VOLATILITY AND CORRELATION ASSUMPTIONS

Stable long-term forecast; rising risks in the short term

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IN BRIEF

- Our long-run volatility expectations remain stable. Although markets have become further entrenched in late-cycle dynamics since last year, we see little in the way of structural change to alter our long-term view for most asset classes.
- Equity market movements have become more significant recently, which translates into marginally higher equity volatility forecasts, led by the U.S.
- Portfolio construction that includes a measure of downside risk can help mitigate drawdowns – especially relevant when recession risk increases.
- Our case study finds that, compared with a conventional Sharpe ratio-based portfolio optimization, a Sortino ratio-based optimization realized lower drawdowns during market downturns.

Please note that our long-term capital market assumptions were calculated as of September 30, 2019 and published in November 2019, and thus do not reflect recent extreme price moves in many asset markets resulting from the ongoing COVID-19 disruption. Please reach out to ltcma.inquiries@jpmorgan.com for more information.

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LITTLE CHANGE IN LTCMA VOLATILITY FORECASTS

Since Q4 2018, stock and bond prices have experienced sizable volatility spikes. As we discussed in last year's edition of *Long-Term Capital Market Assumptions (LTCMAs)*, we expect higher volatility as fragility increases the further economies travel along the business cycle into late-cycle territory. Indeed, equity market movements have clearly become more extreme recently (**Exhibit 1**). When we compare the past 30 years with the 12 months ended July 2019, the incidence of both right- and left-tail occurrences – extreme events at both ends of the spectrum – rose. This amplified market movement translates into marginally higher long-term volatility forecasts this year for equity markets, led by the U.S. market, the epicenter of the sell-offs and subsequent recoveries in the months prior to publication.

That risk has grown is not surprising; however, what may be unexpected is how small the magnitude of the adjustments to our LTCMA volatility forecast is this year, considering the increased frequency of large market moves, shown in Exhibit 1. We remind readers that our assumption is an expectation of the volatility and correlation environment over a 10- to 15-year time horizon – the expected long-run average experience. As **Exhibit 2** highlights, the outlook is stable from a long-run perspective, as we had already built increased short-term volatility into prior years' forecasts.

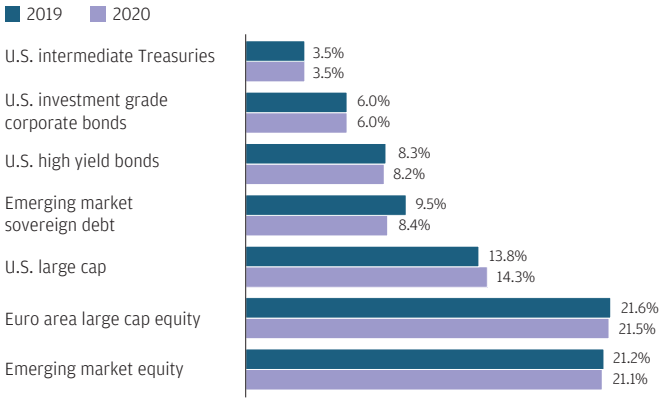
Histogram of S&P 500 monthly returns highlights the increased frequency recently of more extreme market movements

EXHIBIT 1: HISTORICAL DISTRIBUTION OF U.S. LARGE CAP STOCK RETURNS

Source: Bloomberg, J.P. Morgan Asset Management; data as of July 31, 2019. For illustrative purposes only.

Forecast: Stable long-term volatility despite increased likelihood of short-term vol spikes

EXHIBIT 2: COMPARISON OF LTCMA VOLATILITY FORECASTS BY ASSET CLASS, 2019 VS. 2020 (USD)



Source: Bloomberg, J.P. Morgan Asset Management; data as of September 30, 2018, and September 30, 2019. For illustrative purposes only.

STABLE LTCMA VOLATILITY FORECAST DOES NOT IMPLY SMOOTH SAILING IN THE NEAR TERM

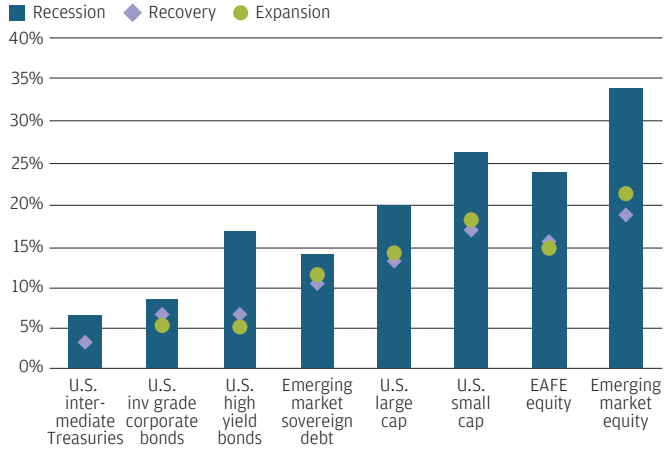
The stability of our 2020 forecast compared with last year's masks a key message about the dynamic nature of risk and correlation: Although long-run expectations can be rather stable, volatility and correlation tend to change under different economic regimes.

To illustrate this, we define three economic regimes: expansion, recession and recovery. Our definitions combine National Bureau of Economic Research (NBER) definitions and J.P. Morgan Asset Management's proprietary business-cycle assessment.[1] The most significant change in volatility occurs during the recession period, when volatility can increase by almost 50% compared with the expansion period (**Exhibit 3**). Among the three regimes, recoveries tend to have the lowest volatility. The implication is that, based on shorter-term measures, investors should expect increasing volatility approaching and heading into an economic contraction.

[1] In addition to the NBER definition, we leverage J.P. Morgan Asset Management's business-cycle indicator, or BCI, based on a collection of 20-plus macroeconomic indicators, such as output gap, employment rates and personal consumption expenditures (PCE) core inflation. Each indicator independently determines the business-cycle phase: early, mid, late and recession. After aggregating individual signals, the output is the economic phase with the highest probability. BCI's and NBER's business cycles are mostly aligned (recession periods from the two indices overlap, and BCI's early to late phases map to NBER's expansion period). In this illustration, we define NBER's contraction periods as recession and BCI's early phase as recovery, and combine BCI's mid and late phases into expansion.

Volatility varies significantly under recovery, expansion and recession regimes. Recession vol can be 50% higher than during calmer expansion periods

EXHIBIT 3: HISTORICAL VOLATILITY UNDER VARYING ECONOMIC REGIMES SINCE 1978



Source: Bloomberg, J.P. Morgan Asset Management; data as of June 30, 2019. Data starts from 1978 or earliest available. For illustrative purposes only.

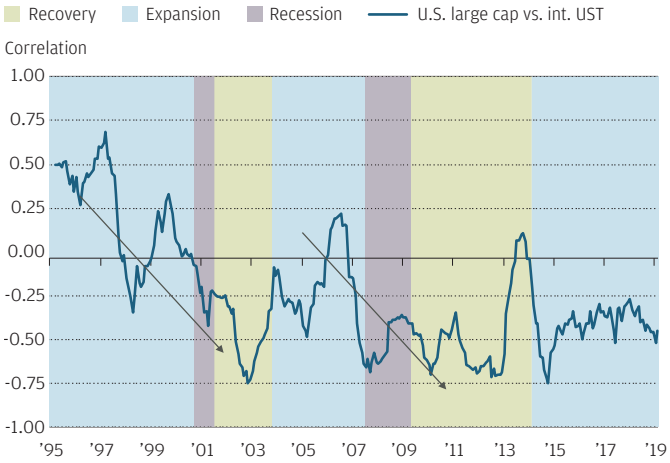
Correlation is another aspect of risk that is highly variable by time. In this year's LTCMA correlation assumptions, the pairwise correlation between equity and government bonds (hedged) is typically between -0.2 and -0.3. This negative correlation is built into how investors, including our own, design multi-asset portfolios. One may question the benefit from stock-bond diversification, given the prevailing levels of correlation, but historically, government bonds tend to be more negatively correlated to equities as economies move toward recession (**Exhibit 4**). The correlation assumption embedded in our LTCMA forecasts represents the average long-run experience between stocks and core government bonds. Over a full economic cycle, the typical value lies between 0.3 and -0.7. Our expectation is that short-term correlations will retest historical lows when recession occurs. As we discuss in the "Rethinking safe haven assets" paper in this edition of *LTCMA*, low stock-bond correlations mean that core government bonds still have a role to play in portfolio protection, even as ultra-low starting yields have increased the opportunity cost of ownership.

LONG-TERM VOLATILITY ASSUMPTIONS: OUR 2020 LTCMAS

Although markets have become further entrenched in late-cycle dynamics since last year's edition, we see little in the way of structural change to alter our long-term view for most assets. Our unbiased forward-looking probability of stressed and high volatility periods remains unchanged at 15% – typical for the modern economy since the 1980s. This 15% figure represents the cycle-independent probability that a downturn might occur in any given future year and is simply based on the historical frequency of downturns. Readers with a cyclical outlook will note – as do we – that with the business cycle in an advanced stage, the prevailing probability of a downturn currently sits some way above the 15% baseline across a range of common economic metrics. This leads us to keep our long-term risk forecast close to last year's assumptions.

Correlation between stocks and bonds tends to fall and become more negative going into and during recessions

EXHIBIT 4: ROLLING 1-YEAR CORRELATION BETWEEN U.S. LARGE CAP EQUITIES AND TREASURY BONDS SINCE 1990s



Source: Bloomberg, J.P. Morgan Asset Management; monthly data as of June 30, 2019. Rolling 12-month correlation between S&P 500 and U.S. intermediate Treasuries (UST). For illustrative purposes only.

One change in our 2020 vs. 2019 forecast is a decline in the relative attractiveness of government bonds, on both an absolute and a risk-adjusted return basis, as a result of their recent rally. In last year's assumptions, the risk-adjusted returns of fixed income, including both government and corporate bonds, along with real assets, were rather attractive. In this year's estimates, the relative risk-adjusted returns/Sharpe ratios for government bonds – especially long-duration bonds – have deteriorated substantially. Credit assets, such as high yield (HY) and loans, are the bright spots within fixed income. Equities are in the middle of the pack, and real assets continue to offer the best risk-adjusted returns and diversification benefits.

However, with concerns looming about the late cycle, it will be important to keep a close eye on the downside risk of assets with a nonsymmetric return profile, such as credit. In last year's edition of *LTCMA*, we highlighted as a cautionary tale a number of assets that have historically exhibited "fat tails."[2] This year, we continue the conversation with our Special Topic section on how to construct portfolios with an eye on downside.

[2] Situations in which the probability of a negative return is more frequent and the probability of a decline more sizable than a simple normal distribution would suggest.

Central bank activity has risen once again around the world as global growth has slowed and trade tensions have risen. The distortion in short-duration instruments has continued dampening fixed income volatility, especially on the short end of government bond markets. Our volatility assumptions incorporate the normalization of volatility levels for short-duration instruments, to reflect the eventual removal of central bank stimulus over our forecast horizon. The magnitude of this adjustment is marginally reduced, as the normalization seems more distant than it did last year.

Select credit markets are likely to undergo higher volatility over the forecast horizon compared with historical experience. We flag the gradual decline in quality in the composition of the investment grade corporate bond market over the past decade: With the majority of U.S. investment grade bond market issues now BBB rated, risk has increased relative to past years, when more bonds were of better quality. The risk of downgrade to junk bond status has also increased. A similar decline in credit quality can be observed in Europe, contributing to our view that forward-looking risks in investment grade corporate bonds are likely to be higher than history would suggest in the U.S. and the euro area.

Not all credit markets should see increased volatility. We expect European high yield, for example, to be less volatile relative to historical standards. The quality of euro HY bonds has improved in recent years, and we expect strong demand, driven by investors' search for yield, to help stabilize price volatility (as more fixed income assets in Europe have turned to negative yields). Emerging market sovereign debt is also seeing quality improvements and better issuers. The inclusion of the Gulf Cooperation Council (GCC) countries has helped upgrade the asset class structurally, aligning its risk outlook to higher credit quality assets. Another structural change: The benchmark Bloomberg Barclays Global Aggregate Bond Index's inclusion of Chinese bonds – the world's third-largest bond market – should, over time, impact the fixed income index's composition and risk relative to history.[3]

Within equities, we expect risks to stay in line with long-run historical levels. Our risk forecasts for alternative assets have been reduced marginally, in particular for real estate. We retain the view that leverage in real estate and REITs is likely to stay below the peaks reached during the last cycle.

[3] Chinese bonds will account for a 6% weight once this phase of inclusion is rolled out, over the 20 months beginning April 2019.

SPECIAL TOPIC: DOWNSIDE RISK REMAINS A FOCUS AS LATE-CYCLE DYNAMICS DEEPEN

As economies venture deeper into the late-cycle environment, answering the question of how to construct a robust strategic portfolio is becoming more crucial. While a mean-variance (M-V) framework is essential and useful, its assumptions inherently lead to underestimating the risks when return distribution is not symmetrical, something especially relevant going into recession. The Sharpe ratio, one of the most referenced measures in the mean-variance framework, is therefore not a robust measure of risk-adjusted return for portfolios with large concentrations of assets with higher downside risks. Investors may want to consider expanding their portfolio construction objectives to include downside risk mitigation beyond the standard M-V optimization.

Exhibit 5 shows how portfolio construction that includes a measure of downside risk can help mitigate drawdowns. We select eight assets[4] from our LTCMA universe and consider two portfolio optimization approaches: a traditional mean-variance optimization that maximizes the Sharpe ratio[5] and an alternative optimization that maximizes the Sortino ratio.[6] Both optimizations are subject to the same set of constraints. The difference between the Sharpe and Sortino ratios is that the Sharpe ratio focuses on the return volatility of the full distribution, while the Sortino ratio focuses on the downside risks – i.e., returns below a target value.

Sample diversified portfolio with four fixed income assets and four equity assets, optimized with two objective functions

EXHIBIT 5: PORTFOLIO OPTIMIZATION SETUP

Objective	Constraints
Maximize Sharpe ratio	Long only
Maximize Sortino ratio	Sum positions = 100%
	Total fixed income or equity notionals </= 70%
	Single asset percentage risk contribution </= 20%
	Total fixed income percent risk contribution </= 40%

Source: Bloomberg, J.P. Morgan Asset Management; monthly data as of June 30, 2019. For illustrative purposes only.

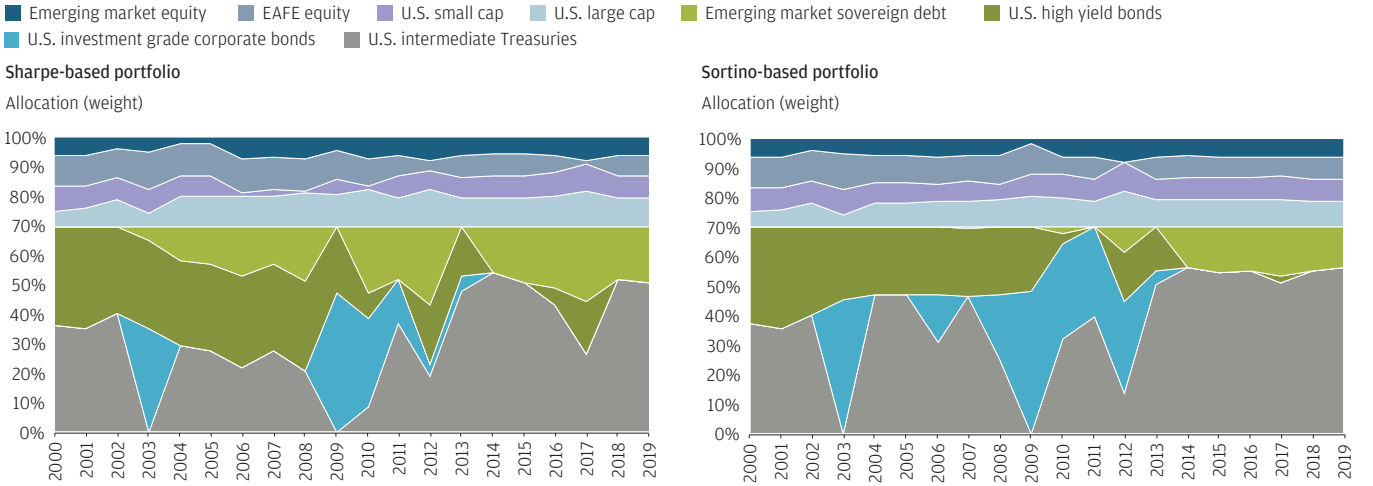
[4] U.S. intermediate Treasuries, U.S. investment grade corporate bonds, U.S. high yield bonds, emerging market sovereign debt, U.S. large cap equity, U.S. small cap equity, EAFE equity and emerging market equity.

[5] Sharpe ratio: $\frac{r_p - r_f}{\sigma_p}$ (i.e., excess portfolio expected return over portfolio volatility).

[6] Sortino ratio: $\frac{r_p - r_f}{\sigma_p^{down}}$ (i.e., excess portfolio expected return over portfolio downside volatility).

The Sortino ratio-based portfolio has more weight allocated to Treasuries and less to risky assets than the Sharpe ratio-based portfolio

EXHIBIT 6: ASSET ALLOCATION FROM TWO OPTIMIZATIONS WITH ANNUAL REBALANCE



Source: Bloomberg, J.P. Morgan Asset Management; annual data as of June 30, 2019. For illustrative purposes only.
We used 10-year historical average returns as the target for individual assets, so the downside risk term in the Sortino ratio case captures the volatility of returns below the mean.

We run a historical out-of-sample test using return assumptions from our 2000 to 2019 LTCMAs, assuming annual rebalancing at the beginning of each calendar year. The covariance and downside covariance matrices are calculated from 10-year historical monthly returns prior to each rebalance date. At the beginning of each rebalance period, we run both optimizations, obtain their allocation weights and buy and hold assets accordingly until the next rebalance date. **Exhibit 6** shows the asset allocations over the testing period from 2000–19. As expected, allocations to low risk assets (i.e., Treasuries and investment grade bonds) are substantially higher in the Sortino ratio-based portfolio than in the Sharpe ratio-based portfolio. Meanwhile, allocations to assets with higher downside risks – such as high yield bonds, emerging market debt and equities – are much smaller in the Sortino ratio-based portfolio.

Performance-wise, the two portfolios result in similar returns. However, the Sortino ratio-based portfolio realizes less volatility and smaller drawdowns, reflected in smaller annual risk, value at risk (VaR) and maximum drawdown values (**Exhibits 7A** and **7B**). The Sortino optimization also has a lower annual turnover, which could further lift performance after transaction costs.

An alternative measure that highlights the difference in risk mitigation between the two approaches is to compare the performance of long-term buy-and-hold strategies.[7] Results show that maximum drawdowns over a 10-year holding period appear less severe with Sortino optimization for portfolios incepted at different times, as shown in **Exhibit 8**, and that the two approaches have similar portfolio values at the end of the 10-year holding period.

The result of comparing a Sortino ratio optimization with a conventional mean-variance optimization is intuitive. This illustration is constructed using very simple constraints and doesn't consider path dependencies or transaction costs for portfolio rebalancing. It does, however, highlight the potential benefit of further incorporating downside considerations into portfolio design.

[7] In order to match the 10- to 15-year time frame of our LTCMAs, we compare the 10-year buy-and-hold performance of 11 portfolios with inception dates from 2000 to 2010 under the Sharpe ratio and Sortino ratio approaches. Optimization was only done at inception with LTCMAs from the previous year.

Our case study finds Sortino optimization has similar risk-adjusted returns but lower drawdowns and less severe left-tail realizations

EXHIBIT 7A: OUT-OF-SAMPLE PERFORMANCE FOR SHARPE RATIO- VS. SORTINO RATIO-BASED OPTIMIZED PORTFOLIOS WITH ANNUAL REBALANCE (2000–19)

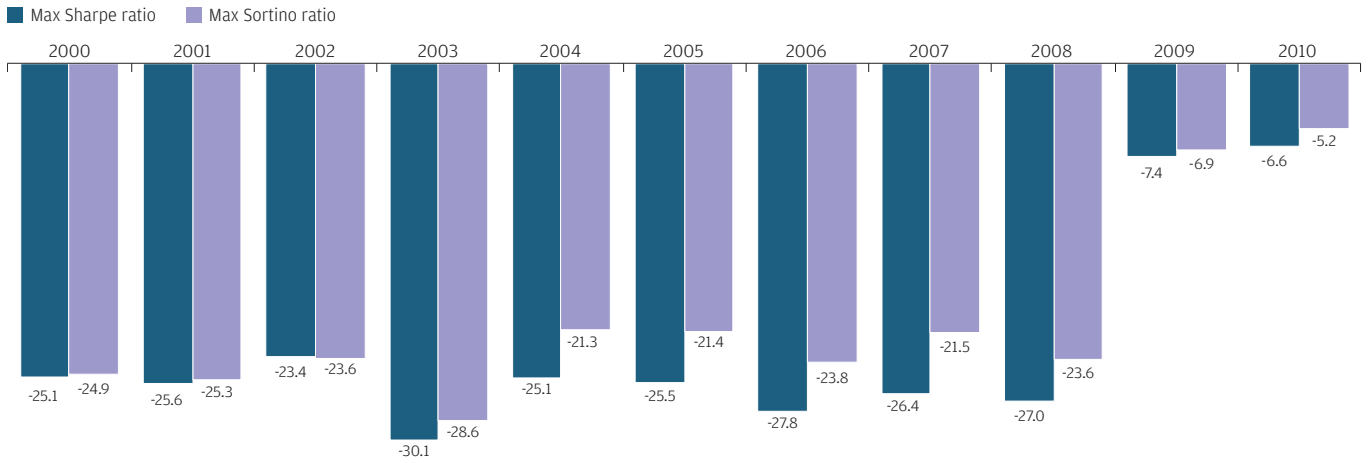
Performance 2000–19	Max Sharpe ratio	Max Sortino ratio
Annual return	6.5%	6.0%
Annual risk	10.8%	9.7%
Risk-adjusted return	0.60	0.62
Annual turnover	42.7%	37.7%
Maximum drawdown	-21.1%	-16.8%
Maximum drawdown period	2008	2008
95% VaR	-12.3%	-10.1%

EXHIBIT 7B: YEAR-OVER-YEAR RETURNS, SHARPE RATIO- VS. SORTINO RATIO-BASED OPTIMIZED PORTFOLIOS WITH ANNUAL REBALANCE (2000–19)

Source: Bloomberg, J.P. Morgan Asset Management; annual data as of June 30, 2019 (2019 return is from January 1, 2019, to June 30, 2019). For illustrative purposes only.

Portfolio optimization with a focus on downside risk vs. symmetric risk may be better able to mitigate risk in a major market drawdown for buy-and-hold strategies

EXHIBIT 8: MAXIMUM DRAWDOWNS OVER 10-YEAR PERIOD FOR BUY-AND-HOLD STRATEGIES BY INCEPTION YEAR USING SHARPE RATIO- VS. SORTINO RATIO-BASED OPTIMIZATIONS



Source: Bloomberg, J.P. Morgan Asset Management; annual data as of June 30, 2019 (2019 return is from January 1, 2019, to June 30, 2019). For illustrative purposes only.

VOLATILITY AND CORRELATION ASSUMPTIONS METHODOLOGY

Long-term asset class volatilities and correlations tend to exhibit stability when measured over multiple cycles. As such, we use the following process in estimating long-term volatility and correlation assumptions for the main asset classes:

1. START WITH MONTHLY HISTORICAL RETURN DATA

- In last year's estimates, we used 12 years of historical data as the anchor. This year, we increase the data window again, from 12 years to 13 years.

2. FILTER DATA OUTLIERS

- Extreme data outliers could bias volatility estimation and are filtered to improve robustness. This is done by winsorizing* historical raw data.

3. CONSTRUCT ANCHOR MATRIX

- We leverage historical experience to help anchor our forward-looking expectations, focusing on:
  - Simple historical return series (with each data point equally weighted)
  - Historical return series with each data point weighted by "relevance" (based on forward-looking expectations of the frequency of the economic regimes: recovery, expansion and recession)
- The variance-covariance matrix is calculated using the filtered dataset.
  - Demean filtered data
    - After filtering the data, we demean each data point by the average of the full sample and compute the variance-covariance matrix.

4. ADJUST FOR KEY THEMES AND STRUCTURAL CHANGES

- Key themes and structural changes that are expected over the forecast horizon, such as those highlighted in this article, are reflected in the long-term risk forecast accordingly.

5. ENSURE STABLE NUMERICAL PROPERTY – SYMMETRIC POSITIVE SEMIDEFINITE COVARIANCE MATRIX

- For a covariance matrix to be used in optimizations, it needs to be symmetric and positive semidefinite (PSD).† Due to inconsistencies in the underlying datasets (e.g., monthly returns for liquid assets and quarterly returns for illiquid assets), a covariance matrix including both liquid and illiquid assets may not be guaranteed to be PSD. Therefore, we introduce a methodology by Higham (1988)‡ to find the nearest symmetric positive semidefinite matrix in Frobenius norm to the original covariance matrix computed from raw returns. We then calculate the adjusted volatilities and correlations from the PSD covariance matrix, and these numbers become our official assumptions.

Alternative assets have fundamental differences from public assets, in the frequency of their data and the subjectivity of their mark-to-market process. Because comparability across asset classes, to evaluate their relative attractiveness, is an essential part of the LTCMA forecast, we forecast alts' underlying economic volatility. That is, we provide risk forecasts that represent the inherent risk of owning the assets, instead of the assets' reported accounting volatility. More details on this adjustment can be found in the full methodology paper, available on the 2020 LTCMA website.

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* Winsorization applies a cap and a floor to extreme data values to remove the impact of potentially spurious outlier data on statistical results.

† A positive semidefinite matrix is defined as a symmetric matrix with nonnegative eigenvalues; this property guarantees a global minimum solution for a mean-variance optimization.

‡ Nicholas J. Higham, "Computing a nearest symmetric positive semidefinite matrix," *Linear Algebra and Its Applications* 103 (May 1988).

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