies during drawdowns periods of the S&P 500, the annualized (geometric) return during drawdown, normal, all periods, and the hit rate (percentage of drawdowns with positive return). The authors consider both buying one put and spending 1% of wealth on puts each month. The index data are as before and based on the CBOE S&P 500 PutWrite Index. The OTC data are from a large broker. The data are monthly from 1996 to 2018.

a host of different quality metrics and point out the importance of using a beta-neutral portfolio construction, rather than using the dollar-neutral formulation that is more common in published papers.

In the late stage of a bull market, it is prudent for investors to plan for the inevitable drawdown that might be accompanied by a recession. We analyze a number of passive and active strategies and detail the effectiveness of these strategies across various crises. However, investors need to be careful in defining "best" when selecting the best of strategies in the worst of times. It is essential to understand not just the performance but the overall cost of implementing various protective measures.

Every crisis is different. For each crisis, some defensive strategies will turn out to be more helpful than others. Therefore, diversification across a number of promising defensive strategies may be most prudent.

APPENDIX

LONG PUTS USING OVER-THE-COUNTER PUT OPTION DATA FROM A BROKER

Before, we used the CBOE S&P500 PutWrite Index, for which we have daily at-the-money (ATM) S&P 500 put returns starting in 1986. As a robustness check, here we also use mid-quote data for over-the-counter (OTC) S&P 500 put options from a large broker, which are available since 1996 and include 5% and 10% out-of-the-money (OTM) put data. Because the OTC put data are monthly, we extend our drawdown periods to span whole calendar months.

The passive strategy based on these OTC options initiates a long one-month put position at month end, and the puts are held until expiry at the subsequent month end. In contrast, the PutWrite Index positions are initiated and expire on the third Friday of the month, and the payoff at expiry is based on the special open quotation.

We first consider the strategy of holding one put option; that is, the return is the net payoff of one option, divided by the index level at option initiation. This mimics the PutWrite Index methodology. The return of passively investing in the OTC one-month ATM S&P 500 puts has a correlation of 0.85 to the short PutWrite Index returns, and the all-period return is similarly negative (see Exhibit A1). Both ATM option strategies generate positive returns for all drawdown periods (100% hit rate), though during the tech bubble burst, shorting the PutWrite Index performs notably better.

Turning to 5% and 10% OTM options, one can see from Exhibit A1 that the all-period return is less negative, which is intuitive given the lower premium relative to an ATM put. However, the drawdown period performance is no longer consistently positive and is mostly negative in the case of 10% OTM puts. The intuition is that these OTM puts do not pay off when there is a more gradual decline (and monthly returns do not exceed −5% and −10%, respectively).

Rather than buying a fixed number of puts, one can also spend a fixed fraction of wealth on option premiums. We consider the case of spending 1% per month. This arguably creates a more like-for-like comparison between ATM and OTM options. Furthermore, such a strategy naturally buys fewer options when they are expensive. From the bottom rows of Exhibit A1, we see that the ATM option strategy provides the best cost–benefit trade-off. This should come as no surprise because insurance against (just) the worst states of the world commands a disproportionately high risk premium.

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REFERENCES

AQR. 2015. "Good Strategies for Tough Times." White paper, Alternative Thinking 2015Q3.

Arnott, R., C. R. Harvey, V. Kalesnik, and J. Linnainmaa. 2019. "Alice's Adventures in Factorland: Three Blunders That Plague Factor Investing." *The Journal of Portfolio Management* 45 (4): 18–36.

Asness, C., A. Frazzini, R. Israel, T. Moskowitz, and L. Pedersen. 2018. "Size Matters, If You Control Your Junk." *Journal of Financial Economics* 129 (3): 479–509.

Asness, C., A. Frazzini, and L. Pedersen. 2019. "Quality Minus Junk." *Review of Accounting Studies* 24 (1): 34–112.

Asvanunt, A., L. Nielsen, and D. Villalon. 2015. "Working Your Tail Off: Active Strategies versus Direct Hedging." *The Journal of Investing* 24 (2): 134–145.

Baele, L., G. Bekaert, and K. Inghelbrecht. 2010. "The Determinants of Stock and Bond Return Comovements." *Review of Financial Studies* 23 (6): 2374–2428.

Cook, M., E. Hoyle, M. Sargaison, D. Taylor, and O. Van Hemert. 2017. "The Best Strategies for the Worst Crises." Working paper, Man Group.

Demeterfi, K., E. Derman, M. Kamal, and J. Zou. 1999. "More Than You Ever Wanted to Know about Volatility Swaps." Quantitative Strategies Research Notes, Goldman Sachs.

Erb, C. B., and C. R. Harvey. 2013. "The Golden Dilemma." *Financial Analyst Journal* 69 (4): 10–42.

Fama, E., and K. French. 2015. "A Five-Factor Asset Pricing Model." *Journal of Financial Economics* 116 (1): 1–22.

Frazzini, A., and L. Pedersen. 2014. "Betting against Beta." *Journal of Financial Economics* 111 (1): 1–25.

Funnell, B. 2017. "Fire, Then Ice." Man GLG Views.

Hamill, C., S. Rattray, and O. Van Hemert. 2016. "Trend Following: Equity and Bond Crisis Alpha." Working paper, Man AHL.

Harvey, C. R., E. Hoyle, R. Korgaonkar, S. Rattray, M. Sargaison, and O. Van Hemert. 2018. "The Impact of Volatility Targeting." *The Journal of Portfolio Management* 45 (1): 14–33.

Kaminski, K. 2011. "In Search of Crisis Alpha: A Short Guide to Investing in Managed Futures." Working paper, RPM.

Levine, A., and L. Pedersen. 2015. "Which Trend Is Your Friend?" *Financial Analyst Journal* 72 (3): 51–66.

Liang, C., Z. Tang, and X. Xu. 2019. "Uncertainty, Momentum, and Profitability." *The Journal of Portfolio Management* 45 (4): 91–104.

Luu, B. V., and P. Yu. 2011. "The Credit Risk Premium: Should Investors Overweight Credit, When, and by How Much?" *The Journal of Investing* 20 (4): 132–130.

Shephard, N., and K. Sheppard. 2010. "Realising the Futures: Forecasting with High-Frequency-Based Volatility (HEAVY) Models." *Journal of Applied Econometrics* 25: 197–231.