2016 Long-Term Capital Market Forecasts

White Paper | January 2016

By
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Introduction

Our long-term capital market forecasts provide our estimates of expected returns, volatilities and correlations among major U.S. and global asset classes over a ten-year horizon. These estimates guide strategic asset allocations for our multi-asset portfolios and provide a context for shorter-term economic and financial forecasting.

As has been the case for the past six years, our forecast models an explicit process of convergence to a steady-state equilibrium for global economies and financial markets through 2025. We make this explicit forecast in recognition of the ongoing effects of the 2007–09 financial crisis and recession, the European debt crisis, and the fiscal and monetary policy responses to these events. Although the world economy is several years past its most acute point of crisis in 2008 and the U.S. economy has been recovering from the Great Recession for more than six years, a number of economic and financial variables remain far from levels consistent with the steady state. In particular, short-term interest rates remain near zero in most developed economies, long-term interest rates have declined substantially, and government debt-to-GDP ratios remain elevated. Figure 1 shows the 2025 values from this forecast, which is consistent with our estimates of longer-term steady-state values for key U.S. economic variables.

Figure 1. U.S. Economic and Financial Variables

	2025 Forecast (%)
GDP Growth	2.0
Inflation (CPI-U)	2.2
Federal Funds Rate	3.6
Ten-Year Treasury Yield	4.4
S&P 500 Earnings Growth	3.5

Source: Voya Investment Management, Macroeconomic Advisers

In our modeling process we have again worked with Macroeconomic Advisers for the United States and utilize input from Oxford Economics for non-U.S. economies. We believe that cyclical fluctuations are an inevitable aspect of market economies and therefore recognize that the steady-state equilibrium incorporated as the terminal point of our forecast is unlikely ever to be fully attained under real world conditions. Nonetheless, we believe that this is a useful theoretical construct for anchoring the forecast. As a result, the forecast does not assume a further recession or contraction over its ten-year horizon.

As expected we find that cyclically sensitive assets like equities and the riskiest credit instruments are likely to provide risk-adjusted returns superior to those of most fixed income assets, particularly government bonds, over the ten-year horizon. Nevertheless the relative attractiveness of risky versus less-risky assets, as measured by their respective Sharpe ratios, is becoming more balanced than it was a year ago. This results from the modest performance of U.S. equity categories in 2015 and from the decrease in GDP growth expectations and associated terminal sovereign bond yields. More modest growth expectations also contribute to the lowest Sharpe ratios since the onset of the post-crisis recovery.

Risk-adjusted returns for other developed market assets are in most cases less than those for comparable U.S. assets. For example, we forecast an arithmetic mean return of 6.4% for the S&P 500 Index but 5.0% for the MSCI EAFE Index, and we expect an arithmetic mean return of 2.8% for the Barclays U.S. Aggregate Bond Index but just 0.1% for the Barclays Global Aggregate excluding U.S. fixed income assets. This partially reflects our expectation that the U.S. dollar will appreciate over the ten-year horizon versus other developed market currencies as the U.S. current account deficit shrinks as a share of GDP. However, it also reflects lower expected domestic currency returns for these markets. Returns from large-capitalization European equities are likely to be somewhat lower than U.S. returns over the period because slower trend economic growth should translate into slower earnings growth. Other developed country bond returns are expected to be lower than U.S. fixed income returns as the process of interest rate normalization should prove slower in Europe and Japan than in the U.S. Quantitative easing (QE) programs promised by European and Japanese central banks should be more significant, and government bond yields in both locations are starting the period from lower levels than U.S. Treasury yields.

By contrast returns for emerging market equities and debt are in line with or higher than those for comparable U.S. assets, even after adjusting for their greater volatility. This return forecast assumes that political reform in the emerging world remains successful on balance, so that GDP growth in these countries remains higher than in the developed world over the forecast horizon and that one or more emerging markets is able to transition successfully into a middle-income country. It also assumes that emerging market currencies appreciate on average over the interval as a result of faster productivity growth.

Base Case and Alternative Scenario

We continue to believe that return forecasts resulting from the combination of a base case forecast with an alternative scenario capture the most important risks facing the world economy and markets over the ten-year interval. As is our practice, the base case forecast assumes gradual convergence to steady-state values for variables such as GDP and its components, inflation and interest rates. In steady-state equilibrium, real GDP grows broadly in line with its potential growth rate, driven by productivity and labor-force growth, inflation consistent with central bank targets and real long-term interest rates consistent with GDP growth. As Figure 1 illustrates, we expect that convergence to equilibrium will be fully complete by 2020, assuming that Federal Reserve policy by then will have returned to historical relationships fully compatible with a long-run economic equilibrium. That is, by 2020 short- and long-term U.S. interest rates should have returned to steady-state values, setting the stage for real GDP growth trending around 2.0% per annum.

The alternative scenario posits that at least one of the fundamental drivers of the U.S. economy's potential growth returns to longer-run equilibrium levels. We assume that productivity growth, which has been below its long run average of about 2% over the past five years, reverts to the mean going forward. We project the impact of higher productivity to increase trend growth by about 0.3%. Another feature of our alternative scenario is stronger aggregate demand supported by higher equity wealth and generally more favorable financial conditions. Returns to risky assets, interest rates and inflation are higher in the alternative scenario as well. We assign a probability of 70% to the base case and 30% to the alternative scenario. The higher probability for the base scenario reflects our concerns that recent trends toward an aging labor force, reduced labor-force participation and more restrictive immigration could continue and result in a sustained downward step in the U.S. growth rate.

Methodology

We derive return forecasts for asset classes from the blend of base case and alternative economic scenarios. For U.S. bonds, we use the blended scenario interest rate expectations to calculate expected returns for bonds of various durations. Bond expected returns are modeled as the sum of current yield and a capital gain (or loss) based on duration and expected change in yields. For non-U.S. bonds, the process is similar and includes an adjustment for currency movements. Return expectations also reflect spreads, expected default and recovery experience.

For U.S. equities, we estimate earnings and dividends for the S&P 500 Index using the above macroeconomic assumptions. Earnings growth is constrained by the neoclassical assumption that profits as a share of GDP cannot increase without limit, but must rather converge to a long-run equilibrium determined by productivity. We then use a dividend discount model to determine fair value for the index each year during the forecast period. Returns for other U.S. equity indices, including REITs, are derived from the S&P 500 forecast. These other equity classes are modeled on the basis of a single-index factor model in which beta sensitivities of each asset class with respect to the market portfolio are derived from our forward-looking covariance matrix estimation described below. Each equity asset class return is the sum of the risk-free interest rate and a specific risk premium determined from our estimate of beta sensitivity and market risk premium forecasts.

Expected returns for non-U.S. equities are produced from the same process but are also adjusted for expected currency movements. As noted above, we expect the U.S. dollar to appreciate modestly relative to other developed market currencies over the forecast horizon but expect emerging market currencies on balance to appreciate modestly. Our return estimates for commodities assume a positive real spot return above the real risk-free rate, partially offset by a modest penalty for a negative expected roll yield on front-month futures contracts.

Covariance and Correlation Matrices

Our approach in estimating the covariance matrix is regime-based. In developing a covariance matrix between asset classes, we start with the empirical fact that risk parameters are unstable because the underlying return distributions change depending on the underlying economic regime, and that correlation and volatility are positively related. Our long-term equilibrium risk forecasts take that instability into account and are based on a forward-looking covariance matrix model. We reduce parameter instability by imposing structure in the covariance matrix estimation.

Our process starts by identifying turbulent market regimes (i.e., periods of market stress) and by estimating a covariance matrix covering those periods of market turbulence alone. The identification of turbulent market regimes makes use of the concept of multivariate outliers in a return distribution, which takes into account not only the deviation of a particular asset class's return from the average but also the asset class's own volatility and correlation with other asset classes.

We give an example in Figure 2 on the next page. The turbulence threshold is an ellipse centered in the average returns of the two asset classes. Return pairs that fall outside the ellipse are considered turbulent. Note that there are certain points just outside the boundary that are closer to the center than some points inside the boundary; these are considered turbulent because, for example, the observed correlation between the two assets is of the opposite sign of what it normally is.[1] The boundary that separates normal from turbulent states takes the form of an ellipse rather than a circle because it also takes into account the covariance of the assets involved. The threshold

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[1] Our measure of turbulence is based on the Mahalanobis distance measure defined as follows:

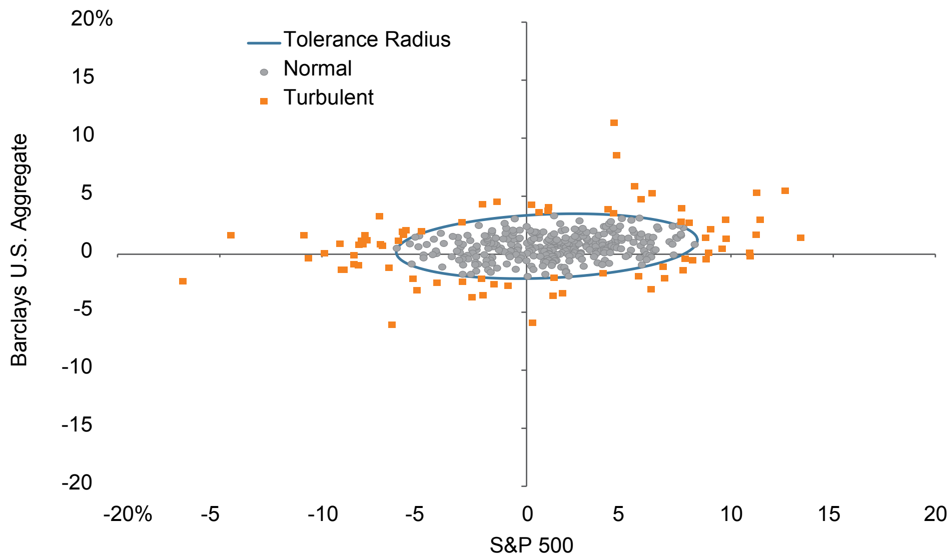
$$d_t = \sqrt{(y_t - \mu)\Sigma^{-1}(y_t - \mu)'}$$

where y is the return vector at time t, μ is the mean vector and Σ is the covariance matrix.

is not static in time but rather is dynamic and is the outcome of a Markov model. We model the underlying state of the market, turbulent or normal, as a Markov process illustrated in Figure 3. Our Markov model performs better in classifying regimes than arbitrary thresholds because such thresholds fail to capture the persistence of regimes and shifts in volatility.

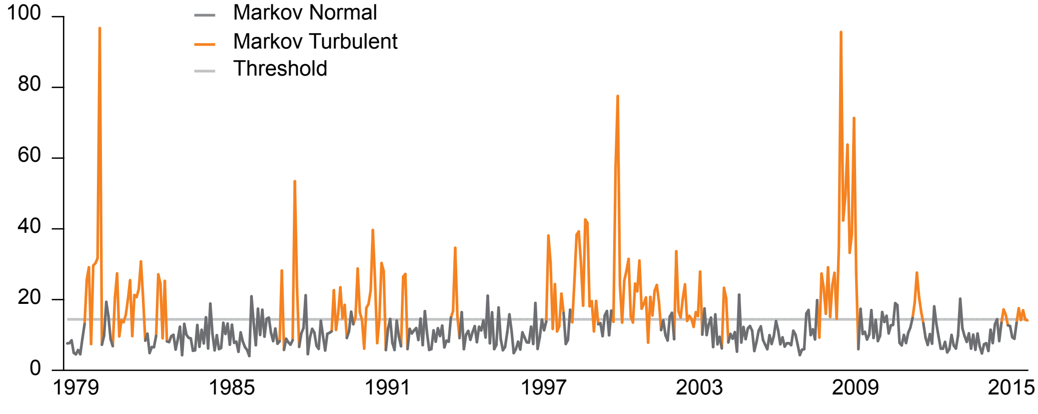
We subsequently estimate a covariance matrix based on periods of normal market performance, and finally we use a procedure to blend these two covariance matrices using weights that allow us to express both views about the likelihood of each regime and differential risk attitudes toward each. The weights we use are 60% "normal" and 40% turbulent, different from the probabilities assigned to the base case and alternative scenario described above. We overweight the turbulent state from its empirical frequency of 30–40%. From this blended covariance matrix, we then extract the implied correlation matrix and volatilities for each asset class embedded in the covariance matrix.

Figure 2. Normal and Turbulent Regimes in Two-Asset Space



Source: Voya Investment Management

Figure 3. Markov 12-Asset Normal and Turbulent Regimes Over Time



Source: Voya Investment Management

Return Estimates

Figure 4 shows estimated arithmetic and geometric mean returns, volatilities and the resulting Sharpe ratios for major U.S. and global asset classes. Returns are shown in U.S. dollar terms. Figure 5 provides a correlation matrix for the time period.

Figure 4. Voya Investment Management Ten-Year Returns Forecast

	Expected Returns					
	Geometric Mean Return (%)	Arithmetic Mean Return (%)	Volatility (%)	Skewness	Kurtosis	Sharpe Ratio
Equity Index						
Russell Top 200	4.7	6.0	16.5	-0.45	0.9	0.19
S&P 500	5.1	6.4	16.7	-0.48	1.0	0.21
S&P 500 Growth	5.2	6.5	17.3	-0.41	0.6	0.21
S&P 500 Value	4.8	6.2	17.2	-0.51	1.2	0.19
Russell 1000	5.3	6.7	16.8	-0.50	1.0	0.22
Russell 1000 Growth	4.3	6.1	19.0	-0.44	0.6	0.17
Russell 1000 Value	6.1	7.2	16.2	-0.53	1.3	0.27
MSCI U.S. Minimum Volatility	4.9	5.5	11.9	-0.62	1.6	0.22
Russell 3000	5.3	6.7	17.1	-0.54	1.1	0.22
Russell Midcap	6.7	8.3	18.7	-0.53	1.1	0.29
Russell Midcap Growth	5.5	7.9	22.3	-0.39	0.7	0.23
Russell Midcap Value	7.3	8.7	17.6	-0.47	1.4	0.32
S&P 400	7.3	9.1	19.9	-0.50	1.0	0.30
Russell 2500	5.9	8.0	20.9	-0.57	1.2	0.24
S&P 600	4.3	6.9	22.8	-0.57	1.2	0.18
Russell 2000	3.9	6.7	23.3	-0.56	1.2	0.16
Russell 2000 Growth	1.6	5.3	26.9	-0.40	0.8	0.09
Russell 2000 Value	5.9	8.0	21.0	-0.72	2.0	0.24
MSCI EAFE	3.0	4.9	19.5	-0.29	0.2	0.11
MSCI EAFE Growth	1.9	3.9	20.0	-0.19	0.3	0.05
MSCI EAFE Value	4.1	6.0	19.8	-0.30	0.2	0.16
MSCI EAFE Small Cap	3.8	5.9	20.6	-0.36	0.6	0.15
MSCI World ex U.S.	3.9	5.9	20.1	-0.43	0.3	0.15
MSCI World ex U.S. Small Cap	4.5	6.7	21.5	-0.46	0.7	0.18
MSCI World	4.7	6.0	16.4	-0.58	0.9	0.19
MSCI EM	5.8	9.6	27.6	-0.49	0.7	0.24
MSCI EM Small Cap	5.1	9.5	29.8	-0.34	0.4	0.22
MSCI ACWI ex U.S.	3.9	5.9	20.1	-0.43	0.3	0.15
MSCI ACWI ex U.S. IMI	4.0	6.0	20.1	-0.44	0.4	0.16
MSCI ACWI ex U.S. Small Cap	4.5	6.7	21.5	-0.46	0.7	0.18
MSCI ACWI	4.9	6.3	17.0	-0.60	1.0	0.20
MSCI ACWI IMI	4.9	6.3	17.3	-0.63	1.1	0.20
MSCI ACWI Small Cap	4.6	6.7	20.4	-0.65	1.3	0.19

Chart continues on the next page.

	Expected Returns					
	Geometric Mean Return (%)	Arithmetic Mean Return (%)	Volatility (%)	Skewness	Kurtosis	Sharpe Ratio
Alternative Assets Index						
Bloomberg Commodity	2.5	3.7	15.9	-0.43	1.5	0.06
CBOE Buy-write	5.1	5.8	12.5	-0.91	2.9	0.23
FTSE EPRA/NAREIT Developed ex U.S.	3.2	5.8	22.9	-0.18	0.6	0.13
FTSE EPRA/NAREIT Developed	4.9	7.2	22.0	-0.33	1.4	0.20
MSCI U.S. REIT	6.0	8.5	22.7	-0.37	3.0	0.24
NCREIF ODCE Private Real Estate	4.0	6.5	21.2	-2.25	18.2	0.16
SLB Real Estate Blend	5.2	7.0	18.3	-2.40	21.5	0.20
U.S. Inflation (CPI)	2.1	2.1	2.4	-0.48	2.2	-0.30
Fixed Income Index						
Barclays U.S. Aggregate	2.6	2.8	7.1	0.55	4.5	0.00
Barclays U.S. Universal	3.1	3.3	7.0	0.52	4.3	0.07
Barclays U.S. Government Long	0.3	1.1	12.4	0.24	0.7	-0.14
Barclays U.S. Gov/MBS	2.3	2.5	6.5	0.63	4.1	-0.05
Barclays U.S. MBS	2.4	2.7	8.1	1.03	9.7	-0.01
Barclays U.S. Municipal	2.0	2.3	7.5	-0.18	5.0	-0.07
Barclays U.S. Aggregate Corporate	3.3	3.7	9.4	0.26	3.4	0.09
Barclays U.S. Corporate Long	3.4	4.1	12.1	0.14	1.7	0.11
Barclays U.S. Liability Benchmark	2.7	3.3	11.8	0.15	1.8	0.04
Barclays U.S. High Yield	6.1	6.7	12.4	-0.25	3.4	0.31
Credit Suisse Leveraged Loan	6.7	6.9	8.8	-0.79	15.2	0.37
S&P/LSTA Leveraged Loan	6.8	7.0	9.3	-0.38	13.2	0.39
Barclays Global Aggregate ex U.S.	-0.5	0.1	10.6	0.17	0.5	-0.25
Barclays Global Aggregate	0.9	1.2	8.5	0.36	1.8	-0.18
JPMorgan EMBI+	5.7	6.4	13.2	-1.70	11.4	0.24
JPMorgan CEMBI Diversified	5.7	6.4	12.9	-0.22	5.5	0.27
JPMorgan GBI-EM Global Diversified	7.0	7.5	12.0	-0.57	1.1	0.38
Barclays U.S. TIPS	2.5	2.9	9.4	0.31	3.4	0.01
Barclays 1-3 Yr Aggregate	2.9	2.9	4.0	1.39	11.8	0.03
Barclays 1-3 Yr Gov/Credit	2.8	2.9	4.1	1.39	11.7	0.02
Barclays Long Gov/Credit	1.9	2.6	11.7	0.19	1.1	-0.02
U.S. Treasury Bill 3-Month	2.8	2.8	1.1	0.61	0.0	0.00
U.S. Treasury 2-Year	2.6	2.6	4.2	1.34	10.4	-0.05
U.S. Treasury 5-Year	2.1	2.3	7.1	0.49	3.0	-0.07
U.S. Treasury 10-Year	1.5	2.0	9.5	0.21	0.4	-0.09
U.S. Treasury 30-Year	-0.3	0.8	15.0	0.20	1.3	-0.13
Barclays 2-Year Swap	2.8	2.9	4.4	1.32	10.2	0.01
Barclays 5-Year Swap	2.2	2.4	7.3	0.45	3.1	-0.06
Barclays 10-Year Swap	1.3	1.8	10.0	0.20	0.9	-0.10
Barclays 30-Year Swap	-2.0	-0.5	17.5	0.52	2.6	-0.18

Source: Voya Investment Management

Figure 5. Correlation Matrix

	S&P 500	S&P 400	S&P 600	MSCI EAFE	MSCI Emerging Markets	Barclays U.S. Aggregate	Barclays 1-3 Yr Gov/Credit	Barclays U.S. Government Long	Barclays U.S. TIPS	Barclays U.S. Municipal	Barclays U.S. Agg Corporate	Barclays U.S. Corporate Long	Barclays U.S. High Yield	S&P/LSTA Leveraged Loan	Barclays Global Aggregate	JPMorgan GBI-EM Global Diversified	U.S. Treasury Bill 3 Month	Bloomberg Commodity	FTSE EPRA NAREIT Developed
S&P 500	1.00	0.92	0.84	0.67	0.71	0.21	0.13	0.09	0.23	0.23	0.30	0.30	0.62	0.45	0.23	0.65	0.05	0.25	0.61
S&P 400	0.92	1.00	0.94	0.65	0.72	0.21	0.13	0.08	0.24	0.24	0.31	0.31	0.65	0.49	0.24	0.67	0.04	0.31	0.64
S&P 600	0.84	0.94	1.00	0.61	0.69	0.15	0.08	0.03	0.17	0.20	0.25	0.26	0.65	0.45	0.18	0.65	0.01	0.29	0.60
MSCI EAFE	0.67	0.65	0.61	1.00	0.74	0.18	0.15	0.05	0.21	0.17	0.28	0.28	0.51	0.35	0.34	0.70	0.05	0.32	0.83
MSCI Emerging Markets	0.71	0.72	0.69	0.74	1.00	0.14	0.11	0.00	0.20	0.16	0.27	0.28	0.59	0.39	0.22	0.91	0.03	0.37	0.71
Barclays U.S. Aggregate	0.21	0.21	0.15	0.18	0.14	1.00	0.91	0.89	0.93	0.76	0.95	0.89	0.29	0.19	0.86	0.19	0.15	-0.02	0.22
Barclays 1-3 Yr Gov/Credit	0.13	0.13	0.08	0.15	0.11	0.91	1.00	0.70	0.84	0.69	0.83	0.71	0.19	0.13	0.80	0.14	0.32	-0.02	0.16
Barclays U.S. Government Long	0.09	0.08	0.03	0.05	0.00	0.89	0.70	1.00	0.82	0.63	0.81	0.83	0.14	0.02	0.74	0.08	0.05	-0.10	0.11
Barclays U.S. TIPS	0.23	0.24	0.17	0.21	0.20	0.93	0.84	0.82	1.00	0.72	0.89	0.83	0.34	0.26	0.84	0.25	0.13	0.10	0.27
Barclays U.S. Municipal	0.23	0.24	0.20	0.17	0.16	0.76	0.69	0.63	0.72	1.00	0.75	0.68	0.31	0.29	0.65	0.17	0.03	-0.01	0.23
Barclays U.S. Agg Corporate	0.30	0.31	0.25	0.28	0.27	0.95	0.83	0.81	0.89	0.75	1.00	0.97	0.47	0.36	0.82	0.30	0.09	0.07	0.31
Barclays U.S. Corporate Long	0.30	0.31	0.26	0.28	0.28	0.89	0.71	0.83	0.83	0.68	0.97	1.00	0.50	0.35	0.77	0.33	0.05	0.06	0.32
Barclays U.S. High Yield	0.62	0.65	0.65	0.51	0.59	0.29	0.19	0.14	0.34	0.31	0.47	0.50	1.00	0.76	0.28	0.59	0.01	0.26	0.53
S&P/LSTA Leveraged Loan	0.45	0.49	0.45	0.35	0.39	0.19	0.13	0.02	0.26	0.29	0.36	0.35	0.76	1.00	0.16	0.33	0.00	0.22	0.38
Barclays Global Aggregate	0.23	0.24	0.18	0.34	0.22	0.86	0.80	0.74	0.84	0.65	0.82	0.77	0.28	0.16	1.00	0.30	0.13	0.13	0.35
JPMorgan GBI-EM Global Diversified	0.65	0.67	0.65	0.70	0.91	0.19	0.14	0.08	0.25	0.17	0.30	0.33	0.59	0.33	0.30	1.00	0.03	0.36	0.71
U.S. Treasury Bill 3 Month	0.05	0.04	0.01	0.05	0.03	0.15	0.32	0.05	0.13	0.03	0.09	0.05	0.01	0.00	0.13	0.03	1.00	0.01	0.02
Bloomberg Commodity	0.25	0.31	0.29	0.32	0.37	-0.02	-0.02	-0.10	0.10	-0.01	0.07	0.06	0.26	0.22	0.13	0.36	0.01	1.00	0.30
FTSE EPRA NAREIT Developed	0.61	0.64	0.60	0.83	0.71	0.22	0.16	0.11	0.27	0.23	0.31	0.32	0.53	0.38	0.35	0.71	0.02	0.30	1.00

Source: Voya Investment Management

Appendix: A Note on the Time Dependency of Asset Returns and Its Impact on Risk Estimation

Recent research documents suggest that expected asset returns change over time in somewhat predictable ways and that these changes tend to persist over long periods of time. Thus changes in investment opportunities — all possible combinations of risk and return — are found to be persistent. This note will set out the economic reasons for return predictability, its consequences for strategic asset allocation and the adjustments we have made to control for it in our estimation process.

In our view, the common source of predictability in financial asset returns is the business cycle. The business cycle itself is persistent, and this makes real economic growth to some extent predictable. The fundamental reason for the business cycle's persistence is that its components are persistent. Consumers, for example, have a tendency to smooth consumption since they dislike large swings in consumption. The permanent income and lifecycle consumption theories provide the theoretical basis for consumers' desire for a stable consumption path. Thus when income is affected by transitory shocks, consumption should not change since consumers can use savings or borrowing to adjust consumption in well-functioning capital markets. Robert Hall has formalized the above ideas by showing that consumers will optimally choose to keep a stable path of consumption equal to a fraction of their present discounted value of human and financial wealth.[2] Investment, the second component of GDP, is sticky, as corporate investment in projects is usually long term in nature. Finally, government expenditures have a low level of variability as well. Over a medium-term horizon, negative serial correlation sets in as the growth phase of the cycle is followed by a contraction and then as that contraction is followed by renewed growth.[3]

How does this predictability of economic variables affect the predictability of asset returns? Consider equities as an example. The value of equities is determined as the present discounted value of future cash flows and thus depends on four factors: expected cash flows, the expected market risk premium, expected market risk exposure and the term structure of interest rates. Cash flows and corporate earnings tend to move with the business cycle. The market risk premium is high at business cycle troughs, when people trying to smooth consumption are less willing to take risks with their income (risk aversion is high), and low at business cycle peaks, when people are more willing to take risks (risk aversion is low). The market risk premium is a component of the discount rate in the present value calculation of the dividend discount model. A firm's risk exposure (beta), another component of the discount rate, changes through time and is a function of the firm's capital structure. Thus a firm's risk increases with leverage, and leverage is related to the business cycle. The last component of the discount rate is the risk-free rate, determined by the term structure of interest rates. The term structure reflects expectations of real interest rates, real economic activity and inflation all connected to the business cycle. Thus equity returns, and financial asset returns in general, are to a certain extent predictable. Expected returns of all assets tend to be high in bad macroeconomic times and low in good times.

This predictability of returns manifests itself statistically through autocorrelation. Autocorrelation (serial correlation) in time series of returns describes the correlation between values of a return process at different points in time. Autocorrelation can be positive when high (low) returns tend to be followed by high (low) returns, implying momentum in the market. Conversely, negative autocorrelation occurs when high (low) returns tend to be followed by low (high) returns, implying mean reversion. In either case autocorrelation induces dependence in returns over time.

Traditional mean-variance analysis focusing on short-term expected return and risk assumes returns do not exhibit time dependence and prices follow a random walk. Expected returns in a random walk are constant, exhibiting

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2 Hall, R. (1978), "Stochastic Implications of the Life-Cycle-Permanent Income Hypothesis: Theory and Evidence", *Journal of Political Economy*, vol. 86, pp. 971–988.

3 Poterba, J. and Summers, L. (1988), "Mean Reversion in Stock Prices: Evidence and Implications", *Journal of Financial Economics*, 22, pp. 27–60.

zero autocorrelation; realized returns are not predictable. Volatilities and cross correlations among assets are independent of the investment horizon. Thus the annualized volatility estimated from monthly return data scaled by the square root of 12 should be equal to the volatility estimated from quarterly return data scaled by the square root of four. In the presence of autocorrelation, the square root of time scaling rule described above is not valid, since the sample standard deviation estimator is biased and the sign of serial correlation matters for its impact on volatility and correlations. Positive (negative) autocorrelation leads to an underestimation (overestimation) of true volatility. A similar result holds for the cross-correlation matrix bias when returns exhibit autocorrelation. So for long investment horizons, the risk/return tradeoff can be very different than that for short investment horizons.

In a multi-asset portfolio, in which different asset classes display varying degrees of autocorrelation, failure to correct for the bias on volatilities and correlations will lead to suboptimal mean variance optimized portfolios in which asset classes that appear to have low volatilities receive excessive allocations. Such asset classes include hedge funds, emerging market equities and private market assets such as private equity or private real estate, among others.

There are at least two ways to correct for serial correlation: 1) a direct method that adjusts the sample estimators of volatility, correlation and all higher moments; and 2) an indirect method that cleans the data first, allowing us to subsequently estimate the moments of the distribution using standard estimators. Given that the direct methods become quite complex beyond the first two moments, our choice is to follow the second method and clean the return data of serial correlation. Before we do that we estimate and test the statistical significance of serial correlation in our data series.

We estimate first-order serial correlation as the regression slope of a first-order autoregressive process. We use monthly return data for the period 1979–2014. We subsequently test the statistical significance of the estimated parameter using the Ljung-Box Q-statistic.[4] The Q-statistic is a statistical test for serial correlation at any number of lags. It is distributed as a chi-square with k degrees of freedom, where k is the number of lags. Here we test for first order serial correlation, thus $k = 1$. About 80% of our return series exhibit positive and statistically significant first-order serial correlation based on associated p-values at the 10% level of significance.[5] Khandani and Lo provide empirical evidence that positive return autocorrelation is a measure of illiquidity exhibited among a broad set of financial assets including small cap stocks, corporate bonds, mortgage-backed securities and emerging markets investments.[6] The theoretical basis is that in a frictionless market, any predictability in asset returns can be immediately exploited, thus eliminating such predictability. While other measures of illiquidity exist, autocorrelation is the only measure that applies to both publicly traded and private securities and requires only returns to compute.

Since the vast majority of the return series we estimate exhibit serial correlation, we subsequently apply the Geltner unsmoothing process to all series. This process corrects the return series for first-order serial correlation by subtracting the product of the autocorrelation coefficient (rho) and previous period's return from the current period's return and dividing by 1-rho. This transformation has no impact on the arithmetic return, but the geometric mean is impacted since it depends on volatility. This correction is thus important for long-horizon asset allocation problems.

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[4] Ljung, G.M. and Box, G.E.P. (1978), "On a Measure of Lack of Fit in Time Series Models", *Biometrika*, 65, pp. 297–303.

[5] The p-value is the probability of rejecting the null hypothesis of no serial correlation when it is true (i.e., concluding that there is serial correlation in the data when in fact serial correlation does not exist). We set critical values at 10% and thus reject the null hypothesis of no serial correlation for p-values <10%.

[6] Khandani, A.E. and Lo, A. (2011), "Illiquidity Premia in Asset Returns: An Empirical Analysis of Hedge Funds, Mutual Funds, and U.S. Equity Portfolios", *Quarterly Journal of Finance*, vol. 1, pp. 205–264.

Figure 6 shows the impact autocorrelation can have on estimated asset returns: When adjusted for autocorrelation and after applying the two-state covariance process described above, the geometric mean return for the S&P 400 Index falls from 8.1% to 7.4%.

Figure 6. Expected Return Autocorrelation Adjustments of S&P 400, MSCI Emerging Markets and Barclays High Yield Indexes

	No Correction for Autocorrelation	Correcting for Autocorrelation Alone	Correcting for Autocorrelation and Applying the Two-State Covariance Process
S&P 400 (Mid Cap)			
Arithmetic Return	9.2%	9.2%	9.2%
Standard Deviation	16.2%	17.5%	19.9%
Skewness	-0.76	-0.65	-0.51
Kurtosis	2.62	2.40	1.05
Geometric Return	8.1%	7.9%	7.4%
MSCI Emerging Markets			
Arithmetic Return	9.8%	9.8%	9.8%
Standard Deviation	21.9%	26.0%	27.7%
Skewness	-0.67	-0.61	-0.50
Kurtosis	2.06	1.78	0.72
Geometric Return	7.6%	6.5%	6.0%
Barclays High Yield			
Arithmetic Return	6.3%	6.3%	6.3%
Standard Deviation	8.2%	11.3%	12.4%
Skewness	-0.93	-0.34	-0.25
Kurtosis	8.80	6.54	3.54
Geometric Return	6.1%	5.8%	5.7%

Source: Voya Investment Management

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