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What's the Worst That *Should* Happen?

Executive Summary

Expected returns on traditional assets are lower than their historical averages, yet the same is not true for risks. Setting expectations — for investors, boards, and other stakeholders — may be more important today than ever.

This article does just that. We provide a framework to set expectations on downside risk, one that can be used for a range of assets, portfolios, and investment decisions. Among our findings, we show that diversification and liquidity may be even more valuable than conventional risk-return statistics suggest.

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About the Portfolio Solutions Group

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

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Introduction

Setting expectations is one of the most important and difficult tasks for any investor. Typically, it involves two assumptions: 1) the expected return, and 2) how far things can deviate from it, i.e., risk.[1] While all investors plan to realize the former, shorter-term outcomes tend to be dominated by the latter.

Investor *actions* are often driven by these shorter-term "risk" outcomes. A larger-than-expected loss or a longer-than-expected period of underperformance can force investors to make changes to their portfolios sooner than they would have otherwise wanted to. The problem? These bad outcomes happen more often than conventional risk-return statistics might seem to suggest.[2]

This matters because a portfolio you can stick with is probably better than one you're forced to change at an inopportune time. Selling in response to a bad outcome is unlikely to improve the chances of harvesting long-term risk premia (and it's one reason some premia might exist in the long run).[3] For this reason, we believe investors with good estimates not only of expected returns but also of *expected bad outcomes* have an advantage over those who don't: they are better-prepared to survive all the painful short terms that lie on the path to achieving their long-term goals.

Part 1: The Model

What's the Worst That *Should* Happen?

For many investors, the most useful definition of "risk" might be one that addresses the simple question "how much can I lose?"

This turns out to be a difficult question to answer credibly.[4] For one, "worst cases" by definition don't happen very often; and when they do, sometimes they're sudden (e.g., October 1987), and other times they unfold over multiple years (e.g., the Tech Bust). History leaves its students

1 Volatility and variance are undoubtedly among the oldest and most used statistical measures. While some investors prefer estimates of "permanent loss of capital", these two don't have to be mutually exclusive (see Peeve #1 in Asness (2014)). A range of other quantitative measures include asymmetric versions of volatility (e.g., downside volatility, semi-variance); higher moments of a distribution, such as skew; covariance with bad states of the world, and "tail" losses, such as VaR (see Linsmeier and Pearson (2000) for an overview). Path-dependent statistics have been suggested as natural complements, and include maximum drawdown (see for example Gray and Vogel (2013)), average drawdown, conditional drawdown, conditional expected drawdown, average squared drawdown, and end-of period drawdown. (Martin and McCann (1989); Chekhlov et al. (2005); Goldberg and Mahmoud (2017); Moller (2018). Other studies have looked to compare and combine multiple drawdown measures, such as in Korn et al. (2020).

2 This could be for a range of reasons, such as skewness, kurtosis, autocorrelation, etc. But even if returns behave "normally", there's still the fact that the distribution of returns (i.e., deviations around an average) is different than the distribution of drawdowns (i.e., distances below a high point).

3 This doesn't mean investors should ignore bad outcomes altogether, but they should understand what even 3- to 5-year returns data can and can't tell us about future returns (see Goyal and Wahal (2008) for evidence on active managers, and Goyal, Ilmanen and Kabiller (2015) for more related findings).

4 In some cases, the cynical answer of "100%" could be credible (e.g., an investment in a single security), but for diversified investments and portfolios, we believe investors can come up with more plausible — and thus more valuable — estimates.

with little data to confidently predict how bad — and how long — a future "worst case" will be.[5]

In this article we use simulations to tackle the challenge of limited sample size.[6] These simulations are built on multi-month blocks[7] (rather than individual monthly returns), which allows us to preserve some of the real-world, messy behavior intrinsic to markets, such as "fat tails", skewness, autocorrelation, and time-varying correlations.[8,9]

Specifically, we run 100,000 simulations over a 30-year investment horizon (see next section for why we chose 30 years). From each of these simulations, we take the worst cumulative, excess-of-cash return outcome[10] for a given "evaluation period" — e.g., worst 12-month outcome, worst 24-month outcome, etc. We then build a distribution of these 100,000 worst outcomes for each evaluation period. Throughout this article, we report the median worst outcome of these simulations to answer the question "what are the *worst outcomes I should expect to see* during my investment horizon?"[11,12]

What Horizon Should We Use?

Just how bad a bad outcome can be clearly depends on the portfolio in question (e.g., a portfolio with a high expected return and low risk should look better than a portfolio with low returns and high risk). A less-obvious factor is investment horizon: an investor who holds equities for 30 years is more likely to experience a stock market crash at some point over those 30 years than an investor who holds equities for only one year.

We illustrate the role of horizon in **Exhibit 1**. We show the cumulative average excess-of-cash return of a U.S. 60/40 portfolio for reference[13] (dashed line) and below it add the simulated worst outcomes for investors with three different

5 Even though quantifying a "bad year" is something that can be answered fairly well with, say, 100 years of evidence, answering "what's a bad decade" is fraught with uncertainty. Even 100 years of history provides only ten independent observations — hardly enough to come up with a satisfactorily robust answer. This challenge is even harder for "newer" asset classes and strategies, and for those where the data suffers from biases (e.g., smoothed returns).

6 We are far from the first to tackle the problem this way. Various studies have looked at drawdowns using simulations for single assets. Recently, for example, Hemert et al. (2020) look at the probability of hitting a drawdown level for a single asset in terms of its standard deviations.

7 Specifically, our approach uses stationary block bootstrapped returns with block lengths chosen randomly from an exponential distribution with a mean equal to the maximum optimal block length for each of the asset classes considered (though our general results hold for a range of simulation techniques and specifications) to create 100,000 simulated return paths. The historical data used in our analysis is from August 1957 to May 2021. Although this range doesn't include the Great Depression (some readers might anyway assert that structural changes in markets since then make it less relevant now, almost a century later), it does include a wide range of other major drawdown events (e.g., the 1970s recession, October 1987, the Tech Bust, and GFC), so we don't believe our dataset has "bad outcomes" meaningfully underrepresented.

8 On autocorrelation, Moskowitz, Ooi and Pedersen (2012) find past 12-month excess returns are predictive of subsequent returns for a range of liquid assets. Babu et al. (2020) find this behavior holds up in a broad range of non-traditional assets and factor strategies. Bailey and Lopez de Prado (2015) argue that ignoring serial correlation can lead to underestimating downside potential for a range of hedge fund strategies.

9 On correlations — e.g., how correlations change in stress versus non-stress periods — see Page and Panariello (2018) and Kinlaw et al. (2021). Other papers related to this topic include Erb et al. (1994, 1995); Longin and Solnik (1995, 2001); Karolyi and Stulz (1996); de Santis and Gerard (1997); Bekaert et al. (2002); Ang and Bekaert (2002); and Ang and Chen (2002). Additionally, for research on how stock market stress can "spill over" to bond markets see Hartmann et al. (2004). And Asness, Israelov and Liew (2011) show while diversification can disappoint during short term panics, it has been effective in reducing losses over longer horizons.

10 Investors whose expectations and/or objectives are stated in total or real terms can adjust these by expected cash rates or expected inflation rates, respectively. These adjustments will have minor effects over short horizons but larger effects over longer horizons. Such adjustments and results can be provided on request.

11 Please note: this is not the same as "drawdowns", which calculate peak-to-trough returns, regardless of horizon. "Worst outcomes" here address the question "what's the worst return I should expect over a specific period" – which means, for example, short-lived drawdowns might not show up at all for a multi-year "bad outcome".

12 We can share other statistics, such as mean worst, or 95th percentile worst outcomes (to build more conservative estimates), on request. This article is about setting expectations; investors who want to go further – by asking not "what's the worst that should happen", but rather "what's the worst that *could* happen" should use these more conservative estimates.

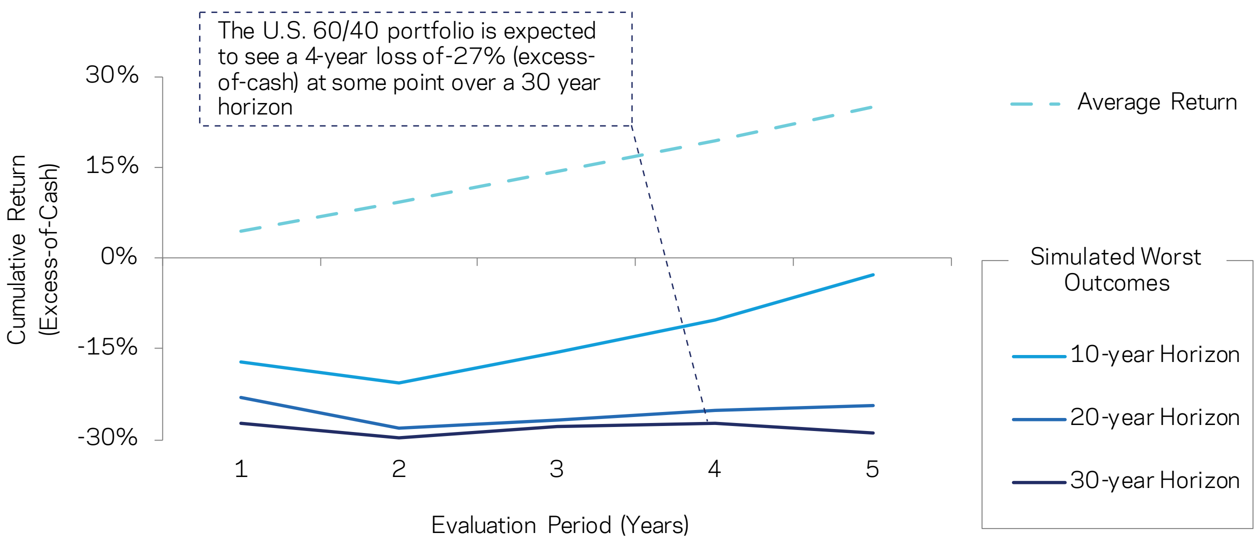
13 Compared to other country 60/40 portfolios, the U.S. experience has been quite benign for average returns and worst cumulative outcomes. This article uses U.S. 60/40 because it has the longest return history, but we can run this analysis for other country portfolios on request.

horizons: 10, 20 and 30 years. The horizontal axis, "Evaluation Period", is a subset of the investor's horizon — for example, a 4-year evaluation period for a 30-year horizon shows the worst 4-year return outcome that an investor with a 30-year horizon should expect to see (see text box in the Exhibit).

So, what horizon should investors use to set their own expectations? Conservatism would suggest erring toward longer horizons, and this would certainly be the case for long-lived organizations (e.g., endowments). Arguably, so should investors with finite lives. Even though individuals might *themselves* have relatively short horizons, their *investments* might have long ones (e.g., via wealth transfer or gifting), suggesting longer horizons might be more relevant even in this case. For these reasons, we use a 30-year horizon in the rest of the exhibits in this article.[14]

Exhibit 1: The Worst You Can Expect Varies with Horizon

U.S. 60/40 Portfolio



Source: AQR. For illustrative purposes only. The simulation uses 60/40 portfolio (rebalanced monthly) data from August 1957 – May 2021 (i.e., the underlying asset returns are from the same periods, to preserve information such as correlations). The dashed line is the cumulative excess-of-cash return using the full-sample mean; the solid lines are the results of 100,000 30-year simulations. All returns are excess-of-cash. Hypothetical data has inherent limitations, some of which are disclosed in the Appendix.

14 There are cases where shorter horizons can be more appropriate – for example, for a tactical decision or any investment that is expected to be held for a short time. Another is for organizations with a finite life: The Gates Foundation has the stated objective to spend all its resources within 20 years of its founders' deaths.

Part 2: Results — Asset Class Diversification

It's Not Perfect, But It Grows on You

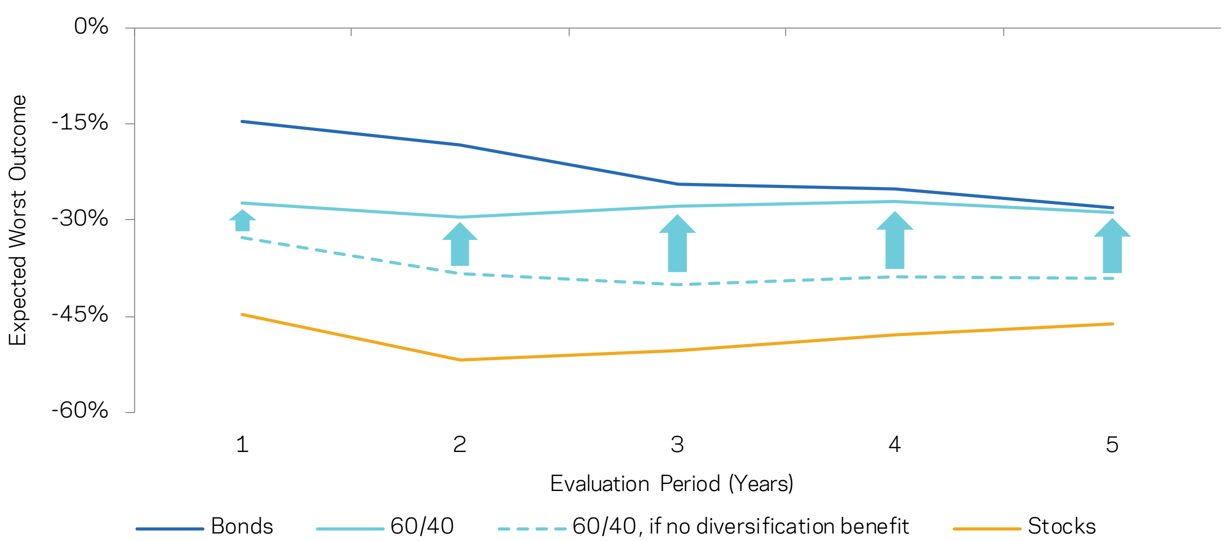
A common criticism of diversification is that it doesn't protect you from a crash. Unfortunately, assets that are designed to protect investors from crashes (e.g., direct hedges) tend to be costly over the long term.[15]

Fortunately, shorter-term crashes themselves don't matter as much to long-term wealth outcomes as may be feared. The big risk for investors with multi-year horizons isn't short-term worst outcomes; it's long-term ones.[16] Multi-year bad outcomes are the ones that are more likely to prevent investors from reaching their long-term return goals — so with this in mind, we look at diversification's ability to mitigate bad multi-year outcomes.[17]

Exhibit 2 once again shows the worst expected outcomes for the 60/40 portfolio, but now we add its two underlying asset classes as separate lines. Stocks are clearly riskier than bonds, as shown by the depth of worst expected outcomes.

So, what about diversification? Over a 1-year evaluation period, it doesn't look like diversification has done much. The 60/40 line is what we might expect for something made of 60% the orange line and 40% the blue line (for comparison, the simple 60/40 average of the stock and bond lines is the dashed line; this can be thought of as 60/40 if there were no benefit to diversification).

Exhibit 2: Better Late Than Never



Source: AQR. For illustrative purposes only. The simulation uses 60/40 portfolio data (monthly rebalanced) from August 1957 – May 2021 (i.e., the underlying asset returns are from the same periods, to preserve information such as correlations). The solid lines are the results of 100,000 30-year simulations. The dashed line is 60% the Stocks line and 40% the Bonds line. All returns are excess-of-cash; had we shown total returns the general results still hold. Simulations in this exhibit use 30-year horizons, but the results are directionally robust to the other horizons described in this article. Hypothetical data has inherent limitations, some of which are disclosed in the Appendix.

15 See Ilmanen et al. (2021) and references therein.
16 McQuinn, Thapar and Villalon (2021).
17 Following the general concept of Asness, Israelov and Liew (2011), though here using simulations.

The story changes once we look out a few years. Even though 60/40 has more than half its weight in the risky asset, it starts to look more and more like the low-risk asset from an "expected worst outcome" perspective. This is because worst outcomes tend to happen at different times for different assets — and this can become economically meaningful at multi-year horizons. Bottom line: even though diversification might not seem to do much at an annual evaluation period, it can add a lot of value over multiple years.

(Additional) Asset Class Diversification Works

Our focus so far has been on U.S. stocks and bonds, and our results can largely be extended to similar asset classes, such as international stocks and corporate credit. In this section, we go a step further by examining the addition of a non-traditional asset class to a traditional portfolio.

Traditional portfolios are less diversified than they may seem — for example, because stocks are riskier than bonds, they end up accounting for more than 90% of the canonical 60/40 portfolio's risk budget. One alternative approach to asset class diversification is risk parity, which weighs stocks and bonds in a more risk-balanced way and generally seeks to include additional asset classes — almost always including an inflation-related asset class, such as commodities.

In **Exhibit 3**, we repeat our previous analysis of worst expected outcomes for 60/40 but now compare it to two other portfolios: the first a "simple risk parity" (SRP) portfolio, and the second, a 50/50 combination of the two (i.e., 50% in 60/40 and 50% in SRP).[18]

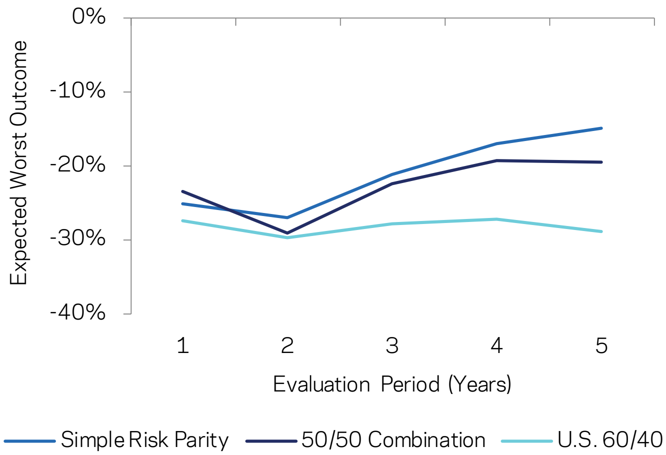
As we'd expect, the more-diversified SRP has better expected worst outcomes than 60/40 — a benefit of not being dominated by a single source of risk (and its higher risk-adjusted returns). But maybe surprisingly, the *50/50 combination looks almost identically as good as SRP*. Why? Once again, diversification: the worst periods for SRP did not happen at the same times as the worst periods for 60/40, and vice versa.

This highlights the fact that when it comes to diversification, getting "perfectly" diversified (in this case, SRP) doesn't have to be the goal – for many investors, a valuable objective can be merely getting more diversified than they are today.

But what if the evidence from the past 60+ years is misleading? What if SRP doesn't have an edge in terms of returns or risk-adjusted returns — is asset class diversification still "worth it"? Yes. In this case, largely due to the reduction in overall portfolio volatility, which we focus on next.

18 The SRP portfolio is a hypothetical strategy made of three asset classes: developed equities (GDP-weighted), government bonds (GDP-weighted) and commodities (equal-weighted). SRP targets a volatility of 10% by allocating equal volatility to the three assets based on their trailing 12-month volatility. See Exhibit 3 for summary statistics. Even though SRP tends to have a larger bond allocation than 60/40, Hurst, Mendelson and Ooi (2013) show falling yields were not the primary reason for its long-term outperformance.

Exhibit 3: Diversification: Where "Good Enough" Can Be Pretty Great



	U.S. 60/40	SRP	50/50 Combination
Excess-of-Cash Return	4.6%	7.2%	5.9%
Volatility	9.4%	9.7%	8.8%
Sharpe ratio	0.49	0.74	0.67

Source: AQR. For illustrative purposes only. The simulation uses stock, bond, and commodities data from August 1957 – May 2021 to build the 60/40 and SRP portfolios (all portfolios follow monthly rebalance schedules). The SRP portfolio is a hypothetical strategy made of three asset classes: developed equities (GDP-weighted), government bonds (GDP-weighted) and commodities (equal-weighted). SRP targets a volatility of 10% by allocating equal volatility to the three assets based on their trailing 12-month volatility. All returns are cumulative excess-of-cash returns; had we shown total returns, the results would be directionally similar. For illustrative purposes only and not representative of a portfolio AQR currently manages. Hypothetical data has inherent limitations, some of which are disclosed in the Appendix.

Part 3: Results — Beyond Traditional Asset Classes

Same Returns with Less Risk Is a Really Good Thing

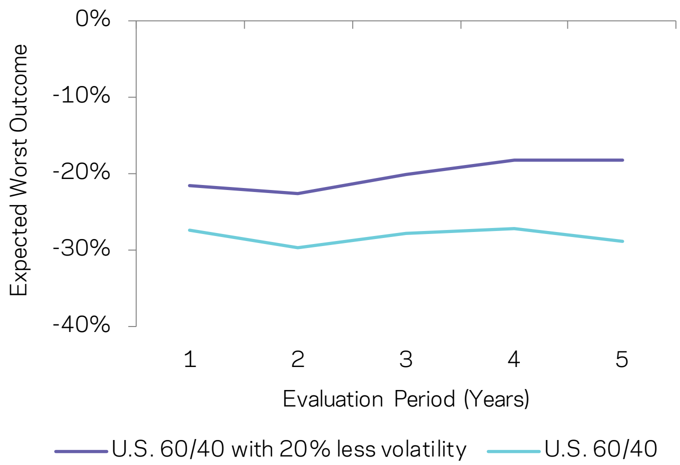
Not enough is said about the value of reducing a portfolio's risk while maintaining its expected return — a goal that is common to many alternative asset classes and strategies. While most investors can easily quantify the return impact (none), the risk part is harder, and maybe because of this it is often underappreciated.

Exhibit 4 compares two portfolios: the first a U.S. 60/40 portfolio, and the second a portfolio with the same average return but with 20% lower volatility.[19] The two lines are the expected worst outcomes for each.

The lower-risk portfolio has clear advantages beyond "merely" lower volatility. Its expected worst cases aren't as bad, and as a consequence, it has shorter lengths of time experiencing losses (due to having the same average returns).

19 To keep things apples-to-apples, these portfolios are 1.0 correlated with each other. Why 20% volatility reduction? For many portfolios this is in the range of possibility: for example, allocating 20% of a 60/40 portfolio, pro rata, to an uncorrelated asset with the same volatility as 60/40 results in a "new" portfolio with about 20% less volatility. In practice, investors have a range of choices to reduce portfolio volatility while maintaining expected returns, from allocating to "defensive" assets, to incorporating diversifying assets and strategies that often use prudent leverage to target 60/40-like returns (not all investors use diversification to lower portfolio volatility – some investors might instead choose to use more aggressive diversifiers to monetize higher expected risk-adjusted returns).

Exhibit 4: More Vol, More Problems



	U.S. 60/40	U.S. 60/40 (20% Less Vol)
Excess-of-Cash Return	4.6%	4.6%
Volatility	9.4%	7.5%
Sharpe ratio	0.49	0.61

Source: AQR. For illustrative purposes only. The simulation uses 60/40 portfolio data from August 1957 – May 2021 (both portfolios follow monthly rebalance schedules). Data above uses 100,000 30-year simulations and reports the median worst cumulative excess-of-cash return over the periods shown on the x-axis. Results are directionally similar had we shown total returns. Hypothetical data has inherent limitations, some of which are disclosed in the Appendix.

Not So Smooth(ed) Sailing...

Many illiquid strategies, such as private equity, have prices that are lagged or otherwise smoothed compared to their liquid counterparts. This smoothing mechanically reduces the strategy's reported volatility – and gives the investor returns that appear less risky than the strategy's underlying economic exposures would suggest.[20]

One practical consequence of this "feature" is that it can allow investors to increase their exposure to illiquids without much of an effect on their overall portfolio's reported month-to-month volatility. But this ignores a problem: while the risk from smoothing might not manifest itself in brief tail events (e.g., the Covid drawdown), it has nowhere to hide in longer ones.

Exhibit 5 provides an idea of how much smoothing can matter. The green line represents an aspiration for many illiquids: equity-like returns with lower volatility, which we achieve in the exhibit by taking S&P 500 returns and mechanically reducing their volatility by 50%. The blue line is very similar – S&P 500 returns with 50% of the volatility – but with one important difference: the volatility reduction here has been achieved by smoothing (specifically, by averaging each current and previous month's S&P 500 return).[21]

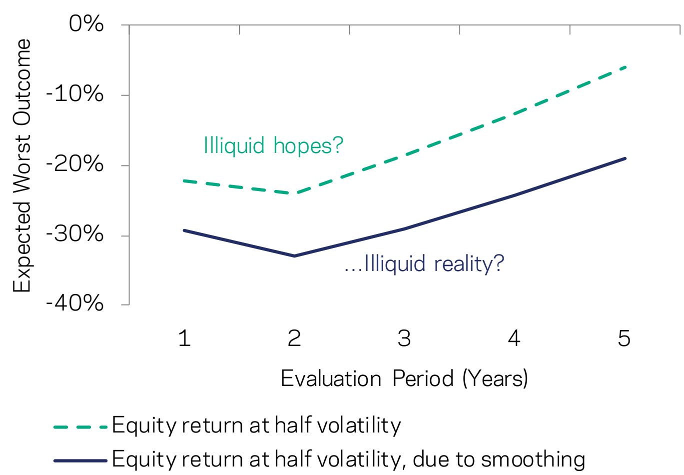
What this means for investors is that risk estimates of their illiquid assets may be meaningfully understated. Investors who hold illiquid assets should expect deeper (and more sustained) worst outcomes than what conventional risk/return statistics might suggest. This, paired with the economic fact that many kinds of illiquid assets are fundamentally akin to their liquid counterparts suggests the purported "risk reduction" benefits of private assets may indeed be too good to be true.[22]

20 See Ilmanen, Chandra and McQuinn (2020) for how to build assumptions for illiquid asset classes; and Ilmanen (2020) for the return impact that smoothing can have on private equity returns.

21 This amount of smoothing is probably a conservative (and thus, kind) representation of major illiquid assets. The smoothed series in Exhibit 5 has quarterly returns that are 0.20 serially correlated, compared to 0.59, 0.28 and 0.31 for the Cambridge U.S. Venture, U. S. Buyout and U.S. Private Equity indexes, respectively (using Cambridge data starting from 3/31/1981, 3/31/1986, and 3/31/1994 through 6/30/2020). If we were to match Exhibit 5's smoothed series to these empirical serial correlations, the worst outcomes would be even worse. (Note: we compare quarterly returns in this footnote, as that's the frequency of the Cambridge data.)

22 There are benefits of illiquidity, many of which are outlined in Asness's "The Illiquidity Discount?". The focus of this article, though, is to estimate the economic magnitude of multi-year bad outcomes.

Exhibit 5: Smoothed Returns Are Riskier Than You Might Think



	Equity return at half vol	Equity return at half vol, due to smoothing
Excess-of-Cash Return	6.5%	6.5%
Volatility	7.3%	7.3%
Sharpe ratio	0.89	0.89
Autocorrelation (monthly)	0.0	0.5

Source: AQR. For illustrative purposes only. Data above uses 100,000 30-year simulations and reports the median worst cumulative excess-of-cash return over the periods shown on the x-axis. "Equity return at half volatility, due to smoothing" uses S&P 500 returns, adjusted to have a 0.5 autocorrelation in monthly returns. "Equity return at half volatility" also uses S&P 500 returns, but with the volatility adjusted down to match that of the smoothed series. All returns are cumulative excess-of-cash returns. Hypothetical data has inherent limitations, some of which are disclosed in the Appendix.

Conclusion

Making Matters Worse...

Expected returns across a range of asset classes today are lower than their historical averages, yet the same is not true for expected risks. The past decade presented overall very friendly conditions for stocks and bonds (generally growth above forecasts, inflation below, and falling yields), but it would be imprudent to assume these conditions will repeat themselves over the next decade. Setting expectations — for investors, boards, and other stakeholders — is arguably going to be much more important from here. This paper introduces a framework to help investors set and quantify "worst case" expectations, and it can be used for a range of portfolios and sizing decisions.

We remind readers that the results shown in these exhibits are "expected" worst cases; this article describes not how bad something could be, but rather how bad something *should* be. For those investors who believe the future will look worse than the past, we can easily quantify less probable, but still very possible, outcomes that stakeholders should be prepared to face on the path to achieving their long-term objectives.

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APPENDIX

Throughout this article "expected bad outcomes" are the median worst cumulative excess-of-cash returns from 100,000 stationary block bootstrapped simulations, using 46-month long blocks, over a 30-year horizon.

U.S. Stocks are represented by the S&P 500 Index. Source: AQR, Ibbotson, Bloomberg.

U.S. Bonds are represented by 10-year U.S. Treasury Notes. Source: AQR, DataStream, Global Financial Data.

Cash is represented by the BofA 3-Month T-bill Index. Source: Bloomberg.

Simple Risk Parity is a hypothetical long-only model portfolio that allocates equal risk across three major asset classes (GDP-weighted developed equities, GDP-weighted developed nominal bonds, and equal-weighted commodities). Developed equities and developed nominal bonds include Australia, Canada, France, Germany, Italy, Japan, Netherlands, Spain, the United Kingdom, and the United States. Commodities include agriculturals, energies, and metals. The portfolio is constructed with a dynamic risk model that attempts to size positions so that each asset class contributes equally to marginal portfolio-level risk at each point in time. The dynamic risk model is composed of volatility and correlation forecasts for each asset class, which will vary in response to changes in the risk environment. The portfolio targets an annualized volatility of 10%. The portfolio imposes exposure limits on individual asset classes. Each asset class is built with the most relevant instrument available at each time point, including individual stocks, equity indexes, equity index futures, equity index swaps, developed bonds, developed bond futures, and commodity futures. The portfolio is gross of fees and net of transaction cost estimates.

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