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Not all factors are created equal: Factors' role in asset allocation

- Factors are characteristics of securities that drive return and risk in the market. Factor-based investing aims to achieve specific risk or return objectives by accessing these drivers through systematic, rules-based strategies. Long-term investors may consider a factor allocation in their portfolios to harvest factor risk premia.
- Factor construction—making factors a key consideration in security selection—can materially affect portfolio outcomes. Two commonly used approaches, market-capitalization-weighted and signal-weighted, lead to different factor exposures and portfolio risks. A signal-weighted portfolio generally offers investors higher risk and factor exposure, potentially saving them capital to deploy to other types of assets. But a cap-weighted approach to security weighting typically provides lower deviation from the broad market, with lower overall exposure to the target factor.
- Both construction methods can play important roles in investors' portfolios, depending on their risk appetite, investment objectives, and existing asset allocation. Investors and their financial advisors should carefully evaluate the choice between cap-weighted and signal-weighted portfolio approaches.

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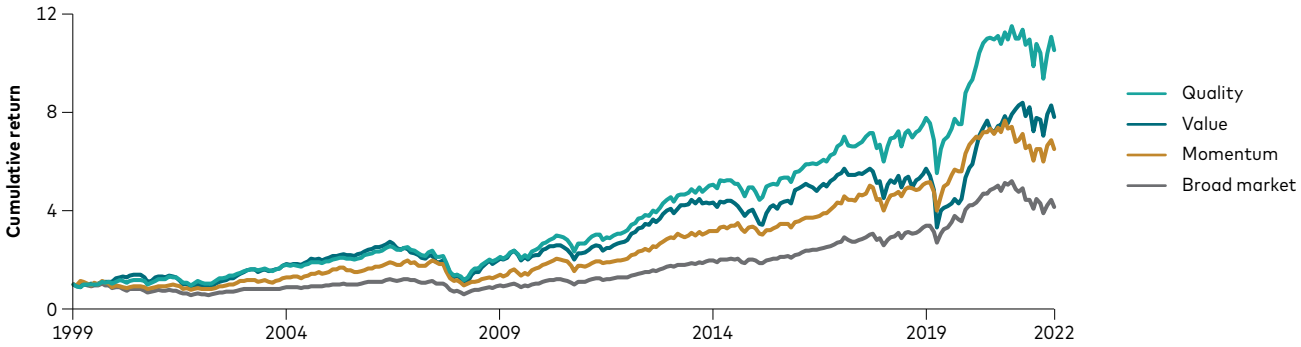
Factor-based investing offers a different perspective for viewing a range of investment strategies beyond traditional asset-class categorizations. Incorporating factors into a portfolio offers investors several advantages (Grim et al., 2017). First, factor funds have the potential to enhance returns. **Figure 1** shows the cumulative returns of large-cap value, momentum, and quality factors compared with market returns from yearend 1999 through December 2022.[1] All those factors exceeded the market returns. Growing evidence shows that those factors have not been arbitraged away despite growing interest in factor funds (Ilmanen et al., 2021).

Not all factors are equal, though. There is extensive literature discussing how factors are defined. For example, recent thinking focuses on how to use intangible assets on a company's balance sheet—such as intellectual property—to enhance the value factor (Ahn, 2019) and the quality factor (Bacciardi et al., 2023), how to use risk mitigation tools to improve the momentum factor (Dierkes and Krupski, 2022), and how factors interact with one another (Kimura et al., 2021). Less explored is how these factor portfolios are constructed and their implications for factor premia (Zhang, 2022) and, more broadly, for asset allocation.

FIGURE 1

Over two-plus decades, value, momentum, and quality factors outpaced the market

Cumulative returns of large-cap value, momentum, and quality



Notes: Quality is the average of profitability and investment in the Fama/French data library. Data cover December 31, 1999, through December 31, 2022.
Sources: Vanguard, based on data from the Fama/French data library.
Past performance is no guarantee of future returns.

1 We use the average of high profitability factor and low investment factor to approximate the quality factor in this paper, following Aliaga-Díaz et al. (2019).

Generally, there are three methods for constructing factor portfolios. The most straightforward is the cap-weighted method, where stocks are selected based on a specific factor and weighted by market capitalization. At the other end of the spectrum is the signal-weighted method, which involves selecting stocks based on a specific factor, disregarding their market caps, and assigning weights based on the size of each stock's individual factor exposures. A third approach is a hybrid that blends aspects of both methods, such as combining market cap with signals in weighting different stocks in a portfolio. To illustrate how these construction methods affect investment goals and preferences, we focus in this paper on the cap-weighted and signal-weighted approaches, which offer the sharpest contrast in terms of factor exposure, return, and risk. **Figure 2** summarizes some of the pluses and minuses of these two methods.

The rest of this paper highlights the distinct roles played by cap-weighted and signal-weighted portfolio construction approaches in asset allocation. It is crucial that individual investors and financial advisors carefully consider the trade-offs of the two construction methods when choosing factors.

FIGURE 2

Each portfolio construction method has advantages and drawbacks

Comparing cap-weighted versus signal-weighted construction

Portfolio characteristic	Cap-weighted factor construction	Signal-weighted factor construction
Factor exposure	Relatively low (drawback)	Relatively high (advantage)
Long-term premia capture	Relatively low (drawback)	Relatively high (advantage)
Tracking error	Low (advantage)	High (drawback)
Capital intensity	High (drawback)	Low (advantage)

Note: Capital intensity refers to the ability to get the same exposure with less capital.
Source: Vanguard.

Factor exposures

To begin our analysis, we constructed value, momentum, and quality factor portfolios from the universe of stocks represented in the Russell 1000 Index, using both cap-weighted and signal-weighted approaches. We defined the value factor as book value divided by price, the momentum factor as total return for the 11 months before the latest month (the 12-month return minus the final month), and the quality factor as the combination of asset growth and gross profitability, weighted equally. (See **Appendix 1** on page 15 for the detailed construction methodology for these portfolios.)

Figure 3 presents these factor portfolios' descriptive statistics. Over the 23-year period that we analyzed, the cap-weighted factor portfolios exhibited lower tracking error than the signal-weighted ones. Intuitively, the added risk in the signal-weighted approach is driven by higher exposure to the target factors. Investors who believe in long-term factor premia would expect greater returns for more targeted factor exposure. The results shown in Figure 3 confirm this relationship over the period, as the signal-weighted approaches outperformed the cap-weighted portfolios.

FIGURE 3

How the value, momentum, and quality factors compare

Descriptive statistics for the three factors

	Value factor		Momentum factor		Quality factor		Stock universe (Russell 1000 Index)
	Cap-weighted	Signal-weighted	Cap-weighted	Signal-weighted	Cap-weighted	Signal-weighted	Cap-weighted
Annual return	6%	11%	7%	11%	8%	10%	7%
Tracking error	10%	13%	7%	11%	5%	8%	—
Target factor exposure	0.50	0.83	0.37	0.51	1.06	1.14	—

Notes: The period analyzed is December 31, 1999, through December 31, 2022, using monthly data. Target factor exposure means the factor exposure, respectively, of value, momentum, and quality. The factor exposure is the weighted sum of the underlying security exposures to the target factor. For more details about the factor exposure construction, see Appendix 1 on page 15.

Source: Vanguard.

Past performance is no guarantee of future returns. The performance of an index is not an exact representation of any particular investment, as you cannot invest directly in an index.

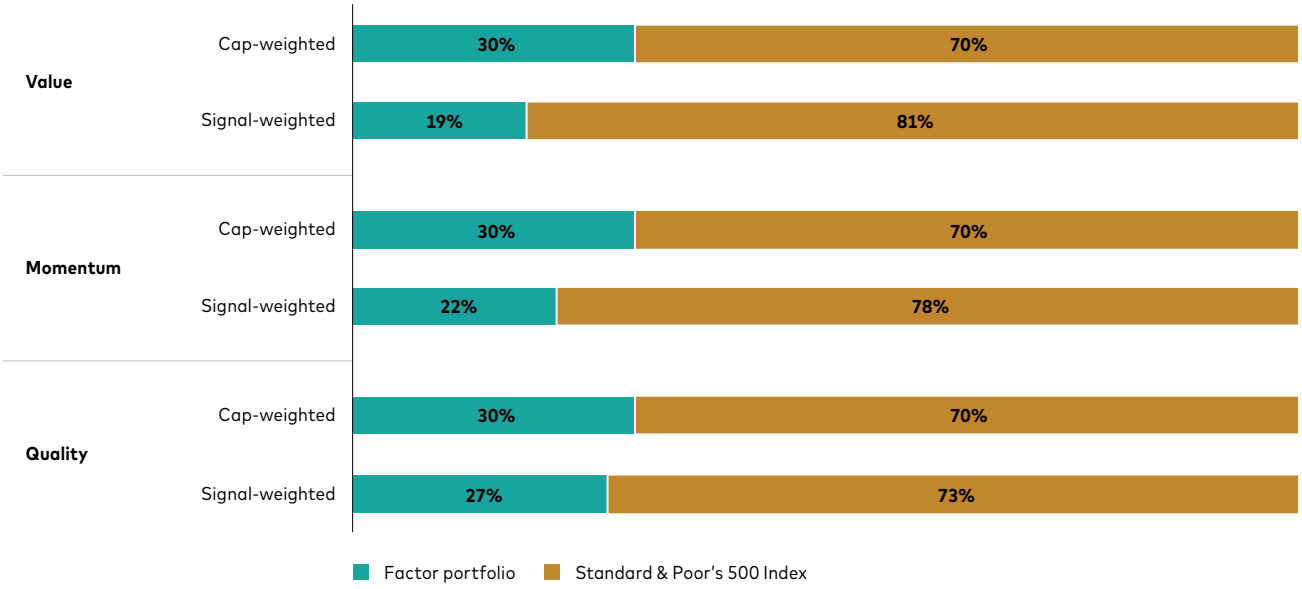
Capital efficiency with a targeted allocation

An investor may choose to allocate assets to both a broad-based market portfolio and a factor portfolio to achieve a desired risk/return profile. As discussed earlier, the choice of factor construction methodology will affect the resulting allocation and risk/return profile. To illustrate this, let's say a client wants to achieve a certain target factor exposure and has the choice of a signal-weighted or cap-weighted portfolio. **Figure 4** depicts the corresponding investment in a signal-weighted factor to achieve the same target exposure. Using value as an example, an investor can achieve the same level of factor exposure by investing 19% in the signal-weighted portfolio versus 30% in a cap-weighted portfolio.[2] Similarly, an investor could invest 10% less in a signal-weighted momentum portfolio and achieve the same exposure as with a cap-weighted momentum portfolio. The signal-weighted approach, because it provides greater exposure to the target factor, can be more efficient and less costly.

FIGURE 4

Different allocations of cap- and signal-weighted factors can achieve the same exposure

Asset allocations to attain the same factor exposure



Note: The broad-based market portfolio is represented by the Standard & Poor's 500 Index.
Sources: Vanguard calculations, based on data from Compustat and Axioma.

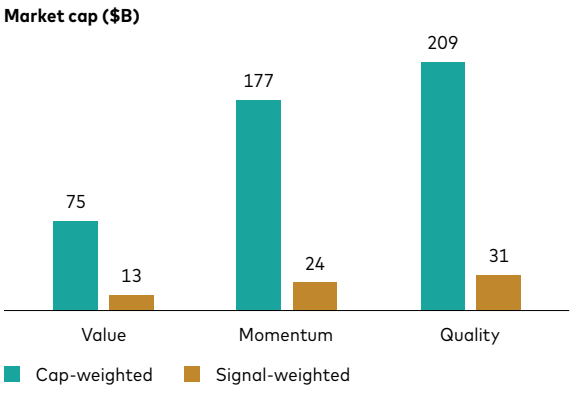
2 Axioma's risk factors do not necessarily overlap with our factor definitions stated earlier. Axioma defines value as an average of book to price, earning to price, and sales to price. It defines momentum as a smoothed 12-month minus the latest month total return. Axioma does not have a quality risk factor.

Crucially, the capital savings associated with signal-weighted factor portfolios come with a trade-off: the need to tolerate higher tracking error. As Figure 4 shows, the signal-weighted portfolio exhibits higher tracking error than a cap-weighted portfolio. One driver of the higher tracking error is a deeper exposure to the target factor. Another cause is greater exposure to small-cap stocks. Because the signal-weighted approach does not consider a company's market capitalization when selecting holdings, it tends to own more small-caps than large-caps. At a portfolio level, this tendency leads to a size "tilt" whereby the portfolio has greater exposure to small-caps relative to the broad market (**Figure 5**).

FIGURE 5

Cap-weighted factor portfolios tilt more toward large-caps than signal-weighted ones

Weighted average market cap in the factor portfolios



Sources: Vanguard calculations, based on data from Compustat and Axioma.

Changing factor allocations

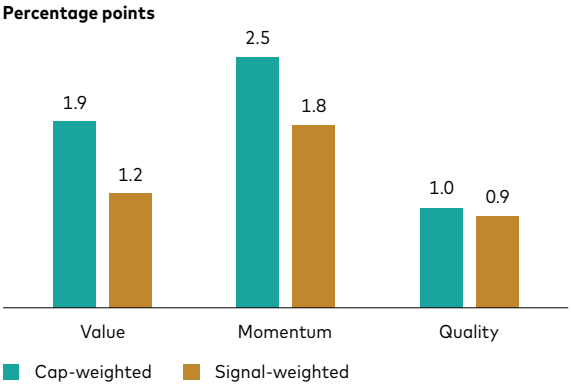
Some financial advisors may prefer, or be required, to adjust factor allocations either periodically or on an ad hoc basis. For example, some advisors may choose to overweight a factor based on their change of tactical view or a client's changing situation. In such cases, understanding the implications of marginal factor contribution becomes essential.

Figure 6 provides insights into the incremental asset allocation to factor portfolios when advisors aim to increase their factor exposure by one percentage point, irrespective of their initial allocation decisions. To achieve this new allocation with a cap-weighted factor, the advisor would need to shift approximately 1.9% of their assets from the Standard & Poor's 500 Index to the factor theme. But to achieve this new allocation with a signal-weighted factor, the advisor would need to adjust 1.2% of their assets from the S&P 500 Index to a signal-weighted value factor portfolio. The "deeper" exposure of the signal-weighted approach leads to a larger impact on factor allocations when trading.

FIGURE 6

Signal-weighted factors attain the same factor exposure more efficiently

Allocation to factors with a one-point increase in exposure



Sources: Vanguard calculations, based on data from Compustat and Axioma.

Factor investing is not for everyone

The weighting of different factor exposures in a portfolio grows out of an investor's preferences and beliefs about the risk and return characteristics of each factor. In this sense, the factor decision is akin to a security selection decision. Different investors with different beliefs will have different exposures to a particular stock. Factor investing can be a suitable strategy for some investors, depending on their investment objectives, risk tolerance, investment horizon, and expertise. As with any investment strategy, it's essential to understand the risks and benefits and to ensure that it aligns with your overall financial goals and objectives.

Investment objectives: Investors have different objectives, and factor investing may not align with each one's goals. For example, investors who prioritize stable income streams may prefer dividend-paying stocks, while those seeking capital appreciation may prefer growth-oriented stocks.

Risk tolerance: Some investors may have a higher tolerance for risk than others. Factor investing can be riskier than investing in broader indexes, because it involves focusing on specific factors that can perform differently under different market conditions. Investors with a low risk tolerance may prefer more diversified portfolios.

Investment horizon: Investors with different horizons may have different needs when it comes to factor investing. For example, investors with a long-term horizon may be better suited for factor investing, as they can ride out short-term fluctuations in specific factors. In contrast, investors with a short-term horizon may not have the luxury of waiting for factors to play out and may prefer to invest in broader indexes.

Investment expertise: Factor investing requires a certain level of expertise to execute effectively. Investors who lack the necessary knowledge or experience may be better off investing in index funds or seeking the assistance of a professional financial advisor.

Constructing portfolios with factors

In this section, we use the Vanguard Capital Markets Model® (VCMM), a powerful forecasting tool used for setting reasonable investment return expectations and evaluating the risk/return trade-offs inherent in portfolio decisions, to construct different portfolio scenarios that include factors. We evaluate the merits of including different factors in a strategic portfolio by using the Vanguard Asset Allocation Model (VAAM) for determining asset allocations among active, passive, and factor investment vehicles, where it can simultaneously optimize across the three dimensions of risk/return trade-off: alpha, systematic, and factor. Furthermore, we explore the trade-offs between the market-cap-weighted and signal-weighted approaches. We discuss the advantages and disadvantages of each approach and analyze how they can be used in constructing portfolios that include factors. Ultimately, this section offers investors a deeper understanding of the various approaches to factor-based investing and how they can be used to help achieve investment goals.

IMPORTANT: The projections and other information generated by the VCMM regarding the likelihood of various investment outcomes are hypothetical in nature, do not reflect actual investment results, and are not guarantees of future results. Distribution of return outcomes from VCMM are derived from 10,000 simulations for each modeled asset class. Simulations as of December 31, 2022. Results from the model may vary with each use and over time. For more information, please see Appendix 2 on page 15.

Use Case 1: Improving return performance with factor investing

The most direct use case for factor investing is to express a viewpoint on the market. For example, say a hypothetical U.S. wealth management firm has a diverse range of clients, including some who are more aggressive and patient in terms of risk tolerance. These clients are comfortable taking on factor risk in pursuit of higher returns. After thoroughly researching the market outlook, the firm forms a long-term conviction on harvesting the momentum factor premium.

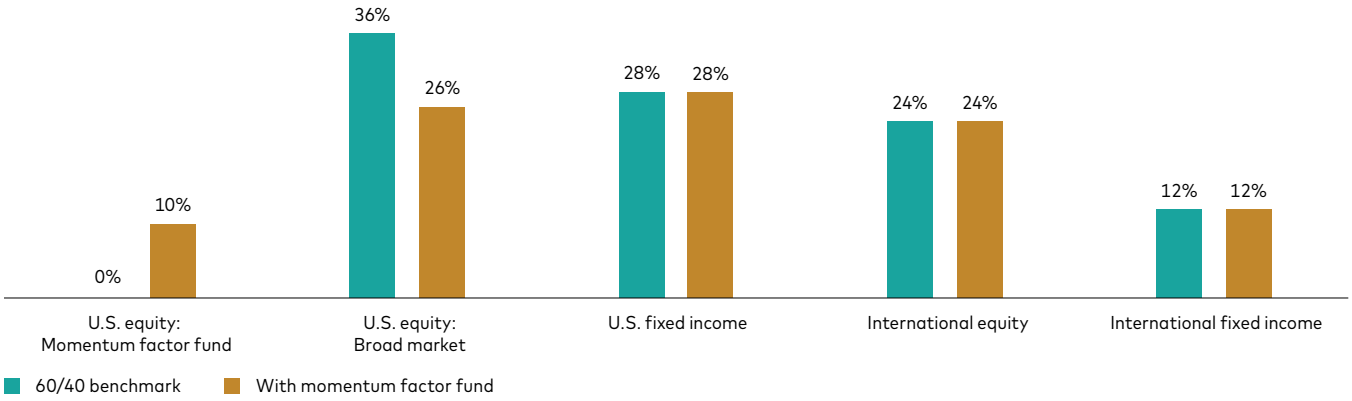
To capitalize on this market view and enhance returns, the firm decides to tilt a segment of its more aggressive clients' portfolios toward the momentum factor. This decision is based on the understanding that these clients have shown a willingness to tolerate factor risk and can handle potential underperformance of the broad equity market.

In line with the firm's guidelines, the maximum allocation for any single asset within the portfolio is 10%. This constraint ensures that the portfolio remains diversified, and it mitigates the risk associated with concentrating too heavily on a single factor or asset. **Figure 7a** provides a sample portfolio based on VAAM that expresses a 10% tilt in both the cap-weighted and signal-weighted factors for a traditional 60% equity/40% fixed income investor who is considering starting with a 60% equity home bias and a 70% fixed income home bias. **Figure 7b** presents the results of this analysis, which show that the signal-weighted method leads to higher annualized portfolio-level returns. This portfolio, though, also shows higher standard deviation, reflecting an increase in risk.

FIGURE 7

Harvesting the momentum factor premium with a minimum allocation

a. Factor allocation in the portfolio comes from the U.S. equity segment



Notes: The portfolio allocations were determined by the VAAM. The assets under consideration were U.S. and non-U.S. equities and fixed income, in addition to a signal-weighted momentum factor fund and a market-cap-weighted momentum factor fund. The momentum factor fund is represented by the Russell 1000 Momentum Focused Factor Index, U.S. equity by the MSCI US Broad Market Index, U.S. fixed income by the Bloomberg U.S. Aggregate Bond Index, international equity by the MSCI All Country World ex USA Index, and international fixed income by the Bloomberg Global Aggregate Index ex USD. The 60/40 portfolio consists of 60% stocks and 40% bonds.

Source: Vanguard, using VCMM 10-year steady-state projections as of December 31, 2022.

b. Same-allocation signal-weighted factors provide higher Sharpe ratios

	60/40 benchmark	Cap-weighted momentum factor	Signal-weighted momentum factor
Annualized return	8.56%	8.71%	8.86%
Standard deviation	17.07%	17.19%	17.38%
Sharpe ratio	0.25	0.25	0.26
Tracking error	—	0.68%	1.29%
Portfolio momentum factor exposure	0.30	0.45	0.51

Notes: Portfolio expectations are based on VCMM 10-year steady-state asset class projections as of December 31, 2022. The Sharpe ratio measures return above the risk-free rate that adjusts for volatility. A higher ratio indicates a higher expected risk-adjusted return.

Source: Vanguard.

Both the cap-weighted and signal-weighted methods would increase the portfolio's momentum factor exposure. The choice between them depends on the investor's risk and return preferences. An investor more focused on improving returns might favor the signal-weighted approach, while one more concerned with managing risk might opt for the cap-weighted method.

Use Case 2: Portfolio completion with factor investing

Say a financial advisor is helping with a portfolio review for a client who has exposure to several active equity managers. The client is comfortable with taking the active risk; however, the advisor realizes during the risk assessment that the client's aggregate public equity portfolio is over its tolerance range because of high exposure to the momentum factor and low exposure to the size effect. Selling out of the active funds directly is difficult because of tax implications and the interaction between different factor exposures. For example, selling an active fund with high momentum factor exposure might also decrease the overall portfolio's exposure to the minimum volatility factor.

To mitigate the factor risk exposure and achieve a more balanced portfolio, the advisor considers using factor investing for portfolio completion. **Figure 8a** shows how the advisor is able to use a few passive funds to complete the process, using the VAAM not only to keep the active block but also to optimize it among the more liquid passive funds. **Figure 8b** illustrates how allocations to cap-weighted and signal-weighted factors can help manage risk exposure in the whole portfolio. The result shows a slightly higher expected return while keeping the portfolio within its tolerance level.

FIGURE 8

Allocating to signal-weighted factors provides less size exposure than cap-weighted ones

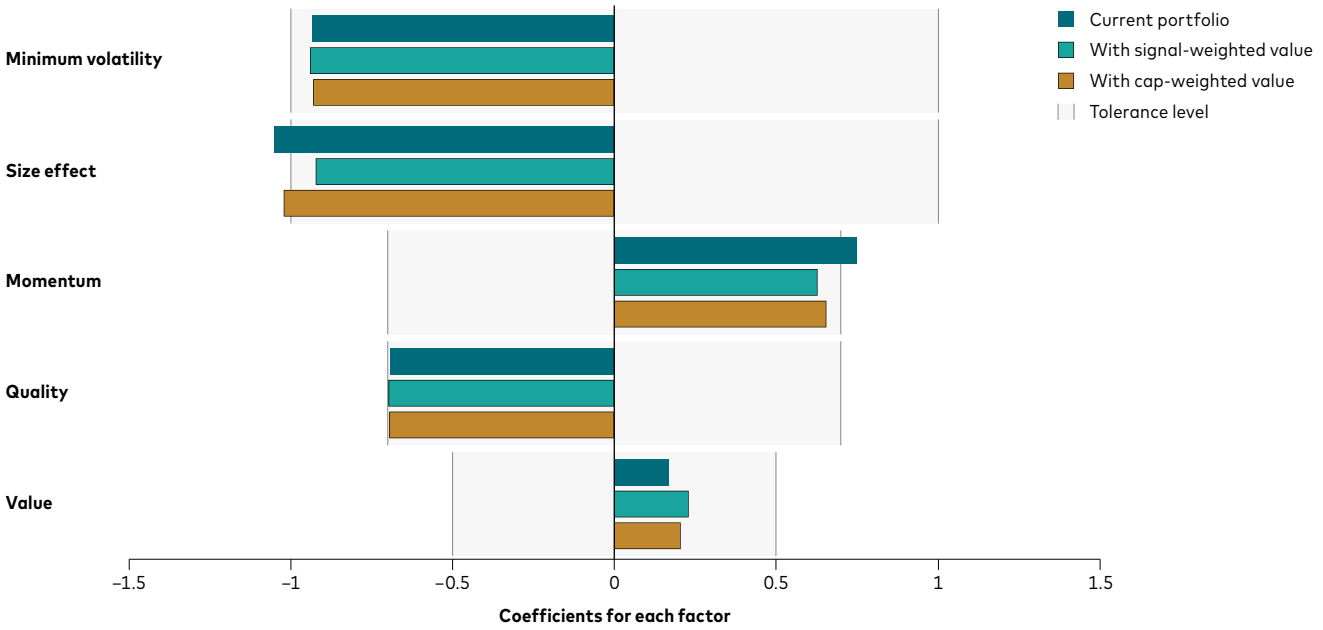
a. Portfolio weightings when using each factor construction method

	Current portfolio	With cap-weighted value factor	With signal-weighted value factor
Value factor fund	0%	5%	5%
Total passive equities	76%	71%	71%
Total active equities	24%	24%	24%
Return	8.93%	9.01%	9.16%
Volatility	17.05%	17.03%	17.15%
Sharpe ratio	0.26	0.27	0.28

Notes: Portfolio allocations were determined by the VAAM. Assets under consideration were U.S. equities, non-U.S. equities, active global equities, active developed market equities, and active large-cap equities, in addition to a cap-weighted value factor fund and a signal-weighted value factor fund. For more about the VAAM methodology and optimization process, see Appendix 3 on page 16.

Sources: Vanguard, using VCMM 10-year steady-state projections as of December 31, 2022.

b. Portfolio risk exposure when using cap- and signal-weighted factors



Notes: Portfolio expectations are based on VCMM 10-year steady-state asset class projections as of December 31, 2022. The factor analysis was done with a multivariable regression using value, quality, momentum, size, and minimum volatility factors.

Source: Vanguard.

In the scenario depicted in Figure 8, a 5% allocation to the value factor could help offset the large momentum factor exposure introduced by all the active equity managers. In the aggregate, though, the portfolio also has a tilt toward the large-cap exposure. The advisor's selection of a signal-weighted value factor fund could help balance the portfolio's exposure by providing not only value factor exposure but also some small-cap exposure. This would bring all of the portfolio's factor exposures within the client's risk tolerance ranges.

On the other hand, if the original portfolio was above the upper bound of size factor exposure, a cap-weighted value factor fund would be more appropriate, as the signal-weighted factor fund might increase the size effect. In this case, the advisor could allocate to a cap-weighted value factor fund to neutralize the portfolio's size exposure.

By carefully selecting appropriate factor funds based on the client's specific situation, the financial advisor can effectively manage risk within the portfolio and achieve a more balanced factor exposure that aligns with the client's risk tolerance.

Use Case 3: Reduce portfolio risk with factor investing

A U.S. school endowment is conducting its annual review of its holdings, with a particular focus on risk budget assessment. During the assessment, the endowment discovers that its aggregate portfolio has exceeded its risk tolerance level of 8% volatility, and worse, there is limited room to decrease the portfolio's expected return (7.5% expected return limit) by simply investing in more bond funds.

This situation is primarily due to recent market fluctuation and the concentration of the endowment's investments in a few high-beta stocks, which it cannot easily unwind. To address this issue, the endowment considers incorporating a quality factor fund or minimum volatility factor fund into its portfolio. It decides to use a quality factor fund because of the fund's ability to reduce the portfolio's overall volatility exposure to a level within its risk tolerance without compromising its expected return.

Figure 9 shows how an allocation to a quality factor fund can help reduce volatility risk without affecting the expected return based on the VCMM projection. It also highlights the trade-offs between the cap-weighted and signal-weighted methods, which can yield different results. By incorporating either a cap-weighted or signal-weighted quality factor fund, the endowment can achieve a more targeted reduction in portfolio volatility while maintaining the expected return. Conversely, a signal-weighted quality factor fund may introduce additional tracking error into the mix. It's noteworthy, though, that the signal-weighted quality factor fund offers superior risk-adjusted returns, as evidenced by its higher Sharpe ratio, making it a worthwhile consideration for those focusing on risk-adjusted performance. In this case, the endowment should choose the factor investing method based on the endowment's varying needs and objectives.

FIGURE 9

How a quality factor allocation affects portfolio volatility and risk-adjusted returns

Comparing cap-weighted versus signal-weighted methods

		What-if analysis	
	Current portfolio	Adding a cap-weighted quality factor fund	Adding a signal-weighted quality factor fund
Return	7.99%	7.88%	8.49%
Standard volatility	10.01%	7.94%	7.93%
Sharpe ratio	0.36	0.45	0.53
Tracking error	—	0.79%	1.03%
Maximum drawdown	–7.02%	–3.87%	–3.12%
U.S. equity allocation (excluding factor fund)	36%	15%	7%
Quality factor fund allocation	0%	14%	20%

Notes: The portfolio allocations were determined by the VAAM. Portfolio expectations are based on VCMM 10-year steady-state asset class projections as of December 31, 2022. For more about the VAAM methodology and optimization process, see Appendix 3 on page 16.

Source: Vanguard.

Figure 10 is a scenario analysis that examines, on a more level playing field, the effects of different economic environments on portfolios with a quality factor allocation; it takes into consideration both high inflation and deflation situations as well as high and low interest rate environments. These scenarios represent a broad spectrum of economic conditions that investors may face, enabling a more holistic understanding of the potential implications of factor investing under various circumstances.

The analysis concluded, in general, that incorporating a quality factor allocation reduced downside risk across almost all the scenarios. This suggests that the quality factor may boost portfolio resilience, helping to mitigate potential losses in adverse economic conditions.

When considering the trade-offs in different economic environments, the analysis provides some interesting insights. If the primary objective is to reduce volatility, the market-cap-weighted quality factor emerges as a particularly compelling candidate. This factor was able to reduce risk while providing a higher expected return in both high inflation and high interest rate scenarios. This suggests that a cap-weighted quality factor could be an effective tool for risk management in turbulent economic environments.

FIGURE 10

How different economic environments affect portfolio performance

Inflation scenario analysis

	Deflation			High inflation		
	60/40 portfolio	Cap-weighted portfolio	Signal-weighted portfolio	60/40 portfolio	Cap-weighted portfolio	Signal-weighted portfolio
Annualized return*	8.35%	8.32%	8.56%	3.49%	3.58%	3.74%
Standard deviation*	11.55%	11.46%	11.59%	10.47%	10.37%	10.54%
Sharpe ratio*	0.55	0.55	0.56	–0.06	–0.05	–0.04
Maximum drawdown*	–8.29%	–8.20%	–8.29%	–15.49%	–15.04%	–15.02%

* Adjusted for inflation.

Interest rate scenario analysis

	Low interest rate environment			High interest rate environment		
	60/40 portfolio	Cap-weighted portfolio	Signal-weighted portfolio	60/40 portfolio	Cap-weighted portfolio	Signal-weighted portfolio
Annualized return	6.08%	6.00%	6.25%	7.99%	8.09%	8.24%
Standard deviation	10.21%	10.05%	10.24%	10.01%	9.88%	10.04%
Sharpe ratio	0.53	0.53	0.55	0.36	0.38	0.39
Maximum drawdown	–9.49%	–9.41%	–9.36%	–7.01%	–6.72%	–6.79%

Notes: Portfolio expectations are based on VCMM 10-year steady-state asset class projections as of December 31, 2022. To keep the analysis level, an additional constraint of a maximum 5% quality factor fund allocation has been added from Use Case 3. Deflation in the figure is defined as the expected inflation rate being below zero. High inflation is defined as the inflation rate being above 3%. A low interest rate environment is defined as the short-term U.S. Treasury rate being between 0% and 1%. A high interest rate environment is defined as that Treasury rate being 3% or higher.

Source: Vanguard.

Conclusion

Factor investing has dramatically reshaped the investment landscape, transforming the way investors perceive market dynamics, diversification, and portfolio construction. By using systematic factors, investors may extract better return performance, achieve portfolio completion, and efficiently manage risk. These advantages make factor-based investing a compelling proposition, particularly given the rapid evolution and maturity of this field.

Our research points to the crucial role of factor construction in shaping portfolio performance and risk profiles. We found that although market-cap-weighted portfolios tend to offer lower risk, signal-weighted factor portfolios capture higher factor exposures, yielding more robust total returns. This trade-off between return enhancement and risk management underscores the importance of the investor's personal preferences and risk tolerance.

To harness the full potential of factor-based strategies, advisors must delve deeper, rigorously dissecting specific risks and characteristics. This demands the incorporation of formal factor risk decomposition at the portfolio level, surpassing the conventional methods of targeting and adjusting asset allocations to style-based buckets. Undertaking this detailed approach unveils the inherent advantages of crafting a more tailored portfolio.

Our research underscores the crucial role of factor investing in modern portfolio construction. Although not all factors are created equal, understanding the trade-offs and nuances of factor investing may help investors optimize their portfolios and achieve their investment objectives. As the field further evolves, we anticipate that factor investing will become an increasingly integral part of the investment landscape, providing a robust framework for risk management, portfolio completion, and return enhancement.

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Appendix 1

FIGURE 11

How to build cap-weighted and signal-weighted factor portfolios

Factor	Cap-weighted factor portfolio	Signal-weighted factor portfolio	Factor calculation
Value	Rank stocks based on their book-to-price ratio, select the top-ranked third, and weight the selected stocks by relative value ranking	Rank stocks based on their book-to-price ratio, select the top-ranked third, and weight the selected stocks by relative value ranking	Use the Axioma value factor (book-to-price)
Momentum	Rank stocks based on their total return for the 11 months before the latest month (12-month return minus the final month), select the top-ranked third, and weight the selected stocks by relative market cap	Rank stocks based on their total return for the 11 months before the latest month (12-month return minus the final month), select the top-ranked third, and weight the selected stocks by relative momentum ranking	Use the Axioma momentum factor (12-month return minus the most recent month)
Quality	Rank stocks based on the average of their profitability and the inverse of their asset growth, select the top-ranked third, and weight the selected stocks by relative market cap	Rank stocks based on the average of their profitability and the inverse of their asset growth, select the top-ranked third, and weight the rselected stocks by their respective quality ranking	Calculate each stock's z-scores for profitability and the inverse of its asset growth (a z-score measures how much a data point diverges from the mean of a data set) and use the average of the two z-scores to rank the stocks

Notes: The universe of stocks used for factor analysis typically includes all stocks in a benchmark. For this paper, rankings are based on monthly data for the Russell 1000 Index from January 1, 1999, through December 31, 2022.

Source: Vanguard.

Appendix 2

The Vanguard Capital Markets Model

IMPORTANT: 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 will 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.

The Vanguard Capital Markets Model® is a proprietary financial simulation tool developed and maintained by Vanguard's primary investment research and advice teams. 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 from as early as 1960. 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.

Appendix 3

The Vanguard Asset Allocation Model

The VAAM is a proprietary model for allocating assets simultaneously among active, passive, and factor investment vehicles that is driven by uncertainty in active returns and an investor's risk preferences toward that uncertainty. The model leverages the distributional forecasting framework of the VCMM and benefits from the features embedded in it, such as sensitivity to initial valuations, forward-looking capital market equilibrium assumptions, non-normal distributions, the capturing of autocorrelation and cross-asset correlation, and important linkages between asset returns and macroeconomic factors.

The VAAM selects the asset allocation strategy that maximizes the expected utility of an investor's wealth at the end of a given investment period (10 years, for example). The total expected utility score of a portfolio is the sum of the expected utility scores for systematic risk, alpha risk, and factor risk. The portfolio that results in the highest total expected utility score is considered optimal. In other words, the VAAM solves for optimal portfolios by maximizing the expected utility of wealth at maturity while penalizing portfolios with higher risk. The optimization comes with constraints that often take the form of upper and/or lower bounds for exposure. For example, in our model, U.S. equities must account for at least 60% of the total equity allocation. Our model allows for linear constraints to be taken into account. The model follows the process and methodology from Aliaga-Díaz et al. (2019).

The VAAM optimization method is an expected utility-based model that assesses the risk and return trade-offs for all possible portfolio combinations that meet certain constraints or guardrails.

The utility-based optimization that the model is solving for is:

$$\max_x \mathbb{E}\left[U\left(\frac{W_T}{W_0}\right)\right] \rightarrow$$

$$\max_x \left\{ \mathbb{E}\left[\frac{W_p^{\,1-\gamma_p}}{1-\gamma_p}\right] + \mathbb{E}\left[\frac{W_f^{\,1-\gamma_f}}{1-\gamma_f}\right] + \mathbb{E}\left[\frac{W_a^{\,1-\gamma_a}}{1-\gamma_a}\right] \right\}$$

$$s.t.\ \{x_i \in \mathbb{R} \mid 0 \le x_i \le 1\} \wedge \sum_i x_i = 1$$

$$\sum_i C \cdot x_i \le b$$

where W_p, W_f, and W_a are the wealth at maturity coming from systematic, factor, and factor-adjusted alpha exposures, respectively; γ_p, γ_f, and γ_a are the systematic, factor, and alpha risk aversions, respectively; and C and b refer to the set of linear inequality constraints.

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Diversification does not ensure a profit or protect against a loss.

Factor funds are subject to investment style risk, which is the chance that returns from the types of stocks in which a fund invests will trail returns from U.S. stock markets. Factor funds are also subject to manager risk, which is the chance that poor security selection will cause a fund to underperform its relevant benchmark or other funds with a similar investment objective, and sector risk, which is the chance that significant problems will affect a particular sector in which a fund invests, or that returns from that sector will trail returns from the overall stock market.

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