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Portfolio perspectives

Market and economic environments and their potential influence on asset allocation

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- Market and economic environments tend to evolve over time, sometimes quite rapidly. As they change, fundamentals such as interest rates and price/earnings ratios fluctuate and cause expected returns of assets to vary as well. If investors are willing to take on active risk in the form of "model forecast risk," their portfolio's asset allocation can vary in tandem with an asset's **long-term** expected returns, its underlying fundamental drivers, and the state of the economy.

- In this research note, we highlight an innovative machine-learning clustering technique to objectively classify the full range of capital market scenarios into five states: recession, recovery, expansion, slowdown, and high inflation. For the most part, these states resemble the business cycle and key economic states we've historically experienced. We discuss their specific characteristics, fundamental valuations, and implications for long-run return expectations.

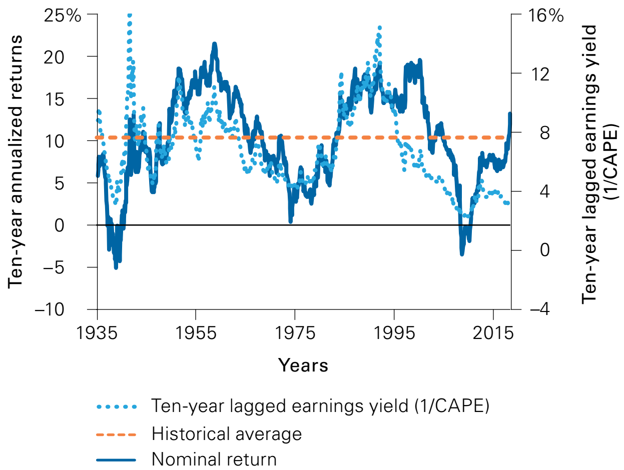
- For investors who are unwilling to take on active risk in terms of the uncertainty surrounding statistical model estimation, a static portfolio approach works best. For those willing to take on active risk, a market and economic state-based, time-varying asset allocation is more suitable.

Introduction

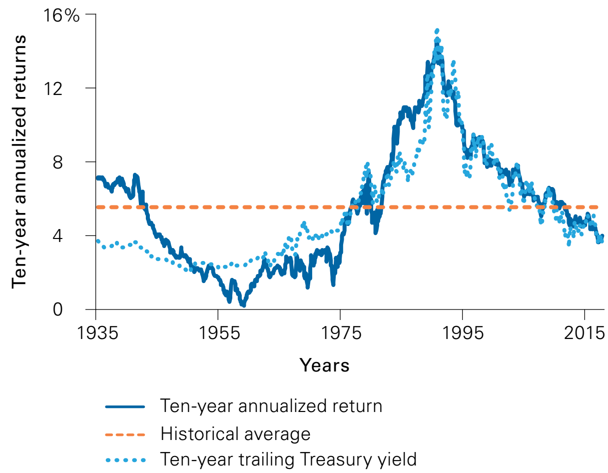
Long-horizon equity and fixed income returns can vary quite drastically over time. For instance, **Figure 1** shows that ten-year annualized U.S. equity returns have oscillated between –5% and 20% since 1935. Because such fluctuations can have a dramatic impact on portfolio outcomes, forming a range of reasonable asset returns can be a valuable exercise for investors.

Figure 1: Long-run returns are time-varying

a. U.S. equity



b. U.S. fixed income



Notes: Figures show the traditional predictive regression of ten-year annualized returns on the starting Shiller CAPE valuation metric. Data are from December 1935 through October 2018.

Sources: Vanguard calculations, based on Robert Shiller's website: aida.wss.yale.edu/~shiller/data.htm.

Notes on risk

All investments are subject to risk, including the possible loss of the money you invest. Diversification does not ensure a profit or protect against a loss. There is no guarantee that any particular asset allocation or mix of funds will meet your investment objectives or provide you with a given level of income. Past performance is no guarantee of future results. Foreign investing involves additional risks including currency fluctuation and political uncertainty. Currency hedging transactions may not perfectly offset a fund's foreign currency exposures and may eliminate any chance for a fund to benefit from favorable fluctuations in those currencies. A fund will incur expenses to hedge its currency exposures.

IMPORTANT NOTE: The projections and other information generated by the Vanguard Capital Markets Model® regarding the likelihood of various investment outcomes are hypothetical in nature, do not reflect actual investment results, and are not guarantees of future results. VCMM results may vary with each use and over time. The VCMM projections are based on a statistical analysis of historical data. Future returns may behave differently from the historical patterns captured in the VCMM.

More important, the VCMM may be underestimating extreme negative scenarios unobserved in the historical period on which the model estimation is based.

In some cases, there is a systematic relationship between future expected ten-year annualized returns and initial conditions–price/earnings ratios for equities and interest rates for fixed income. Figure 1 illustrates that ten-year-ahead equity returns are directly proportional to 1/CAPE (cyclically adjusted price/earnings ratio), and ten-year-ahead fixed income returns are directly proportional to initial yield. (Using out-of-sample forecasts made since 1985, the correlation of predicted and actual returns is 0.9.)

However, price/earnings ratios and interest rates are not the only predictors of equity and fixed income returns over long horizons. Other macroeconomic and market variables such as inflation, economic growth, and market volatility are also influential (Davis et al., 2014). It's important to capture all the core variables that describe the market and economic environment. Vanguard's Capital Market Model (VCMM), our probabilistic asset return forecasting engine, follows this principle and forecasts a distribution of core variables to reflect the full range of economic possibilities that could arise. It then translates how those core variables map to asset return distributions.

We want to differentiate our approach from more common tactical asset allocation strategies followed in the industry and based on business cycle indicators. These strategies have several potential limitations: 1) they are either too narrowly defined (based on one or two economic indicators), too subjective, or based on data with a considerable lag; 2) they don't take into account asset return uncertainty or a range of possible outcomes; and 3) their methodology is tactical (short-term) and not particularly robust rather than being a strategic (long term) robust approach.

In this paper, we propose a more robust and objective methodology consisting of three steps:

1. We group the VCMM core driver simulations to reflect intuitive states of the economy and markets such as recession, recovery, expansion, and slowdown. Specifically, we use a machine-learning technique known as K-means clustering (Hastie et al., 2009) to objectively group 10,000 VCMM core simulations into a small number of well-defined economic and market states.
2. We extract asset return forecasts (expected means, volatilities, and correlations) that are specific to these states of the economy. The expected returns are meaningfully different for each economic state.
3. We implement our time-varying asset allocation (TVAA) methodology (see Aliaga-Díaz et al., 2020) to derive a time-varying portfolio that can account for the transition through different market states and their corresponding expected returns.

TVAA is an appealing option for investors willing to take on active portfolio risk in the form of "model forecast risk" when faced with time-varying expected returns due to changing economic conditions and environments. But TVAA is not equivalent to market timing. In fact, it is reflective of a well-established value-investing principle: An asset's valuation is the main determinant of long-horizon expected returns. The allocation reacts to the observed current valuations and attempts to harvest risk premia over the long term without relying on myopic market timing. The resulting portfolios can better reflect investors' return objectives and risk preferences (including tolerance to active risk) and increase the odds of investment success.

Step 1: A machine-learning-based clustering approach

VCMM presents a probabilistic, forward-looking view of the economy and asset returns. Rather than subjectively grouping variables into various cohorts by assigning ad-hoc ranges, we propose an objective and quantitative method of categorizing the various macroeconomic environments: We use a machine-learning algorithm to group similar VCMM scenarios together. Grouping objects is one type of problem that machine learning has thrived at solving. We apply a well-studied unsupervised learning technique, K-means algorithm, to accomplish this task.

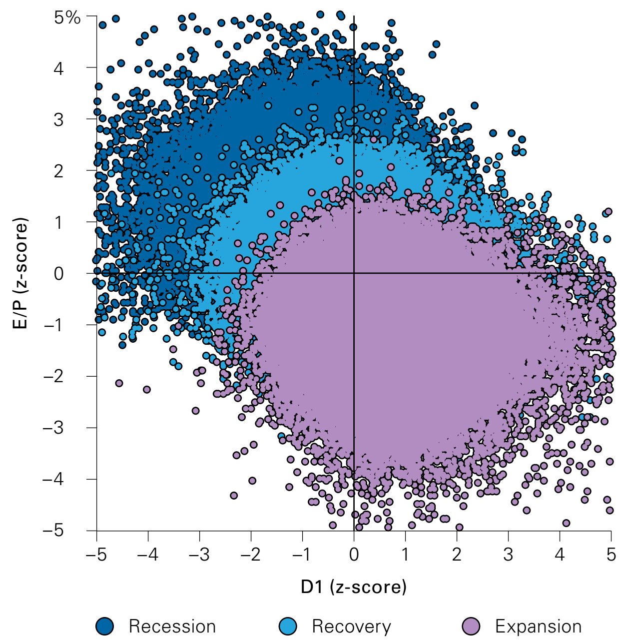
A standard K-means algorithm often involves iterating between two steps. Step 1, the **assignment step**, assigns every observation to its "closest" (measured by Euclidean distance[1]) center. Step 2, the **update step**, computes centers ("means") of all of the observations assigned to each cluster during Step 1. The algorithm repeats these steps until those assignments no longer change significantly.

Instead of grouping asset returns directly, we apply the K-means clustering algorithm to the VCMM core variables, classifying their simulations into five groups (K = 5). The key core variables that reflect the state of the economy and markets in VCMM are:

- Interest rates. Note that we specify interest rates by the level (D1), slope (D2), and curvature (D3) of the yield curve (Diebold and Li, 2006).
- Inflation.
- Vanguard Leading Economic Indicator (VLEI) index (a proxy for economic growth).
- The equity price/earnings ratio.
- Equity market volatility.

Figure 2 illustrates how K-means clustering results are visualized on a two-dimensional plane. (Expansion has a high D1 and low earnings/price (E/P), while recession has low D1 and high E/P.)

Figure 2. Clustering core variables simulations: An example



Source: Vanguard calculations, using 10,000 VCMM simulations in long-term equilibrium.

1 For the purpose of this work, we have focused on the Euclidean distance, but in the future we will also explore distance metric learning and other distance metrics to identify this data.

Figure 3 depicts the median value of each VCMM core variable in each of the five market environments:

1. **Recession.** Growth (Vanguard leading economic indicator, or VLEI) is negative, the price/earnings ratio and interest rates are low, and equity market volatility is elevated.
2. **Recovery/low inflation.** Growth is low but improved from the recession state, the interest rate level is slightly higher than in a recession, but the yield curve is steep (as depicted by the high and negative slope). The price/earnings ratio is higher than in the recession state and the equity volatility is at a normal level.
3. **Expansion.** Growth and interest rate level is high and the yield curve is somewhat flat. In this environment, the price/earnings ratio is high and volatility is extremely low.
4. **Slowdown.** Economic growth is near zero and the other variables are close to normal levels.
5. **High inflation.** Inflation is particularly high relative to the central bank target of about 2%, and interest rate levels are high as a result.

Figure 3. K-means algorithm-based (K = 5) market environments

Environment	D1 (level)	D2 (slope)	D3 (curvature)	Price/ earnings	VLEI (z-score)	Short-term equity volatility	Inflation
Recession	3.02	−0.77	−1.75	10.9	−0.27 (−0.77)	29.00%	0.90%
Expansion	4.97	−1.5	0.95	26.8	0.27 (0.79)	8.90	2.70
Slowdown	3.37	1.2	2.81	17	−0.03 (−0.09)	15.30	1.80
Recovery	4.08	−3.07	−3.35	17.2	0.07 (0.2)	15.80	0.30
High inflation	4.74	−1.03	0.36	16.5	−0.05 (−0.15)	18.40	4.90

Source: Vanguard calculations, using 10,000 VCMM simulations in the long-term equilibrium.

Step 2: Long-horizon expected returns in each environment

We now examine whether the clustered market and economic environments make economic sense or not. **Figure 4** includes the median value of expected returns over the next ten years (in the annualized geometric sense) after each environment has occurred.

In a recession state with a low price/earnings ratio, the expected return for U.S. equity over the next decade is 11%; in an expansion, when price/earnings ratios are high, it's much lower, at 4.1%. As return forecasts are forward-looking, the drop in the price/earnings ratio during the recession actually improves the forward-looking return prospects for equities; thus, expected returns are higher than average.

The opposite is true during an expansion. An investor incorporating TVAA may allocate more to equity if a recession has just occurred, and vice versa in an expansion. Similarly, in an environment of low (high) inflation, when the interest rate is expected to normalize and rise (fall) in the future, expected returns for bonds will be low (high) over the next ten years. The expected returns in Figure 4 follow an intuitive pattern, keeping in mind that today's market conditions send a contrarian signal to forward-looking future returns.

Figure 4. Long-term expected returns based on five market and economic environments

Environment	U.S. equity	U.S. bond	International equity	International bond
Recession	11.00%	3.60%	10.90%	3.50%
Expansion	4.10	5.00	7.00	4.40
Slowdown	7.20	4.90	8.70	4.60
Recovery	7.20	3.30	8.90	3.20
High inflation	7.80	5.10	9.10	4.40

Note: Expected returns are ten-year annualized nominal returns.

Source: Vanguard calculations, using 10,000 VCMM simulations in long-term equilibrium.

Step 3: Market environment-dependent asset allocation

After estimating expected returns, a natural next question is: What does this imply for an investor's asset allocation? Before we can calculate portfolio weights, we need one more variable: the transition probability, which measures the likelihood that the economy will evolve from one market environment to another. While there are numerous ways to calibrate this value, we simply compute the proportion of transitions of VCMM simulations as the market environment changes.

Figure 5 shows a state transition matrix. Each entry represents the probability of going from the state in the row to the corresponding state in the column of the table.[2] The state transition matrix is combined with the state-dependent return expectations from Figure 4 to calculate optimal portfolios for each market environment.

With both expected returns and transition probability in the tool kit, we can calculate the optimal asset allocation given an investor's risk aversion when the objective is to maximize the utility of wealth at the end of the investment horizon. This utility-based, multiperiod asset allocation is determined using a TVAA technique that considers long-term expected returns, their distributional framework, and their transition probabilities. The advantage of this methodology is that it's entirely rules-based and nondiscretionary. The asset allocation is laid out as a contingency tree, with a different optimal solution for each possible future state.

Figure 5. State transition probability matrix

Environment	Recession	Expansion	Slowdown	Low inflation	High inflation
Recession	53.40%	2.20%	15.60%	17.00%	11.80%
Expansion	2.20	52.80	12.00	16.90	16.10
Slowdown	15.60	11.00	53.60	6.40	13.30
Recovery	12.40	15.30	5.20	56.20	10.90
High inflation	15.00	14.80	16.30	13.30	40.50

Source: Vanguard calculations, using 10,000 VCMM simulations in long-term equilibrium.

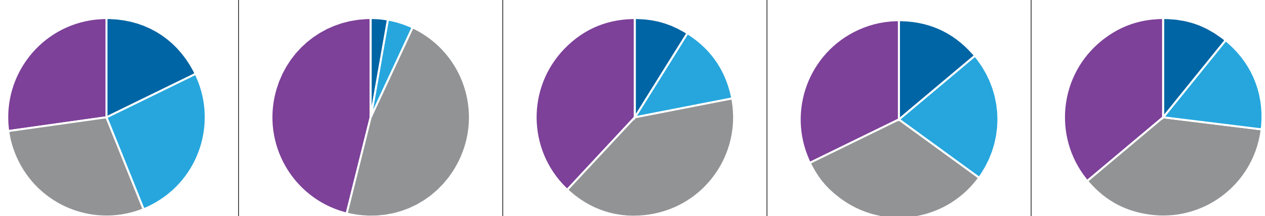
2 If a recession has just occurred, the simulations indicate that we will most likely experience another in the next quarter, with a probability of 53.4%. We observe a similar likelihood in other market environments. It seems counterintuitive but, even after nine consecutive quarters of recession, the probability of recession in the next quarter is still 53.4%. However, a scenario with ten consecutive quarters of recession has a probability of only approximately 0.534 x 10=0.002, or 0.2%. Among 10,000 VCMM simulation paths, only 20 of them could be expected to include such a scenario.

A hypothetical example of state-dependent portfolios is illustrated in **Figure 6.** The multiperiod asset allocation approach requires investors to take on the active (model) risk of changing their allocation in response to the evolving environment. We believe that, for those willing to accept this risk, the strategic approach is fundamentally sound when compared with other tactical asset allocation strategies.

Conclusion

In this research note, we highlight an innovative machine-learning clustering technique to objectively classify the macroeconomic and market environment into five states: recession, recovery, expansion, slowdown, and high inflation. For the most part, these states intuitively resemble the business cycle and key market states we've historically experienced. We discuss the characteristics, fundamental valuations, and long-run return expectations of each of these states and find that for investors willing to take on active risk, this dynamic, state-dependent approach is more suitable than a static portfolio

Figure 6. A hypothetical example of state-dependent portfolios



	Recession	Expansion	Slowdown	Recovery	High inflation
U.S. equity	18%	3%	9%	14%	11%
International equity	27%	4%	13%	21%	16%
U.S. bond	29%	47%	40%	33%	37%
International bond	26%	46%	38%	32%	36%

Source: Vanguard.

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Appendix. Vanguard Capital Markets Model

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The VCMM projections are based on a statistical analysis of historical data. Future returns may behave differently from the historical patterns captured in the VCMM. More important, the VCMM may be underestimating extreme negative scenarios unobserved in the historical period on which the model estimation is based.

The VCMM is a proprietary financial simulation tool developed and maintained by Vanguard's Investment Strategy Group. The model forecasts distributions of future returns for a wide array of broad asset classes. Those asset classes include U.S. and international equity markets, several maturities of the U.S. Treasury and corporate fixed income markets, international fixed income markets, U.S. money markets, commodities, and certain alternative investment strategies. The theoretical and empirical foundation for the Vanguard Capital Markets Model is that the returns of various asset classes reflect the compensation investors require for bearing different types of systematic risk (beta).

At the core of the model are estimates of the dynamic statistical relationship between risk factors and asset returns, obtained from statistical analysis based on available monthly financial and economic data. Using a system of estimated equations, the model then applies a Monte Carlo simulation method to project the estimated interrelationships among risk factors and asset classes as well as uncertainty and randomness over time. The model generates a large set of simulated outcomes for each asset class over several time horizons. Forecasts are obtained by computing measures of central tendency in these simulations. Results produced by the tool will vary with each use and over time.

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