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When Valuation Fails

Cesare Buiatti and Sébastien Page

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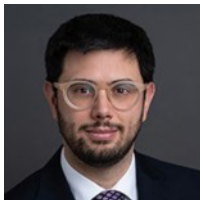


Cesare Buiatti, Ph.D., CFA

Cesare Buiatti is a senior quantitative investment analyst in the Multi-Asset Division.

Cesare has been with T. Rowe Price since 2019, beginning in the Multi-Asset Division. Prior to this, Cesare was employed by the European Central Bank in Frankfurt, Germany, as a summer graduate researcher in directorate general-research/monetary policy. Cesare also was a summer intern at Allianz Investment Management SE in Munich, working in credit investment strategy.

Cesare earned an M.Sc. in finance from Bocconi University in Milan, Italy, and a Ph.D. in economics from the University of Illinois, Urbana-Champaign. He also has earned the Chartered Financial Analyst® designation.

Sébastien Page, CFA

Sébastien Page is head of Global Multi-Asset and chief investment officer. He is a member of the Asset Allocation Committee, which is responsible for tactical investment decisions across asset allocation portfolios. Sébastien also is a member of the Management Committee of T. Rowe Price Group, Inc.

Sébastien's investment experience began in 2000, and he has been with T. Rowe Price since 2015. Prior to this, Sébastien was employed by PIMCO as an executive vice president, where he led a team focused on research and development of multi-asset solutions. He also was a senior managing director at State Street Global Markets.

Sébastien earned a B.S. in business administration and an M.S. in finance from Sherbrooke University in Quebec, Canada. Sébastien also has earned the Chartered Financial Analyst® designation.

Sébastien coauthored award-winning research papers for *The Journal of Portfolio Management* in 2003, 2010, 2011, and 2022 and the *Financial Analysts Journal* in 2010 and 2014. He is the author of the book "Beyond Diversification: What Every Investor Needs to Know About Asset Allocation" (McGraw Hill, 2020) and the coauthor of the book "Factor Investing and Asset Allocation" (CFA Institute Research Foundation® , 2016). Sébastien is a member of the editorial boards of The Journal of Portfolio Management and the Financial Analysts Journal, and he is a member of the Research Committee of the Institute for Quantitative Research in Finance (Q Group). He regularly appears in the financial media, including Bloomberg TV and CNBC, and was recently named among the 15 Top Voices in Finance for 2022 by LinkedIn.

When Valuation Fails

Cesare Buiatti and Sébastien Page

Cesare Buiatti
is a senior quantitative investment analyst, Global Multi-Asset, at T. Rowe Price in Baltimore, MD.
cesare.buiatti@troweprice.com

Sébastien Page
is the head of Global Multi-Asset and chief investment officer at T. Rowe Price in Baltimore, MD.

KEY FINDINGS

- Our industry should value research on failures as much as successes to learn and improve investment strategies.
- Value stocks' underperformance since the 2008–2009 financial crisis is due to technological disruptions and inadequate accounting for intangible assets.
- A new methodology, *data mining confidence bands*, provides transparency in backtesting performance. It helps avoid overfitted models by revealing the sensitivity of results to different parameter choices.
- Despite the challenges, relative valuation investing is still viable. Investors must adapt by incorporating momentum adjustments, using judgment, making accounting adjustments, and staying informed about technological and macroeconomic trends.

ABSTRACT

Is relative valuation investing dead? Are markets "broken"? The authors attribute the long period of underperformance of value stocks to technological disruptions and inadequate accounting for intangible assets. They introduce a new methodology, *data mining confidence bands*, to provide transparency in backtesting performance and avoid overfitted models. Backtesting 24 strategies shows modest returns for valuation-based approaches, with improved results when incorporating momentum adjustments. Despite the diminished effectiveness of relative valuation signals over the past two decades, relative valuation investing remains viable. Successful investors must adapt by incorporating judgment, accounting adjustments, fundamental research, and awareness of technological and macroeconomic trends.

As an industry, we like to publish research that "works" (at least on paper). Otherwise, we sweep failed experiments under the rug. This problem is not specific to finance. Academics in all fields are in a never-ending quest for high *r*-squareds and *t*-statistics.

This article is different. In the context of the 50th anniversary issue of this journal, we hope it will encourage researchers to contribute more articles on what *doesn't* work as much as what does. We learn *more* from mistakes, failures, losses, and setbacks than when everything goes as expected. "The obstacle is the way," wrote modern philosopher Ryan Holiday.[1]

We examine the failure of a basic model: the relative valuation discipline at the core of most tactical asset allocation (TAA) processes. Nowhere has this been more evident than in the failure of value stocks to catch up to their growth counterparts

[1] See Holiday (2014).

since the Global Financial Crisis of 2008–2009. We attribute this failure to technology disruption and accounting's misreporting of intangibles. We discuss how skilled asset allocators have avoided this value trap's gravitational pull, including with a momentum adjustment, which has been one of the simplest ways to cure the relative valuation malaise. When an asset class is cheap and shows positive short-term momentum, the valuation signal works better.[2]

We also propose a new methodology to evaluate backtesting performance, that is, what works. Statistical measures, with their beautiful star notation (**, ***), project rigor and appease referees. However, they are silent on the sensitivity of the model's performance to the choices of lookback data windows and portfolio construction ("bucketing") methodologies. Our *data mining confidence bands* complement traditional statistical measures to provide transparency on model parameter choice. This information is what practitioners need to know if they want to avoid using overfitted models.

HOW IS "VALUE" DEFINED AND IS THERE A VALUE PREMIUM?

An easy way to distinguish between value and growth stocks is to rank them by their book-to-market ratio (B/M). This ratio can be a yardstick for disagreements between accountants and money managers about a company's value.

- Book value (B) is what accountants think the company is worth—the difference between the company's assets and liabilities.
- Market value (M) is the market capitalization (shares outstanding multiplied by price). It's what investors think the company is worth based on its future earnings prospects.

Theoretically, companies with a high B/M are "cheap," and those with a low B/M are "expensive." Of course, it's not that simple. Valuing a company is difficult. It requires forecasting future earnings and putting a price on risk. On the one side, accountants use rules. They try to avoid making messy judgment calls. These rules are necessary to make financial statements comparable across companies but often fail to capture future earnings growth. Despite efforts to measure "intangibles," accountants don't have the tools to value a fast-growing company's ability to gain market share. There's too much judgment involved.

On the other side, it's an investor's job to make judgment calls. We don't care whether our forecasts are comparable with those of other investors—active managers want a proprietary edge. Two accountants should not disagree on a company's earnings or book value, but money managers are expected to disagree on a company's market value. A stock's price reflects a collection of independent judgments.

Over time, who's been right more often? Accountants or money managers?

There's evidence that money managers should pay more attention to book values. Between 1926 and 2023, stocks with high B/M outperformed those with low B/M by an average of 4.2%.[2] Academic careers have been built on discovering and explaining this value premium, and money management careers have been built on harvesting it.

Academics explain it as compensation for risk. Value stocks are more cyclical; hence, investors should require a premium to invest in them (see, for example, Fama and French 1992 and Zhang 2005). Some money managers prefer to explain it as an anomaly caused by irrational investor behavior. They posit that value stocks have outperformed over time because they're boring. The idea is that

[2] See Asness, Moskowitz, and Pedersen (2013) and Bhansali et al. (2015).

investors tend to overpay for "glamour," high-growth, and high-momentum stocks (Hagens and Magwa 2022).

Unfortunately for the value zealots, the value premium has weakened. The average value premium over the last 20 years was –1.4%. Growth stocks outperformed despite their low B/M.[3]

THE TAA PROBLEM

This disappearance of the value premium has challenged not just stock pickers but also tactical asset allocators, most of whom use relative valuation metrics to overweight cheap and underweight expensive asset classes. This strategy sounds simple, but it's not. There are two big challenges.

- It isn't easy to catch turning points. To unlock a valuation advantage, you need a catalyst. That's why most TAA processes incorporate fundamental, macroeconomic, and sentiment factors.
- Secular changes can create value traps. For the last 20 years, the relative valuation of value stocks has trended down, as shown in Exhibit 1. Relative to growth stocks, value stocks have gotten cheaper and cheaper… and cheaper. For investors who seek to make money from relative valuations reverting to the mean—which historically has tended to work over time and across asset class pairs (Page 2020)—that's a disheartening chart.

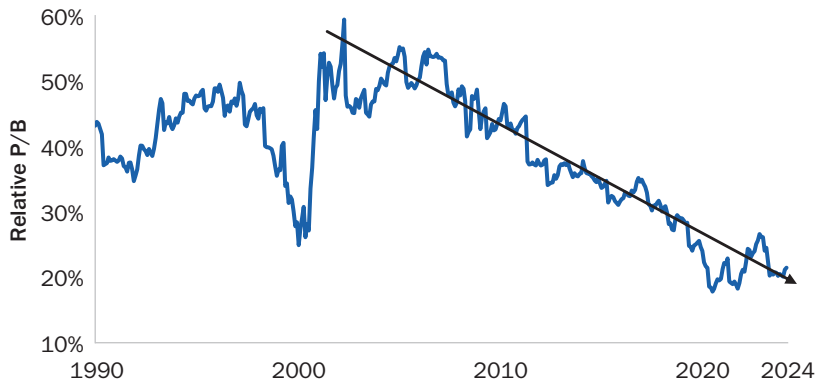
Our study evaluates the implications of this lack of mean reversion for TAA models.

OUR EXPERIMENTS: DATA AND METHODOLOGY

We explore the effectiveness of relative valuation as a tactical allocation signal by backtesting various trading strategies. Each strategy aims to overweight value

EXHIBIT 1

Price-to-Book Ratio: Russell 1000 Value/Russell 1000 Growth



SOURCE: FTSE/Russell.

[3]The premiums of 4.2% and –1.4% are from Kenneth French's data library: 4.2% is the arithmetic average of annual (calendar) "HML" (high minus low B/M) factor returns between 1927 and 2023, and –1.4% is the average for the last 20 years (2004–2023).

stocks versus growth stocks when the former are relatively cheaper than the latter, and vice versa. The strategies differ in terms of their trading parameters.

We use data from the Kenneth R. French database, focusing on the six portfolios from Fama and French (1993).[4] We build a value portfolio as the value-weighted average of the small value and the big value portfolios, and a growth portfolio as the value-weighted average of the small growth and the big growth portfolios. We compute monthly value-weighted returns and monthly value-weighted book-to-price ratios. This dataset allows us to go back to July 1926, thereby incorporating several decades of data on which little—if any—TAA research has been conducted.

Our benchmark is a portfolio with a 50%/50% strategic allocation in the value and growth portfolios. We define the relative valuation signal as the ratio of the value portfolio's B/M to the growth portfolio's B/M. When relative valuation is high (low), value is relatively cheaper (richer) than growth.[5]

To test for sensitivity to data mining, we backtest 24 strategies that trade on the relative valuation signal. Each strategy represents a different implementation that a portfolio manager might use. Four strategies focus on the rolling average of the relative valuation. These strategies tilt toward value (growth) if the latest relative valuation is higher (lower) than its rolling average, defined over 12, 36, 60, or 120-month lookback horizons.

The other 20 strategies are based on relative valuation percentiles, varying in thresholds and lookback periods. We overweight the cheaper asset class between value and growth based on median, tercile, quartile, quintile, and decile thresholds. A sample rule would be "Overweight value when it's in its top decile of B/M relative to growth. When no such signal is triggered, hold the 50/50 portfolio." The lookback periods for computing the percentiles are 12, 36, 60, or 120 months. In the appendix, Exhibit A1 provides a summary of the strategies.

We lag the relative valuation signal by one month: In month t, we invest according to the signal from the relative valuation at the end of month $t - 2$. This setup is realistic in replicating actual trading dynamics, reducing the risk of lookahead bias.

If relative valuation favors value (growth), the tactical portfolio allocation is 100% value (growth). If the signal is neutral, we invest in the 50%/50% mix. Trading costs are 10 basis points (bps) if the portfolio allocation shifts from 100% growth (value) to 100% value (growth), 5 bps if the tactical allocation moves away or reverts to the strategic allocation, or zero if no trade occurs from the previous month.

We also test whether accounting for momentum enhances the performance of the valuation-based strategies. Again, to test for sensitivity to data mining, we build a momentum signal according to 10 alternative implementations.

[4] The authors sort all NYSE, AMEX, and NASDAQ stocks on the intersection of size (market capitalization) and book-to-market ratio (excluding stocks missing market capitalization and/or book value information). The resulting portfolios are Small Value, Small Neutral, Small Growth, Big Value, Big Neutral, and Big Growth. Portfolio rebalancing occurs at the end of every June. The market capitalization as of the end of June is the reference size measure, and the median NYSE stock's market capitalization is the breakpoint for sorting stocks into the Small and Big buckets. A stock's B/M is the ratio of the stock's book value as of the last fiscal year end in the year preceding the current one to its market capitalization as of the previous calendar year end. The 30th and 70th percentiles of the NYSE stocks' B/Ms are the breakpoints to sort the stocks into the Growth (low B/M), Neutral, and Value (high B/M) buckets. For the six portfolios, we observe value-weighted returns, value-weighted B/Ms, and market capitalizations at a monthly frequency, between July 1926 and March 2024. The stocks' book-to-market ratios are computed once a year and are constant from July of year t to June of year $t + 1$. All the month-to-month variation in the portfolios' B/M from July to the following June is generated by the variation in the stocks' market capitalization, which is used to compute the stocks' weight in the weighted-average computation.

[5] Obviously, the average relative valuation is higher than one: Value is on average cheaper than growth by definition.

All have in common that momentum favors the asset class that has outperformed in the recent past. Four definitions look at the relative return of value versus growth over different lookback periods, which are 3, 6, 12, or 36 months.

The other six definitions compare a shorter-window and a longer-window rolling average of the relative return of value over growth. Momentum is positive for value if the shorter-window rolling average is higher than the longer-window rolling average. We compare the 3-month rolling average with the 6-, 12-, and 36-month rolling averages, the 6-month rolling average with the 12- and 36-month rolling averages, and the 12-month rolling average with the 36-month rolling average. In the appendix, Exhibit A2 provides a summary of the definitions of momentum.

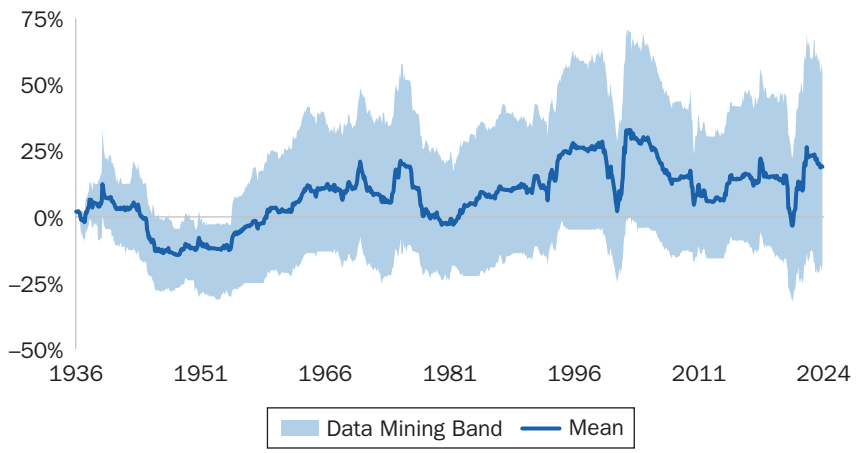
We use the relative valuation signal only if momentum supports it. The goal is to buy the cheaper asset class only when its momentum has been positive. Hence, the strategy "buys low and sells high" and recognizes that "the trend is your friend." We include a one-month lag to the momentum signal as we do for the relative valuation signal. The momentum signal for positioning the portfolio in month t uses the relative performance of value over growth as of the end of month $t - 2$.

In presenting our results, we use a new tool that we call *data mining confidence bands*. These bands' lower and upper bounds correspond to the 10th and 90th percentiles of the multiple strategies'/implementations' performance measures in any given month. Thus, the bands show the relative valuation signal's performance range in the backtest, corresponding to an 80% likelihood. This increases the transparency of our results in that we are not cherry-picking any favorable combination of trading parameters. In the appendix, we show how we compute the bands.

RESULTS

Tactically overweighting value or growth based on their relative valuation delivered modest excess return over a 50%/50% value/growth benchmark, as shown in Exhibits 2 and A5. From August 1936 to March 2024, the average after-cost cumulative alpha of the 24 valuation-based trading rules was 19% or 20 bps per annum. The data mining confidence band was (–22.1%, 58.9%). A quarter of the strategies underperformed the benchmark. Interestingly, most of these losing strategies are characterized by a long lookback horizon (60 or 120 months). Hence, the first lesson is to avoid comparing current valuations with the distant past. This is unsurprising given the tectonic shifts of the value and growth styles discussed earlier.

EXHIBIT 2
Cumulative Alpha



The average information ratio of the 24 trading strategies, computed on the full August 1936–March 2024 sample, was 0.06. Its data mining confidence band was (–0.03, 0.15).

In Exhibits 3 and A6, we show the information ratio over rolling 20-year periods. Over the last 20 years, the average information ratio across the 24 strategies was –0.01. This is a clear indication that the relative valuation signal's effectiveness disappeared in the last two decades.

Valuation has failed as a stock selection approach and tactical allocation signal. However, for those who like to look at the glass half full, the current 20-year weakness is not unprecedented. The information ratio followed a cyclical pattern. In the late 1950s and during the 1980s, it was at levels comparable to the present. It recovered in the 1960s–1970s and in the 1990s.

In any case, buying cheap is not enough: We need a catalyst that reflects the trend toward repricing. Consistent with Asness, Moskowitz, and Pedersen (2013), momentum improves the performance of valuation-based strategies. When we control for momentum, the average cumulative alpha across the 24 valuation-based strategies improved from 19% to 48.8%, as shown in Exhibit 4.

Of the 10 alternative momentum definitions, only one generated a lower average cumulative alpha than the one based on relative valuations only. We obtained the best outcomes by measuring momentum in terms of trailing 6- and 12-month relative returns and the difference between the 12-month and 36-month relative returns. The worst outcome occurred when we defined momentum based on the rolling 36-month relative return. This indicates that such a horizon is too long to capture momentum.

Across all the strategies, when we combine valuation and momentum, the average cumulative alpha increased from 19%, with a (–22.1%, 58.9%) data mining confidence band, for the relative valuation signal to 48.8%, with a (3.9%, 101.8%) data mining confidence band. Momentum delivered a risk-adjusted performance improvement in terms of information ratio, as shown in Exhibit 5. When we combine valuation and momentum, the full-sample information ratio increased from 0.06, with a (–0.03, 0.15) data mining confidence band, for the relative valuation signal to 0.13, with a (0.02, 0.26) data mining confidence band.

Momentum helps avoid value traps. Nonetheless, the information ratio over the last 20 years was low and close to the bottom of the historical range, even if we control for momentum. Better capturing inflection points enhances the relative valuation

EXHIBIT 3

Rolling 20-Year Information Ratio

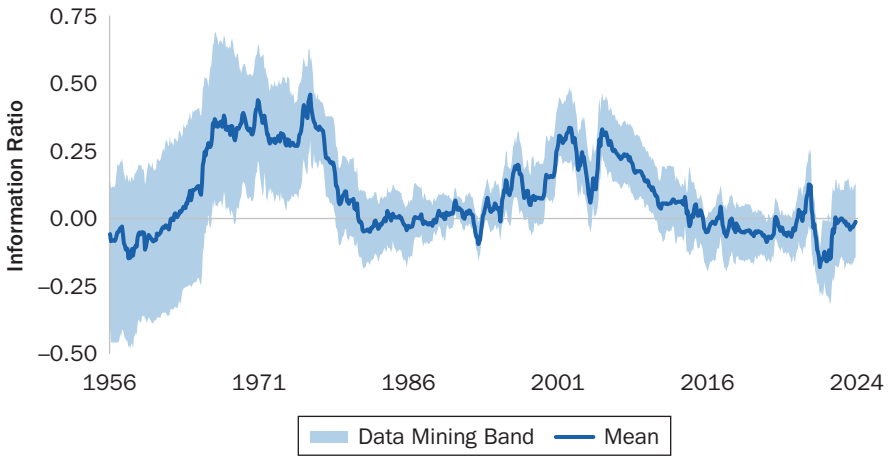


EXHIBIT 4

Average Cumulative Alphas with Momentum Control

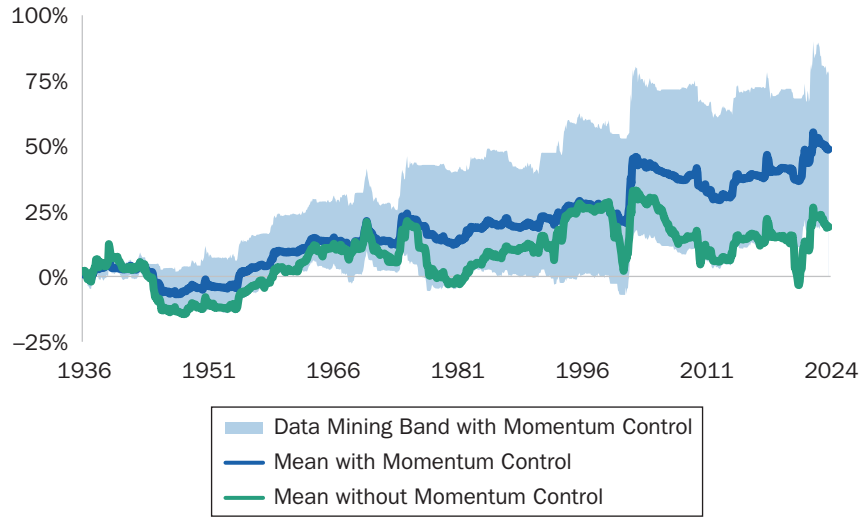
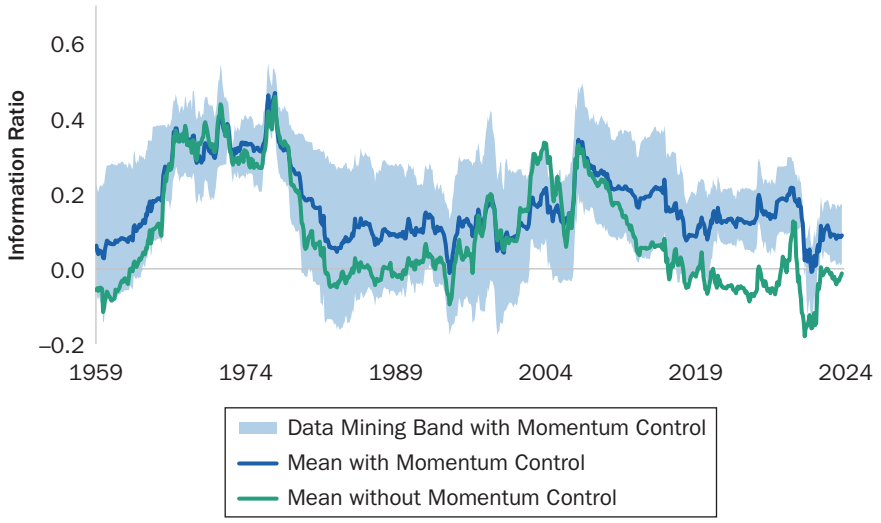


EXHIBIT 5

Average Information Ratios with Momentum Control



signal's performance, but it is not a silver bullet. It doesn't amend the structural headwinds value stocks have experienced.

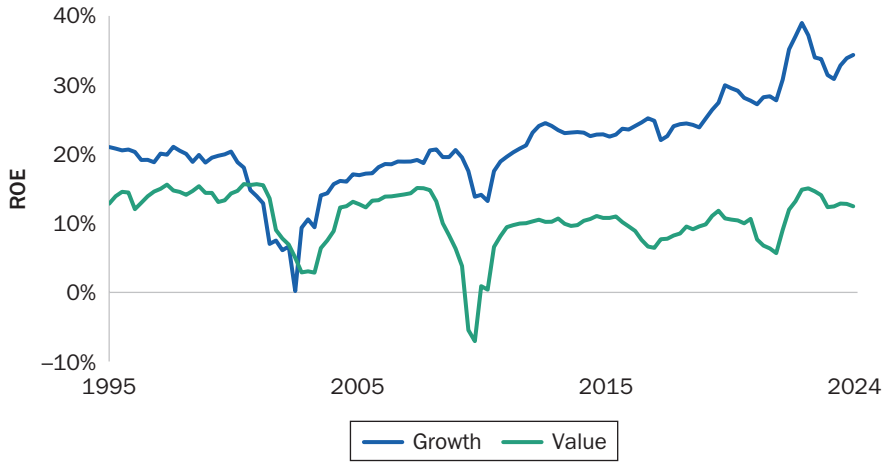
Exhibits A3 and A4 in the appendix report cumulative alphas and full-sample information ratios for the 24 valuation-based trading strategies, either with no momentum control or combined with each of the 10 alternative momentum definitions. In total, we have 264 performance measures.

DISCUSSION

What has created the mother of all value traps over the last 20 years? In one word, technology. Lev and Srivastava (2022), explain that corporate business models have shifted from investing in hard assets (property, plant, and equipment) to intangibles (research and development). The breakthroughs from these intangible

EXHIBIT 6

Return on Equity: Russell 1000 Growth vs. Russell 1000 Value



SOURCE: FTSE/Russell.

investments have been highly disruptive to legacy business models. Unfortunately, accounting practices have failed to adapt to this shift. According to the authors, growth companies—especially tech companies—that invest in intangibles have looked increasingly expensive due to deflated book values. "A firm investing heavily in R&D, IT, brands, or business processes (e.g., customer recommendation algorithms), may appear to be an overvalued company … whereas in reality its valuation isn't excessively high when book value is properly measured," they explain (Lev and Srivastava 2022).

Earnings and cash flows have also been understated because intangibles are immediately expensed. This has led to inflated price-to-earnings ratio (P/E) and price-to-cash flow ratio (P/CF) for growth stocks. Therefore, over the last 20 years, using P/E or P/CF to construct value portfolios did not perform better than using P/B. The premium was –2.1% when using P/E and –2.3% when using P/CF, compared with –1.4% for P/B, as mentioned earlier.[6]

To be clear, it's not just the fault of accountants. Like relative valuations, fundamentals have trended rather than mean-reverted. As measured by return-on-equity (ROE), profitability has steadily improved for growth relative to value stocks, as shown in Exhibit 6. Value has underperformed because platform companies operating in a digital world have demonstrated sustained and exceptional growth.

CONCLUSIONS

Some of the most important valuation models in finance, those we learn in business schools, have failed for the last 20 years. By the standards of money management careers, that's an eternity. Most clients evaluate portfolio managers over 1-, 3-, 5-,

[6]The premiums of –2.1% and –2.3% are from Kenneth French's data library: –2.1% is the arithmetic average of annual (calendar) high (top tercile) E/P stocks' value-weighted returns minus low (bottom tercile) E/P stocks' value-weighted returns between 2004 and 2023. The –2.3% value is the arithmetic average of annual (calendar) high (top tercile) CF/P stocks' value-weighted returns minus low (bottom tercile) CF/P stocks' value-weighted returns between 2004 and 2023.

and 10-year periods. As Lev and Srivastava (2022) note, "A Google search of the 'death of value investing' and related morbid terms yields hundreds of articles, including in *Forbes*, *Barron* [sic], *The Wall Street Journal*, *Seeking Alpha*, *Bloomberg*, and [the] *Financial Times*." Chandrashekaran (2021) asks rhetorically whether value factors are "the hill that quants may die on?"

This failure can be explained, in part, by technology and the accounting treatment of intangibles.

While some investors have thrown their hands in the air and declared that "fundamentals don't work" or "markets are broken," skilled stock pickers and tactical asset allocators have adapted.

Relative valuation investing is not dead. This discipline has historically paid off for those willing to endure the discomfort of being contrarian.

But to avoid a 20-year performance drought, skilled investors have had to abandon relative valuation dogma and turn instead to a mix of judgment, accounting adjustments, fundamental research, an understanding of technology trends, and a view on macro and sentiment catalysts.

APPENDIX

EXHIBIT A1

Valuation-Based Trading Strategies

Reference	Rule for Portfolio Weight of Value (w)	Lookback Months (T)	Quantile (Q)
Mean, 12M	$w_t = \begin{cases} 1 \text{ if } RV_{t-2} > \frac{\sum_{s=0}^{T-1} RV_{t-2-s}}{T} \\ 0 \text{ if } RV_{t-2} < \frac{\sum_{s=0}^{T-1} RV_{t-2-s}}{T} \\ \frac{1}{2} \text{ otherwise} \end{cases}$	12	–
Mean, 36M		36	–
Mean, 60M		60	–
Mean, 120M		120	–
Median, 12M		12	1/2
Median, 36M		36	1/2
Median, 60M		60	1/2
Median, 120M		120	1/2
Terciles, 12M		12	1/3
Terciles, 36M		36	1/3
Terciles, 60M		60	1/3
Terciles, 120M		120	1/3
Quartiles, 12M	$w_t = \begin{cases} 1 \text{ if } \frac{\sum_{s=0}^{T-1} \mathbb{I}(RV_{t-2-s} \le RV_{t-2})}{T} > 1-Q \\ 0 \text{ if } \frac{\sum_{s=0}^{T-1} \mathbb{I}(RV_{t-2-s} \le RV_{t-2})}{T} < Q \\ \frac{1}{2} \text{ otherwise} \end{cases}$	12	1/4
Quartiles, 36M		36	1/4
Quartiles, 60M		60	1/4
Quartiles, 120M		120	1/4
Quintiles, 12M		12	1/5
Quintiles, 36M		36	1/5
Quintiles, 60M		60	1/5
Quintiles, 120M		120	1/5
Deciles, 12M		12	1/10
Deciles, 36M		36	1/10
Deciles, 60M		60	1/10
Deciles, 120M		120	1/10

NOTES: w_t denotes the portfolio weight of value during month t. RV_t is the relative valuation at the end of month t (value B/M over growth B/M). $\mathbb{I}(x)$ is an indicator function that returns a value equal to 1 if the argument x is true and 0 if x is false.

EXHIBIT A2

Momentum Definitions

Reference	Rule for Momentum Signal (M)	Trailing Average I (T)	Trailing Average II (N)
3MMA > 0	$M_t = \begin{cases} 1 \text{ if } \frac{\sum_{s=0}^{T-1} R_{t-2-s}^{VG}}{T} > 0 \\ 0 \text{ otherwise} \end{cases}$	3	–
6MMA > 0		6	–
12MMA > 0		12	–
36MMA > 0		36	–
3MMA > 6MMA	$M_t = \begin{cases} 1 \text{ if } \frac{\sum_{s=0}^{T-1} R_{t-2-s}^{VG}}{T} > \frac{\sum_{s=0}^{N-1} R_{t-2-s}^{VG}}{N} \\ 0 \text{ otherwise} \end{cases}$	3	6
3MMA > 12MMA		3	12
3MMA > 36MMA		3	36
6MMA > 12MMA		6	12
6MMA > 36MMA		6	36
12MMA > 36MMA		12	36

NOTES: M_t denotes the momentum signal at the end of month t. R_t^{VG} is the relative return of value over growth in month t.

DATA MINING CONFIDENCE BANDS

Rolling 20-year information ratio. Let α_t^i represent the excess return of trading strategy i over the benchmark in month t. The rolling 20-year information ratio of strategy i at the end of month t is

$$IR_t^i = \frac{\left(\frac{1}{240}\sum_{s=0}^{240-1}\alpha_{t-s}^i\right)12}{\sqrt{\left[\frac{1}{240}\sum_{s=0}^{240-1}\left(\alpha_{t-s}^i - \frac{1}{240}\sum_{s=0}^{240-1}\alpha_{t-s}^i\right)^2\right]12}}$$

The bounds of the data mining confidence band for the rolling 20-year information ratio in month t – (IR_t^{LB}, IR_t^{UB}) are

$$IR_t^{LB} = argmin_x\left[\frac{1}{24}\sum_{i=1}^{24}\mathbb{I}(IR_t^i \le x) \ge 0.1\right]$$

$$IR_t^{UB} = argmin_x\left[\frac{1}{24}\sum_{i=1}^{24}\mathbb{I}(IR_t^i \le x) \ge 0.9\right]$$

Cumulative alpha. From month τ to month t, strategy i's cumulative excess return over the benchmark (the cumulative alpha) equals

$$c\alpha_{\tau,t}^i = \left[\prod_{s=\tau}^{t}(1+\alpha_t^i)\right] - 1$$

The bounds of the data mining confidence band for the cumulative alpha from month τ to month t – $(c\alpha_{\tau,t}^{LB}, c\alpha_{\tau,t}^{UB})$—are

$$c\alpha_{\tau,t}^{LB} = argmin_x \left[\frac{1}{24} \sum_{i=1}^{24} \mathbb{I}(c\alpha_{\tau,t}^{i} \le x) \ge 0.1 \right]$$

$$c\alpha_{\tau,t}^{UB} = argmin_x \left[\frac{1}{24} \sum_{i=1}^{24} \mathbb{I}(c\alpha_{\tau,t}^{i} \le x) \ge 0.9 \right]$$

EXHIBIT A3

Cumulative Alphas (August 1936–March 2024)

Relative Valuation Trading Rule	Momentum Control										
	No Momentum	3MMA > 0	6MMA > 0	12MMA > 0	36MMA > 0	3MMA > 6MMA	3MMA > 12MMA	3MMA > 36MMA	6MMA > 12MMA	6MMA > 36MMA	12MMA > 36MMA
Mean, 12M	90.6	125.2	213.5	157.4	63.7	73.3	49.1	68.9	74.4	137	144.1
Mean, 36M	–2.1	32.6	65.7	7.7	–8.4	18.6	25.7	7.6	–2.8	–14.5	3
Mean, 60M	13.2	73.6	139.9	96.5	25.2	32.6	14.5	30.3	35.1	83.6	85.6
Mean, 120M	–46.8	18.2	64.6	34.2	–13.8	–9.7	–22.4	–11.9	–7.6	25.9	26.3
Median, 12M	52.5	98.5	172.2	138	51.6	53.2	34.4	51.3	56.6	111.4	125
Median, 36M	38.1	84.9	172.7	120.3	43.5	48	26.4	40.5	49.8	111.2	110.7
Median, 60M	4.8	69.3	128.3	90.2	21	26.6	9.4	23.4	28.1	71.7	80.2
Median, 120M	–22.2	35.3	99.1	62.8	–2.4	4.4	–8.7	2.2	4.6	55.5	56.2
Terciles, 12M	63.2	105.4	142.7	134	30.6	72.6	51.8	88	53.6	103.2	140.1
Terciles, 36M	53.9	64.9	121.8	99	30	102	33.2	34.2	49.2	73.3	93.1
Terciles, 60M	11.1	75.9	96.9	70.8	12	37.9	20.9	36.6	30.1	50.5	84.1
Terciles, 120M	–22	15	54.1	40.1	–8.9	14.2	1	1.2	2	26	45.6
Quartiles, 12M	15.1	17.2	64.5	48.8	–6.8	3.8	10.4	13.8	31.6	41.4	44.7
Quartiles, 36M	41	62.2	106.3	96	17.8	90.9	32.8	37.8	35	56.8	98.6
Quartiles, 60M	5.8	44.9	94.9	62.6	11.6	51.6	17.4	23.8	18	46.8	80.2
Quartiles, 120M	–9	31.3	65.8	40.2	–9	35.1	17.2	8.5	18.7	34.7	46.2
Quintiles, 12M	15.1	17.2	64.5	48.8	–6.8	3.8	10.4	13.8	31.6	41.4	44.7
Quintiles, 36M	22.3	54.9	95.6	96.7	11.5	74.7	21.5	34.5	22.3	42.2	89.7
Quintiles, 60M	–8.9	29.6	65.8	51.2	7.9	37.5	4.3	1.5	3.6	14	59.1
Quintiles, 120M	9	46.6	75.8	57.1	–0.3	58.8	23.6	22.6	21.5	37.7	54.1
Deciles, 12M	37.3	15.6	42.5	34.2	13.2	24.9	27.8	15.6	46.6	28.7	28.5
Deciles, 36M	54.6	68.2	95.7	99.7	15.4	74.4	33.7	51.4	40	62.3	117.8
Deciles, 60M	3.1	30.5	61.8	59.5	4.3	39	15.9	11.6	10.6	21.9	61
Deciles, 120M	35.2	50.5	76.4	59.2	15.3	85.7	37.8	32.2	24.4	31.2	57.7

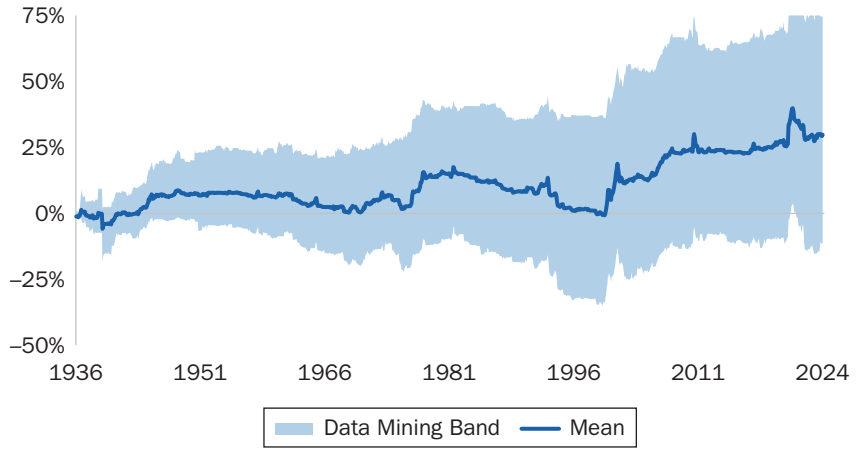
EXHIBIT A4

Information Ratios (August 1936–March 2024)

Relative Valuation Trading Rule	Momentum Control: No Momentum	3MMA > 0	6MMA > 0	12MMA > 0	36MMA > 0	3MMA > 6MMA	3MMA > 12MMA	3MMA > 36MMA	6MMA > 12MMA	6MMA > 36MMA	12MMA > 36MMA
Mean, 12M	0.16	0.16	0.36	0.31	0.19	0.17	0.13	0.16	0.17	0.25	0.28
Mean, 36M	0.03	0.03	0.16	0.04	–0.01	0.07	0.08	0.04	0.02	–0.02	0.03
Mean, 60M	0.05	0.05	0.27	0.21	0.09	0.1	0.06	0.09	0.1	0.19	0.19
Mean, 120M	–0.1	–0.1	0.17	0.1	–0.04	0	–0.04	–0.01	0	0.09	0.08
Median, 12M	0.11	0.11	0.32	0.29	0.16	0.14	0.1	0.14	0.15	0.23	0.27
Median, 36M	0.09	0.09	0.31	0.25	0.14	0.13	0.08	0.11	0.14	0.23	0.22
Median, 60M	0.04	0.04	0.25	0.2	0.08	0.08	0.05	0.08	0.09	0.17	0.18
Median, 120M	–0.02	–0.02	0.22	0.16	0.01	0.03	0	0.03	0.03	0.15	0.14
Terciles, 12M	0.13	0.13	0.31	0.31	0.12	0.18	0.14	0.21	0.15	0.24	0.32
Terciles, 36M	0.12	0.12	0.29	0.26	0.14	0.23	0.11	0.11	0.15	0.19	0.23
Terciles, 60M	0.05	0.05	0.23	0.19	0.06	0.12	0.08	0.12	0.1	0.14	0.21
Terciles, 120M	–0.04	–0.04	0.17	0.13	–0.03	0.06	0.02	0.02	0.02	0.09	0.14
Quartiles, 12M	0.06	0.06	0.21	0.18	–0.02	0.03	0.05	0.06	0.11	0.14	0.16
Quartiles, 36M	0.11	0.11	0.29	0.29	0.1	0.26	0.12	0.13	0.12	0.17	0.27
Quartiles, 60M	0.04	0.04	0.25	0.19	0.06	0.16	0.07	0.09	0.07	0.15	0.21
Quartiles, 120M	0	0	0.2	0.14	–0.03	0.12	0.07	0.04	0.08	0.12	0.14
Quintiles, 12M	0.06	0.06	0.21	0.18	–0.02	0.03	0.05	0.06	0.11	0.14	0.16
Quintiles, 36M	0.08	0.08	0.28	0.29	0.07	0.23	0.09	0.12	0.09	0.14	0.26
Quintiles, 60M	–0.01	–0.01	0.21	0.19	0.06	0.14	0.03	0.02	0.03	0.06	0.19
Quintiles, 120M	0.04	0.04	0.24	0.19	0.01	0.19	0.1	0.09	0.09	0.14	0.17
Deciles, 12M	0.11	0.11	0.17	0.15	0.08	0.1	0.11	0.07	0.17	0.12	0.13
Deciles, 36M	0.16	0.16	0.32	0.35	0.11	0.26	0.14	0.18	0.16	0.22	0.36
Deciles, 60M	0.03	0.03	0.25	0.26	0.05	0.16	0.08	0.06	0.06	0.1	0.23
Deciles, 120M	0.12	0.12	0.28	0.24	0.13	0.3	0.16	0.14	0.11	0.13	0.21

EXHIBIT A5

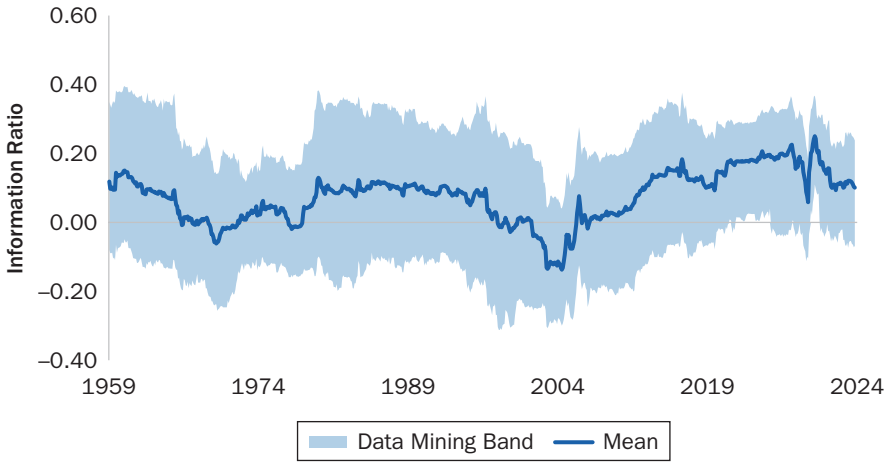
Excess Cumulative Alpha



NOTES: For each of the original 24 strategies, we compute the extra cumulative alpha generated by each of the 10 alternative momentum definitions, in excess of the original cumulative alpha. This exercise leaves us with 240 series of excess cumulative alpha. We plot their average and the data mining confidence band.

EXHIBIT A6

Excess Rolling 20-Year Information Ratio



NOTES: For each of the original 24 strategies, we compute the extra rolling 20-year information ratio generated by each of the 10 alternative momentum definitions, in excess of the original rolling 20-year information ratio. This exercise leaves us with 240 series of excess rolling 20-year information ratio. We plot their average and the data mining confidence band.

REFERENCES

Asness, C., T. Moskowitz, and L. Pedersen. 2013. "Value and Momentum Everywhere." *The Journal of Finance* 68 (3): 929–985.

Bhansali, V., J. Davis, M. Dorsten, and G. Rennison. 2015. "Carry and Trend in Lots of Places." *The Journal of Portfolio Management* 41 (4): 82–90.

Chandrashekaran, V. 2021. "Value Factors—The Hill Quants May Die On?" Unpublished white paper.

Fama, E., and K. French. 1992. "The Cross-Section of Expected Stock Returns." *The Journal of Finance* 47: 427–456.

——. 1993. "Common Risk Factors in the Returns of Stocks and Bonds." *Journal of Financial Economics* 33 (1): 3–56.

Hagens, J., and L. Magwa. 2022. "Human Instincts Drive the Value Premium." Robeco Insight (February). https://www.robeco.com/it-it/approfondimenti/2022/02/human-instincts-drive-the-value-premium.

Holiday, R. 2014. *The Obstacle Is the Way: The Timeless Art of Turning Trials into Triumph*. Portfolio.

Lev, B., and A. Srivastava. 2022. "Explaining the Recent Failure of Value Investing." *Critical Finance Review* 11 (2): 333–360.

Page, S. 2020. *Beyond Diversification: What Every Investor Needs to Know about Asset Allocation*. McGraw Hill.

Zhang, L. 2005. "The Value Premium." *The Journal of Finance* 60 (1): 67–103.

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