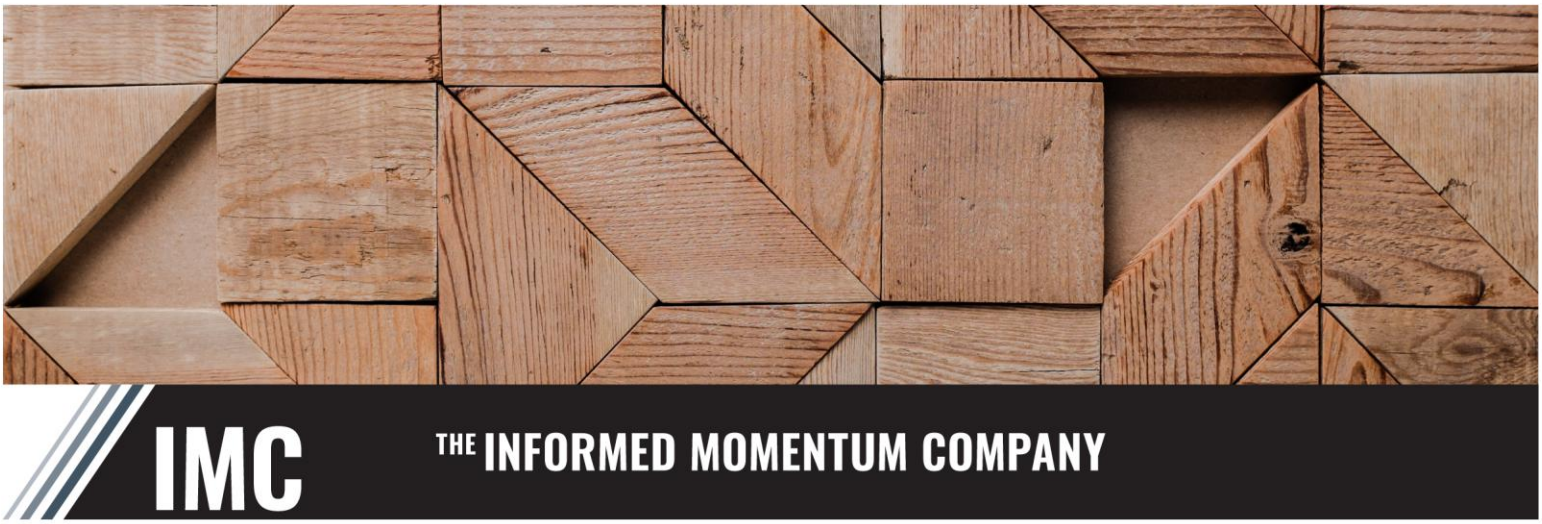

Momentum and Quality

Academic research, including our own (see Momentum Works Everywhere), has shown that momentum and quality factors have generated positive excess returns above an equity market portfolio across most market caps and geographies. This paper looks at the relationship between long-only momentum and quality portfolios across nine sub-segments of global equity markets. We then compute optimized portfolios based on maximizing information ratios to determine the optimal mix of momentum, quality, value and growth within each market segment.

Key Findings

- Momentum and quality, along with value, deserve a place as part of a diversified portfolio in global equity markets.
- Quality outperforms the market everywhere except for emerging markets small cap, while momentum outperforms the market across every market segment.
- Correlations between momentum and quality fluctuate through time, however, are on average mildly positive everywhere except in US small cap.
- Quality tends to exhibit a lower tracking error, providing a substantial use case in an optimal portfolio of factors.
- Because of the varying risk/return profiles, the optimal mix of factors will vary depending on the sub-segment examined.

Travis Prentice
Chief Investment Officer
Portfolio Manager

David Wroblewski
Director of Applied Research

The Birth of Quality

Investing in companies that are profitable (or realize higher profits relative to a competing company), at face value, appears very logical. Ball (1978) described earnings yield (E/P) as a direct proxy for expected future returns. Later, Basu (1983) documented an empirical relationship directly, by demonstrating that high earnings yield (E/P) firms earn, on average, higher risk-adjusted returns compared to that of low (E/P) firms.

The seminal work of Fama and French (1993) laid the foundation for the Fama-French three factor model based on size, value, and the market. Their paper concluded with section 7.3, entitled "Open questions", with perhaps the biggest one being, "How profitability and earnings behavior influences the cross-section of returns above and beyond size and value metrics". Further, Novy-Marx (2013) studied gross profits-to-assets and showed that profitable firms generated significantly higher returns than unprofitable ones. This again seems intuitive as profitable firms are less prone to distress, have longer cash flow durations, and have lower levels of operating leverage.

Given that the Fama-French three factor model had trouble explaining the earnings yield anomaly, Fama and French (2015) appended two factors to the Fama French (1993) model: Quality - defined by the ratio of operating profitability to book equity, and Investments - based on a company's debt and investments. Around the same time, Hou, Xue, and Zhang (2015) also used a profitability factor (income divided by one quarter lagged book-equity) in their q-factor model and achieved success in explaining the cross-section of asset returns. Both papers led to the prominence of a quality factor in describing stock returns.

In our research, we not only find quality to be a persistent generator of excess returns across different market regions, but also utilizing quality can be quite substantial in minimizing portfolio tracking error.

A Closer Look at Momentum and Quality

Momentum and quality, along with value, are strategies that have historically displayed significant excess returns above a market portfolio. To demonstrate this dynamic, we construct long-only portfolios for quality and momentum across a diverse set of global equity markets using the Fama-French data set. In each sub-segment, the quality strategy is defined as one that buys the top quintile operating profitability stocks[1], while the momentum strategy is defined as one that buys the top quintile prior return stocks[2].

For each sub-segment, we then analyze the dynamics between momentum and quality by examining their risk/return characteristics, excess return correlations, and rolling 3-year annualized excess returns.

In summary, we find long-term correlations between momentum and quality have been positive in every market except for US small cap. However, the correlations have fluctuated significantly over time and trended increasingly negative in recent periods, particularly in US small cap and emerging markets (Table 1). Generally, the varying degrees of relationship between momentum and quality results in a beneficial pairing particularly in periods of major market regime shifts.

[1] Operating Profitability is annual revenues minus cost of goods sold, interest expense, and selling, general, and administrative expenses divided by book equity for the last fiscal year end. For emerging markets, due to the limited data set, we use the top 30% of each characteristic.
[2] We follow Carhart (1997), which defines the standard momentum factor based on the trailing eleven-month return lagged by one month.

Table 1: Correlations of Momentum/Quality – Summarized by Market Segment

	Current Trailing 3-Year	Full Sample Period
US Small Cap	**-0.33**	**-0.10**
US Large Cap	**-0.10**	0.18
US Mid Cap	**-0.19**	0.16
Global Small Cap	**-0.19**	0.17
Global Large/Mid Cap	**-0.02**	0.37
Non-US Small Cap	0.17	0.35
Non-US Large/Mid Cap	0.14	0.48
EM Small Cap	**-0.08**	0.14
EM Large/Mid Cap	**-0.36**	0.13

Current trailing 3-year correlation is as of April 30, 2024. Full sample period correlations are for the period analyzed in each market segment: US (July 1963 – April 2024), Global, Non-US and EM (July 1991 – April 2024).

Building Portfolios with Momentum and Quality

Based on these dynamics, we compute optimized portfolios based on maximizing information ratios to determine the optimal mix of momentum, quality, value and growth. Table 2 is a summary of the optimal factor mix computed for each market segment. The inputs used are the expected returns (arithmetic means of the historical returns) and the sample covariance matrix of the returns for each factor. We then compute the expected portfolio return and portfolio tracking error and plot the efficient frontier along with the information ratios. Optimal weights are determined by maximizing an information ratio objective function.

Table 2: Optimal Weights – Summarized by Market Segment

	Momentum	Quality	Value	Growth
US Small Cap	47%	23%	30%	0%
US Large Cap	28%	50%	16%	5%
US Mid Cap	42%	33%	26%	0%
Global Small Cap	23%	41%	35%	0%
Global Large/Mid Cap	10%	58%	29%	2%
Non-US Small Cap	17%	41%	42%	0%
Non-US Large/Mid Cap	14%	51%	36%	0%
EM Small Cap	46%	0%	54%	0%
EM Large/Mid Cap	35%	33%	32%	0%

The sections that follow contain further detail on each market segment tested.
Click on the links below to review results and optimal portfolios in each sub-segment:

US Small Cap
US Mid Cap
US Large Cap
Global Small Cap
Global Large/Mid Cap
Non-US Small Cap
Non-US Large/Mid Cap
EM Small Cap
EM Large/Mid Cap

Global Small Cap

Summary: Over the entire sample set in global small cap from July 1991 to April 2024, both momentum and quality have outperformed the market return. However, momentum has outperformed quality by nearly 300 basis points annualized. Quality displays a much lower tracking error to the market and lower volatility than momentum. Still, momentum has superior Sharpe and information ratios. Quality has underperformed the market over the trailing 3- and 5-year time periods (Table 3).

Over the sample period, excess return correlations have been positive on average (0.17), but these correlations have fluctuated significantly over time. To wit, since approximately 2020, momentum and quality have been showing a trend towards lower or negative correlations. This dynamic indicates varying degrees of relationship between momentum and quality (Table 4 and Figure 1).

Examining rolling 3-year annualized excess returns through time in Figure 2, quality has shown more stable and less volatile, albeit lower excess returns than that of momentum. But the movements of excess returns suggest a beneficial pairing of momentum and quality specifically when the market has major regime shifts including the mid to late 1990's internet build out and subsequent bust period, the lead up to and around the global financial crisis in 2008-2009, and COVID-19 pandemic in 2020.

Taken together, these dynamics point to an optimal blend (maximizing information ratio) of strategies as outlined in Table 5 and depicted graphically in Figure 3. Momentum, quality, and value have significant roles to play in an optimal portfolio, while growth is left out due to its inferior risk/returns characteristics in global small cap. Based on these dynamics, investors can look to momentum strategies as a stand-alone alpha satellite due to its leading risk/return characteristics or as a complement to value and quality.

Table 3: Performance & Risk of Momentum/Quality - Global Small Cap
July 1991 – April 2024

	Momentum	Quality	Market
Return (Annualized)	13.48%	10.39%	8.77%
Trailing 1-Year Return	11.85%	8.50%	8.14%
Trailing 3-Year Return (Ann.)	0.02%	-3.15%	-2.05%
Trailing 5-Year Return (Ann.)	9.99%	5.36%	5.66%
Volatility (Annualized)	17.96%	16.53%	16.14%
Tracking Error (to Market)	7.13%	2.74%	--
Beta (to Market)	1.02	1.01	--
Sharpe Ratio	0.62	0.48	0.39
Information Ratio (to Market)	0.66	0.59	--
T-Stat (Excess Return)	3.69	3.25	--
Batting Average (Excess Return)	63%	59%	--

Global Small Cap construction notes: Fama-French historical returns from July 1991 – April 2024. The portfolio is the combination of 90% developed markets and 10% emerging markets. In developed markets, small cap represents the weighted average of the bottom three market cap quintiles: (Q1, Q2, Q3) = (23%,31%,46%). For emerging markets, small cap is the bottom 10% of the market cap. The factors displayed are referenced by Ken French as follows: Momentum (High Prior Return), Quality (High Operating Profitability), Value (High Book/Market), Growth (Low Book/Market). We use the top quintile for each factor except in emerging markets where we use the top 30%.

Table 4: Correlations of Excess Returns - Global Small Cap

July 1991 – April 2024

	Momentum	Quality	Value	Growth
Momentum	1.00	0.17	-0.24	0.52
Quality	0.17	1.00	-0.06	0.15
Value	-0.24	-0.06	1.00	-0.76
Growth	0.52	0.15	-0.76	1.00

Figure 1: Correlation of Momentum/Quality Over Time - Global Small Cap

July 1991 – April 2024

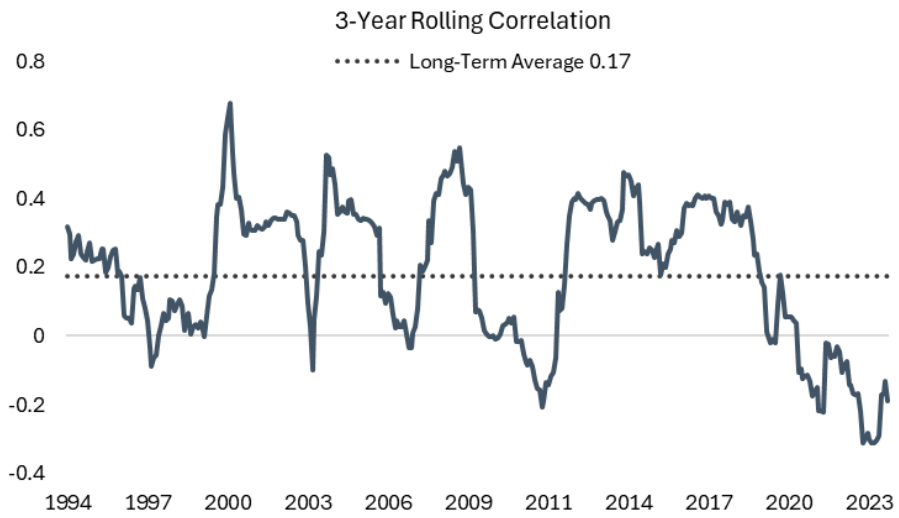

Figure 2: Performance Over Time - Global Small Cap

July 1991 – April 2024

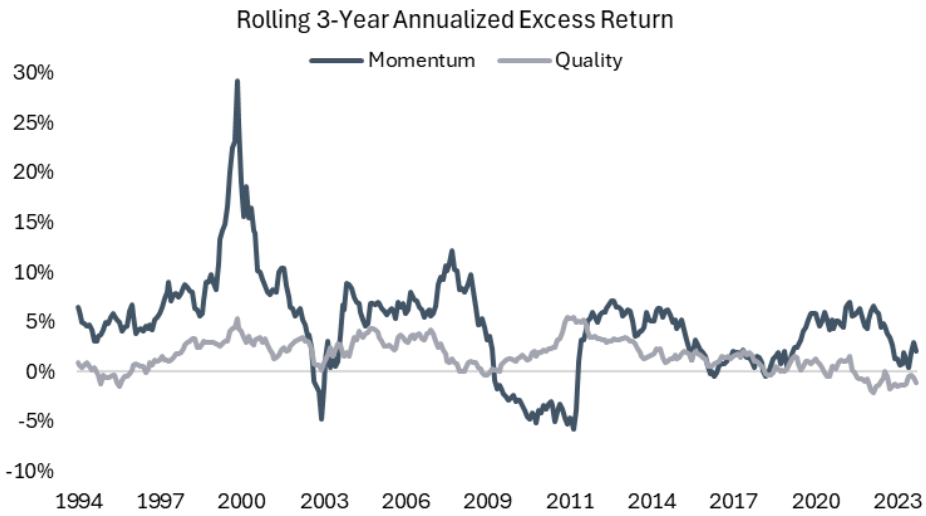

Table 5: Optimal Weights in Global Small Cap

Momentum	Quality	Value	Growth
23.48%	41.15%	35.37%	0.00%

Figure 3: Optimal Portfolio in Global Small Cap

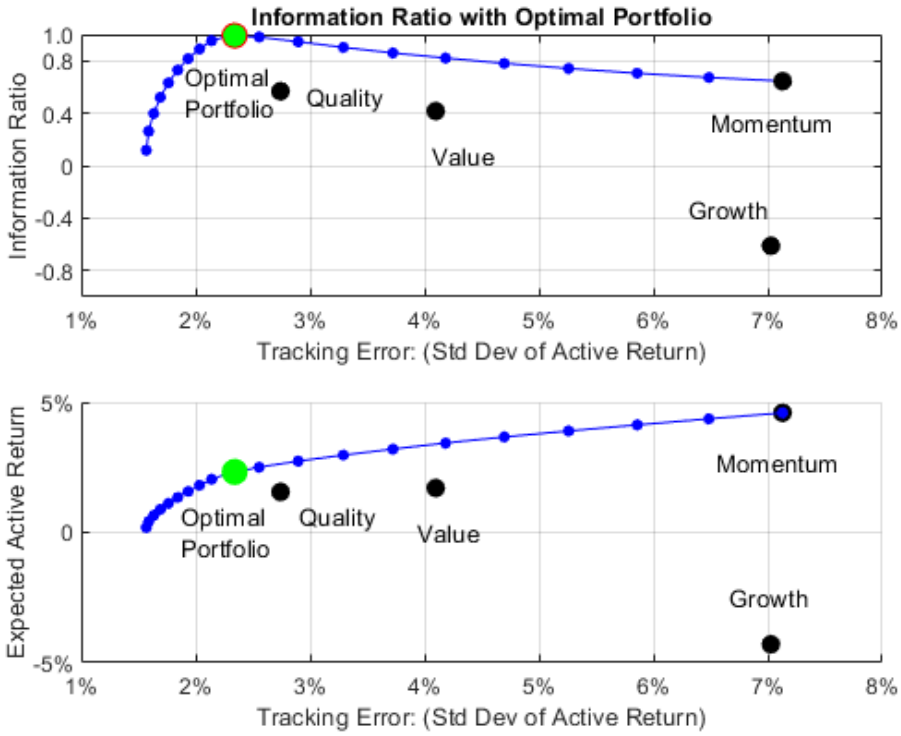

Table 6: Performance & Risk of Optimal Portfolio & Component Factors - Global Small Cap

July 1991 – April 2024

	Momentum	Quality	Value	Growth	Optimal Global Small Cap	Market
Return (Annualized)	13.48%	10.39%	10.68%	3.67%	11.30%	8.77%
Trailing 1-Year Return	11.85%	8.50%	14.44%	-3.70%	11.39%	8.14%
Trailing 3-Year Return (Ann.)	0.02%	-3.15%	4.76%	-12.90%	0.42%	-2.05%
Trailing 5-Year Return (Ann.)	9.99%	5.36%	8.04%	0.58%	7.48%	5.66%
Volatility (Annualized)	17.96%	16.53%	15.86%	19.10%	16.17%	16.14%
Tracking Error (to Market)	7.13%	2.74%	4.10%	7.03%	2.34%	--
Beta (to Market)	1.02	1.01	0.95	1.10	0.99	--
Sharpe Ratio	0.62	0.48	0.52	0.07	0.55	0.39
Information Ratio (to Market)	0.66	0.59	0.47	-0.73	1.08	--
T-Stat (Excess Return)	3.69	3.25	2.39	-3.50	5.68	--
Batting Average (Excess Return)	63%	59%	54%	44%	68%	--

Global Large/Mid Cap

Summary: Over the entire sample set in global large/mid cap from July 1991 to April 2024, both momentum and quality have outperformed the market return. However, momentum has displayed the strongest annualized return and higher batting average of excess returns. Quality displays a much lower tracking error to the market and lower volatility than momentum (Table 7).

Over the sample period, excess return correlations have been positive on average (0.37) but do vary significantly in its degrees of positive correlation (Table 8 and Figure 4).

Examining rolling 3-year annualized excess returns in Figure 5, momentum does provide beneficial diversification to quality in strong absolute market regimes in the late 1990's or in strongly trending markets of 2003-2007.

Due to quality's strong risk/return characteristics in global large/mid, it makes up a substantial portion of the optimal portfolio (formed by maximizing information ratio) along with value (Table 9). Momentum's role in this sub-segment can be as an alpha satellite due to its highest excess returns through time or a more significant role in an optimal portfolio than that of growth (Figure 6 and Table 10).

Table 7: Performance & Risk of Momentum/Quality - Global Large/Mid Cap
July 1991– April 2024

	Momentum	Quality	Market
Return (Annualized)	10.61%	9.97%	8.11%
Trailing 1-Year Return	26.40%	16.66%	16.71%
Trailing 3-Year Return (Ann.)	4.54%	6.85%	4.16%
Trailing 5-Year Return (Ann.)	11.67%	13.34%	9.32%
Volatility (Annualized)	17.07%	14.40%	15.30%
Tracking Error (to Market)	8.93%	3.60%	--
Beta (to Market)	0.95	0.92	--
Sharpe Ratio	0.48	0.52	0.37
Information Ratio (to Market)	0.28	0.52	--
T-Stat (Excess Return)	1.66	2.50	--
Batting Average (Excess Return)	56%	54%	--

Global Large/Mid Cap construction notes: Fama-French historical returns from July 1991 – April 2024. The factors displayed are referenced by Ken French as follows: Momentum (High Prior Return), Quality (High Operating Profitability), Value (High Book/Market), Growth (Low Book/Market). We use the top quintile for each factor except in the Emerging Markets where we use the top 30%. We form the Global portfolios by combining 90% Developed and 10% Emerging Markets. Within the non-US developed markets, large/mid cap represents the top two size quintiles with market cap weights of (Q4, Q5) = (14%, 86%). For Emerging Markets (we have less data) large/mid cap corresponds to the top 90% of the market cap. For the characteristic sorts on momentum, quality, growth and value we use the top 30%.

Table 8: Correlations of Excess Returns - Global Large/Mid Cap

July 1991 – April 2024

	Momentum	Quality	Value	Growth
Momentum	1.00	0.37	-0.41	0.34
Quality	0.37	1.00	-0.56	0.58
Value	-0.41	-0.56	1.00	-0.76
Growth	0.34	0.58	-0.76	1.00

Figure 4: Correlation of Momentum/Quality Over Time - Global Large/Mid-Cap

July 1991 – April 2024

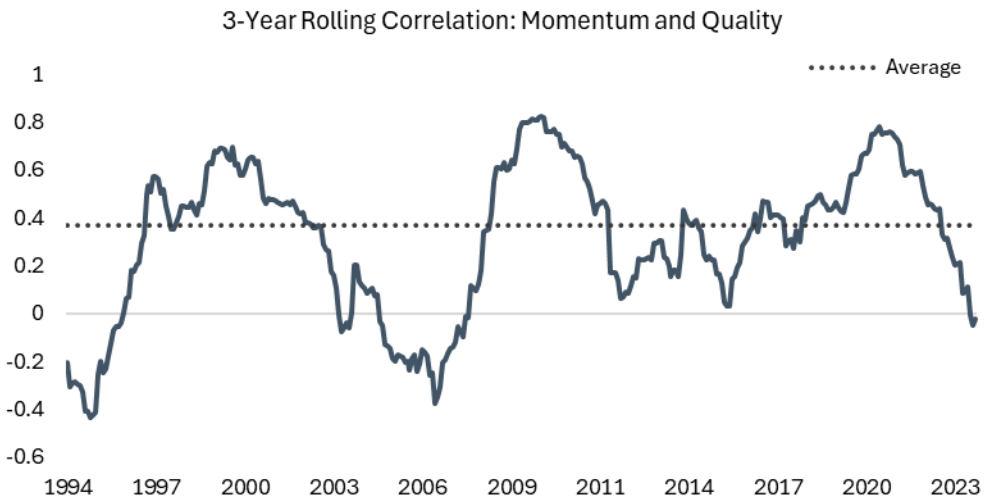

Figure 5: Performance Over Time - Global Large/Mid-Cap

July 1991 – April 2024

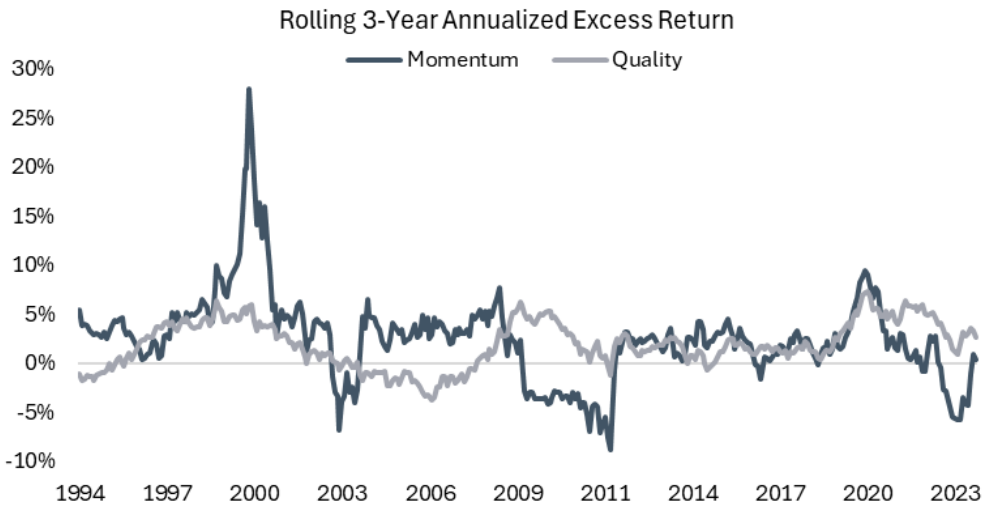

Table 9: Optimal Weights in Global Large/Mid Cap

Momentum	Quality	Value	Growth
10.34%	58.05%	29.46%	2.15%

Figure 6: Optimal Portfolio in Global Large/Mid Cap

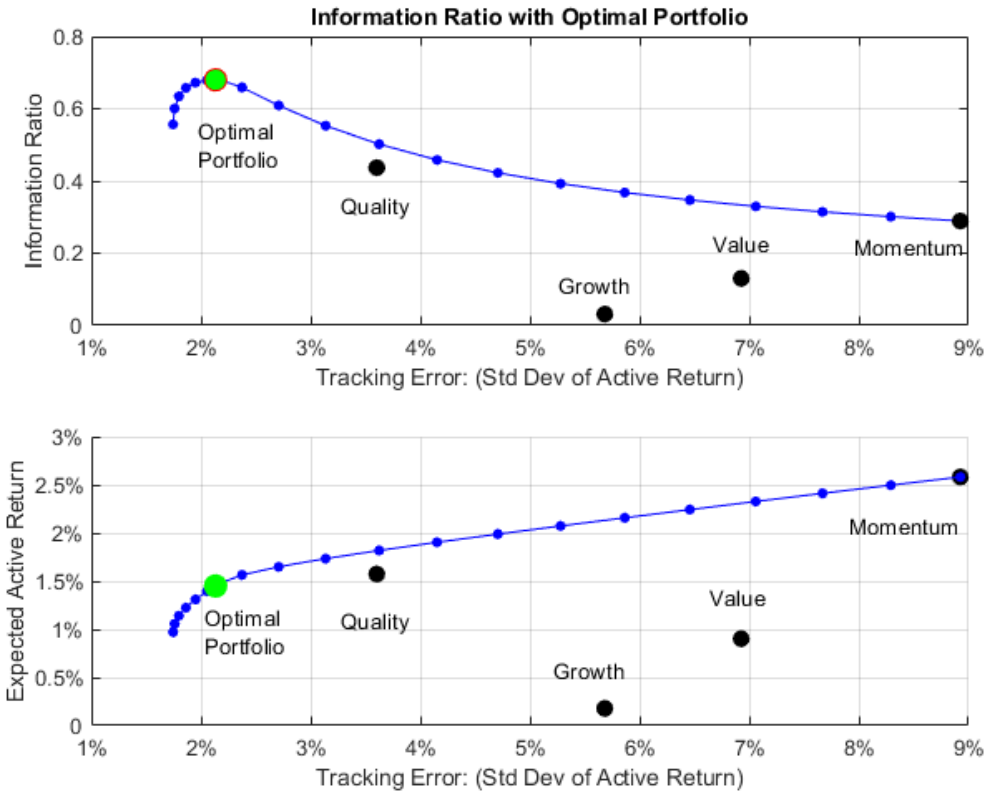

Table 10: Performance & Risk of Optimal Portfolio & Component Factors - Global Large/Mid Cap

January 1997 – April 2024

	Momentum	Quality	Value	Growth	Optimal Global Large/Mid Cap	Market
Return (Annualized)	10.61%	9.97%	8.59%	8.17%	9.73%	8.11%
Trailing 1-Year Return	26.40%	16.66%	18.70%	20.26%	18.44%	16.71%
Trailing 3-Year Return (Ann.)	4.54%	6.85%	9.57%	3.82%	7.55%	4.16%
Trailing 5-Year Return (Ann.)	11.67%	13.34%	8.73%	13.21%	12.06%	9.32%
Volatility (Annualized)	17.07%	14.40%	17.94%	16.08%	14.99%	15.30%
Tracking Error (to Market)	8.93%	3.60%	6.93%	5.68%	2.13%	--
Beta (to Market)	0.95	0.92	1.09	0.98	0.97	--
Sharpe Ratio	0.48	0.52	0.34	0.36	0.49	0.37
Information Ratio (to Market)	0.28	0.52	0.07	0.01	0.76	--
T-Stat (Excess Return)	1.66	2.50	0.75	0.18	3.90	--
Batting Average (Excess Return)	56%	54%	50%	51%	60%	--

US Small Cap

Summary: Over the entire sample set in US small cap from July 1963 to April 2024, both momentum and quality have outperformed the market return. However, momentum has outperformed quality by 364bps annualized over the sample period. Quality displays a lower tracking error to the market, but only marginally lower volatility than momentum. Momentum has a superior Sharpe ratio and nearly double the information ratio of quality. Quality has outperformed the market dramatically over the trailing 1-year period (Table 11).

Over the sample period, excess return correlations have been negative on average (-0.10), but these correlations have fluctuated significantly over time as we see in Figure 7. To wit, since approximately 1999, momentum and quality have been much more negatively correlated, while the preceding period displayed positive correlations. This dynamic indicates varying degrees of relationship between momentum and quality through time.

Due to its superior risk/return characteristics in US small cap, momentum plays a prominent role in an optimal portfolio as we see in Table 13 and depicted in Figure 9). Again, growth is omitted from the optimal portfolio due to its negative excess return and higher tracking error. With this analysis, momentum can be used as a stand-alone alpha source due to its superior risk/return characteristics or as a better complement to value and quality in place of growth.

Table 11: Performance & Risk of Momentum/Quality - US Small Cap
July 1963 – April 2024

	Momentum	Quality	Market
Return (Annualized)	17.42%	13.78%	11.72%
Trailing 1-Year Return	16.28%	21.76%	12.07%
Trailing 3-Year Return (Ann.)	0.83%	2.04%	-3.20%
Trailing 5-Year Return (Ann.)	13.11%	10.13%	7.11%
Volatility (Annualized)	22.12%	21.28%	19.74%
Tracking Error (to Market)	7.09%	5.45%	--
Beta (to Market)	1.06	1.04	--
Sharpe Ratio	0.59	0.44	0.37
Information Ratio (to Market)	0.80	0.38	--
T-Stat (Excess Return)	6.09	3.11	--
Batting Average (Excess Return)	62%	56%	--

US Small Cap construction notes: Fama-French historical returns from July 1963 – April 2024. Small Cap represents the bottom three size quintiles with market cap weights of (Q1, Q2, Q3) = (17%,29%,53%). The factors displayed are referenced by Ken French as follows: Momentum (High Prior Return), Quality (High Operating Profitability), Value (High Book/Market), Growth (Low Book/Market). We use the top quintile for each factor.

Table 12: Correlations of Excess Returns - US Small Cap

July 1963 – April 2024

	Momentum	Quality	Value	Growth
Momentum	1.00	-0.10	-0.27	0.34
Quality	-0.10	1.00	0.18	-0.07
Value	-0.27	0.18	1.00	-0.72
Growth	0.34	-0.07	-0.72	1.00

Figure 7: Correlation of Momentum/Quality Over Time - US Small Cap

July 1963 – April 2024

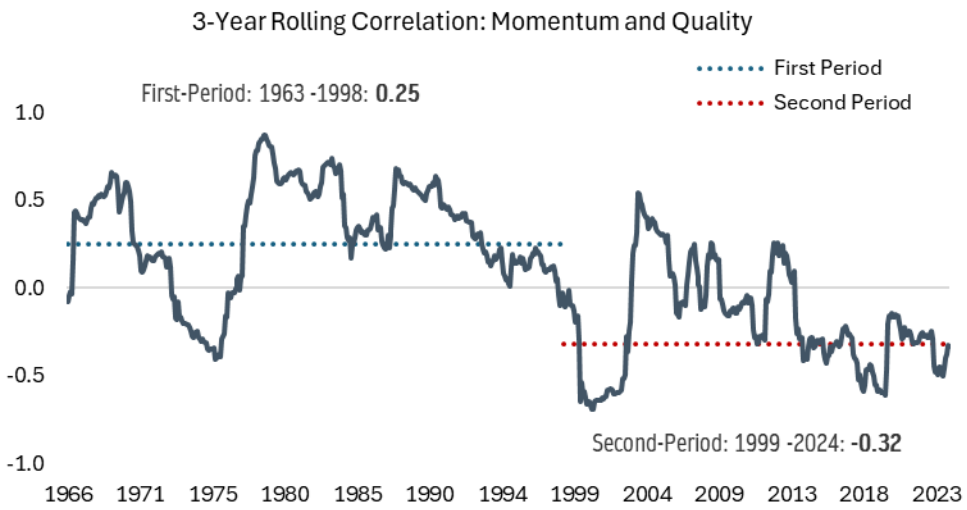

Figure 8: Performance Over Time - US Small Cap

July 1963 – April 2024

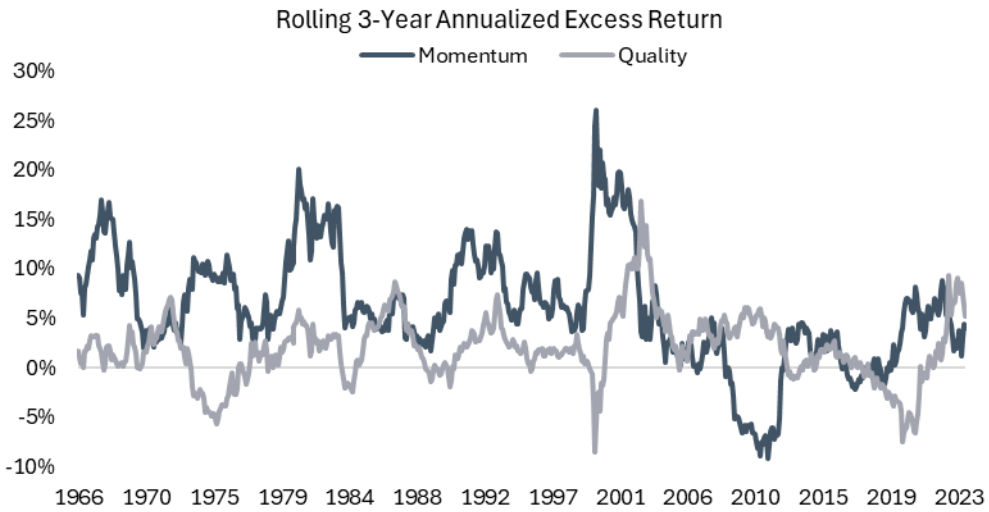

Table 13: Optimal Weights in US Small Cap

Momentum	Quality	Value	Growth
46.71%	23.45%	29.84%	0.00%

Figure 9: Optimal Portfolio in US Small Cap

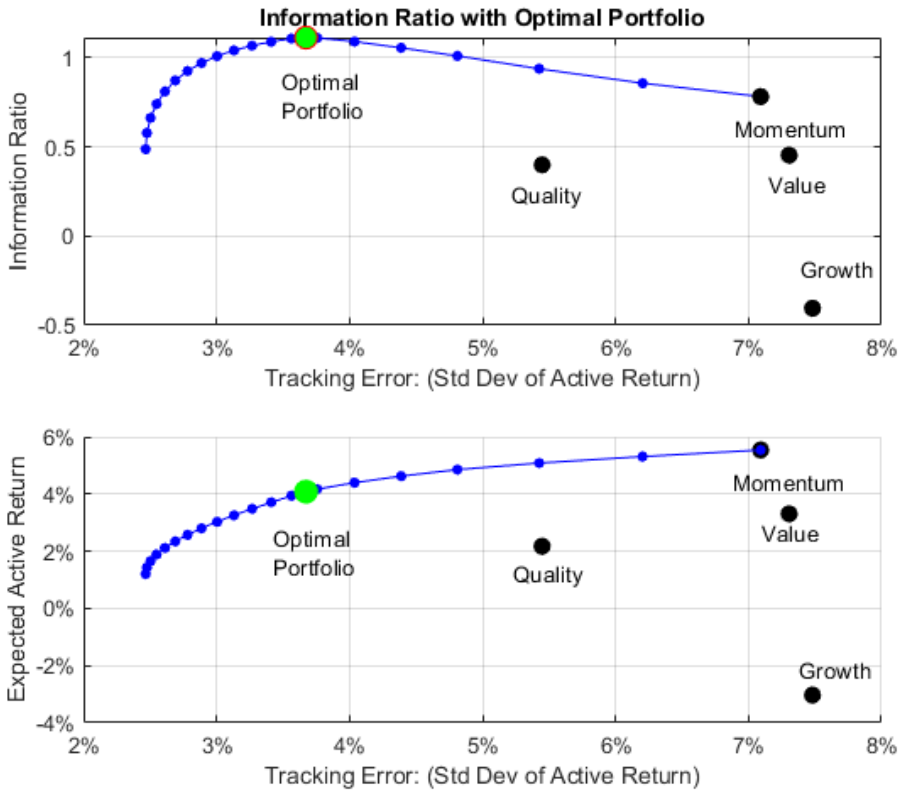

Table 14: Performance & Risk of Optimal Portfolio & Component Factors – US Small Cap

July 1963 – April 2024

	Momentum	Quality	Value	Growth	Optimal US Small Cap	Market
Return (Annualized)	17.42%	13.78%	15.24%	7.45%	16.09%	11.72%
Trailing 1-Year Return	16.28%	21.76%	14.94%	4.63%	17.34%	12.07%
Trailing 3-Year Return (Ann.)	0.83%	2.04%	4.77%	-12.65%	2.52%	-3.20%
Trailing 5-Year Return (Ann.)	13.11%	10.13%	9.67%	3.43%	11.70%	7.11%
Volatility (Annualized)	22.12%	21.28%	20.55%	23.79%	20.68%	19.74%
Tracking Error (to Market)	7.09%	5.45%	7.31%	7.48%	3.67%	--
Beta (to Market)	1.06	1.04	0.97	1.15	1.03	--
Sharpe Ratio	0.59	0.44	0.53	0.13	0.56	0.37
Information Ratio (to Market)	0.80	0.38	0.48	-0.57	1.19	--
T-Stat (Excess Return)	6.09	3.11	3.53	-3.16	8.67	--
Batting Average (Excess Return)	62%	56%	55%	45%	65%	--

US Mid Cap

Summary: Over the entire sample set in US mid cap from July 1963 to April 2024, both momentum and quality have outperformed the market return. However, momentum has outperformed quality by 232bps annualized over the sample period. Quality displays a lower tracking error to the market, but only marginally lower volatility than momentum. Momentum has superior Sharpe and information ratios than those of quality (Table 15).

Over the sample period, excess return correlations have been positive on average (0.16), but these correlations have fluctuated significantly over time as we see in Figure 8. This dynamic indicates varying degrees of relationship between momentum and quality through time.

Due to its superior risk/return characteristics in US mid cap, momentum plays a prominent role in an optimal portfolio (Table 17 and Figure 10). Again, growth is omitted from the optimal portfolio. With this analysis, momentum can be used as a stand-alone alpha source due to its superior risk/return characteristics or as a better complement to value and quality in place of growth.

Table 15: Performance & Risk of Momentum/Quality - US Mid Cap
July 1963 – April 2024

	Momentum	Quality	Market
Return (Annualized)	15.54%	13.22%	11.77%
Trailing 1-Year Return	25.28%	23.37%	18.22%
Trailing 3-Year Return (Ann.)	2.20%	4.64%	1.33%
Trailing 5-Year Return (Ann.)	11.81%	11.85%	9.68%
Volatility (Annualized)	20.19%	18.67%	17.71%
Tracking Error (to Market)	8.47%	5.01%	--
Beta (to Market)	1.04	1.02	--
Sharpe Ratio	0.55	0.47	0.41
Information Ratio (to Market)	0.45	0.29	--
T-Stat (Excess Return)	3.53	2.29	--
Batting Average (Excess Return)	59%	53%	--

US Mid Cap construction notes: Fama-French historical returns from July 1963 – April 2024. Mid Cap represents the second highest size quintile. The factors displayed are referenced by Ken French as follows: Momentum (High Prior Return), Quality (High Operating Profitability), Value (High Book/Market), Growth (Low Book/Market). We use the top quintile for each factor.

Table 16: Correlations of Excess Returns - US Mid Cap

July 1963 – April 2024

	Momentum	Quality	Value	Growth
Momentum	1.00	0.16	-0.28	0.34
Quality	0.16	1.00	-0.08	0.20
Value	-0.28	-0.08	1.00	-0.65
Growth	0.34	0.20	-0.65	1.00

Figure 8: Correlation of Momentum/Quality Over Time - US Mid Cap

July 1963 – April 2024

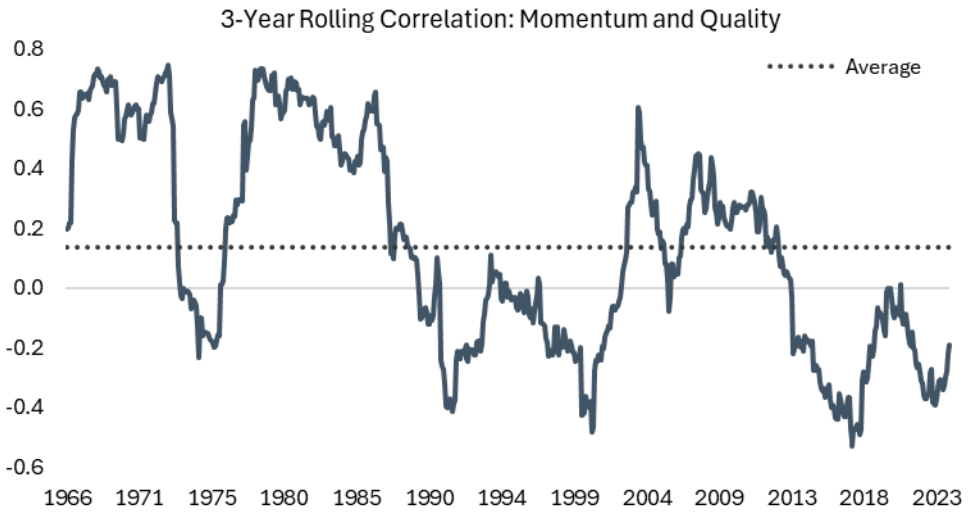

Figure 9: Performance Over Time - US Mid Cap

July 1963 – April 2024

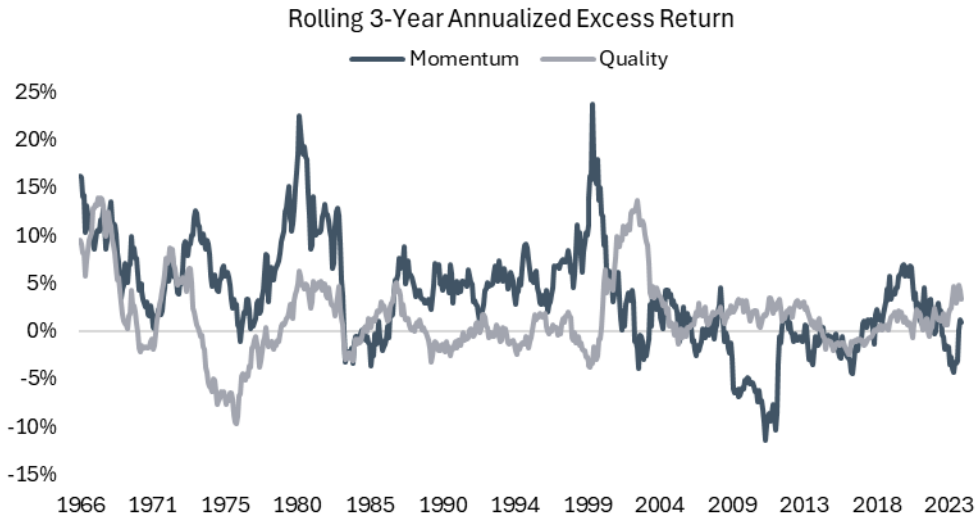

Table 17: Optimal Weights in US Mid Cap

Momentum	Quality	Value	Growth
41.68%	32.61%	25.71%	0.00%

Figure 10: Optimal Portfolio in US Mid Cap

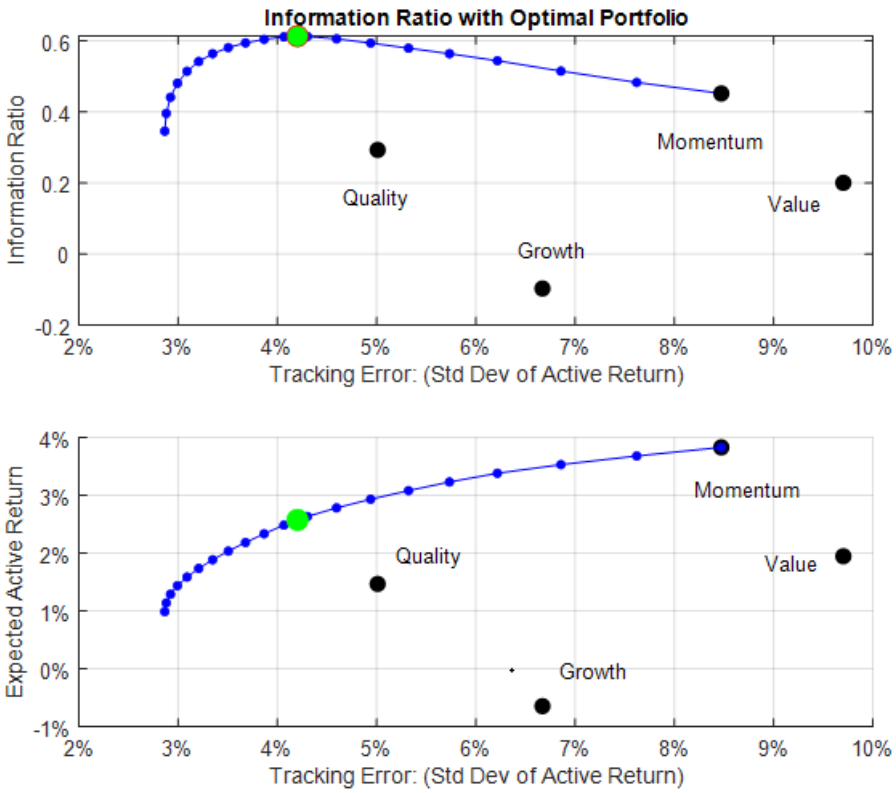

Table 18: Performance & Risk of Optimal Portfolio & Component Factors – US Mid Cap

July 1963 – April 2024

	Momentum	Quality	Value	Growth	Optimal US Mid Cap	Market
Return (Annualized)	15.54%	13.22%	13.39%	10.54%	14.48%	11.77%
Trailing 1-Year Return	25.28%	23.37%	17.49%	16.62%	22.87%	18.22%
Trailing 3-Year Return (Ann.)	2.20%	4.64%	3.11%	-3.42%	3.55%	1.33%
Trailing 5-Year Return (Ann.)	11.81%	11.85%	5.41%	9.09%	10.56%	9.68%
Volatility (Annualized)	20.19%	18.67%	20.25%	20.27%	18.56%	17.71%
Tracking Error (to Market)	8.47%	5.01%	9.70%	6.67%	4.20%	--
Beta (to Market)	1.04	1.02	1.00	1.08	1.02	--
Sharpe Ratio	0.55	0.47	0.44	0.30	0.54	0.41
Information Ratio (to Market)	0.45	0.29	0.17	-0.19	0.64	--
T-Stat (Excess Return)	3.53	2.29	1.57	-0.75	4.79	--
Batting Average (Excess Return)	59%	53%	52%	49%	59%	--

US Large Cap

Summary: Over the entire sample set in US large cap from July 1963 to April 2024, both momentum and quality have outperformed the market return. However, momentum has outperformed quality by 181bps annualized over the sample period. Quality displays a lower tracking error to the market and lower volatility than momentum. However, momentum has superior Sharpe and information ratios than those of quality (Table 19).

Over the sample period, excess return correlations have been positive on average (0.18), but these correlations have fluctuated significantly over time as we see in Figure 11. This dynamic indicates varying degrees of relationship between momentum and quality through time.

Due to its superior risk/return characteristics in US large cap, momentum plays a prominent role in an optimal portfolio (Table 21 and Figure 13). However, the makeup of the optimal portfolio in US large cap is significantly different than in other sub-segments. Value plays a much smaller role, and growth has a place in an optimal portfolio in US large cap.

Table 19: Performance & Risk of Momentum/Quality - US Large Cap
July 1963 – April 2024

	Momentum	Quality	Market
Return (Annualized)	13.30%	11.49%	10.25%
Trailing 1-Year Return	32.64%	19.99%	24.60%
Trailing 3-Year Return (Ann.)	7.09%	10.13%	7.87%
Trailing 5-Year Return (Ann.)	13.47%	16.79%	13.72%
Volatility (Annualized)	17.90%	15.23%	14.88%
Tracking Error (to Market)	9.09%	4.19%	--
Beta (to Market)	1.04	0.98	--
Sharpe Ratio	0.49	0.46	0.39
Information Ratio (to Market)	0.34	0.30	--
T-Stat (Excess Return)	2.79	2.20	--
Batting Average (Excess Return)	57%	54%	--

US Large Cap construction notes: Fama-French historical returns from July 1963 – April 2024. Large Cap represents the highest size quintile. The factors displayed are referenced by Ken French as follows: Momentum (High Prior Return), Quality (High Operating Profitability), Value (High Book/Market), Growth (Low Book/Market). We use the top quintile for each factor.

Table 20: Correlations of Excess Returns - US Large Cap

July 1963 – April 2024

	Momentum	Quality	Value	Growth
Momentum	1.00	0.18	-0.15	0.15
Quality	0.18	1.00	-0.28	0.56
Value	-0.15	-0.28	1.00	-0.48
Growth	0.15	0.56	-0.48	1.00

Figure 11: Correlation of Momentum/Quality Over Time - US Large Cap

July 1963 – April 2024

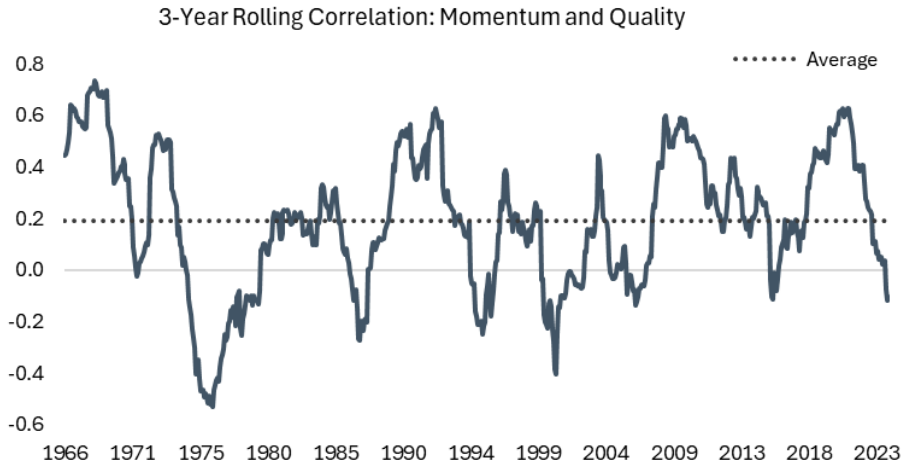

Figure 12: Performance Over Time - US Large Cap

July 1963 – April 2024

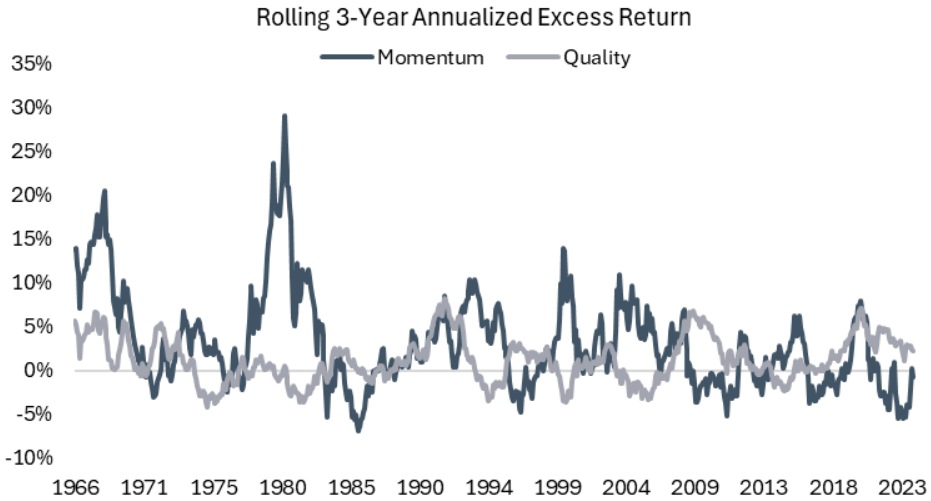

Table 21: Optimal Weights in US Large Cap

Momentum	Quality	Value	Growth
28.46%	49.72%	16.40%	5.42%

Figure 13: Optimal Portfolio in US Large Cap

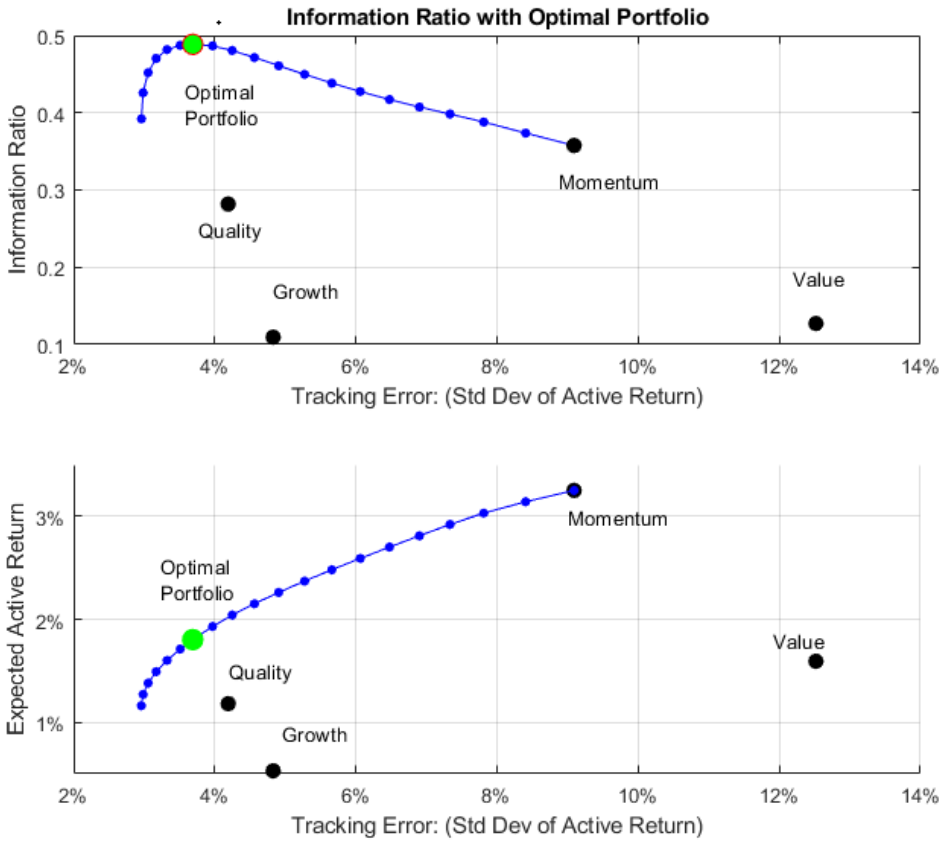

Table 22: Performance & Risk of Optimal Portfolio & Component Factors – US Large Cap

July 1963 – April 2024

	Momentum	Quality	Value	Growth	Optimal US Large Cap	Market
Return (Annualized)	13.30%	11.49%	11.07%	10.60%	12.14%	10.25%
Trailing 1-Year Return	32.64%	19.99%	25.84%	29.67%	25.26%	24.60%
Trailing 3-Year Return (Ann.)	7.09%	10.13%	9.72%	9.33%	9.54%	7.87%
Trailing 5-Year Return (Ann.)	13.47%	16.79%	13.12%	17.31%	15.70%	13.72%
Volatility (Annualized)	17.90%	15.23%	19.72%	16.28%	15.46%	14.88%
Tracking Error (to Market)	9.09%	4.19%	12.52%	4.83%	3.69%	--
Beta (to Market)	1.04	0.98	1.02	1.05	1.01	--
Sharpe Ratio	0.49	0.46	0.34	0.38	0.50	0.39
Information Ratio (to Market)	0.34	0.30	0.07	0.07	0.51	--
T-Stat (Excess Return)	2.79	2.20	0.99	0.85	3.81	--
Batting Average (Excess Return)	57%	54%	51%	51%	56%	--

Non-US Small Cap

Summary: Over the entire sample set in non-US small cap from July 1991 to April 2024, both momentum and quality have outperformed the market return. However, momentum has outperformed quality by 350bps annualized over the sample period. Quality displays a significantly lower tracking error to the market and lower volatility than momentum. Still, momentum has superior Sharpe and information ratios than those of quality and a higher batting average of excess returns. Quality has had a difficult time in recent years as its trailing 1, 3, and 5-year annualized returns have lagged the market (Table 23).

Over the sample period, excess return correlations have been positive on average (0.35), but these correlations have fluctuated significantly over time as we see in Figure 14. This dynamic indicates varying degrees of relationship between momentum and quality through time.

Examining the rolling 3-year excess returns in Figure 15, momentum and quality seem to have a beneficial pairing due to momentum's ability to capture upside in strong absolute (late 1990's) and strongly trending markets (2003-2007), while quality provides a ballast in difficult markets like in and around the global financial crisis (2008-2009). Moreover, momentum has provided useful diversification to quality since 2020 as their correlations have trended downward and quality has underperformed the market.

Mostly due to their lower tracking errors, value and quality play a prominent role in an optimal portfolio that maximizes the information ratio in non-US small cap (Table 25 and Figure 16). Still, momentum's role in the optimal portfolio can be taking the place of growth or as a stand-alone alpha source due to its superior absolute performance, highest information ratio, and compelling risk-adjusted returns.

Table 23: Performance & Risk of Momentum/Quality - Non-US Small Cap
July 1991 – April 2024

	Momentum	Quality	Market
Return (Annualized)	13.01%	9.51%	7.40%
Trailing 1-Year Return	10.73%	4.48%	5.33%
Trailing 3-Year Return (Ann.)	0.39%	-5.00%	-3.06%
Trailing 5-Year Return (Ann.)	9.69%	4.15%	4.27%
Volatility (Annualized)	17.39%	16.60%	16.28%
Tracking Error (to Market)	5.79%	2.92%	--
Beta (to Market)	1.01	1.00	--
Sharpe Ratio	0.61	0.43	0.31
Information Ratio (to Market)	0.97	0.72	--
T-Stat (Excess Return)	5.28	3.96	--
Batting Average (Excess Return)	66%	59%	--

Non-US Small Cap construction notes: Fama-French historical returns from July 1991 – April 2024. The portfolio is the combination of 75% developed (non-US) and 25% emerging markets. In developed markets (non-US), small cap represents the market cap weights of: (Q1, Q2, Q3) = (23%,31%,46%). For emerging markets, small cap is the bottom 10% of the market cap. The factors displayed are referenced by Ken French as follows: Momentum (High Prior Return), Quality (High Operating Profitability), Value (High Book/Market), Growth (Low Book/Market). We use the top quintile for each factor except in emerging markets where we use the top 30%.

Table 24: Correlations of Excess Returns - Non-US Small Cap
July 1991 – April 2024

	Momentum	Quality	Value	Growth
Momentum	1.00	0.35	-0.16	0.40
Quality	0.35	1.00	-0.44	0.57
Value	-0.16	-0.44	1.00	-0.71
Growth	0.40	0.57	-0.71	1.00

Figure 14: Correlation of Momentum/Quality Over Time - Non-US Small Cap
July 1991 – April 2024

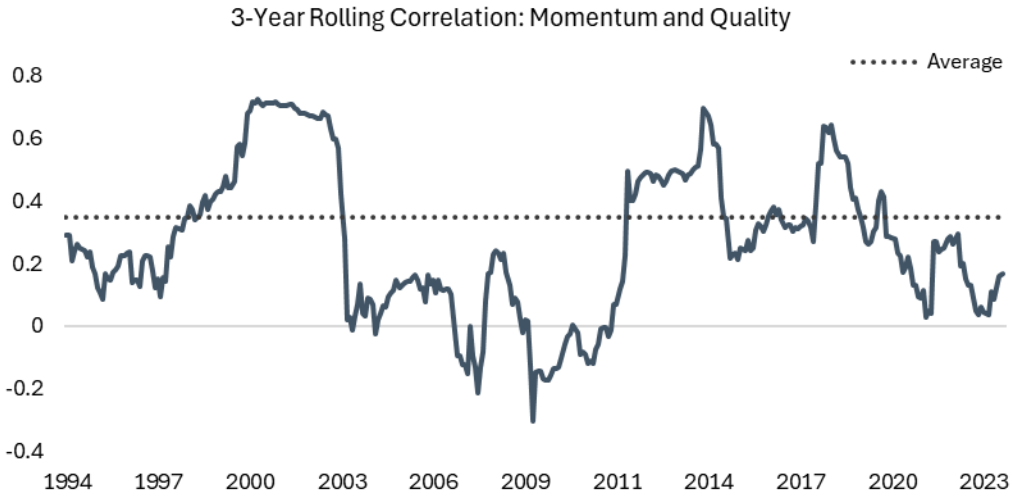

Figure 15: Performance of Over Time - Non-US Small Cap
July 1991 – April 2024

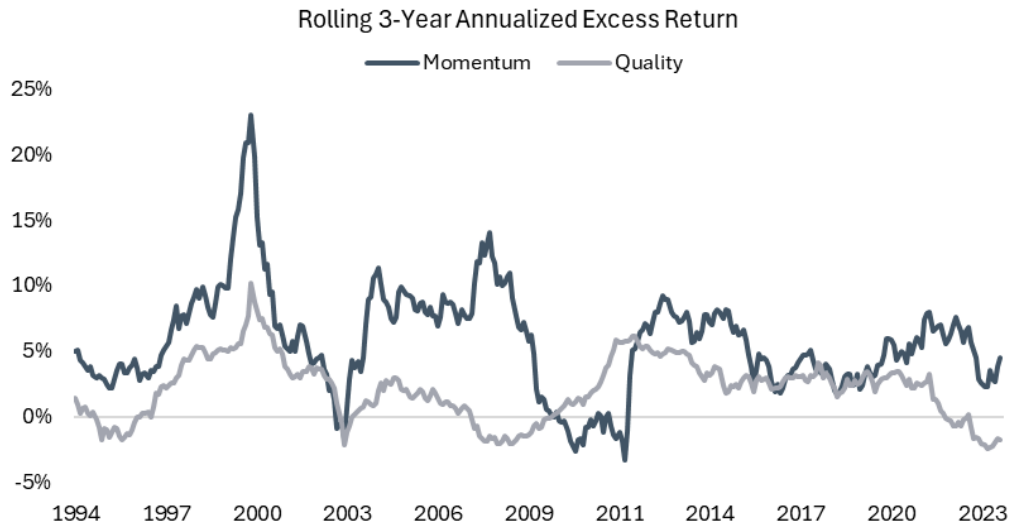

Table 25: Optimal Weights in Non-US Small Cap

Momentum	Quality	Value	Growth
17.04%	41.29%	41.68%	0.00%

Figure 16: Optimal Portfolio in Non-US Small Cap

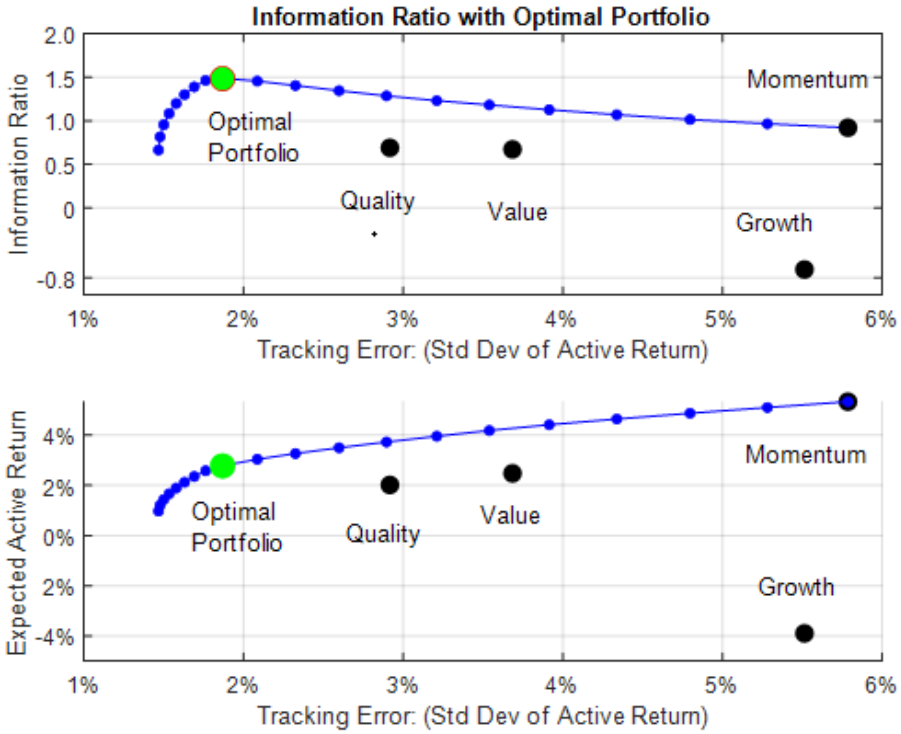

Table 26: Performance & Risk of Optimal Portfolio & Component Factors – Non-US Small Cap

July 1991 – April 2024

	Momentum	Quality	Value	Growth	Optimal Non-US Small Cap	Market
Return (Annualized)	13.01%	9.51%	10.07%	2.95%	10.39%	7.40%
Trailing 1-Year Return	10.73%	4.48%	14.16%	-7.90%	9.53%	5.33%
Trailing 3-Year Return (Ann.)	0.39%	-5.00%	5.84%	-13.93%	0.39%	-3.06%
Trailing 5-Year Return (Ann.)	9.69%	4.15%	8.37%	-1.07%	6.91%	4.27%
Volatility (Annualized)	17.39%	16.60%	16.38%	18.21%	16.30%	16.28%
Tracking Error (to Market)	5.79%	2.92%	3.68%	5.51%	1.87%	--
Beta (to Market)	1.01	1.00	0.98	1.07	0.99	--
Sharpe Ratio	0.61	0.43	0.47	0.03	0.49	0.31
Information Ratio (to Market)	0.97	0.72	0.72	-0.81	1.60	--
T-Stat (Excess Return)	5.28	3.96	3.86	-4.05	8.51	--
Batting Average (Excess Return)	66%	59%	57%	41%	72%	--

Non-US Large/Mid Cap

Summary: Over the entire sample set in non-US large/mid cap from July 1991 to April 2024, both momentum and quality have outperformed the market return. However, momentum has outperformed quality by 109bps annualized over the sample period. Quality displays a lower tracking error to the market and marginally lower volatility than momentum. However, momentum has a superior Sharpe ratio, while quality has a slightly higher information ratio (Table 27).

Over the sample period, excess return correlations have been highly positive (0.48) on average. These correlations have fluctuated but have spent most of the time in positive territory (Figure 17).

Due to its risk/return characteristics, quality plays a prominent role in an optimal portfolio (maximizing information ratios) in non-US large/mid cap (Table 29 and Figure 19). Still, momentum has a role to play as a better complement to quality and value than growth in an optimal portfolio or as a stand-alone source of alpha due to its high absolute and risk adjusted returns.

Table 27: Performance & Risk of Momentum/Quality - Non-US Large/Mid Cap
July 1991 – April 2024

	Momentum	Quality	Market
Return (Annualized)	8.94%	7.85%	6.51%
Trailing 1-Year Return	13.28%	9.95%	8.77%
Trailing 3-Year Return (Ann.)	-0.15%	2.19%	0.73%
Trailing 5-Year Return (Ann.)	8.09%	8.15%	5.52%
Volatility (Annualized)	16.83%	15.79%	16.57%
Tracking Error (to Market)	7.16%	3.57%	--
Beta (to Market)	0.92	0.93	--
Sharpe Ratio	0.39	0.34	0.25
Information Ratio (to Market)	0.34	0.37	--
T-Stat (Excess Return)	1.84	1.79	--
Batting Average (Excess Return)	58%	55%	--

Non-US Large/Mid Cap construction notes: Fama-French historical returns from July 1991 – April 2024. The portfolio is the combination of 75% developed (non-US) and 25% emerging markets. In developed markets (non-US), large/mid cap represents the top two size quintiles with market cap weights of (Q4, Q5) = (14%, 86%). For emerging markets, large/mid cap is the top 90% by market cap. The factors displayed are referenced by Ken French as follows: Momentum (High Prior Return), Quality (High Operating Profitability), Value (High Book/Market), Growth (Low Book/Market). We use the top quintile for each factor except in emerging markets where we use the top 30%.

Table 28: Correlations of Excess Returns - Non-US Large/Mid Cap
July 1991 – April 2024

	Momentum	Quality	Value	Growth
Momentum	1.00	0.48	-0.42	0.37
Quality	0.48	1.00	-0.62	0.67
Value	-0.42	-0.62	1.00	-0.70
Growth	0.37	0.67	-0.70	1.00

Figure 17: Correlation of Momentum/Quality Over Time - Non-US Large/Mid Cap
July 1991 – April 2024

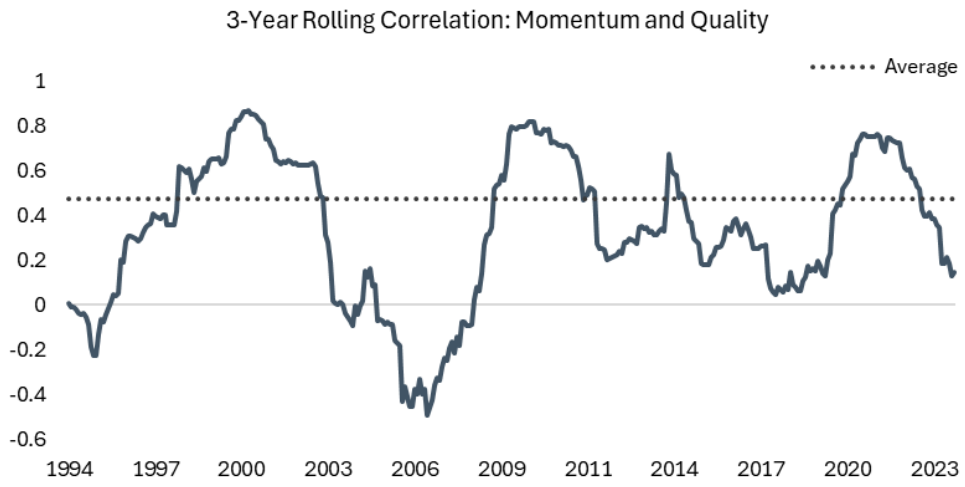

Figure 18: Performance Over Time - Non-US Large/Mid Cap
July 1991 – April 2024

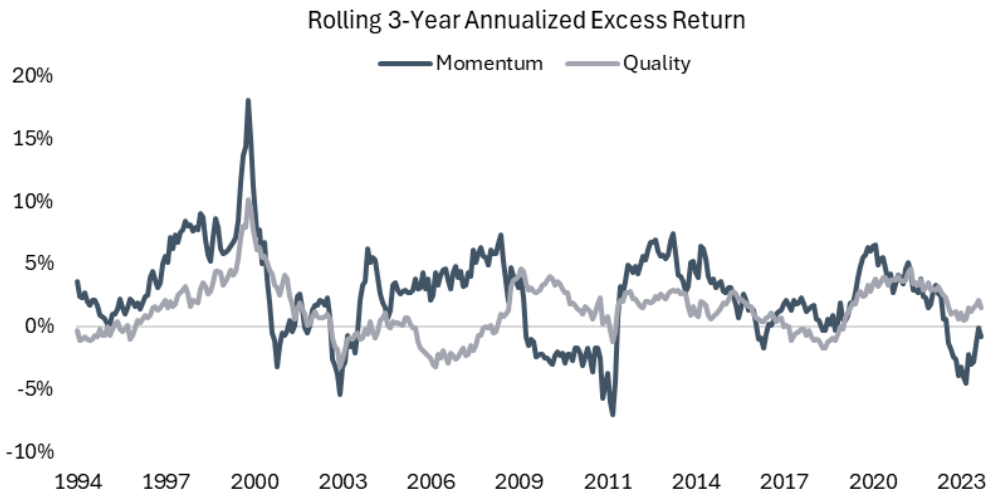

Table 29: Optimal Weights in Non-US Large/Mid Cap

Momentum	Quality	Value	Growth
13.55%	50.55%	35.90%	0.00%

Figure 19: Optimal Portfolio in Non-US Large/Mid Cap

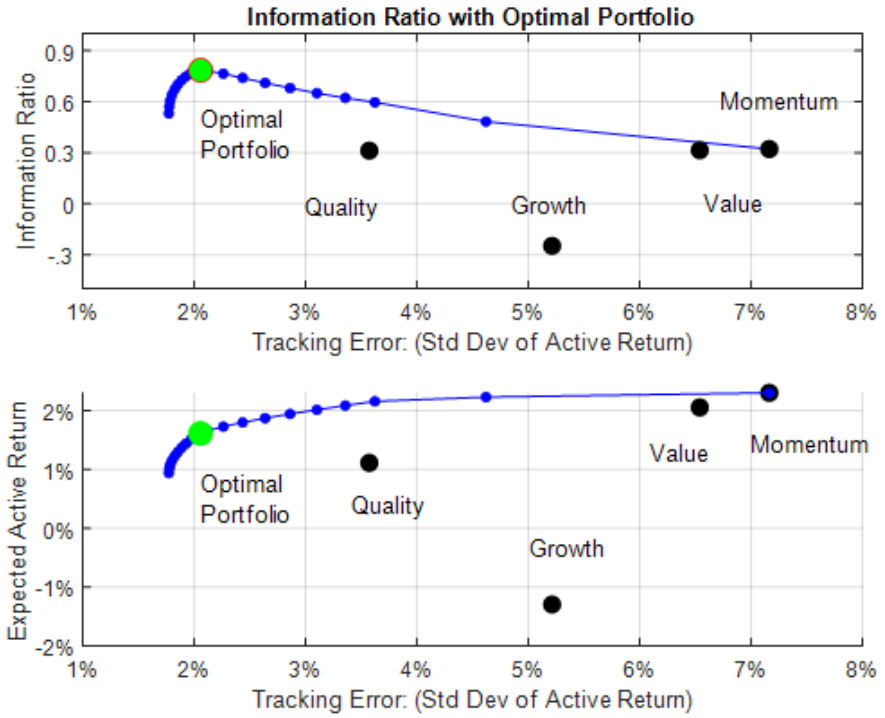

Table 30: Performance & Risk of Optimal Portfolio & Component Factors – Non-US Large/Mid Cap

July 1991 – April 2024

	Momentum	Quality	Value	Growth	Optimal Non-US Large/Mid Cap	Market
Return (Annualized)	8.94%	7.85%	8.16%	5.13%	8.24%	6.51%
Trailing 1-Year Return	13.28%	9.95%	19.51%	4.95%	13.81%	8.77%
Trailing 3-Year Return (Ann.)	-0.15%	2.19%	9.75%	-2.58%	4.67%	0.73%
Trailing 5-Year Return (Ann.)	8.09%	8.15%	8.38%	6.37%	8.42%	5.52%
Volatility (Annualized)	16.83%	15.79%	19.33%	16.68%	16.56%	16.57%
Tracking Error (to Market)	7.16%	3.57%	6.54%	5.21%	2.06%	--
Beta (to Market)	0.92	0.93	1.10	0.96	0.99	--
Sharpe Ratio	0.39	0.34	0.30	0.16	0.35	0.25
Information Ratio (to Market)	0.34	0.37	0.25	-0.27	0.84	--
T-Stat (Excess Return)	1.84	1.79	1.80	-1.42	4.49	--
Batting Average (Excess Return)	58%	55%	54%	47%	60%	--

Emerging Markets Small Cap

Summary: Over the entire sample set in emerging markets small cap from July 1991 to April 2024, quality has underperformed the market return by 149bps annualized, while momentum has strongly outperformed the market by 531bps annualized. Further, momentum has outperformed quality with a lower tracking error with about the same volatility (Table 31).

Over the sample period, excess return correlations have been mildly positive (0.14) on average, but these correlations have fluctuated significantly over time as we see in Figure 20. This dynamic indicates varying degrees of relationship between momentum and quality through time.

Examining the rolling 3-year excess returns in Figure 21, similarly to the non-US small cap market, quality and momentum have diverged since 2020 where momentum has strongly outperformed while quality has lagged the market.

The optimal portfolio (maximizing information ratio) in emerging markets small cap looks much different than most sub-segments as only value and momentum strategies are utilized at roughly equal weights (Table 33). Therefore, the role of momentum in emerging markets small cap is as a substantial portion of a diversified factor portfolio or a as a stand-alone source of alpha due its superior risk/return characteristics.

Table 31: Performance & Risk of Momentum/Quality - EM Small Cap
July 1991 – April 2024

	Momentum	Quality	Market
Return (Annualized)	15.44%	8.64%	10.13%
Trailing 1-Year Return	24.28%	10.07%	11.00%
Trailing 3-Year Return (Ann.)	8.03%	-1.29%	0.26%
Trailing 5-Year Return (Ann.)	16.00%	4.95%	7.06%
Volatility (Annualized)	20.79%	20.64%	20.47%
Tracking Error (to Market)	5.98%	7.77%	--
Beta (to Market)	0.97	0.94	--
Sharpe Ratio	0.63	0.30	0.38
Information Ratio (to Market)	0.89	-0.19	--
T-Stat (Excess Return)	4.61	-0.98	--
Batting Average (Excess Return)	65%	50%	--

Emerging Markets Small Cap construction notes: Fama-French historical returns from July 1991 – April 2024. Small cap represents the bottom 10% of the market cap. The factors displayed are referenced by Ken French as follows: Momentum (High Prior Return), Quality (High Operating Profitability), Value (High Book/Market), Growth (Low Book/Market). We use the top 30% for each factor.

Table 32: Correlations of Excess Returns - EM Small Cap

July 1991 – April 2024

	Momentum	Quality	Value	Growth
Momentum	1.00	0.14	0.10	0.04
Quality	0.14	1.00	-0.13	0.24
Value	0.10	-0.13	1.00	-0.40
Growth	0.04	0.24	-0.40	1.00

Figure 20: Correlation of Momentum/Quality Over Time - EM Small Cap

July 1991 – April 2024

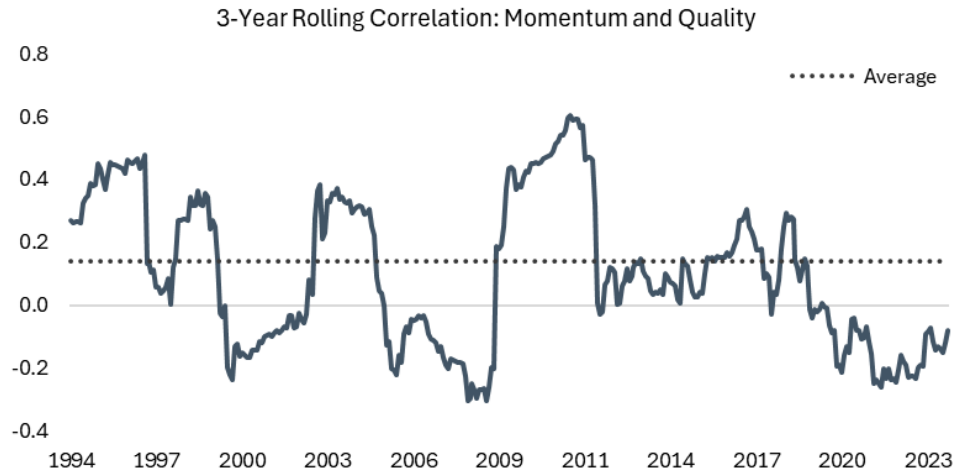

Figure 21: Performance Over Time - EM Small Cap

July 1991 – April 2024

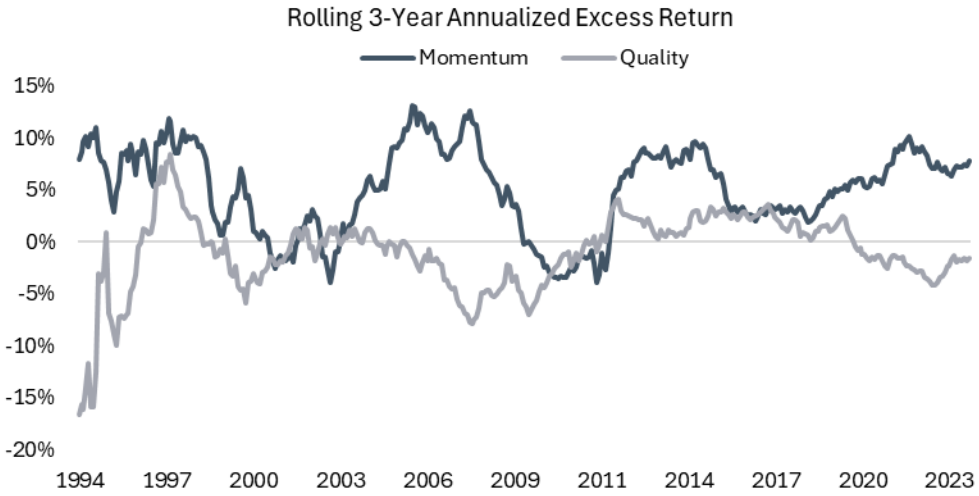

Table 33: Optimal Weights in EM Small Cap

Momentum	Quality	Value	Growth
45.54%	0.00%	54.46%	0.00%

Figure 22: Optimal Portfolio in EM Small Cap

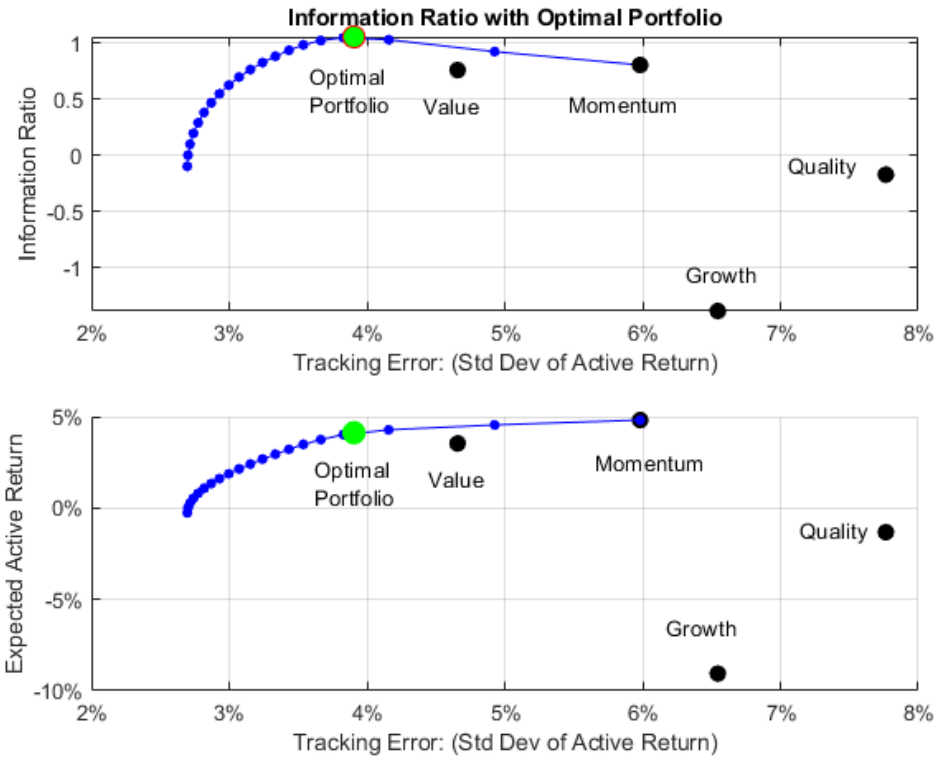

Table 34: Performance & Risk of Optimal Portfolio & Component Factors – EM Small Cap

July 1991 – April 2024

	Momentum	Quality	Value	Growth	Optimal EM Small Cap	Market
Return (Annualized)	15.44%	8.64%	14.03%	0.41%	14.74%	10.13%
Trailing 1-Year Return	24.28%	10.07%	19.71%	-6.00%	21.78%	11.00%
Trailing 3-Year Return (Ann.)	8.03%	-1.29%	7.26%	-12.52%	7.63%	0.26%
Trailing 5-Year Return (Ann.)	16.00%	4.95%	11.74%	-3.66%	13.70%	7.06%
Volatility (Annualized)	20.79%	20.64%	20.65%	21.33%	20.40%	20.47%
Tracking Error (to Market)	5.98%	7.77%	4.66%	6.55%	3.91%	--
Beta (to Market)	0.97	0.94	0.98	0.99	0.98	--
Sharpe Ratio	0.63	0.30	0.56	-0.09	0.60	0.38
Information Ratio (to Market)	0.89	-0.19	0.84	-1.48	1.18	--
T-Stat (Excess Return)	4.61	-0.98	4.35	-7.93	6.04	--
Batting Average (Excess Return)	65%	50%	62%	29%	73%	--

Emerging Markets Large/Mid Cap

Summary: Over the entire sample set in emerging markets large/mid Cap from July 1991 to April 2024, both momentum and quality have outperformed the market return. However, momentum has outperformed quality by 252bps annualized over the sample period. Quality displays a lower tracking error to the market, but with about the same level of volatility. However, momentum has a superior Sharpe ratio and nearly double the information ratio than that of value (Table 35).

Over the sample period, excess return correlations have been mildly positive (0.13) on average. However, these correlations have fluctuated significantly over time including a sharp negative trend recently as we see in Figure 23.

Mostly due to its lower tracking error, quality plays a useful role in the optimal portfolio (maximizing information ratios) with momentum and value at nearly equal parts. Once again, growth is left out of the optimal portfolio (Table 37 and Figure 25). Momentum is useful in emerging markets large/mid cap as a stand-alone source of alpha due to its strong absolute and risk adjusted returns or plays a prominent role in an optimal portfolio.

Table 35: Performance & Risk of Momentum/Quality - EM Large/Mid Cap
July 1991 – April 2024

	Momentum	Quality	Market
Return (Annualized)	11.77%	9.25%	7.18%
Trailing 1-Year Return	14.16%	15.47%	11.24%
Trailing 3-Year Return (Ann.)	-0.16%	-1.88%	-3.65%
Trailing 5-Year Return (Ann.)	8.98%	6.81%	2.91%
Volatility (Annualized)	20.87%	20.73%	21.06%
Tracking Error (to Market)	6.10%	4.80%	--
Beta (to Market)	0.95	0.96	--
Sharpe Ratio	0.45	0.33	0.23
Information Ratio (to Market)	0.75	0.43	--
T-Stat (Excess Return)	3.92	2.19	--
Batting Average (Excess Return)	60%	53%	--

Emerging Markets Large/Mid Cap construction notes: Fama-French historical returns from July 1991 – April 2024. Large/mid cap represents the top 90% of the market cap. The factors displayed are referenced by Ken French as follows: Momentum (High Prior Return), Quality (High Operating Profitability), Value (High Book/Market), Growth (Low Book/Market). We use the top 30% for each factor.

Table 36: Correlations of Excess Returns - EM Large/Mid Cap
July 1991 – April 2024

	Momentum	Quality	Value	Growth
Momentum	1.00	0.13	-0.07	0.21
Quality	0.13	1.00	-0.32	0.47
Value	-0.07	-0.32	1.00	-0.58
Growth	0.21	0.47	-0.58	1.00

Figure 23: Correlation of Momentum/Quality Over Time - EM Large/Mid Cap
July 1991 – April 2024

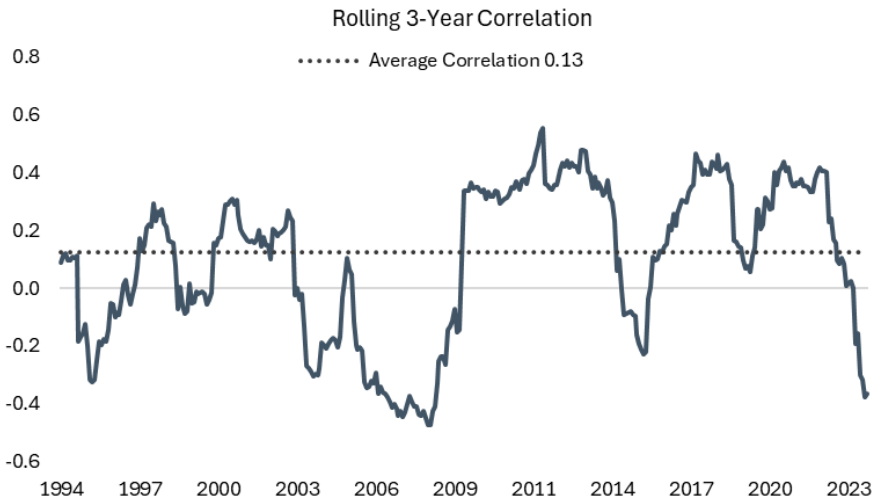

Figure 24: Performance Over Time - EM Large/Mid Cap
July 1991 – April 2024

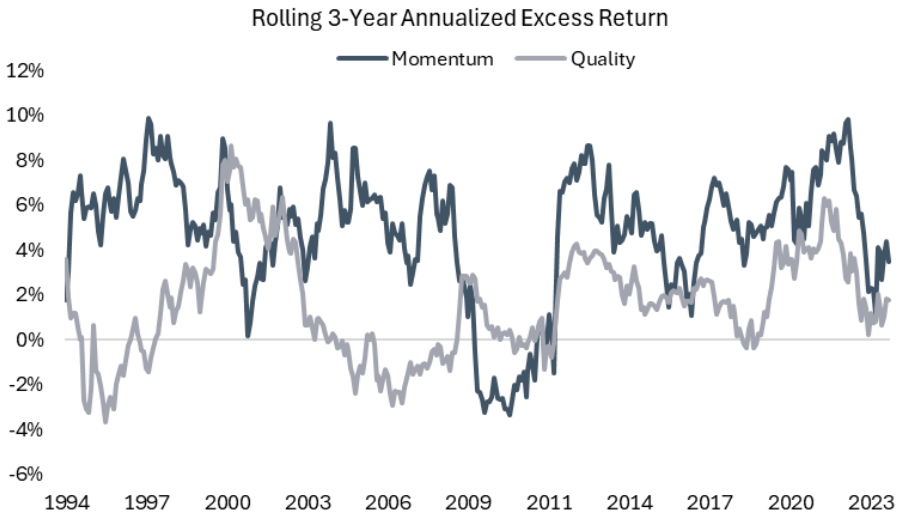

Table 37: Optimal Weights in EM Large/Mid Cap

Momentum	Quality	Value	Growth
34.52%	33.06%	32.42%	0.00%

Figure 25: Optimal Portfolio in EM Large/Mid Cap

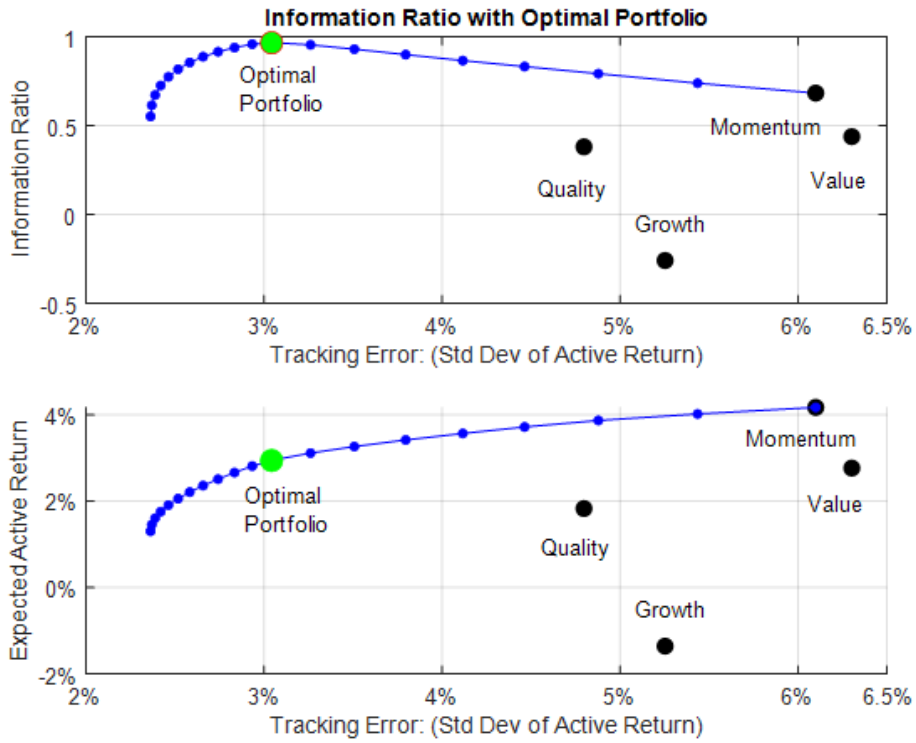

Table 38: Performance & Risk of Optimal Portfolio & Component Factors – EM Large/Mid Cap

July 1991 – April 2024

	Momentum	Quality	Value	Growth	Optimal EM Large/Mid Cap	Market
Return (Annualized)	11.77%	9.25%	9.89%	5.89%	10.45%	7.18%
Trailing 1-Year Return	14.16%	15.47%	21.14%	6.31%	16.89%	11.24%
Trailing 3-Year Return (Ann.)	-0.16%	-1.88%	6.39%	-9.16%	1.45%	-3.65%
Trailing 5-Year Return (Ann.)	8.98%	6.81%	7.18%	2.05%	7.85%	2.91%
Volatility (Annualized)	20.87%	20.73%	22.28%	20.49%	20.72%	21.06%
Tracking Error (to Market)	6.10%	4.80%	6.30%	5.25%	3.04%	--
Beta (to Market)	0.95	0.96	1.01	0.94	0.97	--
Sharpe Ratio	0.45	0.33	0.34	0.17	0.39	0.23
Information Ratio (to Market)	0.75	0.43	0.43	-0.25	1.07	--
T-Stat (Excess Return)	3.92	2.19	2.52	-1.48	5.54	--
Batting Average (Excess Return)	60%	53%	53%	45%	63%	--

Appendix 1: Axioma Factor Correlations

Another way to view factor dynamics is through the lens of Axioma risk models. The Axioma factor returns are computed differently compared to those of the Fama-French returns displayed in the previous correlation tables. The Axioma factor returns are computed via a cross-sectional regression of all assets returns (in a particular universe) at a fixed point in time onto the asset exposures. The regression coefficients are then defined as the factor returns. It is often helpful to find asset weights that lead to a portfolio that realizes the factor returns. This portfolio is called a Factor Mimicking Portfolio (FMP). Working backwards from the Ordinary Least Squares solution to the regression model one discovers two very helpful properties for the FMP. Firstly, the FMP has unit exposure to the factor it mimics, and secondly it has zero exposure to the other factors in the model. The FMP is best thought of as a long-short portfolio that realizes the factor returns.

These correlations can differ from the Fama-French excess return correlations of the long-only top quintile strategies. The Axioma correlations are simply another way to view the factor dynamics – keeping in mind that the Axioma factor returns are not constructed in isolation as the Fama-French factors (other than size) are but rather depend on all factors in the model.

Table A1.1: Axioma Factor Correlations – US Equity Model
January 1982 – April 2024

	Momentum	Quality	Value	Growth
Momentum	1.00	-0.10	-0.41	0.20
Quality	-0.10	1.00	0.11	-0.11
Value	-0.41	0.11	1.00	-0.33
Growth	0.20	-0.11	-0.33	1.00

Table A1.2: Axioma Factor Correlations – World-Wide Equity Model
January 1997 – April 2024

	Momentum	Quality	Value	Growth
Momentum	1.00	-0.11	-0.51	0.11
Quality	-0.11	1.00	0.18	-0.34
Value	-0.51	0.18	1.00	-0.27
Growth	0.11	-0.34	-0.27	1.00

About IMC

IMC is solely focused on helping clients build better portfolios through our Informed Momentum investment approach. This approach has been applied consistently across all strategies since the inception of the firm in 2007 (formerly EAM Investors*). The daily application of our systematic process is designed to deliver consistent and predictable results. Since our entire company works for a single objective, it only makes sense to align the name of our brand with exactly what we do every day.

We are the **Informed Momentum Company.**

About the Authors

TRAVIS PRENTICE

Travis is the chief investment officer, responsible for oversight of all of IMC's strategies, as well as a portfolio manager for IMC's US and Global strategies. Travis co-founded The Informed Momentum Company, formerly EAM Investors, in 2007. Prior to that, Travis was a partner, managing director and portfolio manager with Nicholas-Applegate Capital Management where he had lead portfolio management responsibilities for their Micro and Ultra Micro Cap investment strategies and a senior role in the firm's US Micro/Emerging Growth team. He has 27 years of institutional investment experience specializing in momentum-based strategies. He holds an MBA from San Diego State University and a BA in Economics and a BA in Psychology from the University of Arizona.

DAVID WROBLEWSKI, PHD

David is the director of applied research at IMC. Prior to joining the company in 2021, David was director of research at Denali Advisors, an institutional equity manager with US and Non-US strategies. He has additional experience in research and risk management from Nicholas-Applegate Capital Management. David also serves as an adjunct instructor in the Department of Mathematics at San Diego City College. He has 15 years of investment experience. David received a Ph.D. in Mathematics at the University of California, San Diego, a Master of Science in Applied Mathematics and a Bachelor of Science in Applied Mathematics from San Diego State University. David has published papers in the Journal of Investment Management, Financial Analyst Journal, and Applied Economics, among other financial publications. He has been awarded the "Harry M. Markowitz, Special Distinction Award" from The Journal of Investment Management.

*As of 2/4/2025, EAM Investors, LLC, "EAM" has officially changed its name to The Informed Momentum Company, "IMC". This name change does not impact the integrity or content of the research, reports, or any materials previously published under the old name. All references to "EAM" in past publications and reports now refer to "IMC".

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References:

Carhart, M. Mark, “On Persistence in Mutual Fund Performance.” The Journal of Finance, (1997), 52: 57-82.

Ball, Ray, “Anomalies in relationships between securities' yields and yield-surrogates.” Journal of Financial Economics, Volume 6, Issues 2–3, (1978), Pages 103-126.

Basu, Sanjoy, “The relationship between earnings' yield, market value and return for NYSE common stocks: Further evidence.” Journal of Financial Economics, Volume 12, Issue 1, (1983), Pages 129-156.

Eugene F. Fama, Kenneth R. French, “Common risk factors in the returns on stocks and bonds.” Journal of Financial Economics, Volume 33, Issue 1, (1993), Pages 3-56.

Eugene F. Fama, Kenneth R. French, “A five-factor asset pricing model.” Journal of Financial Economics, Volume 116, Issue 1, (2015), Pages 1-22.

Hou, Kewei, Xue Chen, and Zhang Lu, “Digesting Anomalies: An Investment Approach.” The Review of Financial Studies, Volume 28, Issue 3, (2015), Pages 650–705.

Novy-Marx, Robert “The other side of value: The gross profitability premium”. Journal of Financial Economics (2013), Volume 108, Issue 1.