2017 Long-Term Capital Market Assumptions

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Foreword

Looking back on 2016, it was a year of surprises. The year began with a big equity market sell-off, based on worries about a U.S. recession and a hard landing in China. The weakness culminated in February, with the first panic reading from our equity sentiment indicators in five years. It was then that equities started their long march higher; but bond yields continued to decline, plagued by fears of global deflation.

All of that changed in June with Brexit, when the central banks came to the rescue once again. Fast forward to the end of the year, and the U.S. presidential election win by long-shot candidate Donald Trump was greeted with a resounding cheer from the equity market and the U.S. dollar. In sum, if there was one year that could be characterized by the expression, “May you live in interesting times,” the past year would be it.

One of the unusual hallmarks of this post-financial crisis recovery in asset prices has been the persistence of declining bond yields. In most equity bull markets there is a period early in the recovery that marks the low point of bond yields. This is when asset allocators start to rotate away from the safety of bonds toward equities as they warm to the idea of better growth. But that has not happened in any consistent fashion during this recovery.

Since 2009, bond yields had been gradually — with fits and starts — falling due to rolling crises in Europe, recession in emerging markets such as Brazil, and a collapse of commodity prices. However, we believe that July 2016 marked the cycle low for bonds at 1.36%. It was then the markets started to incorporate the likelihood that the left tail of deflation had likely been cut off, once and for all.

Because this has been such a peculiar environment, we think the exercise to forecast asset class returns is necessary to anchor expectations for the future. Still, this is not an easy task for any fiduciary, and therefore, we take the time in this year’s Long-Term Capital Market Assumptions to explain our forecasting methodology and the quantitative techniques that underpin our strategic asset allocation work on our multi-asset portfolios at Voya.

We hope our readers find this information helpful to share with their investment committees and plan sponsors to frame discussions and formulate decisions. At Voya, we aspire to be America’s Retirement Company, to plan, invest and protect every step of the way. Thank you for your continued confidence in us.

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Executive Summary

This executive summary provides an overview of our long-term capital markets forecast of asset class returns, standard deviation of returns and correlations over the 2017–2026 horizon. These estimates guide the strategic asset allocation for our multi-asset portfolios and provide a context for shorter-term economic and financial forecasting.

As we worked through our return forecasts this year, we found the overarching theme for most asset classes is one of below-average returns. Our current forecast is for U.S. and international developed market equities to produce mid-single digit returns, which is marginally lower than we forecast a year ago. This is due to a continued, below historical average potential growth trajectory influenced by the headwinds of poor demographic trends and weak productivity.

Risk-adjusted returns for other developed market assets are in most cases lower than those for comparable U.S. assets. This partially reflects our expectation that the U.S. dollar will appreciate over the 10-year horizon due to higher relative growth and tighter monetary policy. In contrast, returns for emerging market equities are above U.S. large-cap returns but below U.S. small caps when adjusted for expected volatility.

Our bond return assumptions can be characterized as challenged, with low single-digit returns for most segments within fixed income. We conclude this as our economic growth projections over the coming 10-year period portend below historical average terminal interest rates and the low yield starting point affects the returns to reach equilibrium.

In this report, beyond our return assumptions, we also discuss our methodology of forecasting the covariance and correlations of returns, which are important components of risk for any portfolio. Finally, we look at an important issue on the minds of most readers — how the world might break out of this low growth regime we have been in for some time.

Forecast Environment

Our long-term capital market assumptions provide our estimates of expected returns, volatilities and correlations among major U.S. and global asset classes over a 10-year horizon. These estimates guide the strategic asset allocation for our multi-asset portfolios.

As has been the case for the past seven years, our forecast models an explicit process of convergence to a steady-state equilibrium for global economies and financial markets over the next 10 years, in this case, 2017–2026. In our modeling process, we worked with Macroeconomic Advisers for the United States and Oxford Economics for non-U.S. economies.

We believe that cyclical fluctuations are an inevitable aspect of market economies. Therefore, we recognize that the steady-state equilibrium incorporated at the terminal point of our forecast is unlikely to be fully attained over any single 10-year period. Nonetheless, this is a useful construct for anchoring the forecast. The forecast does not assume a further recession or contraction over its horizon.

We make this explicit forecast in recognition of the ongoing effects of the financial crisis and recession, the European debt crisis and the fiscal and monetary policy responses to these events. Although the world economy is many years past the most acute point of crisis in 2008 and the U.S. economy has been recovering from the Great Recession for more than seven years, a number of economic and financial variables remain far from levels consistent with a steady state. In particular, short-term interest rates remain very low or near zero in most developed economies, long-term interest rates have declined substantially and government debt-to-GDP ratios remain elevated.

Still Slow Growth

Figure 1 shows the 2026 values from this forecast, which are consistent with our estimates of steady-state values for key U.S. economic variables. We believe the U.S. remains in a slow growth environment, as the main sources of incremental growth would likely start with a meaningful increase in the labor force growth rate or in productivity. To elaborate on how we account for these two components, let's take a look at each.

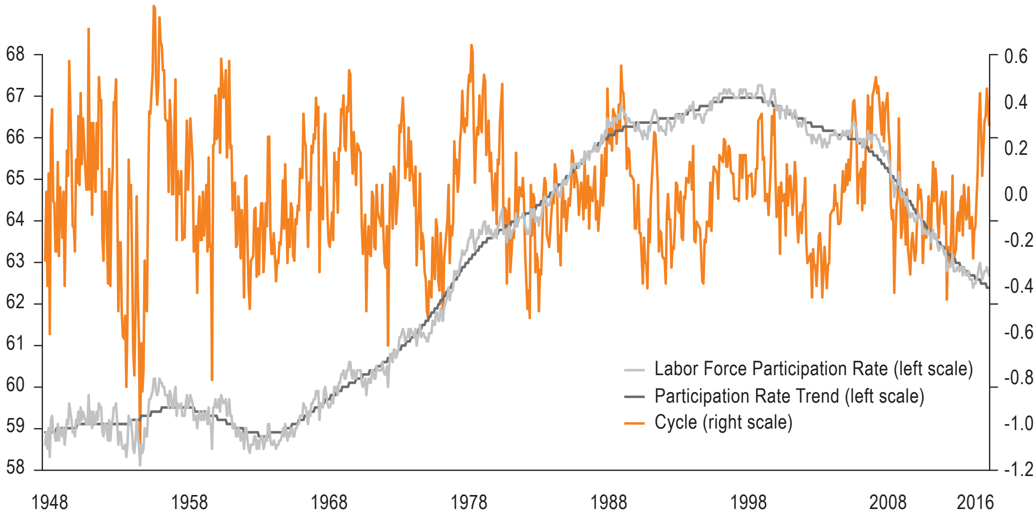
Figure 1. U.S. Economic and Financial Variables

	2026 Forecast (%)
GDP Growth	2.1
Inflation (CPI-U)	2.2
CPI excl. Food and Energy	2.3
Fed Funds Rate	3.1
10-Year U.S. Treasury Yield	4.1
S&P 500 Earnings Growth	3.5
Savings Rate	6.6

Source: Voya Investment Management and Macroeconomic Advisers.
Forecasts are subject to change.
Data as of December 2016.

To evaluate labor, we use a trend/cycle decomposition of the U.S. labor force participation rate shown in Figure 2. The chart shows that the decline in the labor force participation rate is mostly due to its trend component, which is primarily driven by structural factors such as demographics, rather than cyclical factors such as recessions, which would be shorter-term in nature.

Figure 2. Declining Labor Force Participation is Due Mostly to Demographics

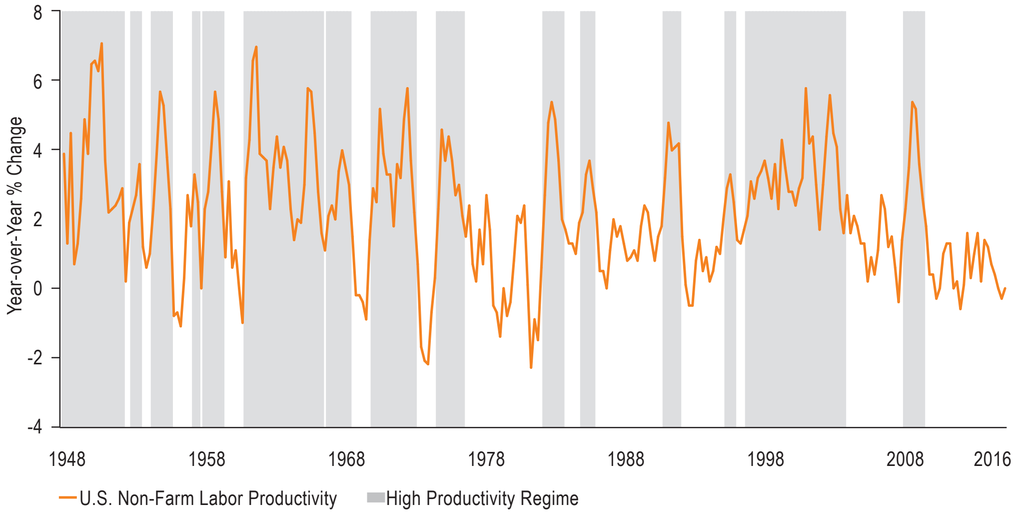


Source: Department of Labor and Voya Investment Management.
Data as of November 2016.

The second component is productivity, or output per hour. Our research shows that labor force productivity growth mean-reverts over long time periods. To determine if productivity growth is characterized by a high or a low productivity regime, we fitted the data through a Markov model (Figure 3). We estimate the current speed of mean reversion to be sluggish; therefore, at present we do not expect a switch from the current low productivity regime to a high one. Our estimates imply a low productivity regime has a mean of 0.9%, whereas the high productivity regime has a mean of 3.5%. As a result, we are likely to see only a marginal increase of productivity growth in the near future.

These two components imply potential GDP growth of only slightly above what we have experienced since the last recession. Given this backdrop, our federal funds forecast has been downgraded to 3.1% from 3.6% last year and the 10-year U.S. Treasury yield forecast has declined to 4.1% from 4.4%. Figure 1 shows the 2026 values of our macro assumptions from this forecast.

Figure 3. Labor Force Productivity Growth Exhibits Long-Run Reversion to Its Mean



Source: Voya Investment Management.
Note: non-shaded areas in the chart above denote a low productivity regime.
Data as of September 2016.

Assumptions for the Glide Path

While the 10-year forecasts guide our strategic asset allocation, the long-run equilibrium return assumptions refer to horizons much longer than our 10-year forecasts, and are the underlying inputs into our target date strategy glide path design. Typically we assume the horizon for these forecasts is 40 years, at which point the economy is in a steady state where GDP grows at its trend rate, inflation is at target and all capital and goods markets are in equilibrium.

These forecasts use a building block type of methodology. Starting with our expectations of real short-term yields and inflation, we generate a risk-free rate and, from that, all equities and fixed income assets are built by adding relevant risk premiums. The risk premium for U.S. equities is derived from the Gordon growth model as the sum of the dividend yield and the nominal earnings growth rate in excess of the risk-free rate. International equities include the addition of an international equity risk premium. Government bond return forecasts are the sum of the risk-free rate and an appropriate term premium. Corporate bond return forecasts further include the addition of a credit risk premium.

From a theoretical perspective, all risk premiums in long-run equilibrium are mean reverting since the economy has reached a steady state. Our econometric work confirms the stationarity of a number of risk premiums, which justifies our assumption of constant average risk premiums, term premiums and credit spreads in the long-run equilibrium. Our equilibrium return forecasts are shown in Figure 4.

Figure 4. Long-Run Equilibrium Return Assumptions

	Equilibrium Return (%)
U.S. Inflation	2.0
Real Risk-Free Rate	1.0
U.S. Cash	3.0
Aggregate Term Premium	0.9
Aggregate Credit Premium	0.3
U.S. Investment Grade (Aggregate)	4.2
10-Year Term Premium	1.2
10-Year U.S. Treasury	4.2
30-10 Year Term Premium	0.5
30-Year U.S. Treasury	4.7
AA Corporate Credit Premium	1.2
U.S. AA Corporate	5.4
U.S. Equity Risk Premium	4.0
S&P 500	7.0
International Equity Premium	0.5
MSCI ACWI	7.5

Source: Voya Investment Management.
Assumptions are subject to change.
Data as of December 2016.

How Returns Are Forecast

We derive asset class return forecasts from the blend of base case and alternative case economic scenarios. Together, these capture the most important upside and downside risks the world economy and markets will face over the forecast horizon. The base case forecasts growth to average 1.9% through 2026 driven by continued weak productivity growth and subdued labor force growth. The alternative scenario forecasts growth to average 2.2% as productivity growth is assumed to be higher. Hence, we project the impact of higher productivity to increase trend growth by about 0.3%. Returns to risky assets, interest rates and inflation are higher in the alternative scenario than in the base case.

We assign a probability of 70% to the base case and 30% to the alternative case in our returns forecast. The higher probability for the base case reflects our view that recent trends of an aging population, reduced labor-force participation and more restrictive immigration could continue and result in a sustained slow U.S. growth rate.

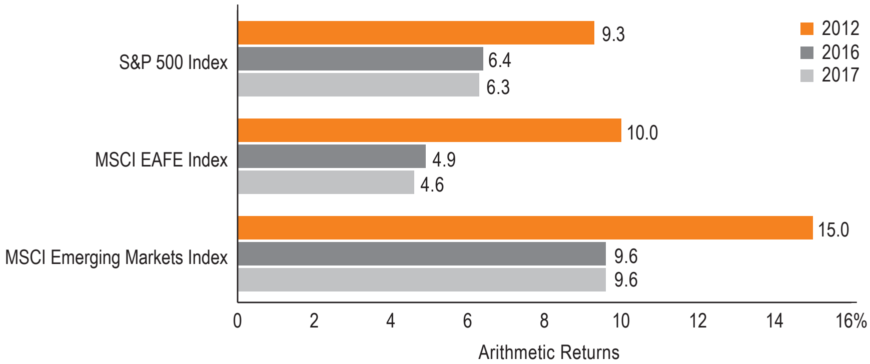
For U.S. equities, we estimate earnings and dividends for the S&P 500 index using our blended macro assumptions. Earnings growth is constrained by the neoclassical assumption that profits as a share of GDP cannot increase without limit, but converge to a long-run equilibrium. We then use a dividend discount model to determine fair value for the index each year during the forecast period. Returns for other U.S. equity indices, including REITs, are constructed using 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. Each equity asset class return is the sum of the risk-free interest rate and a specific market-risk premium determined from our estimate of beta sensitivity and market-risk premium forecasts.

For U.S. bonds, we use the blended scenario interest rate expectations to calculate expected returns for 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 expected currency movements. Return expectations for credit-related fixed income reflect yield spreads and expected default-and-recovery rates.

Return Forecast Summary

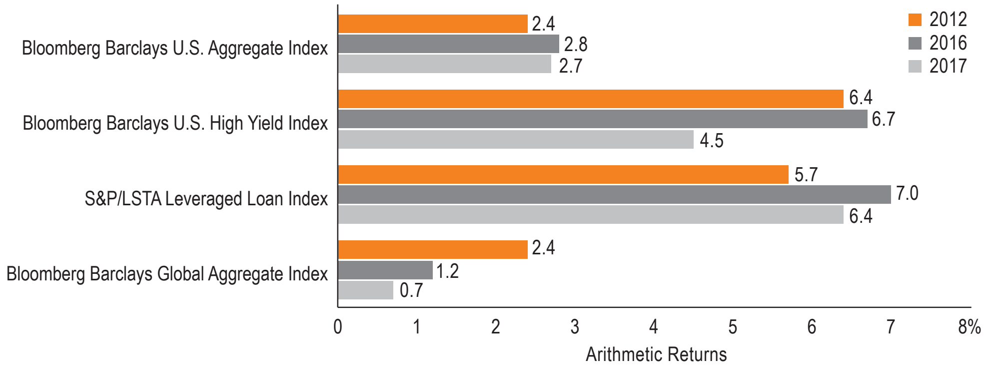
As we worked through our 2017 forecasts, we found an overarching theme of low returns for most asset classes, for example, where large-cap developed market equities deliver mid-single digit returns. However, we think it is instructional to look at our return forecasts over multi-year periods to understand what the trend of forecasts indeed portends. Five years ago, in the 2012 publication, our estimate for returns that would put the S&P 500 index at its long-term equilibrium was 9.3% a year (see Figure 5 for our historical comparison of major asset classes). Since then, the S&P has delivered a compound annual growth rate of 13.9%. Thus, some of the robustness of returns we expected previously has materialized and a measure of the value of the move toward equilibrium has been extracted. In fixed income, we see a somewhat similar pattern, especially within global and high yield segments. While it is quite fashionable to forecast a low return world today, we have only more recently been coming around to the story.

Figure 5A. Voya 10-Year Equity Forecasts Historically have been on a Downward Trajectory



Source: Voya Investment Management.
Data as of December 2016

Figure 5B. Voya 10-Year Fixed Income Forecasts have Declined



Source: Voya Investment Management.
Data as of December 2016.

Figure 6 presents our return forecasts for 2017–2026. We expect U.S. large cap and international developed market equities to deliver mid-single digit returns, which is marginally lower than a year ago. This is due to a growth trajectory still below its historical average, influenced by the headwinds of poor demographics and weak productivity. We forecast emerging market equities to have higher than developed market returns as they benefit from relatively stronger growth dynamics. Within the U.S., the most significant change relative to last year's forecast is the increase in returns for the Russell 2000 index. Our research shows that historically, small-cap equities demand a premium over both mid-cap and large-cap equities, to compensate for the added risk of owning smaller companies. An increase in our forecast for the trade-weighted U.S. dollar gave us further confidence in raising this forecast return, as foreign sales constitute a smaller portion of small-cap revenues than those of larger capitalization equities.

Our bond return assumptions can be characterized as challenged with low single-digit returns for most segments of fixed income. We come to this conclusion because our economic growth projections over the coming 10-year period portend low terminal interest rates. The low yield starting point also affects the forward returns to reach equilibrium. As monetary policy tightens in the U.S. and interest rates gradually renormalize from the extreme lower bound, we expect long duration fixed income to struggle as bond term premiums readjust. U.S. credit-related fixed income maintains a return advantage over government bonds. International developed sovereign bonds have negative risk-adjusted returns, as yields begin the period at the lowest levels in the global bond universe and monetary policy is expected to normalize over a lengthier period than in the U.S.

Figure 6. Voya Investment Management 10-Year Returns Forecast

	Expected Returns					
	Geometric Mean Return (%)	Arithmetic Mean Return (%)	Volatility (%)	Skewness	Kurtosis	Sharpe Ratio
Equity Index						
S&P 500	5.0	6.3	16.7	-0.46	0.87	0.23
S&P 500 Growth	5.0	6.4	17.3	-0.39	0.46	0.22
S&P 500 Value	4.9	6.3	17.2	-0.49	1.04	0.22
MSCI U.S. Minimum Volatility	4.6	5.2	11.9	-0.59	1.42	0.23
Russell Midcap	6.8	8.4	18.8	-0.51	0.97	0.31
Russell Midcap Growth	5.5	7.9	22.4	-0.38	0.57	0.24
Russell Midcap Value	7.5	8.9	17.7	-0.45	1.32	0.35
Russell 2000	7.2	9.8	23.4	-0.54	1.13	0.30
Russell 2000 Growth	4.7	8.3	27.1	-0.39	0.68	0.22
Russell 2000 Value	9.3	11.2	21.1	-0.70	1.85	0.39
MSCI EAFE	2.7	4.6	19.6	-0.27	0.09	0.11
MSCI World	4.5	5.8	16.5	-0.55	0.79	0.20
MSCI EM	5.8	9.6	27.7	-0.47	0.57	0.25
MSCI ACWI	4.8	6.2	17.1	-0.58	0.84	0.22
Alternative Assets Index						
Bloomberg Commodity	2.4	3.7	15.9	-0.41	1.35	0.08
CBOE Buy-write	4.9	5.6	12.4	-0.89	2.74	0.24
FTSE EPRA/NAREIT Developed ex U.S.	2.8	5.5	23.0	-0.17	0.48	0.13
MSCI U.S. REIT	5.7	8.2	22.7	-0.35	2.84	0.25
NCREIF ODCE Private Real Estate	5.8	8.2	21.2	-2.19	17.74	0.23
Fixed Income Index						
Bloomberg Barclays U.S. Aggregate	2.5	2.7	7.1	0.54	4.36	0.04
Bloomberg Barclays U.S. Government Long	0.6	1.4	12.5	0.23	0.62	-0.08
Bloomberg Barclays U.S. TIPS	1.8	2.2	9.4	0.31	3.27	-0.02
Bloomberg Barclays U.S. High Yield	3.8	4.5	12.5	-0.24	3.15	0.16
S&P/LSTA Leveraged Loan	6.1	6.4	9.4	-0.36	12.57	0.37
Bloomberg Barclays Global Aggregate	0.3	0.7	8.6	0.35	1.71	-0.20
Bloomberg Barclays Global Aggregate ex U.S.	-1.2	-0.7	10.7	0.16	0.43	-0.28
JPMorgan EMBI+	5.4	6.2	13.2	-1.67	11.14	0.25
U.S. Treasury Bill 3-Month	2.4	2.4	1.1	0.63	0.04	0.00

Source: Voya Investment Management.
Forecasts are subject to change.
Returns shown are in U.S. dollar terms.

Figure 7. Correlation Matrix

	S&P 500	S&P 500 Growth	S&P 500 Value	MSCI U.S. Minimum Volatility	Russell Midcap	Russell Midcap Growth	Russell Midcap Value	Russell 2000	Russell 2000 Growth	Russell 2000 Value	MSCI EAFE	MSCI World	MSCI EM	MSCI ACWI	Bloomberg Commodity	CBOE Buy-write	FTSE EPRA/NAREIT Developed ex U.S.	MSCI U.S. REIT	NCREIF ODCE Private Real Estate	Bloomberg Barclays U.S. Aggregate	Bloomberg Barclays U.S. Gov't Long	Bloomberg Barclays U.S. TIPS	Bloomberg Barclays U.S. High Yield	S&P/LSTA Leveraged Loan	Bloomberg Barclays Global Aggregate	Bloomberg Barclays Global Aggregate ex U.S.	JPMorgan EMBI+	U.S. Treasury Bill 3-Month
S&P 500	1.00																											
S&P 500 Growth	0.97	1.00																										
S&P 500 Value	0.97	0.87	1.00																									
MSCI U.S. Minimum Volatility	0.94	0.86	0.95	1.00																								
Russell Midcap	0.95	0.91	0.93	0.90	1.00																							
Russell Midcap Growth	0.89	0.91	0.82	0.79	0.95	1.00																						
Russell Midcap Value	0.89	0.78	0.94	0.91	0.92	0.75	1.00																					
Russell 2000	0.83	0.79	0.81	0.77	0.92	0.92	0.79	1.00																				
Russell 2000 Growth	0.81	0.81	0.75	0.71	0.89	0.94	0.69	0.98	1.00																			
Russell 2000 Value	0.81	0.72	0.84	0.79	0.90	0.82	0.86	0.96	0.88	1.00																		
MSCI EAFE	0.67	0.64	0.66	0.63	0.67	0.63	0.61	0.60	0.58	0.59	1.00																	
MSCI World	0.93	0.89	0.90	0.87	0.91	0.86	0.84	0.81	0.78	0.79	0.90	1.00																
MSCI EM	0.71	0.68	0.69	0.65	0.73	0.71	0.65	0.68	0.67	0.64	0.74	0.79	1.00															
MSCI ACWI	0.92	0.89	0.90	0.86	0.91	0.86	0.84	0.81	0.79	0.79	0.90	1.00	0.85	1.00														
Bloomberg Commodity	0.25	0.24	0.25	0.24	0.30	0.29	0.27	0.29	0.29	0.27	0.31	0.31	0.37	0.33	1.00													
CBOE Buy-write	0.91	0.87	0.89	0.86	0.89	0.83	0.83	0.80	0.77	0.78	0.61	0.85	0.67	0.84	0.29	1.00												
FTSE EPRA/NAREIT Developed ex U.S.	0.61	0.56	0.61	0.61	0.63	0.56	0.61	0.56	0.52	0.57	0.86	0.79	0.75	0.81	0.35	0.56	1.00											
MSCI U.S. REIT	0.58	0.51	0.61	0.62	0.62	0.52	0.65	0.59	0.52	0.64	0.75	0.72	0.63	0.73	0.23	0.55	0.86	1.00										
NCREIF ODCE Private Real Estate	0.27	0.24	0.29	0.29	0.28	0.24	0.29	0.26	0.23	0.27	0.21	0.27	0.23	0.27	0.28	0.29	0.22	0.26	1.00									
Bloomberg Barclays U.S. Aggregate	0.20	0.19	0.20	0.23	0.20	0.16	0.23	0.13	0.11	0.15	0.18	0.21	0.15	0.20	-0.02	0.17	0.22	0.20	-0.06	1.00								
Bloomberg Barclays U.S. Gov't Long	0.07	0.08	0.07	0.14	0.07	0.03	0.10	0.00	-0.01	0.02	0.04	0.06	0.01	0.06	-0.10	0.05	0.10	0.11	-0.14	0.89	1.00							
Bloomberg Barclays U.S. TIPS	0.22	0.20	0.23	0.26	0.23	0.18	0.27	0.16	0.13	0.18	0.21	0.24	0.20	0.24	0.10	0.22	0.28	0.24	0.04	0.93	0.81	1.00						
Bloomberg Barclays U.S. High Yield	0.62	0.59	0.61	0.59	0.65	0.60	0.61	0.64	0.61	0.64	0.51	0.63	0.59	0.64	0.26	0.62	0.49	0.53	0.29	0.29	0.14	0.34	1.00					
S&P/LSTA Leveraged Loan	0.45	0.43	0.43	0.43	0.49	0.43	0.48	0.45	0.42	0.45	0.36	0.45	0.39	0.45	0.22	0.45	0.36	0.38	0.37	0.19	0.02	0.26	0.76	1.00				
Bloomberg Barclays Global Aggregate	0.23	0.21	0.23	0.26	0.23	0.18	0.26	0.16	0.13	0.19	0.33	0.30	0.23	0.30	0.12	0.20	0.37	0.31	-0.05	0.87	0.74	0.84	0.28	0.16	1.00			
Bloomberg Barclays Global Aggregate ex U.S.	0.22	0.19	0.23	0.25	0.22	0.17	0.25	0.16	0.13	0.19	0.37	0.31	0.25	0.31	0.18	0.20	0.40	0.33	-0.04	0.72	0.60	0.72	0.25	0.14	0.97	1.00		
JPMorgan EMBI+	0.55	0.52	0.54	0.53	0.57	0.54	0.52	0.53	0.52	0.51	0.53	0.60	0.76	0.64	0.26	0.55	0.60	0.55	0.15	0.21	0.15	0.26	0.52	0.27	0.21	0.19	1.00	
U.S. Treasury Bill 3-Month	0.05	0.04	0.06	0.05	0.04	0.03	0.04	0.01	0.00	0.02	0.05	0.06	0.03	0.05	0.00	0.04	0.03	0.02	0.02	0.15	0.05	0.14	0.00	0.00	0.14	0.12	0.03	1.00

Source: Voya Investment Management.
Projections are subject to change.
Data as of December 2016.

Covariance and Correlation Matrices Methodology

Estimating asset-class covariance and correlation matrices are the underlying pillars of our asset-class standard deviation forecasts. This is a different process than forecasting returns, as evidence tells us that correlations wander through time. If we were to use a historical average or exponentially weighted methodology, which takes a long-run history and puts a heavier weight on recent observations, it could lead to risk forecasts that may be representative of the past but bear little resemblance to the future. Therefore, the forecast of multiple asset-class risk summarized by the return covariance matrix is crucial to our capital market assumptions process.

A simple example using equities and bonds can illustrate this point (Figure 8). Over the past 20 years, the correlation of returns between the S&P 500 index and Bloomberg Barclays U.S. Aggregate Bond index was -0.02; however, this tells us nothing about the relationship of returns between these two asset classes during unusual periods or when financial markets are in very euphoric or pessimistic states. For example, during normal periods of returns over the same 20-year interval, the correlation between equities and bonds was -0.10, whereas during the unusual periods it was +0.07. Incorporating these periods of unusual correlation patterns can lead to a truer estimate of the durability of diversification between asset classes. We capture these unusual periods in our standard deviation and correlation forecasts in an academic framework called turbulence.

Figure 8. Normal and Turbulent Periods of Stock and Bond Correlations, 20 Years Ended December 2016

Source: Voya Investment Management.
Data as of December 2016.

Turbulence: Evolution of a Concept

The turbulence framework we use to estimate correlations and standard deviations of returns among asset classes is derived from the academic work of the applied statistician Prasanta Chandra Mahalanobis. In the early twentieth century, Mahalanobis analyzed human skull resemblances among castes and tribes in India. He created a formula to capture differences in skull size, which incorporated the standard deviation of measures of various skull parts. He then squared and summed the normalized differences, generating a single composite distance measure.[1]

This formula evolved into a statistical measure called the "Mahalanobis distance." The measure was groundbreaking in that it helped analyze data across standard deviations but also incorporated the correlations among data sets. More than 60 years later, the Mahalanobis distance was used by Kritzman and Li to formulate a concept called financial turbulence.[2] They postulated financial turbulence as a condition in which asset prices, given their historical patterns of returns, behave in an uncharacteristic way including extreme price moves. They further noted that financial turbulence often coincides with excessive risk aversion, illiquidity and price declines for risky assets. It is this turbulence framework (or unusualness of returns and correlations of returns) that we have used to forecast risk measures in our capital market assumptions.

Observing Turbulence

Turbulence can be calculated for any given set of asset classes. Back to our example of U.S. equities and bonds, the two dimensions can be visualized as the equation of an ellipse using the returns of the S&P 500 index and the Bloomberg Barclays U.S. Aggregate index (Figure 8). The center of the ellipse represents the average of the joint returns of the two assets. The boundary is a level of tolerance that separates normal from turbulent observations. The boundary takes the form of an ellipse rather than a circle because it takes into account the covariance of the asset classes. The idea captured by this measure is that certain periods are considered turbulent not only because returns are unusually high or low but also because they moved in the opposite direction of what would have been expected given average correlations.

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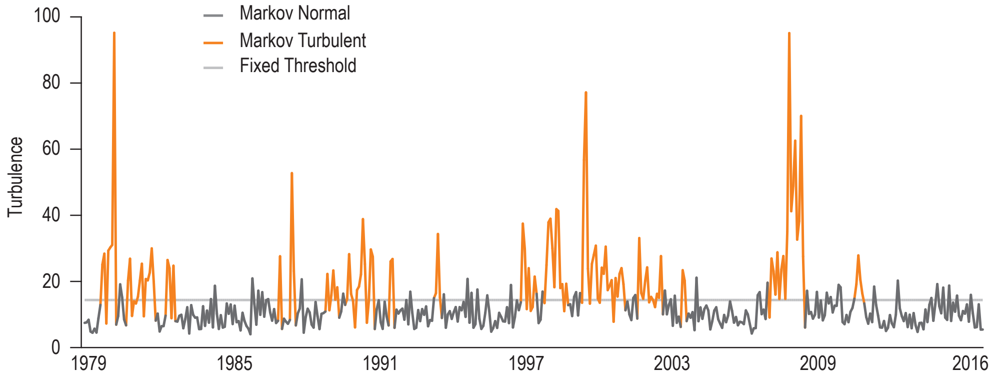
1 Mahalanobis, P., "On the Generalized Distance in Statistics," *Proceedings of the National Institute of Sciences of India* vol. 2 no. 1 (1936): 49-55.

2 Kritzman, M. and Y. Li, "Skulls, Financial Turbulence, and Risk Management," *Financial Analysts Journal* vol. 66 no. 5 (2010): 30-41.

Using Turbulence to Create Portfolios

Note that the threshold of normal and turbulence in Figure 8 is not static but rather is dynamic through time. Our process identifies turbulent market regimes by estimating a covariance matrix covering those periods of market stress alone and is the outcome of a Markov model. The model classifies regimes rather than arbitrary thresholds because thresholds would fail to capture the persistence of shifts in volatility. The Markov model output in Figure 9 illustrates turbulent and normal regimes.

Figure 9. Markov 12-Asset Normal and Turbulent Regimes



Source: Voya Investment Management.
Data as of December 2016.

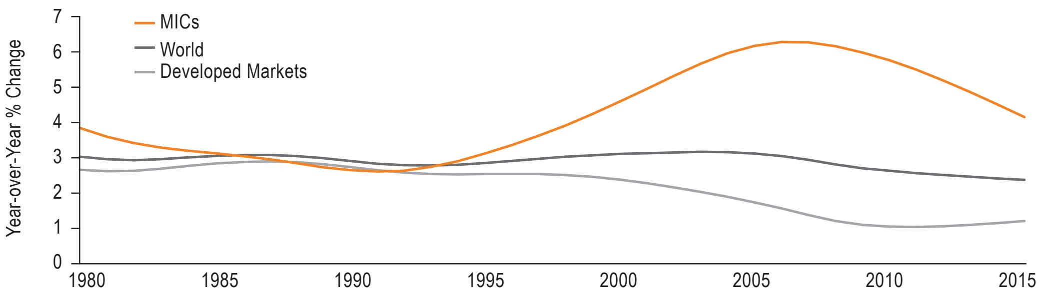
Turbulent market regimes make use of the concept of multivariate outliers in a return distribution. That is, we take into account not only the deviation of a particular asset class's return from the average, but also its volatility and correlation with other asset classes. We subsequently estimate a covariance matrix based on periods of normal and turbulent market performance. 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 normal or turbulent regime and to capture the differential risk attitudes toward each. The weights we use are 60% normal and 40% turbulent to create our strategic asset allocation portfolios.

We overweight the turbulent regime at 40% — higher than its observed frequency of 30% — to account for structural issues such as globalization, demographics and worldwide central bank intervention, which are prevalent today. From this blended covariance matrix, we then extract the implied correlation matrix and standard deviations for each asset class. In our view, this process helps create a strategic asset allocation portfolio that can account for the empirical evidence that correlations will deviate through time.

Appendix A: Low Growth but Does It Have to Last Forever?

There is a school of thought which postulates that in the aftermath of financial crises, periods of sub-trend economic growth can persist for a decade or longer. On the surface, the post-2008 period could be defined by that view. However, developed market growth had been falling steadily for the eight years prior to the financial crisis (see Figure 10). In fact, Organization for Economic Cooperation and Development (OECD) data show that developed market trend growth fell from 2.8% at the end of the 1990s to almost 2% by 2005, and is down to 1.4% at present. The reason that this was somewhat overlooked was due to the pre-financial crisis robust growth in middle income countries (MICs) such as China, India, Turkey, Indonesia, Russia, Malaysia and Brazil. These countries represent about two-thirds of the global population and one-third of global GDP. However, post-financial crisis they have not been immune to the slowdown. Through our research we know that business cycles are persistent in nature; in this Appendix we look at what fundamental changes at the margin might be able to break the world out of its growth slump.

Figure 10. Global Growth Trends in Real GDP

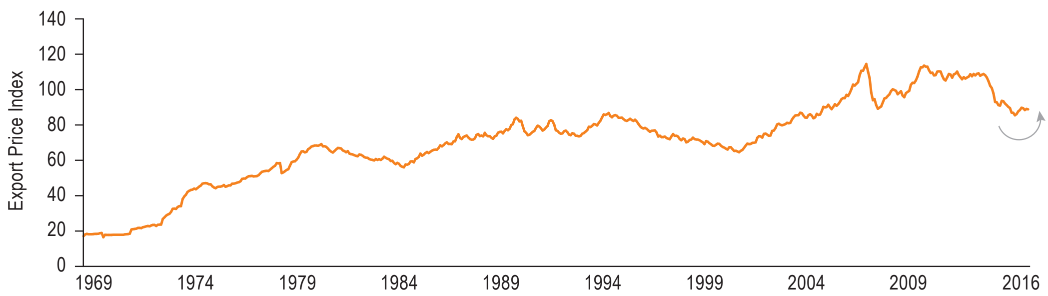


Source: World Bank, OECD and Voya Investment Management.
Data as of December 2016.

The End of Trade Deflation?

This sluggish period has been defined by excess capacity, stagnant wage growth and deflation shocks. While central banks have been relatively successful in fighting the mal-effects of deflation, reliance on central banks alone to generate growth has proven insufficient. The deflationary impulse has been especially acute for foreign trade prices, which have declined 18% since 2011. To be sure, the drop in world export prices has been greatly influenced by commodities, but this has extended to export prices in aggregate. Figure 11 indicates an important trough occurred in the first quarter of 2016. More data will be needed to confirm whether this is a decisive turn, so it bears watching closely.

Figure 11. World Export Prices

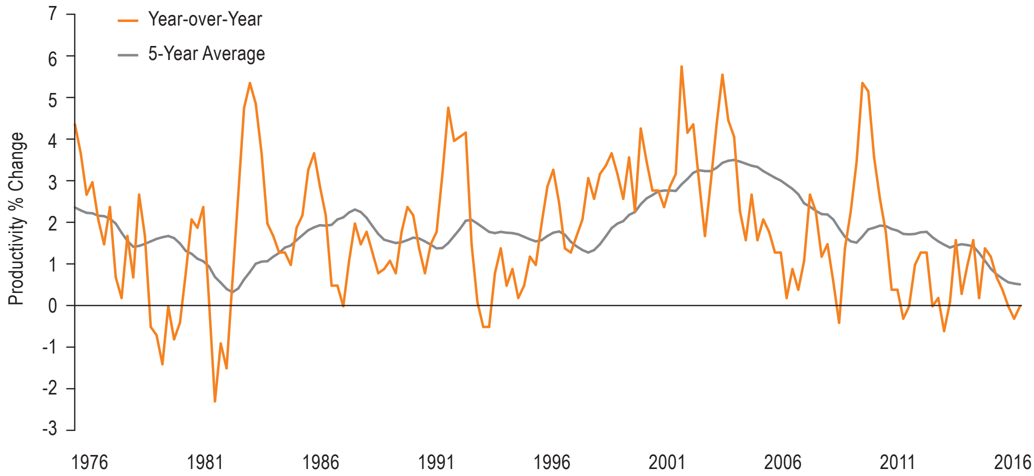


Source: Bloomberg.
Data as of December 2016.

Revival of Productivity Gains

Labor productivity remains another influential trend to watch. In the U.S., we have seen a significant downturn in productivity over the past 15 years, with the five-year average now below 1%. This is not without precedent, however, as the five-year growth rate of non-farm productivity fell to 1% in the late 1970s and in the late-1990s (Figure 12).

Figure 12. U.S. Productivity Cycles Have Traced a Volatile Path over Recent Decades



Source: Bloomberg and Department of Labor.
Data as of September 2016.

What snapped the productivity slump in those periods? Policy changes such as deregulation, tax-rate reductions and a strong U.S. dollar in the Reagan and Clinton administrations helped make the decisive turns. We cannot help but see some modest parallels to those historical examples today. President Trump's policy initiatives appear to be very pro-business, set to cut corporate tax rates, push tax "amnesty" and a focus on deregulation. While the labor market already appears to be at full employment (consistent with the Federal Reserve's long-term objective), Fed Chair Janet Yellen has stated a preference to allow the economy to run hotter; i.e., with more tolerance for inflation. Taken together, there is a potential scenario developing for some higher inflation but importantly with stronger growth. This could contribute to a bottoming of the productivity cycle.

An Elongated Economic Cycle

The current global macroeconomic picture continues to pick up after an earlier lull for all of 2015 and early 2016. Economic reports now show decided improvement across most regions in middle income and OECD countries. The slow growth regime we have been mired in has meant the normal build-up of excesses has not materialized. This in turn has probably elongated the economic cycle. But the more pervasive side of low growth and income inequality has transformed politics. The fiscal policy push, which has been missing from this expansion, is now a possibility. This scenario has the potential to spark better economic performance, including a turn towards higher growth rates. In our view, this is a possible outcome that bears close watching, since it is the changes at the margin that mark a shift from a slow regime to a faster one. At this point, only more data and time will tell if a shift to sustained higher growth needs to be incorporated into investment views.

Appendix B: Time Dependency of Asset Returns and Its Impact on Risk Estimation

Recent research suggests that expected asset returns change over time in somewhat predictable ways and that these changes tend to persist over long periods. Thus, changes among investment opportunities — all possible combinations of risk and return — are found to be persistent. This Appendix will set out the economic reasons for return predictability, its consequences for strategic asset allocation and the adjustments we have made to account 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 share the same quality. Consumers, for example, have a tendency to smooth consumption since they dislike abrupt changes in their lifestyles. Research on permanent income and lifecycle consumption provides the theoretical basis for consumers' desire for a stable consumption path. 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 these 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.[3] Investment, the second component of GDP, is sticky, as corporate investment in projects is usually long-term in nature. Finally, government expenditures also have a low level of variability. Over a medium-term horizon, negative serial correlation sets in as the growth phase of the cycle is followed by a contraction and then that contraction is followed by renewed growth.[4]

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 depends on four factors: expected cash flows, 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 consumers are trying to smooth consumption and are less willing to take risks with their income; and low at business cycle peaks, when people are more willing to take risks. 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 its capital structure. Thus, a firm's risk increases with leverage, which is related to the business cycle. The last component of the discount rate is the risk-free rate, which is determined by the term structure of interest rates. The term structure reflects expectations of real interest rates, real economic activity and inflation, which are connected to the business cycle. Thus, equity returns, and financial asset returns in general, are to a certain extent predictable. Expected returns of many assets tend to be high in bad macroeconomic times and low in good times.

This predictability of returns manifests itself statistically through autocorrelation. Autocorrelation 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 returns tend to be followed by high returns, implying momentum in the market. Conversely, negative autocorrelation occurs when high returns tend to be followed by low returns, implying mean reversion. In either case autocorrelation induces dependence in returns over time.

Traditional mean-variance analysis focused 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 zero autocorrelation; realized short-term returns are not predictable. Volatilities and cross-correlations among assets are independent of the investment horizon. Thus, the annualized volatility estimated from monthly return

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

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

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 autocorrelation matters for its impact on volatility and correlations. Positive autocorrelation leads to an underestimation 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 of 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 non-public market assets such as private equity or private real estate, among others.

There are at least two ways to correct for autocorrelation:

- A direct method that adjusts the sample estimators of volatility, correlation and all higher moments
- 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 autocorrelation. Before we do that we estimate and test the statistical significance of autocorrelation in our data series.

We estimate first-order autocorrelation 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.[5] 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.[6] 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 market investments.[7] 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 and privately traded securities and requires only returns to compute.

Since the vast majority of the return series we estimate exhibits autocorrelation, we 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 ρ and the 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 to make for long-horizon asset allocation portfolios.

New York City
February 2017

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

6 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%.

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

Multi-Asset Strategies and Solutions Team

Voya Investment Management's Multi-Asset Strategies and Solutions (MASS) team, led by Chief Investment Officer Paul Zemsky, manages the firm's suite of multi-asset solutions designed to help investors achieve their long-term objectives. The team consists of 25 investment professionals who have deep expertise in asset allocation, manager selection and research, quantitative research, portfolio implementation and actuarial sciences. Within MASS, the asset allocation team, led by Barbara Reinhard, is responsible for constructing strategic asset allocations based on their long-term views. The team also employs a tactical asset allocation approach, driven by market fundamentals, valuation and sentiment, which is designed to capture market anomalies and/or reduce portfolio risk.