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

CAMPBELL R. HARVEY, EDWARD HOYLE, SANDY RATTRAY, MATTHEW SARGAISON, DAN TAYLOR, and OTTO VAN HEMERT[1]

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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? However, hedging equity portfolios is notoriously difficult and expensive. We 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, as the post-2000 negative bond-equity correlation is a historical rarity. Long gold and long credit protection portfolios sit in 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). We examine both large equity drawdowns and recessions. We also provide some out-of-sample evidence of the defensive performance of these strategies relative to an earlier, related paper.

Keywords: Crisis hedge, Crisis alpha, Recessions, Flight to quality, Drawdown, Downside risk, Portfolio protection, Portfolio hedging, Insurance, Put options, Option-based hedging, Portfolio insurance, Futures, Trend following, Momentum, Quality factor, Profitability factor, Gold, Positive convexity, Safe-haven investments

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# 1. Introduction

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 (the instances where 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 paper.[2]

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, which constitute 86% of our sample and 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, 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 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 in 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 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).[3] We show that such strategies performed well over the eight

[2] See Cook et al. (2017).
[3] Also see, for example, Kaminski (2011).

equity drawdowns and three recessions. We also explore limiting 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, since 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, 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.

## 2. Crisis performance of passive investments

We begin by identifying the eight worst equity drawdowns and three recessions for the US 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 pre-defined 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 is followed by a discussion how a long safe-haven (bond or gold) position fares during equity crises, which includes an analysis of the bond-equity correlation since 1900 and the gold-equity correlation post Bretton Woods.[4]

We do not include transaction costs or fees in the tables and figures in Sections 2 to 4, but we do comment on the approximate cost of implementation. We explicitly account for transaction costs in Section 5, where we evaluate the effectiveness of dynamic strategies.

### 2.1 Crisis definitions

Figure 1 shows the cumulative total return of the S&P 500 (top line) using daily data from 1985 to 2018.[5] 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 paper, we focus on the eight periods in which the S&P 500 lost more than 15% from its peak, with the

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

[5] For 1988-2018, 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.

corresponding peak-to-trough periods shown in grey in Figure 1. We also label the last three US recessions as defined by the National Bureau of Economic Research (NBER).

**Figure 1: Passive investment total return over time**

We show the cumulative return of the S&P 500 (funded and in excess of cash), as well as 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). We highlight in grey the eight worst drawdowns for the S&P 500. NBER recessions are indicated on both the top and bottom of the figure. The data are from 1985 to 2018.

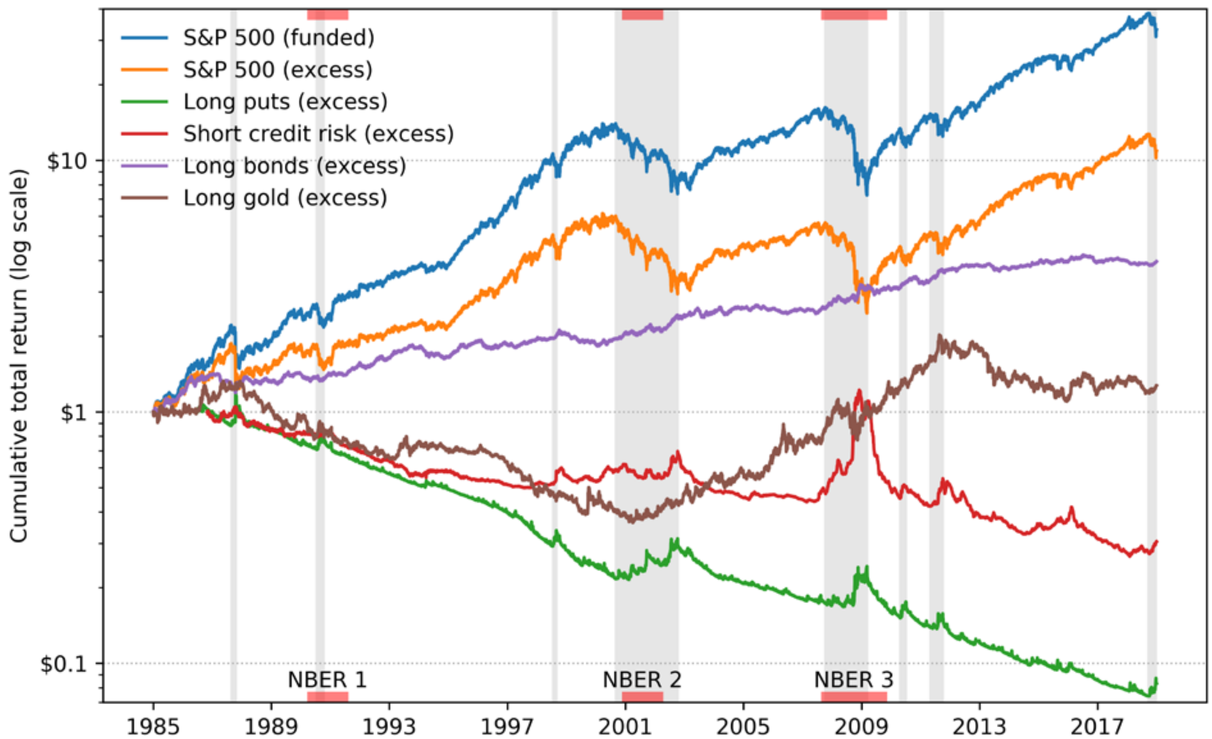


Table 1 provides a more detailed analysis, which includes: returns, peak and trough dates, lengths of the drawdowns, and whether the peak was an all-time high or a local high. The bursting of the tech bubble and the Financial Crisis are the most severe equity crises, with the S&P 500 losing about half 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 also the ruble devaluation and LTCM collapse), two episodes of the euro area sovereign debt crisis, and the 2018Q4 sell-off.[6]

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 crisis and normal periods is -44.3% and 24.4%, respectively, and it is 10.8% overall. Both the total return and annualized return take into account the effect of compounding.[7] The second row in Panel A reports the S&P 500

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

[7] This means that we take into account that a +10% return followed by a -10% return actually means a loss of -1% (computed as 1.1x0.9-1). The annualized return is computed as $(1+\text{geometric mean})^{\text{days per year}}$.

return above that of one-month Treasury bills, which provides an apples-to-apples comparison to the defensive strategies.

**Table 1: Performance over drawdown periods**

We 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, 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.

| | 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 | 25-Aug-87 | 16-Jul-90 | 17-Jul-98 | 1-Sep-00 | 9-Oct-07 | 23-Apr-10 | 29-Apr-11 | 20-Sep-18 | | | | |
| Trough day | 19-Oct-87 | 11-Oct-90 | 31-Aug-98 | 9-Oct-02 | 9-Mar-09 | 2-Jul-10 | 3-Oct-11 | 24-Dec-18 | | | | |
| 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% |

In Table 2, 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 National Bureau of Economic Research (NBER) definitions, only 8% of the sample is in recession. The annualized S&P 500 return during recessions is -12.1% and during expansions it is 13.2%. Not surprisingly, the return difference between recessions and expansions is a lot less 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. While the drawdowns during recessions are less, recessions are often accompanied by painful negative shocks to investors' incomes.[8]

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

**Table 2: Performance over recession periods**

We 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, all periods, and the hit rate (percentage of recessions with positive return). The annualized standard deviation of the various strategies ranges between 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.

| | Gulf war recession | Tech burst recession | Financial crisis recession | Recession (8%) | Expansion (92%) | All (100%) | Hit rate |
|---|---|---|---|---|---|---|---|
| Peak day | 1-Aug-90 | 1-Apr-01 | 1-Jan-08 | | | | |
| Trough day | 31-Mar-91 | 30-Nov-01 | 30-Jun-09 | | | | |
| 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% |

## 2.2 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 since 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, due to the inverse relationship between equity returns and equity volatility. Although only traded over-the-counter, these swaps can be liquid and can also be entered on a forward-starting basis (see, for example, Demerterfi, Derman, Kamal and Zou (1999)). However, as 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 drawdowns we identified, as well as in normal times, we look at the CBOE S&P500 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 towards the put option buyer can be honored. Since we are interested in the returns of buying puts, rather than selling puts, we use the negative of the index's excess returns.[9] We also examine (below) on a shorter sample the performance of out-of-the money puts.

Figure 1 and Table 1 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 appears earned in short periods of time, like 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.

Table 2 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, as well as 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.[10]

As a robustness check, we show in Appendix A 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. While out-of-the-money puts are cheaper than at-the money puts on a per unit basis, they provide a worse cost-benefit trade-off if you factor in that they don't 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, as many reliable indices only 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

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

[10] 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, which is beyond the scope of this paper. First, one can generate income by selling out-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 (for example, Shepherd and Sheppard (2010)), and then increase protection ahead of expected volatility spikes and the associated increased probability of market falls.

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.[11]

From a practical point of view, while 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.[12] 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 Table 1 are on a similar scale to 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 generated a small negative return. It is somewhat surprising the full-period return is not more negative, since the strategy is short the credit risk premium (see also Luu and Yu (2011)). It is noted, however, that Figure 1 shows the strategy has been on a pronounced downward drift since 2000. Based on our trading experience, we expect that the transaction costs for implementing a short credit risk strategy, implemented through synthetic indices such as CDX, to be less than 0.1% per year.

Table 2 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 tradeoff between reliability and cost of the hedge.

### 2.3 Hedging with safe-haven assets: long bonds and long gold

Government bonds and gold are often described as 'safe-haven' assets.[13] A long bond position is sometimes viewed as a crisis hedge, possibly based upon 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 Figure 1, Table 1, and Table 2. Returns are based on 10-year Treasury futures contracts.[14]

In the period 1985-2018, bonds performed well, helped by the compression in 10-year yields, from double digit levels in the mid-80s, to around 2% in recent years. The annualized return over cash for equity drawdown periods is 10.6% in Table 1, which exceeds the still positive value of 3.1% for

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[11] Before scaling, the volatility of the strategy is 2.7%.
[12] Because historical data are limited, we did not use credit default swaps or CDX for our empirical analysis.
[13] 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.
[14] Throughout this paper, 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.

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 Table 2.

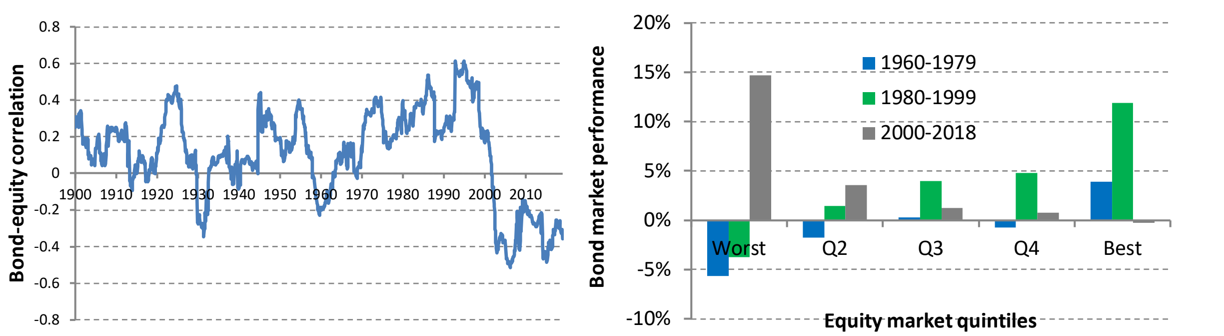
The recent shift in bond-equity return correlations is consistent with the fact that that the recent performance of bonds during equity drawdown periods exceeds that of earlier times. That is to say, since 2000, when stock prices have fallen, Treasuries have rallied. To explore further the long-term evidence for this, we looked at monthly returns for the US equity index and Treasury bond returns extending our sample using returns from Global Financial Data. Figure 2 (panel A) shows the rolling five-year bond-equity correlation. We see that, although post-2000 the correlation was negative, it was positive for most of the 100 years before that. This 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) provides a similar long-term perspective of the bond-equity relationship for the UK.

**Figure 2: Time varying co-movement between equity and bond returns**

In panel A, we plot the rolling 5-year correlation between monthly US equities and US Treasury bond excess returns from 1900 to 2018. In panel B, we plot the annualized bond returns by 3-month equity quintiles and for different sub-periods. The data are from Global Financial Data, Bloomberg and Man-AHL.

Panel A: Rolling 5-year correlation

Panel B: Bond returns by 3m equity return quintile




Another approach to analyzing this effect is to take three subsamples of the 1960-2018 period, each of length around 20 years, and then sort the three-month bond returns into quintiles based on the equity return.[15] Quintile one represents the periods with the worst equity returns, quintile five denotes the periods with the best equity returns. Figure 2 (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 that stocks and bonds should be positively correlated and the empirical evidence, investors should pause. It is not clear that in the future that bonds 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. It does not provide a

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

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, for example, miners' strikes and political instability in mining regions, which may make gold an unreliable hedge in many circumstances.

We use gold futures for the excess returns shown in Tables 1 and 2. Gold shows 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 where positive returns are recorded for only two of the three recessions in Table 2.

Based on our trading experience, we expect that the annual transaction costs for maintaining a bond or gold exposure through futures to be below 0.1% per year.

In Appendix B, we take a longer view of gold, as we did with bonds in Figure 2, 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) extend the analysis back by hundreds of years. Their evidence suggests that gold is an unreliable crisis hedge and an unreliable unexpected inflation hedge. While gold has kept its buying power over millennia (real return is zero), the large amount of idiosyncratic noise means that holding periods need to be measured not in years -- but in centuries.

## 3. Active hedging strategies: Time-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.[16] We explore both an unconstrained strategy and one where 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 and slippage costs of implementing a 3-month momentum strategy to be 0.6-0.8% per annum.[17]

[16] While CTAs may often use moving average crossovers, Levine and Pedersen (2015) show that these are very similar to the time-series momentum strategies that we use in this paper.
[17] Based on execution analysis of live trades at Man Group over a 25 year history.

### 3.1 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 $t$-$i$, $\sigma_{t-1}^{k}$ 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.[18]

For the purpose of 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 indices, 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.

In order 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:

- **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.[19]

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

### 3.2. Securities included

We study the empirical performance of the different strategies using the 50 liquid futures and forwards listed in Table 3. While we evaluate strategy returns from 1985 onwards only, where possible we use data from 1980 to compute risk estimates. Prior to its introduction in 1999, the euro (EUR/USD) is replaced with the Deutsche Mark.

**Table 3: Data for futures time-series momentum analysis**

This table lists the 50 futures and forward markets used for evaluating the times-series momentum strategies. Data are from Bloomberg and Man Group.

| Name | Exchange | Start date | Name | Exchange | Start date | Name | Exchange | Start date |
|---|---|---|---|---|---|---|---|---|
| COMMODITIES - AGRICULTURALS | | | CURRENCIES (AGAINST USD) | | | FIXED INCOME - BONDS | | |
| Corn | CBOT | Jan-80 | Australian dollar | OTC forward | Jan-80 | 2-year Germany | Eurex | Mar-97 |
| Soybeans | CBOT | Jan-80 | Canadian dollar | OTC forward | Jan-80 | 5-year Germany | Eurex | Oct-91 |
| Wheat | CBOT | Jan-80 | Euro (D-Mark) | OTC forward | Jan-80 | 10-year Germany | Eurex | Jun-83 |
| Cocoa | ICE - US | Jan-80 | Norwegian krone | OTC forward | Dec-88 | 10-year Japan | TSE | Mar-83 |
| Coffee | ICE - US | Jan-80 | New Zealand dollar | OTC forward | Dec-88 | 10-year UK | LIFFE | Nov-82 |
| Sugar | ICE - US | Jan-80 | Swiss franc | OTC forward | Jan-80 | 30-year US | CBOT | Jan-80 |
| | | | Swedish krona | OTC forward | Dec-88 | 2-year US | CBOT | Jul-05 |
| COMMODITIES - ENERGIES | | | British pound | OTC forward | Jan-80 | 5-year US | CBOT | Oct-91 |
| Crude oil - Brent | ICE - Europe | Jun-88 | Japanese yen | OTC forward | Jan-80 | 10-year US | CBOT | May-82 |
| Crude oil - WTI | NYMEX | Oct-83 | | | | | | |
| Heating oil | NYMEX | Jan-80 | EQUITIES | | | FIXED INCOME - INTEREST RATE | | |
| Natural gas | NYMEX | Apr-90 | CAC 40 | Euronext | Nov-88 | Eurodollar | CME | Feb-82 |
| Gas oil | ICE - Europe | Apr-81 | DAX | Eurex | Nov-90 | Euribor | LIFFE | Apr-89 |
| Gasoline | NYMEX | Dec-84 | Nasdaq | CME | Apr-96 | Short sterling | LIFFE | Nov-82 |
| | | | Russell | ICE - US | Sep-00 | | | |
| COMMODITIES - METALS | | | S&P 500 | CME | Apr-82 | | | |
| Aluminium | LME | Jan-80 | EuroSTOXX | Eurex | Jun-00 | | | |
| Copper | COMEX | Jan-80 | FTSE | LIFFE | May-84 | | | |
| Gold | COMEX | Jan-80 | Hang Seng | HKFE | Jan-87 | | | |
| Lead | LME | Jun-89 | KOSPI | KSE | Sep-00 | | | |
| Nickel | LME | Jan-80 | Nikkei | SGX | Mar-87 | | | |
| Silver | COMEX | Jan-80 | | | | | | |
| Zinc | LME | Jan-80 | | | | | | |

### 3.3 Performance of futures time-series momentum strategies

We report the total return of the time-series strategies for equity drawdowns in Table 1 and for recessions in Table 2. The 1- and 3-month unconstrained strategies have tended to perform well during equity crises, consistent with HRV, who argue 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 discussion before) 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 Table 4, we report the average 5-, 22-, 65-, and 261-day return (not annualized) of 3-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.

**Table 4: Average return 3-month futures times-series momentum for equity quintiles**

We 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.

| 5-day equity quintiles | | Worst | Q2 | Q3 | Q4 | Best | ALL |
|---|---|---|---|---|---|---|---|
| S&P500 (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&P500 (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&P500 (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&P500 (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% |

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

# 4. 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.

## 4.1 Motivation to look at quality stocks

Asness, Frazzini, and Pedersen (2019, henceforth AFP) argue that while quality stocks logically deserve a higher price-to-book ratio, in reality they do not always exhibit such a premium. In particular, towards 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 derive the following formula for the price-to-book (P/B) ratio:[20]

$$\frac{P}{B} = \frac{\text{Profitability}\times\text{Payout Ratio}}{\text{Required Return}-\text{Growth}} \qquad (3)$$

[20] 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).

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:

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.

## 4.2 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 Table 5, we present results for the Fama and French (2015) five-factor model (the first five factors), as well as factor returns based on AFP and other researchers (the last three factors).[21] Only US stocks are considered in each case.

**Table 5: Equity factor performance over drawdown and recession periods**

We report the total return of various long-short US equity strategies with publicly available return data. In Panel A, we 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, we report the same statistics for recessions and expansions. Strategies are scaled to a dollar long-short. The data are from 1985 to 2018.

**Panel A (Drawdowns)**

| Factor | Total return | | | | | | | | Annualized return | | | Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 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&P500 |
| 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 | | | Correlation |
|---|---|---|---|---|---|---|---|
| | Gulf war recession | Tech burst recession | Financial crisis recession | Recession (8%) | Expansion (92%) | All (100%) | Correl. to S&P500 |
| 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 |

[21] 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.

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.[22] Subsections 4.3 and 4.4 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 in Section 3. 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, whilst 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, for example 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, for example 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.

### 4.3 Individual quality factor performance

In this section, we evaluate various quality metrics. Table 6 lists all the signals we consider, which form a subset of AFP's signals, as 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.[23]

At each date, the raw signal value, $s$, is ranked cross-sectionally, $r(s) = \operatorname{rank} s$, and then a cross-sectional $z$-score is determined, $z(r) = (r - \mu_r)/\sigma_r$, where $\mu_r$ is the cross-sectional mean and $\sigma_r$ 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 $t$ for stock $i$ as $\text{Signal}_{t,i}$, we form a beta-neutral portfolio by defining a neutral signal as:

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[22] Lian, Tang, and Xu (2019) also find that profitability strategies perform better in months with negative equity returns.

[23] Also, AFP use CRSP/XpressFeed Global data, while we use their Worldscope analogues. The accounting data is extracted from the Worldscope fundamental dataset, where we use annual, semi-annual and quarterly data whene available. We generate comparable numbers by constructing trailing 12-month averages for each frequency, per variable.

$$\text{Signal}_{t,i}^{\text{Neutral}} = \begin{cases} \frac{\text{Signal}_{t,i}}{\text{BetaLong}}, & \text{if Signal}_{t,i} \geq 0, \\ \frac{\text{Signal}_{t,i}}{\text{BetaShort}}, & \text{if Signal}_{t,i} < 0, \end{cases} \tag{4}$$

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:

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

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 $2bn at the end of 2016 (and onwards), and for earlier dates is suitably deflated.[24] As an example, the threshold in 1986 was about $200m. This results in a sample with lower turnover, with the number of constituents ranging between 951 and 1,611 over our analysis.

**Table 6: Quality factor definitions**

We list the various quality factors used in our strategies. All fundamental data are from Worldscope.

| 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 (5y change) | Five-year change corresponding profitability metric, i.e. ($\text{CashFlow}_t$ - $\text{CashFlow}_{t-5}$) / $\text{TotalAssets}_{t-5}$ |
| Growth | Gross margin (5y change) | Five-year change corresponding profitability metric |
| Growth | Gross profits over assets (5y change) | Five-year change corresponding profitability metric |
| Growth | Low accruals (5y change) | Five-year change corresponding profitability metric |
| Growth | Return on assets (5y change) | Five-year change corresponding profitability metric |
| Growth | Return on equity (5y 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 volatilty | Minus standard deviation of the daily market-adjusted returns over the past year |
| Safety | Low leverage | Total debt / total assets |

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

Table 7, 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, where in three out of six cases the drawdown-period performance is worse than the normal performance, and moreover the overall performance is around zero for all six growth factors.

### Table 7: Quality factor performance, beta-neutral

We report the total return of various quality factors, where portfolios are constructed to be beta-neutral. In Panel A, we 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, we 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.

**Panel A (Drawdowns)**

| Category | Name | Total return | | | | | | | | Annualized return | | | Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 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&P500 |
| Profitability | Cash flow over 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 over 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 over 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 over assets (5y change) | | | 0.1% | 37.6% | 5.3% | 1.4% | 2.3% | -0.1% | 9.5% | -0.6% | 1.2% | -0.03 |
| Growth | Gross margin (5y change) | | -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 over assets (5y change) | | -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 (5y change) | | | -2.7% | -32.8% | 1.9% | 0.6% | -0.1% | 0.9% | -8.3% | -0.1% | -1.7% | 0.06 |
| Growth | Return on assets (5y change) | | 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 (5y change) | | -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 | | | Annualized return | | |
|---|---|---|---|---|---|---|---|
| | | Gulf war recession | Tech burst recession | Financial crisis recession | Recession (8%) | Expansion (92%) | All (100%) |
| Profitability | Cash flow over assets | | 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 | | 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 | | -3.0% | -9.6% | -4.5% | 3.3% | 2.6% |
| Growth | Cash flow over assets (5y change) | | | 0.7% | 3.9% | 0.9% | 1.2% |
| Growth | Gross margin (5y change) | | -7.6% | 0.4% | 1.5% | -0.6% | -0.4% |
| Growth | Gross profits over assets (5y change) | | -3.2% | 4.0% | 6.2% | -1.6% | -0.9% |
| Growth | Low accruals (5y change) | | | 1.9% | -2.0% | -1.6% | -1.7% |
| Growth | Return on assets (5y change) | | 2.6% | -6.8% | 2.1% | -0.2% | 0.0% |
| Growth | Return on equity (5y change) | | 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% |

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 due to the fact that strategies with embedded leverage underperform when funding constraints tighten (Frazzini and Pedersen (2014)), which often occurs at times of market stress (such 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 Table 7, Panel B, results are a bit more mixed, but some profitability and payout factors show a notable stronger performance during recessions compared to expansionary periods.

In Appendix C, Table C1, 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 the negative equity exposure, rather than performance 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, without performing badly during equity bull markets.

### 4.4 Composite quality factor performance

Table 1 and 2 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 Table 1 we see that profitability, payout, safety, and a grand composite of the four quality composites, denoted “quality all”, performed well during equity market drawdowns, as well as for the full sample. Only the growth composite stands out as performing poorly during both equity market drawdown and normal periods. In Table 2, we see that the annualized performance during recessions is strong for profitability, but not for safety.

In Appendix C, Table C2, 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.[25] Profitability and growth have a negative beta to the value factor, while payout and safety have a positive beta to value. The exposure to the cross-sectional equity momentum factor is small in all cases.

In Table 8 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 Section 3 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.

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

**Table 8: Average return beta-neutral quality composites for equity quintiles**

We 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.

| 5-day equity quintiles | Worst | Q2 | Q3 | Q4 | Best | ALL |
|---|---|---|---|---|---|---|
| S&P500 (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&P500 (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&P500 (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&P500 (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% |

# 5. Can Portfolios be Crisis Proofed?

In Table 9, we present correlations between a selected subset of the strategies considered before. The 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.[26]

**Table 9: Correlation between strategies considered in Sections 2, 3, and 4**

We report the correlations between the five-day overlapping returns of various strategies considered. From Section 2: 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). From Section 3: 1-, 3-, and 12-month futures time-series momentum with equity positions capped at zero. From Section 4: the different beta-neutral quality stock composites. The data are from 1985 to 2018.

| | S&P 500 | Long puts | Short credit risk | Long bonds | Long gold | 1m MOM: EQ pos. cap | 3m MOM: EQ pos. cap | 12m 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 |
| 1m 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 |
| 3m 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 |
| 12m 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 | |

[26] The low correlation between futures time-series momentum and quality stocks also obtains when considering just equity market drawdown or just normal periods.

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, 3-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 Table 10, 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 in each of the eight historical equity market drawdown periods, resulting in an 8 percentage point improvement in the annualized drawdown-period return (from -44.3% to -36.8%).

**Table 10: Effectiveness of dynamic hedges**

We simulated portfolios with varying allocations to the S&P 500, 3-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.

**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% |

## 6. 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 a 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 in 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 as well as recessions. Restricting these strategies from taking long equity positions further enhances their protective properties, but at the cost of a 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 in recessions, likely a result of a flight-to-quality effect. We analyzed a host of different quality metrics, and point out the importance of a beta-neutral portfolio construction, rather than using the dollar neutral formulation that is more common in most 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.

Importantly, 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.

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## Appendix A: Long puts using OTC 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 1-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 (SOQ).

We first consider the strategy of holding 1 put option; i.e., the return is the net payoff of 1 option, divided by the index level at option initiation. This mimics the PutWrite Index methodology. The return of passively investing in the OTC 1-month ATM S&P 500 puts correlates 0.85 to the short PutWrite Index returns and the all-period return is similarly negative (see Table 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.

**Table A1: Long puts**

We 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). We consider both buying 1 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.

| | Asian crisis | Tech burst | Financial crisis | Euro crisis I | Euro crisis II | 2018Q4 | Drawdown (14%) | Normal (86%) | All (100%) | Hit rate |
|---|---|---|---|---|---|---|---|---|---|---|
| Starting month | Jul-98 | Sep-00 | Oct-07 | Apr-10 | Apr-11 | Sep-18 | | | | |
| Ending month | Aug-98 | Oct-02 | Mar-09 | Jul-10 | Oct-11 | Dec-18 | | | | |
| **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% |

Turning to 5% and 10% OTM options, one can see from Table 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 not consistently positive anymore, and 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. Also, such a strategy naturally buys fewer options when they are expensive. From the bottom rows of Table A1, we see that the ATM option strategy provides the best cost-benefit tradeoff. This should come as no surprise, as insurance against (just) the worst states of the world commands a disproportionately high risk premium.

# Appendix B: longer view of gold

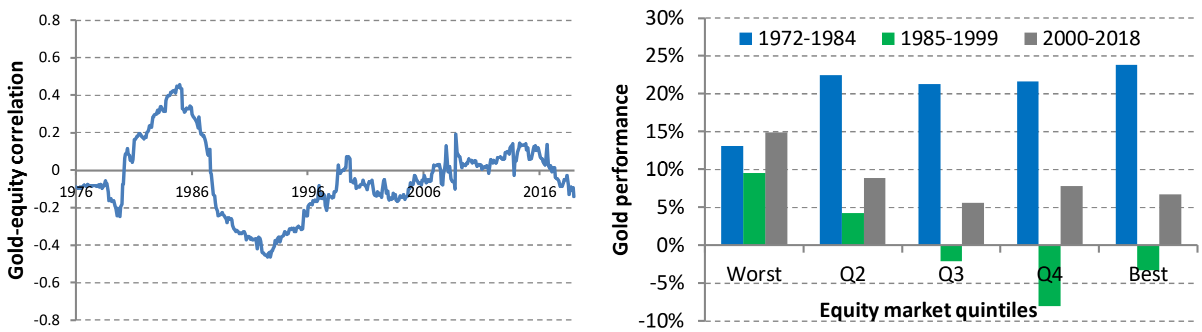
In this appendix we take a longer view of gold. Unfortunately, the analysis of gold prices prior to 1972 is complicated by the Bretton Woods system, which tied major currencies to gold. In Figure B1, we show the five-year rolling correlation of monthly gold spot returns with US equities. Between 1976 and 1985 gold was moderately positively correlated with equities. In the subsequent 10 years, the correlation was moderately negative, and since the mid-1990s has been close to zero. We split the period 1972-2018 into three subsamples and, for each subsample, calculated the mean return of gold by three-month equity quintile. Pre-1985, the returns of gold were strong, and appear largely indifferent to equity returns. The positive equity correlation is perhaps evident in the relatively weaker performance of gold during the worst three-month periods for equities. In the period 1985 to 1999, when the gold-equity correlation was mostly negative, we see gold performing relatively well during the worst equity quintile. This outperformance during difficult periods for equities was carried into the 2000s, but without the negative returns during best equity months.

**Figure B1: Time varying co-movement between equity and gold returns (funded)**

In panel A, we plot the rolling 5-year correlation between monthly US equities and gold spot returns from 1977 to 2018. In panel B, we plot the annualized gold returns by 3-month equity quintiles and for three sub-samples of 1972-2018. The gold data are from Bloomberg, the equity data are from Global Financial Data and Bloomberg.

Panel A: rolling 5-year correlation

Panel B: gold returns by 3m equity return quintile




# Appendix C: additional results for quality stocks

Table C1 report the quality factor performance based on a dollar-neutral portfolio construction, rather than the beta-neutral portfolio construction used in Table 7.

### Table C1: Quality factor performance, dollar-neutral

We report the total return for various quality factors, where portfolios are constructed to be dollar-neutral. We report the total return during 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. All strategies are scaled to 10% annualized volatility (ex-post). The data run from 1986 to 2018.

| Category | Name | Total return | | | | | | | | Annualized return | | | Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 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&P500 |
| Profitability | Cash flow over assets | | 0.3% | 4.2% | 171.9% | 20.2% | 7.7% | 11.9% | 5.9% | 36.4% | -1.2% | 4.0% | -0.40 |
| Profitability | Gross margin | 0.9% | 0.7% | 3.3% | -28.0% | 33.1% | 11.7% | 12.8% | 2.8% | 5.5% | 1.7% | 2.2% | -0.03 |
| Profitability | Gross profits over assets | -2.4% | -5.2% | -1.1% | 109.8% | 19.7% | 2.7% | 10.2% | 2.6% | 22.2% | 3.5% | 6.0% | -0.11 |
| Profitability | Low accruals | | 0.1% | 3.4% | 90.6% | 4.1% | -4.4% | -9.9% | -0.1% | 12.8% | 0.9% | 2.7% | -0.10 |
| Profitability | Return on assets | -2.9% | 0.4% | 2.8% | 128.5% | 29.9% | 10.4% | 9.4% | 6.0% | 31.5% | -1.2% | 3.0% | -0.26 |
| Profitability | Return on equity | -0.7% | -2.0% | 1.0% | 155.1% | 14.0% | 9.2% | 8.6% | 1.1% | 28.7% | 0.2% | 3.9% | -0.24 |
| Payout | Net debt issuance | 2.9% | 9.4% | 10.7% | 96.2% | 29.2% | -7.0% | -4.7% | 3.0% | 24.2% | 6.5% | 8.9% | -0.12 |
| Payout | Net equity issuance | -0.7% | 2.2% | 7.0% | 137.2% | 12.4% | 5.2% | 9.1% | 7.0% | 29.6% | 0.0% | 3.8% | -0.36 |
| Payout | Total net payouts over profits | | 6.9% | 4.2% | 62.0% | 10.8% | 14.1% | -1.1% | 4.9% | 19.9% | -3.7% | -0.4% | -0.23 |
| Growth | Cash flow over assets (5y change) | | | -0.5% | 42.1% | 1.6% | 11.9% | 16.7% | -1.9% | 14.5% | -0.2% | 2.4% | -0.13 |
| Growth | Gross margin (5y change) | | -6.1% | -8.8% | -35.4% | 1.4% | 8.4% | 7.5% | -0.5% | -8.7% | 2.7% | 0.9% | 0.28 |
| Growth | Gross profits over assets (5y change) | | -5.8% | -8.1% | -32.6% | 5.3% | 6.1% | 6.8% | -1.0% | -7.5% | 2.2% | 0.6% | 0.29 |
| Growth | Low accruals (5y change) | | | -2.7% | -41.0% | 15.0% | 3.3% | 0.8% | 3.7% | -7.3% | -1.7% | -2.8% | 0.20 |
| Growth | Return on assets (5y change) | | -4.1% | -6.6% | 18.4% | 9.3% | 12.0% | 8.9% | -0.7% | 7.4% | -0.5% | 0.7% | 0.02 |
| Growth | Return on equity (5y change) | | -7.3% | -8.8% | 24.1% | 10.7% | 14.2% | 13.8% | -2.6% | 8.5% | -0.1% | 1.2% | 0.04 |
| Safety | Low beta | 7.6% | 9.2% | 8.2% | 81.6% | 15.0% | 9.8% | 18.0% | 12.0% | 31.7% | -5.3% | -0.5% | -0.73 |
| Safety | Low idiosyncratic volatility | 2.9% | 9.0% | 10.1% | 93.7% | 18.8% | 6.3% | 10.8% | 7.5% | 29.9% | -3.5% | 0.8% | -0.55 |
| Safety | Low leverage | 0.0% | 3.9% | 3.0% | 69.0% | -15.0% | -0.4% | -0.1% | 2.7% | 9.7% | -2.4% | -0.7% | -0.22 |

In Table C2 we show the output of the following regression, performed using five-day returns, and as before defining the information ratio as the regression alpha divided by the standard deviation of the error.

$$R_t^{\text{strategy}} = \alpha + \beta^{\text{Market}} R_t^{\text{Market}} + \beta^{\text{Size}} R_t^{\text{Size}} + \beta^{\text{Value}} R_t^{\text{Value}} + \beta^{\text{Mom}} R_t^{\text{Mom}} + \varepsilon_t \qquad [6]$$

$$IR = \frac{\alpha}{\sigma(\varepsilon)} \sqrt{261/5}$$

As dependent variables we use the different quality composites reported on in Tables 1 and 2, and as independent variables we use the market, size, value, and momentum factors used before in Table 5.

### Table C2: Quality composites four-factor regression analysis

We report the output of running the regression given in Equation [6] for various quality composites. T-statistics are based on Newey-West corrected errors (25 lags). We consider both dollar-neutral and beta-neutral versions. All strategies are scaled to 10% annualized volatility (ex-post). The data run from 1986 to 2018.

| Category | Construction | IR | Alpha (ann.) | | Market factor | | Size factor | | Value factor | | Mom. factor | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Estimate | Estimate | [t-stat] | Estimate | [t-stat] | Estimate | [t-stat] | Estimate | [t-stat] | Estimate | [t-stat] |
| Profitability | Dollar-neutral | 0.85 | 8.4% | [4.34] | -0.20 | [-9.10] | -0.36 | [-3.92] | -0.22 | [-3.48] | 0.10 | [2.05] |
| Profitability | Beta-neutral | 0.74 | 8.2% | [3.76] | -0.15 | [-5.14] | -0.34 | [-3.16] | -0.05 | [-0.64] | 0.07 | [1.21] |
| Payout | Dollar-neutral | 0.79 | 6.9% | [4.23] | -0.26 | [-9.61] | -0.41 | [-5.21] | 0.40 | [5.86] | 0.06 | [1.27] |
| Payout | Beta-neutral | 0.88 | 8.6% | [4.63] | -0.12 | [-4.15] | -0.43 | [-4.40] | 0.49 | [6.42] | 0.05 | [0.89] |
| Growth | Dollar-neutral | 0.24 | 1.8% | [1.28] | 0.11 | [4.29] | 0.02 | [0.66] | -0.67 | [-19.98] | 0.07 | [2.25] |
| Growth | Beta-neutral | 0.08 | 0.6% | [0.45] | 0.04 | [1.61] | 0.12 | [5.32] | -0.64 | [-16.76] | 0.09 | [2.45] |
| Safety | Dollar-neutral | 0.38 | 2.5% | [2.05] | -0.40 | [-20.66] | -0.37 | [-7.30] | 0.32 | [7.68] | 0.09 | [2.83] |
| Safety | Beta-neutral | 0.54 | 5.4% | [2.87] | 0.01 | [0.35] | -0.37 | [-4.46] | 0.55 | [7.82] | 0.10 | [1.90] |
| Quality All | Dollar-neutral | 0.84 | 6.6% | [4.34] | -0.37 | [-18.53] | -0.45 | [-5.66] | 0.15 | [2.68] | 0.10 | [2.40] |
| Quality All | Beta-neutral | 0.90 | 9.6% | [4.55] | -0.08 | [-2.66] | -0.47 | [-4.06] | 0.33 | [4.06] | 0.11 | [1.80] |