This powerful reference text details the historical performance of the most popular trading strategies of the 21st Century in a condensed, straightforward, and comparable format. The financial factors in this book drive investment decisions for popular ETFs, actively managed funds, and technical trading systems in U.S. Equities.

Anyone considering active management will benefit from understanding these key stylistic benchmarks for over 20 factor portfolios and over a dozen index-like portfoilios.

HIGHLIGHTS INCLUDE:

- *Price to Earnings*
- *Price to Sales*
- *Momentum*
- *Relative Strength Index*
- *Profitability*
- *Volatility*
- *Size*
- *Average Directional Index*
- *Sector benchmarks*
- *Market benchmarks*

The FACTOR Investing Chartbook

Chris Conlan

THE FACTOR INVESTING CHARTBOOK

Chris Conlan

80+ Expertly Crafted Backtests of the 21st Century's Most Popular Quantitative Strategies

The Factor Investing Chartbook

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Preface

Quant trading is the reason I become a programmer. It deepened my love for math, it inspired my passion for statistics, and it is the basis on which Conlan Scientific grew into a nationally recognized authority in financial data science.

Chris Conlan

Chapter 1

Methodology

This chartbook will attempt to document the historical simulated performance of the most popular U.S. equities trading strategies of the 21st century. Each strategy will share a set of standard and common sense trading rules. Wherever there is uncertainty about how to apply a particular strategy in practice, the most common sense approach is chosen.

This is the second edition of the book, rendered on January 2nd, 2025.

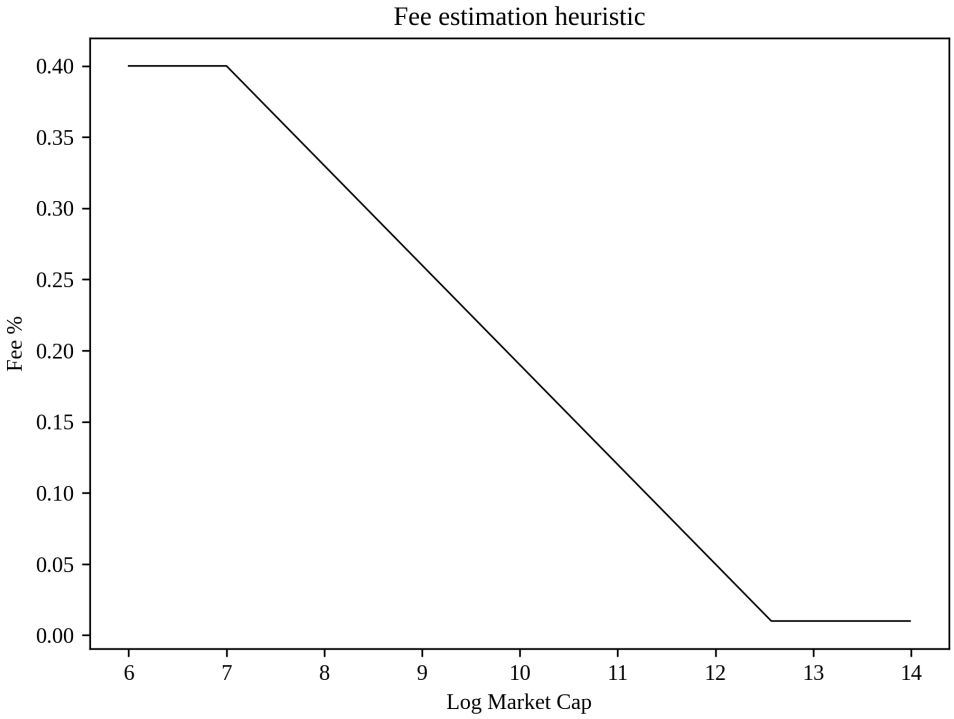
1.1 Trading fees

In the simulations throughout this book, fees are assessed at each trade as a percentage of the price of the asset traded. We employ a fee estimation heuristic based on real-world experience.

Given the market capitalization of the asset, M, and the log market capitalization $m = \log(M)$, we estimate the trading fee on a single trade as a proportion of its price to be the following.

$$\text{Trading fee fraction} = \frac{\max\left(40 - 7 \times \max(m - 7, 0), 1\right)}{10000}$$

The relationship between the market capitalization and the trading fees is plotted below. I believe this heuristic reflects the increased costs of trading small-cap stocks accurately enough.



1.2 Performance metrics

Each simulation comes with a set of summary statistics, descriptions of the six highest historical drawdowns, and a plot of the simulated equity curve.

The performance summary includes the following statistics.

CAGR: The compounded annual growth rate measured from the start to the end of the equity curve. It is calculated as $(E_T/E_0)^{(1/k)} - 1$, where E_t is the equity curve and k is the number of years that have passed in the simulation.

Sharpe Ratio: Our Sharpe Ratio is measured as the average one-year trailing log change in the equity curve divided by the annualized volatility of daily log returns on the equity curve. In our calculation of the Sharpe Ratio, the benchmark rate is assumed to be zero. Because our Sharpe Ratio is measured against one-year trailing returns, it is possible for the CAGR to be positive and Sharpe Ratio to be negative within the same time period.

Max Drawdown: The percentage max drawdown is defined as the largest peak-to-trough drawdown detectable in the equity curve.

Turnover: Turnover is defined as the sum of all trade entry values as a percentage of the portfolio equity value, averaged into a yearly figure. For example, a strategy that sold all of its holdings and bought a brand new basket of stocks once per month would have turnover of 12x.

Fee impact: Fee impact is defined as the sum of all trading fees as a percentage of the portfolio equity value, averaged into a yearly figure. The impact of fees is included in our simulated performance by default. By comparing the CAGR to the fee impact, you can develop a sense of how much of the gains are being lost to trading costs.

All time periods listed in the summary statistics are inclusive. For example, the range *1999-2025* corresponds to the time period starting Jan 1st, 1999 and ending Dec 31st, 2024. Summary statistics for the following time periods are included in each simulation.

Start	End
1999	2025
2000	2009
2010	2019
2019	2025
2021	2025
2023	2025

The drawdown summary contains a summary of each of the six highest drawdowns by percentage size. Each drawdown include a start (the initial peak), a trough (the bottom), and an end (the subsequent peak). If no subsequent peak is present, the end is labeled *ongoing*.

The simulated equity curve is plotted with a starting value of $100 on a log scale. The equity curve plot highlights known recessions for convenience. The time periods of known recessions are as follows. Recessions were identified as any peak-to-trough periods exceeding a 20% drawdown in the S&P 500. The SPY ETF was used as a proxy for the S&P 500 for convenience.

Recession start	Recession end
2000-03-24	2002-10-09
2007-10-09	2009-03-09
2018-09-20	2018-12-24
2020-02-19	2020-03-23
2022-01-03	2022-10-12

1.3 Simulation philosophy

There is no such thing as a perfect trading simulation. Therefore, this book requires a simulation approach that is highly typical, highly standardized, and highly comparable.

We chose a re-allocation period of 21 trading days to represent an approximately monthly re-balancing exercise. The start date of a re-allocation period can have a significant impact on simulated performance, so we always simulate at least eleven times starting on different trading

days. Then, we report out the results of the median strategy according to absolute returns.

Unless otherwise noted, our simulated portfolios always hold 60 distinct stocks. Also, unless otherwise noted, the dollar allocations to each stock are reciprocal to the stock's historical volatility. This ensures that high-vol, low-vol, large-cap, and small-cap stocks are held in an appropriate balance regarding their overall impact on the portfolio. This approach has a number of other mathematically attractive features that we will not document here.

When trading factor strategies, we simply re-allocate to the best or worst stocks according to a particular factor monthly. For example, when trading a long-only P/B strategy, we will re-allocate to the 60 lowest P/B stocks once every month.

Our technical simulations are more complex. We use a time limit of 21 trading days (approximately a month) for each position. We also employ a profit target and stop loss of ± 2 monthly standard deviations. We follow the conventional entry and exit signals associated with each technical indicator. It is common for technical indicators to produce numerous competing signals on the same day. In such cases, we break ties by preferring the companies with the highest market capitalizations. This improves comparability of the technical trading strategies while also minimizing trading fees. As with our factor simulations, we fully allocate capital while holding no more than 60 distinct positions at a time.

When simulating the historical performance of single-asset buy-and-hold strategies and ETFs, we do not explicitly account for fees. We assume trading fees are accounted for in the expense ratios of ETFs via the price of the ETF.

Chapter 2

Factor strategies

This chapter will detail the most popular factor investing strategies and their simulated historical performance. A *factor* is a characteristic of a stock that is hypothesized to be related to future returns.

2.1 The Price to Book Ratio

The Price to Book Ratio (or P/B) is the ratio of a company's market capitalization to the book value of the underlying company. A lower P/B suggests a stock is undervalued relative to its book value.

$$\text{Market Cap} = \text{Stock price} \times \text{Shares Outstanding}$$

$$\text{Book value} = \text{Assets} - \text{Liabilities}$$

$$\text{P/B} = \frac{\text{Market Cap}}{\text{Book value}}$$

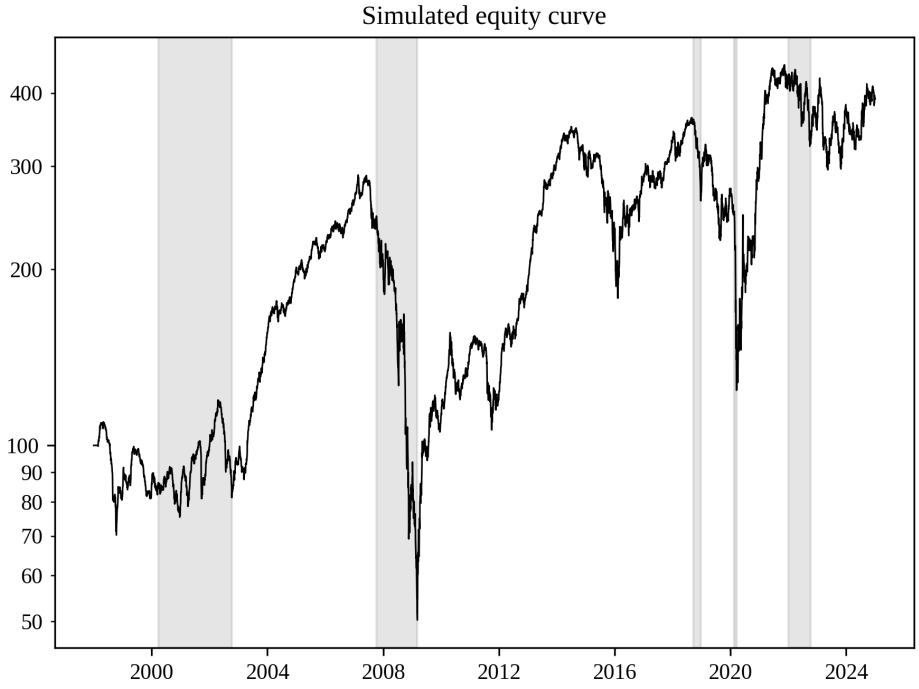
The P/B ratio is the oldest and best-known *value* factor. The Fama-French 3-factor model used an analogue to P/B to represent the value factor in their original paper.

In the following simulations, the long-only portfolio buys the 60 companies with the lowest P/B, and the short-only portfolio shorts the 60 companies with the highest P/B. The long-short strategy holds the top 30 companies from each strategy long and short, respectively.

2.1.1 Price to Book: Long-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	6.05%	0.47	82.6%	3.3x	2.06%
2000-2009	2.62%	0.25	82.6%	3.6x	2.33%
2010-2019	9.23%	0.86	49.1%	3.0x	1.88%
2019-2024	5.72%	0.3	62.0%	2.9x	1.79%
2021-2024	7.28%	1.07	33.8%	2.7x	1.66%
2023-2024	4.66%	-0.1	30.2%	2.5x	1.67%

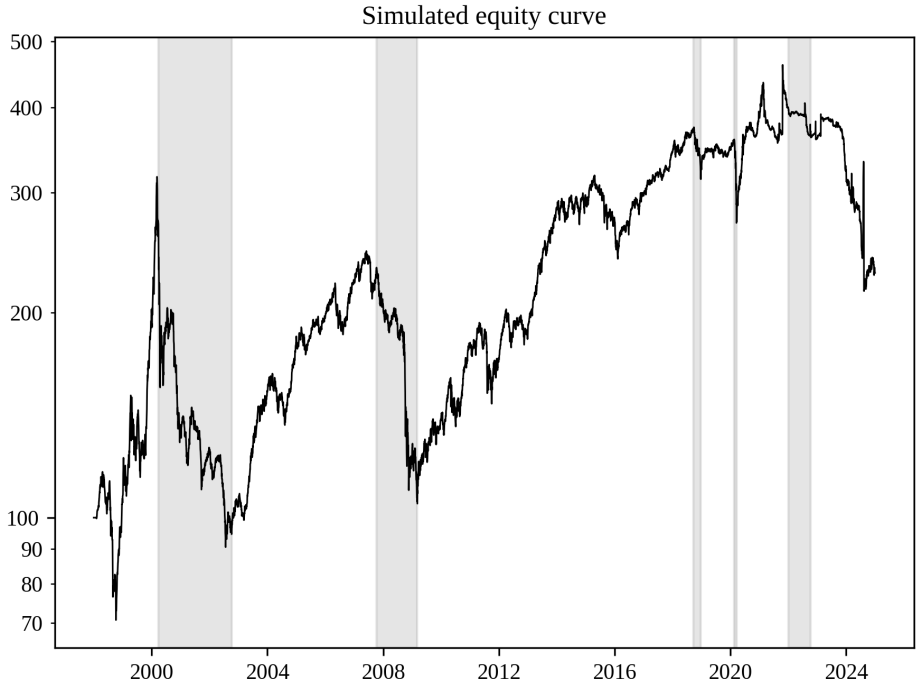
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-02-20	2009-03-09	2013-10-18	83.0%	2432 days
2018-08-31	2020-03-18	2021-02-24	66.0%	908 days
2014-07-03	2016-02-11	2018-06-20	49.0%	1448 days
1998-05-01	1998-10-14	2002-03-06	36.0%	1405 days
2021-11-15	2023-05-16	2024-12-31	34.0%	Ongoing
2002-04-17	2002-10-09	2003-07-09	32.0%	448 days



2.1.2 Price to Book: Short-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	2.93%	0.32	71.4%	2.1x	1.15%
2000-2009	-3.53%	0.19	71.4%	1.9x	1.02%
2010-2019	9.42%	0.84	24.6%	2.0x	1.01%
2019-2024	-5.80%	-0.14	53.4%	3.1x	1.74%
2021-2024	-12.30%	-0.18	53.4%	2.1x	1.22%
2023-2024	-20.49%	-0.41	45.0%	1.1x	0.69%

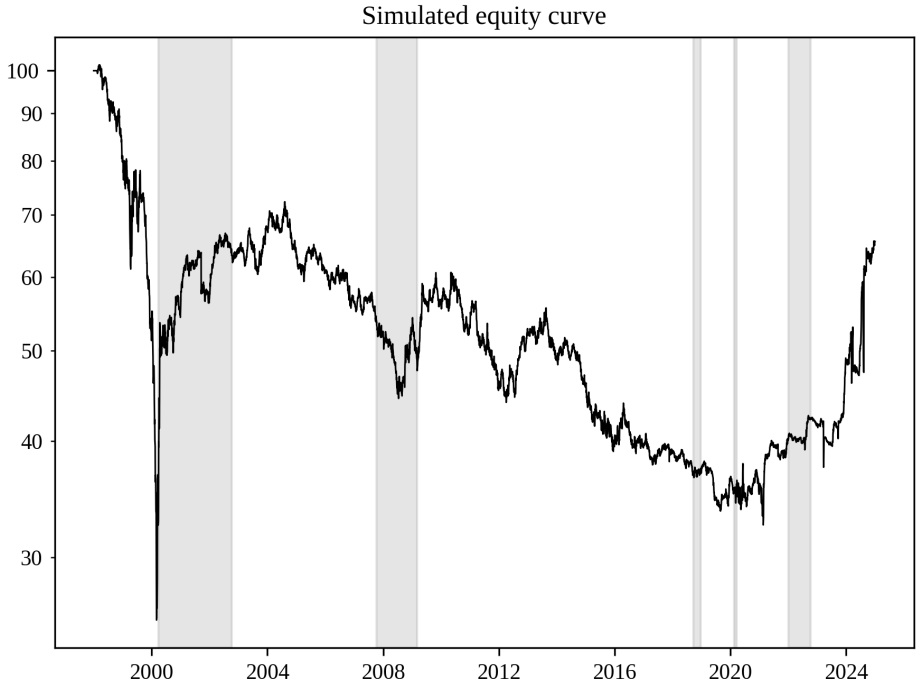
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2000-03-09	2002-07-23	2015-04-15	71.0%	5515 days
2021-10-22	2024-08-14	2024-12-31	53.0%	Ongoing
1998-04-21	1998-10-08	1999-01-08	39.0%	262 days
2018-09-28	2020-03-18	2020-07-22	28.0%	663 days
2015-04-23	2016-02-11	2017-04-26	25.0%	734 days
1999-04-13	1999-08-10	1999-11-05	24.0%	206 days



2.1.3 Price to Book: Long-short portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-0.76%	-0.06	68.0%	3.2x	1.94%
2000-2009	0.73%	-0.05	53.4%	3.1x	1.87%
2010-2019	-4.22%	-0.42	44.6%	3.2x	1.89%
2019-2024	9.86%	0.4	20.1%	3.8x	2.19%
2021-2024	16.33%	0.6	20.1%	2.5x	1.47%
2023-2024	25.67%	0.61	20.1%	2.2x	1.28%

Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
1998-03-17	2000-03-03	2024-12-31	75.0%	Ongoing
1998-03-10	1998-03-16	1998-03-17	1.0%	7 days
1997-12-31	1998-02-17	1998-02-23	1.0%	54 days
1998-03-03	1998-03-05	1998-03-06	0.0%	3 days
1998-02-25	1998-02-26	1998-02-27	0.0%	2 days
1998-03-06	1998-03-09	1998-03-10	0.0%	4 days



2.2 Price to Earnings Ratio

The Price to Book Ratio (or P/E) is the ratio of the price of a share of a company's stock divided by its earnings per share. A lower P/E suggests a stock is undervalued relative to its net income available to common shareholders. The P/E ratio is an alternative approach to representing the value factor. In this book, we calculate earnings using the quarterly trailing twelve month net income.

$$\text{Net income} = \text{Revenue} - \text{Expenses}$$

$$\text{Net income (common)} = \text{Net income} - \text{Preferred dividends}$$

$$\text{EPS} = \frac{\text{Net income (common)}}{\text{Shares outstanding}}$$

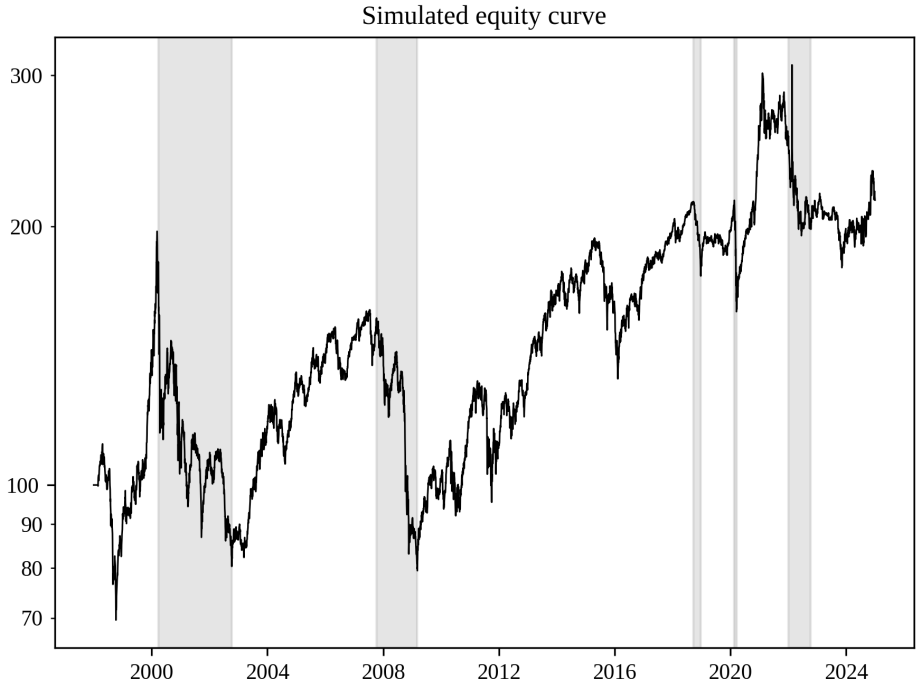
$$\text{P/E} = \frac{\text{Share price}}{\text{EPS}}$$

In the following simulations, the long-only portfolio buys the 60 companies with the lowest P/E, and the short-only portfolio shorts the 60 companies with the highest P/E. The long-short strategy holds the top 30 companies from each strategy long and short, respectively.

2.2.1 Price to Earnings: Long-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	3.35%	0.25	59.7%	3.5x	1.91%
2000-2009	-3.36%	0.09	59.7%	3.6x	2.00%
2010-2019	6.83%	0.51	31.4%	3.4x	1.78%
2019-2024	2.81%	0.08	41.9%	3.6x	1.91%
2021-2024	-3.95%	0.12	41.9%	3.7x	1.97%
2023-2024	1.87%	-0.14	18.1%	3.7x	2.02%

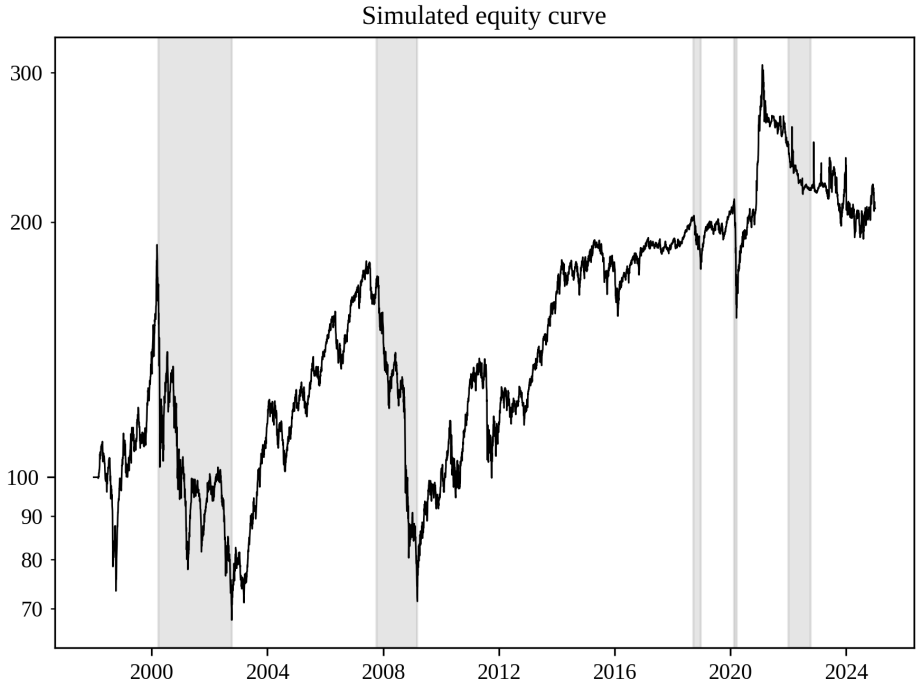
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2000-03-10	2009-03-09	2018-01-02	60.0%	6507 days
2022-02-17	2023-11-09	2024-12-31	42.0%	Ongoing
1998-04-22	1998-10-08	1999-10-29	38.0%	555 days
2021-02-09	2022-01-27	2022-02-17	26.0%	373 days
2020-02-20	2020-03-18	2020-11-17	26.0%	271 days
2018-09-21	2018-12-24	2020-02-20	18.0%	517 days



2.2.2 Price to Earnings: Short-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	2.65%	0.26	63.9%	3.4x	1.90%
2000-2009	-3.11%	0.05	63.9%	3.7x	2.11%
2010-2019	7.18%	0.6	27.7%	3.2x	1.72%
2019-2024	2.34%	0.13	37.6%	3.2x	1.74%
2021-2024	-5.14%	0.14	37.6%	3.2x	1.74%
2023-2024	-2.25%	-0.24	19.8%	3.5x	1.91%

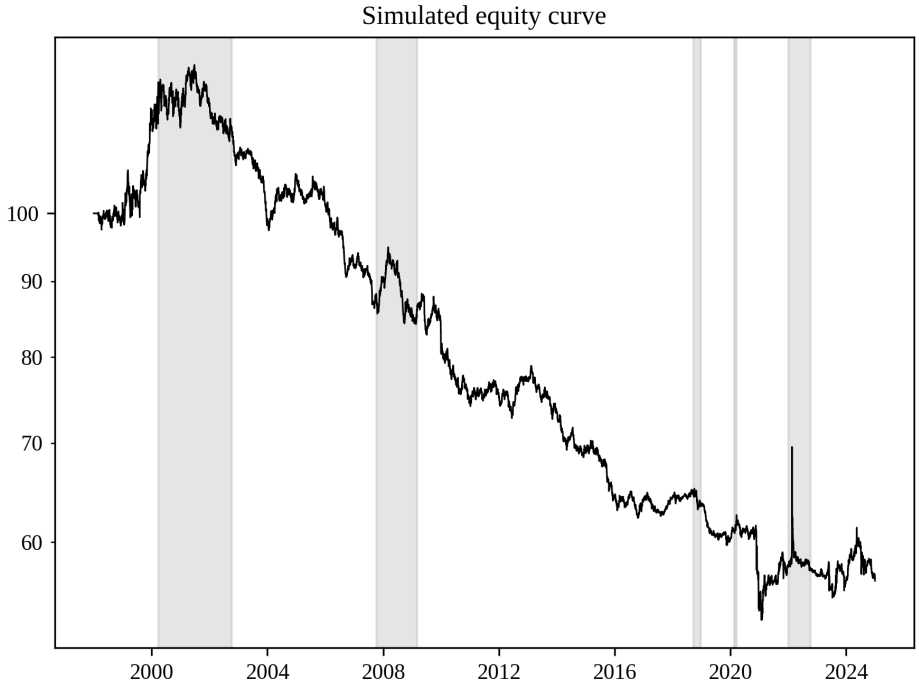
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2000-03-09	2002-10-09	2015-04-08	64.0%	5508 days
2021-02-08	2024-08-05	2024-12-31	38.0%	Ongoing
1998-04-20	1998-10-08	1999-01-08	33.0%	263 days
2020-02-19	2020-03-18	2020-11-25	28.0%	280 days
2015-04-24	2016-02-11	2017-02-15	19.0%	663 days
2018-09-28	2018-12-24	2019-12-16	14.0%	444 days



2.2.3 Price to Earnings: Long-short portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-2.17%	-0.26	57.8%	3.8x	2.14%
2000-2009	-3.52%	-0.26	36.1%	4.1x	2.33%
2010-2019	-2.84%	-0.82	26.9%	3.7x	2.03%
2019-2024	-2.00%	-0.15	20.9%	3.5x	1.93%
2021-2024	0.72%	-0.07	20.9%	3.6x	1.97%
2023-2024	-0.45%	0.02	7.9%	4.2x	2.28%

Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2001-06-25	2021-01-28	2024-12-31	58.0%	Ongoing
2000-04-20	2000-12-29	2001-03-12	7.0%	326 days
1999-03-09	1999-04-07	1999-10-29	7.0%	234 days
2000-03-27	2000-03-31	2000-04-18	5.0%	22 days
2000-03-14	2000-03-20	2000-03-22	4.0%	8 days
2000-02-07	2000-02-29	2000-03-10	4.0%	32 days



2.3 Price to Sales Ratio

The Price to Sales Ratio (or P/S) is the ratio of the price of a share of a company's stock divided by its sales. Sales is a synonym of revenue as reported on quarterly financial statements. Revenue is usually measured on a trailing twelve months (TTM) basis in this context. A lower P/S suggests a stock is undervalued relative to its revenue. The P/S ratio is an alternative approach to representing the value factor.

$$\text{RPS} = \frac{\text{Revenue}}{\text{Shares outstanding}}$$

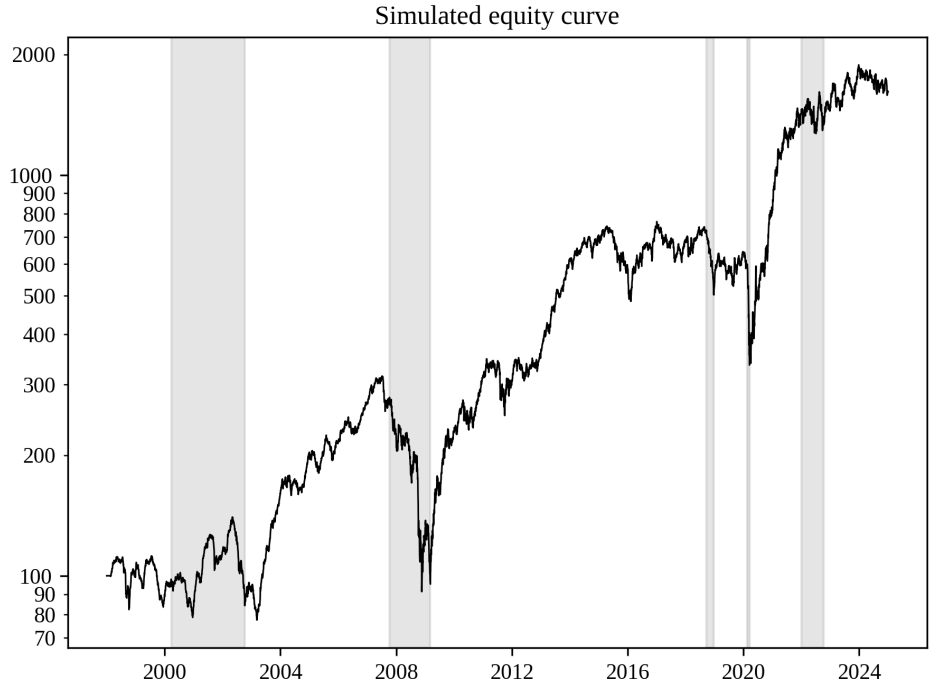
$$\text{P/S} = \frac{\text{Share price}}{\text{RPS}}$$

In the following simulations, the long-only portfolio buys the 60 companies with the lowest P/S, and the short-only portfolio shorts the 60 companies with the highest P/S. The long-short strategy holds the top 30 companies from each strategy long and short, respectively.

2.3.1 Price to Sales: Long-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	11.15%	0.75	71.0%	2.0x	1.18%
2000-2009	9.80%	0.48	71.0%	2.2x	1.35%
2010-2019	10.68%	0.9	35.1%	1.7x	0.98%
2019-2024	19.96%	0.9	47.9%	1.9x	1.13%
2021-2024	18.58%	1.88	19.8%	1.9x	1.14%
2023-2024	4.98%	0.54	16.0%	2.0x	1.24%

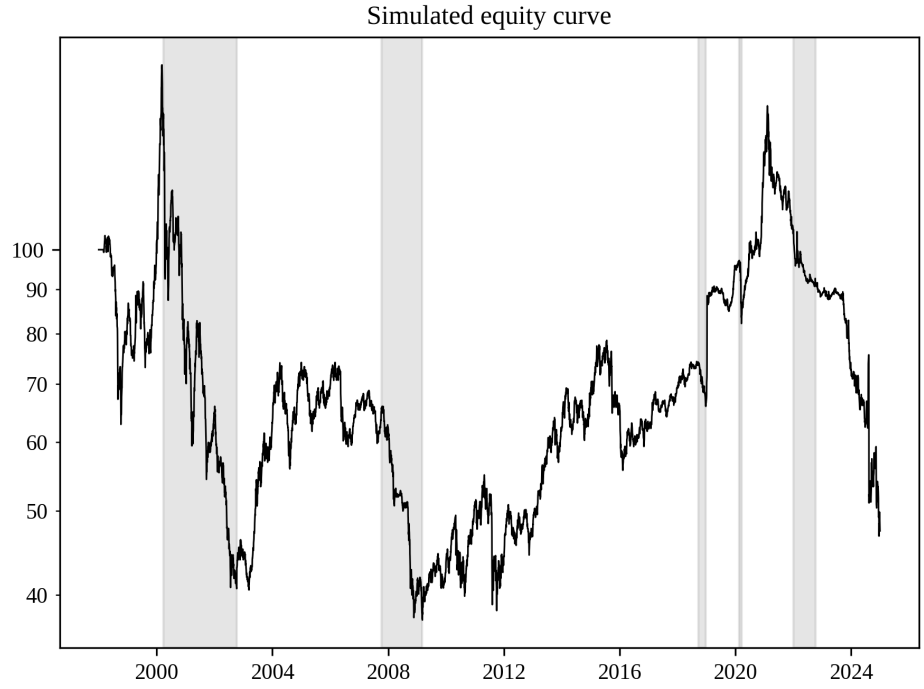
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-07-09	2008-11-20	2011-01-03	71.0%	1274 days
2017-01-04	2020-03-18	2020-11-23	56.0%	1419 days
2002-05-06	2003-03-11	2003-10-30	45.0%	542 days
2015-04-15	2016-02-11	2016-12-20	35.0%	615 days
1999-07-19	2000-12-20	2001-05-07	30.0%	658 days
2011-02-17	2011-10-03	2012-03-26	28.0%	403 days



2.3.2 Price to Sales: Short-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-2.18%	0.06	77.1%	1.5x	0.90%
2000-2009	-8.21%	-0.16	77.1%	1.4x	0.85%
2010-2019	8.01%	0.53	30.2%	1.6x	0.93%
2019-2024	-5.71%	0.01	68.1%	1.4x	0.88%
2021-2024	-21.57%	-0.34	68.1%	1.4x	0.90%
2023-2024	-27.08%	-0.55	48.3%	1.3x	0.93%

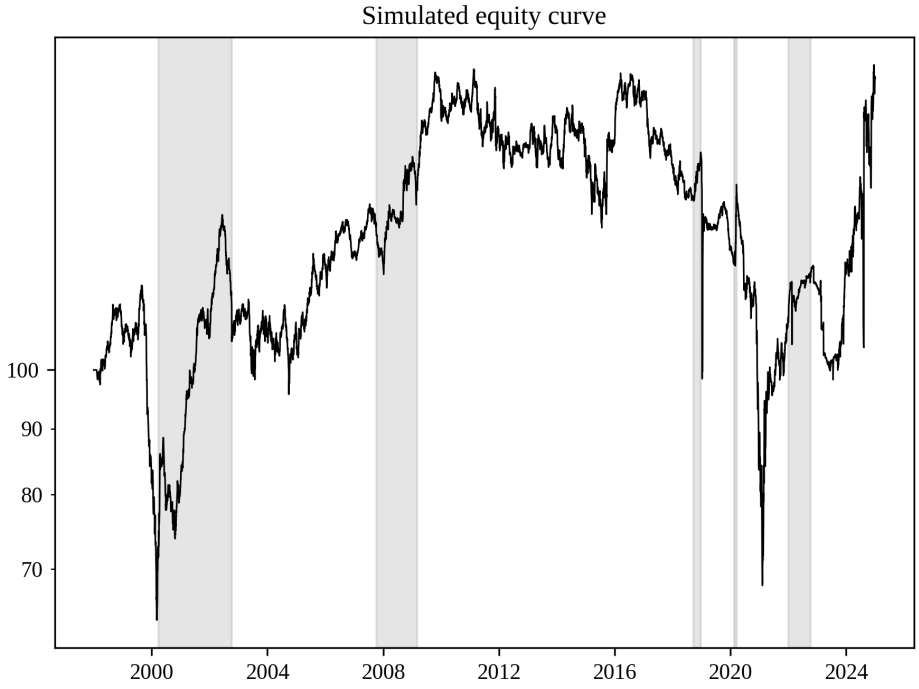
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2000-03-08	2009-03-09	2024-12-31	77.0%	Ongoing
1998-03-20	1998-10-08	2000-01-10	39.0%	661 days
2000-01-26	2000-01-31	2000-02-07	5.0%	12 days
2000-01-10	2000-01-13	2000-01-18	4.0%	8 days
2000-02-17	2000-02-22	2000-02-25	3.0%	8 days
1997-12-31	1998-03-05	1998-03-06	1.0%	65 days



2.3.3 Price to Sales: Long-short portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	1.78%	0.14	60.4%	1.9x	1.19%
2000-2009	6.71%	0.53	27.5%	2.2x	1.39%
2010-2019	-2.31%	-0.1	42.6%	1.7x	1.02%
2019-2024	2.46%	0.06	53.4%	1.7x	1.03%
2021-2024	17.24%	0.23	26.3%	1.8x	1.10%
2023-2024	20.69%	0.31	26.3%	1.9x	1.21%

Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2011-02-18	2021-02-09	2024-12-18	60.0%	5052 days
1999-08-27	2000-03-07	2002-03-04	45.0%	920 days
2002-06-11	2004-09-28	2007-06-25	28.0%	1840 days
2007-07-17	2008-01-08	2008-09-11	12.0%	422 days
1998-11-30	1999-04-13	1999-08-06	9.0%	249 days
2009-10-20	2010-03-29	2011-02-16	9.0%	484 days



2.4 The Acquirer's Multiple

The Acquirer's Multiple is a popular modern interpretation of the value factor that attempts to see the stock through the eyes of an acquirer. It has been reported to work well for finding deep value stocks, because deep value stocks are inherently good acquisition candidates. The Acquirer's Multiple is as follows. Note that Enterprise Value (EV) is a nuanced calculation that can be treated with more complexity than it is treated with here.

$$\text{EBIT} = \text{Revenue} - \text{Operating Expenses}$$

$$\text{Enterprise Value (EV)} = \text{Market Cap} + \text{Debt} - \text{Cash}$$

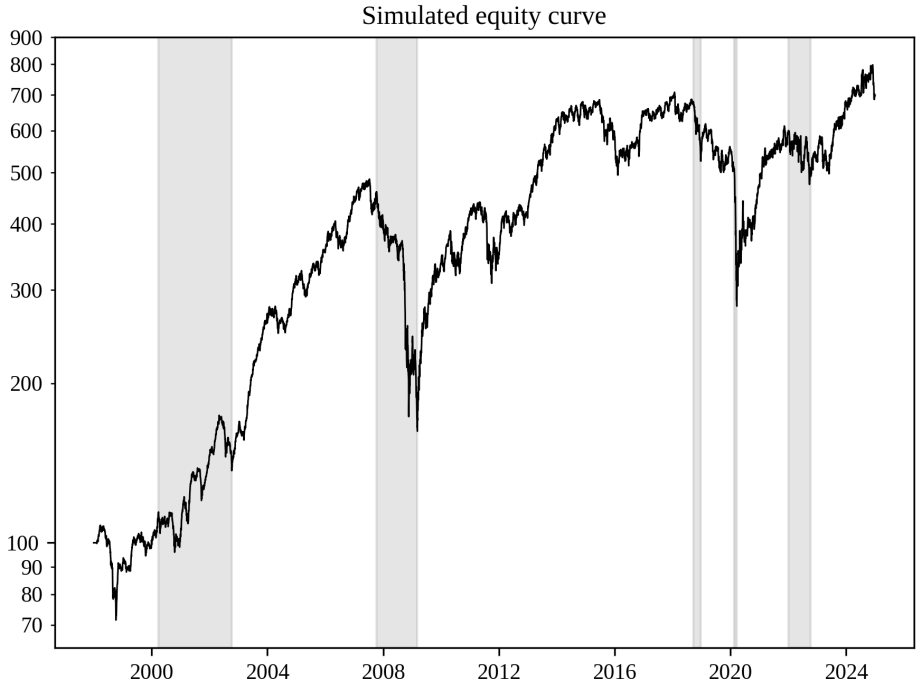
$$\text{Acquirer's Multiple} = \frac{\text{EV}}{\text{EBIT}}$$

In the following simulations, the long-only portfolio buys the 60 companies with the lowest Acquirer's Multiple, and the short-only portfolio shorts the 60 companies with the highest Acquirer's Multiple. The long-short strategy holds the top 30 companies from each strategy long and short, respectively.

2.4.1 Acquirer's Multiple: Long-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	8.13%	0.55	66.6%	2.7x	1.58%
2000-2009	12.78%	0.7	66.6%	2.9x	1.76%
2010-2019	4.96%	0.59	29.7%	2.5x	1.37%
2019-2024	3.86%	0.19	54.7%	2.7x	1.46%
2021-2024	10.45%	0.88	22.4%	2.7x	1.51%
2023-2024	15.65%	0.9	15.1%	2.7x	1.53%

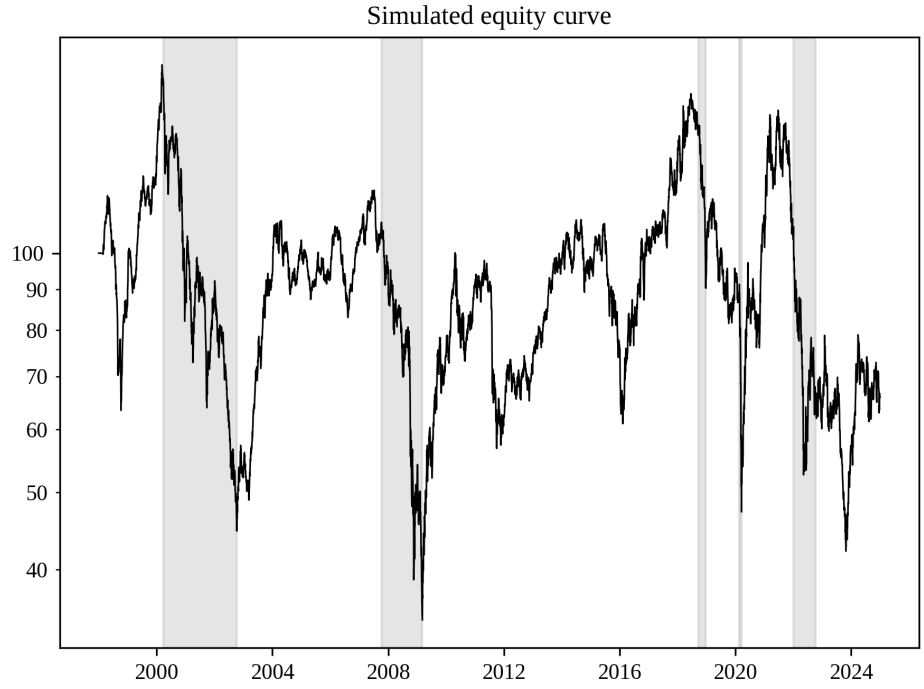
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-07-13	2009-03-09	2013-03-15	67.0%	2072 days
2018-01-26	2020-03-23	2024-03-20	61.0%	2245 days
1998-03-24	1998-10-08	2000-03-16	34.0%	723 days
2015-06-23	2016-02-11	2017-11-29	28.0%	890 days
2002-05-02	2002-10-09	2003-04-21	21.0%	354 days
2000-03-28	2000-10-18	2001-01-22	16.0%	300 days



2.4.2 Acquirer's Multiple: Short-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-1.28%	0.17	80.0%	3.5x	2.22%
2000-2009	-5.60%	-0.02	80.0%	3.4x	2.11%
2010-2019	2.20%	0.43	48.6%	3.2x	1.99%
2019-2024	-6.67%	-0.11	72.1%	4.2x	2.69%
2021-2024	-10.30%	0.14	72.1%	4.2x	2.76%
2023-2024	1.32%	0.01	46.5%	4.2x	2.86%

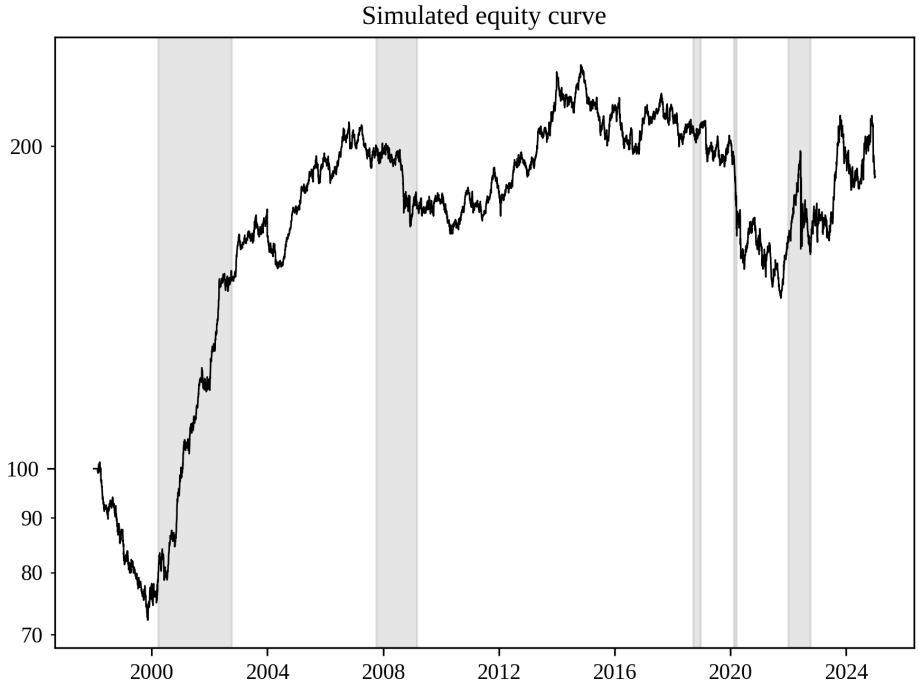
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2000-03-09	2009-03-09	2024-12-31	80.0%	Ongoing
1998-04-21	1998-10-08	1999-06-21	46.0%	426 days
1999-07-16	1999-10-18	1999-12-23	11.0%	160 days
1999-06-22	1999-06-25	1999-07-08	3.0%	16 days
2000-01-26	2000-01-31	2000-02-03	3.0%	8 days
2000-02-17	2000-02-25	2000-02-29	3.0%	12 days



2.4.3 Acquirer's Multiple: Long-short portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	3.02%	0.34	39.4%	3.3x	2.03%
2000-2009	8.56%	1.1	20.1%	3.4x	2.11%
2010-2019	1.34%	0.19	19.7%	3.1x	1.86%
2019-2024	-1.76%	-0.03	31.7%	3.4x	2.08%
2021-2024	3.52%	0.22	19.9%	3.4x	2.05%
2023-2024	6.92%	0.5	14.8%	3.1x	1.96%

Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2014-11-03	2021-09-30	2024-12-31	39.0%	Ongoing
1998-03-18	1999-11-12	2001-02-01	29.0%	1051 days
2006-10-26	2010-04-26	2013-10-21	21.0%	2552 days
2003-12-30	2004-05-10	2004-11-22	12.0%	328 days
2013-12-31	2014-08-07	2014-10-29	8.0%	302 days
2005-12-20	2006-03-06	2006-06-28	6.0%	190 days



2.5 The Enterprise Multiple

The Enterprise Multiple is similar to the Acquirer's Multiple, except it uses EBITDA, rather than EBIT, in the denominator. It is popular among investment bankers.

$$\text{EBITDA} = \text{Revenue} - \text{Operating Expenses} + \text{Depreciation} + \text{Amortization}$$

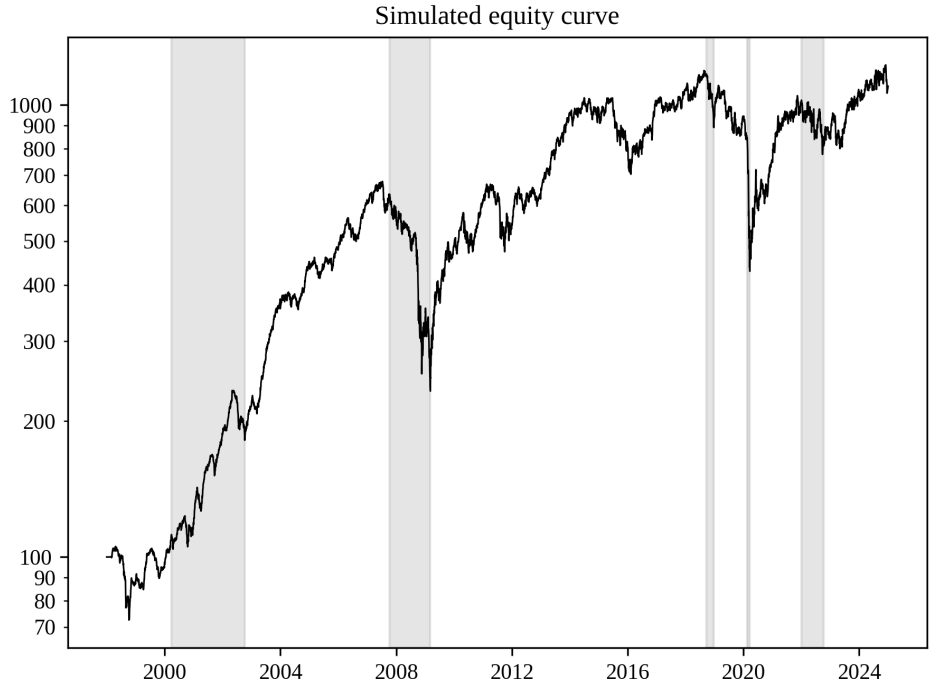
$$\text{Enterprise Multiple} = \frac{\text{EV}}{\text{EBITDA}}$$

In the following simulations, the long-only portfolio buys the 60 companies with the lowest Enterprise Multiple, and the short-only portfolio shorts the 60 companies with the highest Enterprise Multiple. The long-short strategy holds the top 30 companies from each strategy long and short, respectively.

2.5.1 Enterprise Multiple: Long-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	10.14%	0.65	65.6%	2.8x	1.63%
2000-2009	17.44%	0.95	65.6%	3.1x	1.88%
2010-2019	6.68%	0.66	32.2%	2.6x	1.43%
2019-2024	2.35%	0.16	61.2%	2.5x	1.40%
2021-2024	10.22%	0.79	25.8%	2.6x	1.46%
2023-2024	14.51%	0.61	16.6%	2.3x	1.37%

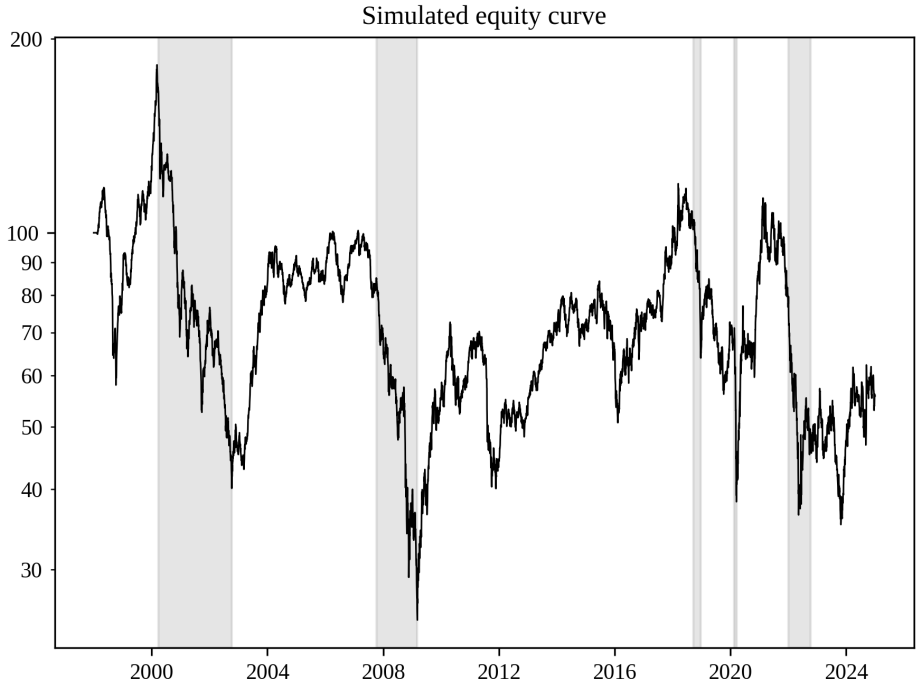
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-07-13	2009-03-09	2013-01-24	66.0%	2022 days
2018-08-22	2020-03-23	2024-07-31	64.0%	2170 days
2014-07-03	2016-02-11	2017-02-14	32.0%	957 days
1998-04-22	1998-10-08	2000-03-10	31.0%	688 days
2002-05-14	2002-10-09	2003-04-23	22.0%	344 days
2000-09-14	2000-10-18	2001-01-10	15.0%	118 days



2.5.2 Enterprise Multiple: Short-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-1.59%	0.14	86.3%	3.5x	2.20%
2000-2009	-7.98%	-0.08	86.3%	3.3x	2.04%
2010-2019	2.23%	0.41	52.9%	3.3x	2.02%
2019-2024	-3.66%	-0.07	68.9%	4.2x	2.70%
2021-2024	-9.55%	0.13	68.9%	4.2x	2.75%
2023-2024	9.04%	0.21	38.5%	4.3x	2.92%

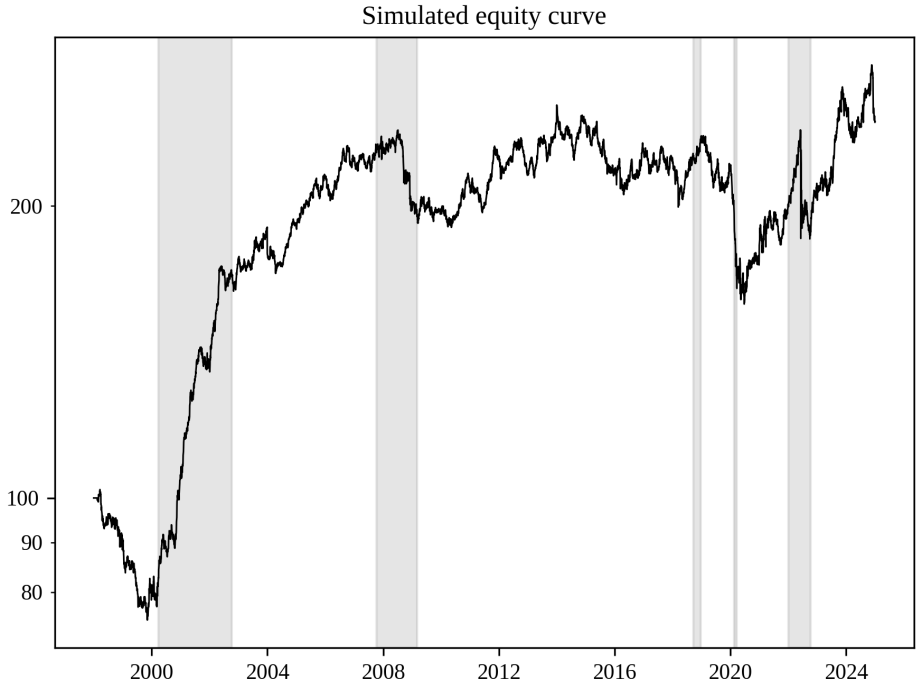
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2000-03-09	2009-03-09	2024-12-31	86.0%	Ongoing
1998-05-08	1998-10-08	1999-11-22	51.0%	563 days
1999-11-26	1999-11-30	1999-12-23	5.0%	27 days
1998-04-21	1998-04-27	1998-04-30	3.0%	9 days
2000-01-27	2000-01-31	2000-02-03	3.0%	7 days
1998-04-02	1998-04-08	1998-04-15	2.0%	13 days



2.5.3 Enterprise Multiple: Long-short portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	3.90%	0.39	37.6%	3.3x	2.07%
2000-2009	9.33%	1.19	19.8%	3.5x	2.16%
2010-2019	1.05%	0.14	21.5%	3.2x	1.92%
2019-2024	0.70%	0.17	32.9%	3.4x	2.08%
2021-2024	7.35%	0.46	22.8%	3.4x	2.12%
2023-2024	9.84%	0.86	12.7%	3.1x	2.05%

Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2013-12-31	2020-06-24	2023-10-17	38.0%	3577 days
1998-03-20	1999-11-08	2000-12-18	27.0%	1004 days
2008-07-07	2010-05-12	2013-12-17	21.0%	1989 days
2024-11-20	2024-12-30	2024-12-31	13.0%	Ongoing
2023-11-15	2024-04-12	2024-10-16	12.0%	336 days
2003-12-30	2004-04-15	2004-10-27	10.0%	302 days



2.6 Free Cash Flow to Price

Free Cash Flow to Price is similar to the reciprocal of P/E, except it uses free cash flow in place of earnings. Many practitioners believe free cash flow is more closely correlated to a company's value than income because it is less susceptible to manipulation by creative accounting.

$$\begin{aligned}\text{Free Cash Flow (FCF)} = \text{Net Income } &+ \text{Non-cash Expenses} + \\ \text{Change in Working Capital } &- \text{ Capital Expenditures}\end{aligned}$$

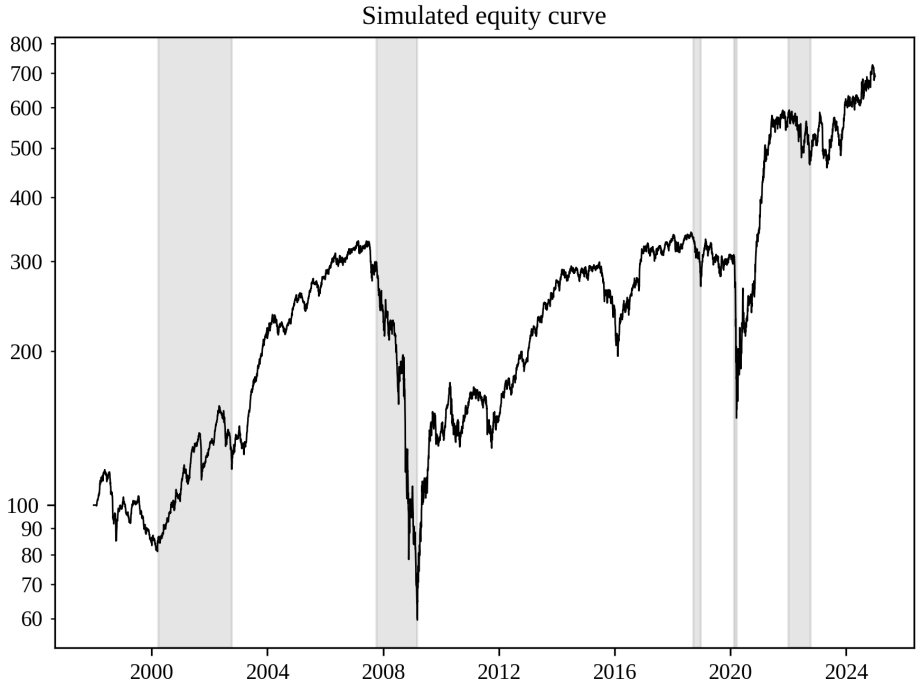
$$\text{Free Cash Flow to Price} = \frac{\text{FCF}}{\text{Market cap}}$$

In the following simulations, the long-only portfolio buys the 60 companies with the highest Free Cash Flow to Price, and the short-only portfolio shorts the 60 companies with the lowest Free Cash Flow to Price. The long-short strategy holds the top 30 companies from each strategy long and short, respectively.

2.6.1 Free Cash Flow to Price: Long-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	7.65%	0.54	81.9%	2.5x	1.48%
2000-2009	5.09%	0.28	81.9%	2.8x	1.69%
2010-2019	8.22%	0.85	34.6%	2.3x	1.32%
2019-2024	16.02%	0.72	55.3%	2.3x	1.31%
2021-2024	18.83%	1.82	22.9%	2.2x	1.29%
2023-2024	16.22%	0.6	22.1%	2.1x	1.24%

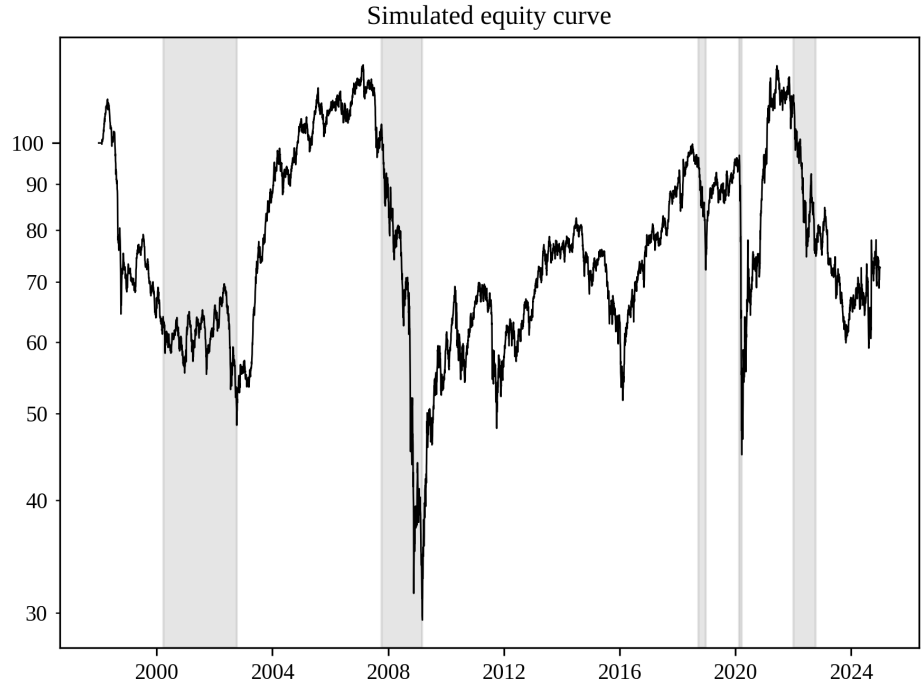
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-02-22	2009-03-09	2017-12-04	82.0%	3938 days
2018-08-22	2020-03-18	2020-12-23	57.0%	854 days
1998-05-20	2000-03-14	2001-02-07	31.0%	994 days
2002-05-03	2002-10-09	2003-05-28	25.0%	390 days
2022-01-14	2023-05-04	2023-12-13	23.0%	698 days
2001-08-23	2001-09-21	2002-03-07	19.0%	196 days



2.6.2 Free Cash Flow to Price: Short-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	0.06%	0.1	75.9%	2.6x	1.54%
2000-2009	-1.10%	-0.02	75.9%	2.6x	1.56%
2010-2019	4.64%	0.49	37.3%	2.3x	1.35%
2019-2024	-0.91%	-0.03	53.6%	2.9x	1.76%
2021-2024	-5.30%	0.16	51.5%	3.0x	1.90%
2023-2024	-2.68%	-0.48	30.3%	3.0x	2.04%

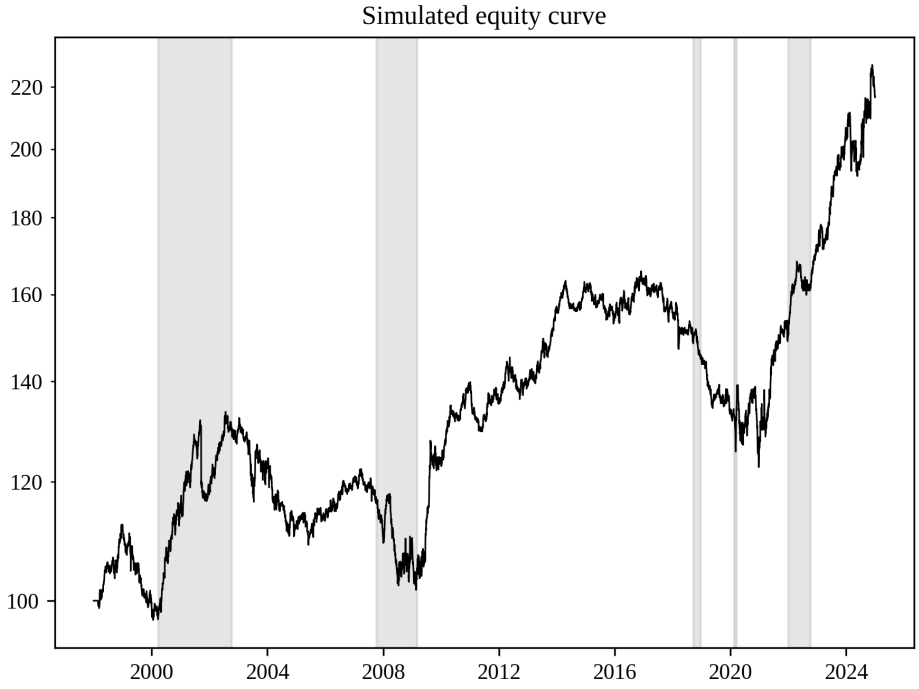
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-02-20	2009-03-09	2024-12-31	76.0%	Ongoing
1998-04-22	2002-10-09	2005-07-19	57.0%	2645 days
2005-08-01	2005-10-13	2006-10-24	12.0%	449 days
2006-10-26	2006-11-09	2006-11-21	3.0%	26 days
2006-12-11	2007-01-09	2007-01-24	2.0%	44 days
2006-11-22	2006-11-27	2006-12-04	2.0%	12 days



2.6.3 Free Cash Flow to Price: Long-short portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	2.61%	0.39	26.0%	2.8x	1.72%
2000-2009	2.27%	0.15	23.9%	3.1x	1.92%
2010-2019	0.81%	0.41	19.7%	2.5x	1.49%
2019-2024	6.90%	0.61	15.6%	2.8x	1.71%
2021-2024	14.36%	1.2	9.3%	2.9x	1.77%
2023-2024	12.52%	1.19	9.3%	2.9x	1.83%

Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2016-11-30	2020-12-24	2022-04-18	26.0%	1965 days
2002-07-23	2009-02-20	2010-04-26	24.0%	2834 days
1998-12-29	2000-01-21	2000-09-21	14.0%	632 days
2001-09-06	2001-11-28	2002-07-10	12.0%	307 days
2024-02-15	2024-05-23	2024-08-19	9.0%	186 days
2011-01-05	2011-06-01	2012-03-02	7.0%	422 days



2.7 Revenue growth

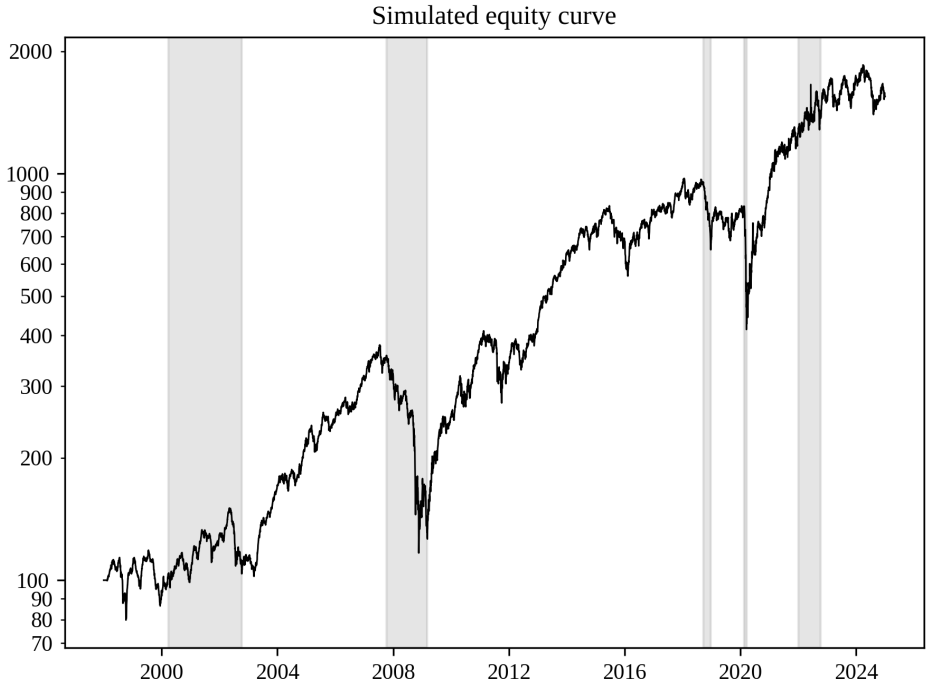
Revenue growth is typically measured as the year-over-year growth in revenue. In our simulations, we rank companies by the quarterly percent change in TTM quarterly revenue. Revenue growth as a factor attempts to identify companies with growing or declining revenue under the assumption that their revenue trajectories will continue in the same direction.

In the following simulations, the long-only portfolio buys the 60 companies with the highest revenue growth, and the short-only portfolio shorts the 60 companies with the lowest revenue growth. The long-short strategy holds the top 30 companies from each strategy long and short, respectively.

2.7.1 Revenue growth: Long-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	10.73%	0.65	69.2%	3.1x	1.75%
2000-2009	10.49%	0.47	69.2%	3.2x	1.88%
2010-2019	12.31%	0.93	33.5%	2.9x	1.60%
2019-2024	14.01%	0.51	50.3%	3.2x	1.72%
2021-2024	14.25%	1.09	24.5%	3.2x	1.72%
2023-2024	1.15%	0.44	24.5%	3.3x	1.85%

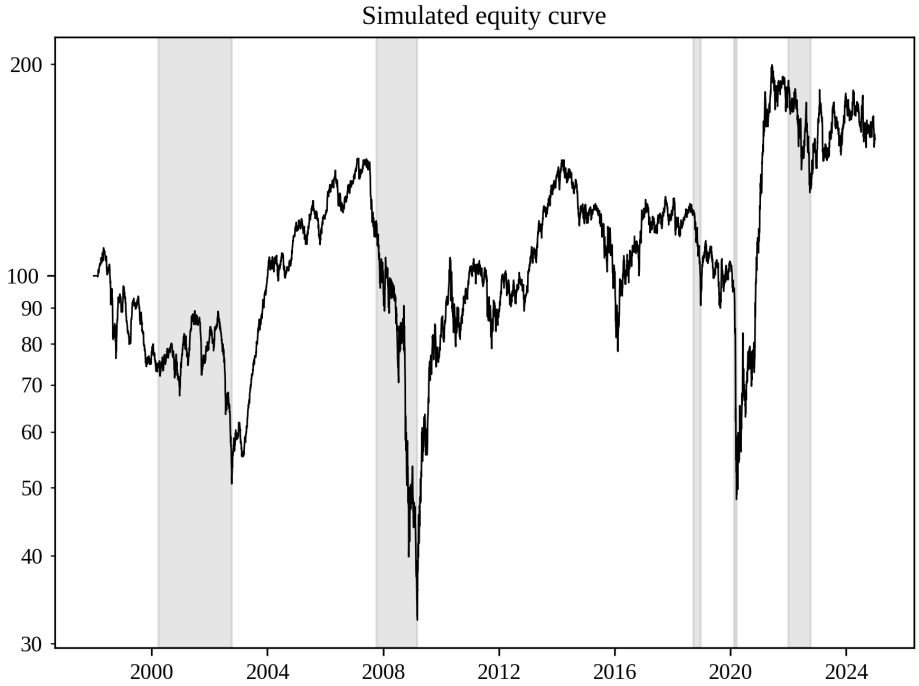
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-07-17	2008-11-20	2010-12-27	69.0%	1259 days
2018-01-22	2020-03-18	2021-01-07	57.0%	1081 days
2011-02-17	2011-10-03	2012-12-18	34.0%	670 days
2015-06-23	2016-02-11	2017-03-16	33.0%	632 days
2002-05-06	2003-03-12	2003-10-14	32.0%	526 days
1998-07-20	1998-10-08	1999-05-20	30.0%	304 days



2.7.2 Revenue growth: Short-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	2.07%	0.31	77.9%	3.5x	2.04%
2000-2009	0.47%	0.05	77.9%	3.5x	2.12%
2010-2019	2.15%	0.42	46.5%	3.3x	1.88%
2019-2024	8.28%	0.55	57.1%	3.8x	2.08%
2021-2024	7.92%	1.46	34.2%	3.6x	2.01%
2023-2024	1.69%	0.14	20.8%	3.5x	2.07%

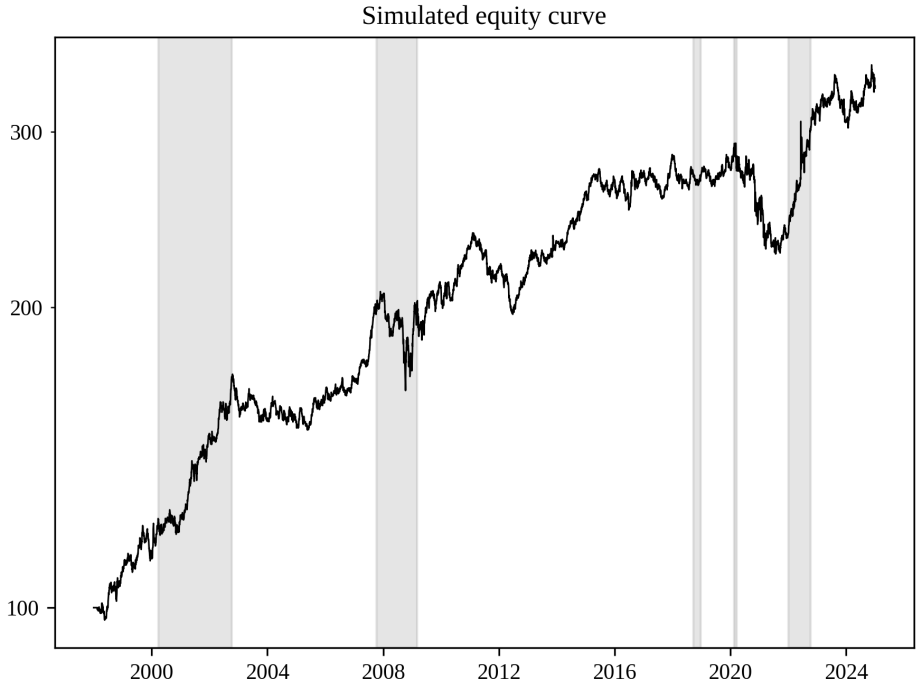
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-02-22	2009-03-09	2021-02-08	78.0%	5100 days
1998-05-05	2002-10-09	2004-11-11	54.0%	2382 days
2021-06-11	2022-09-30	2024-12-31	34.0%	Ongoing
2005-07-28	2005-10-27	2006-01-26	13.0%	182 days
2006-05-08	2006-08-14	2007-01-17	13.0%	254 days
2021-03-15	2021-03-29	2021-05-24	11.0%	70 days



2.7.3 Revenue growth: Long-short portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	4.36%	0.56	22.6%	3.6x	2.08%
2000-2009	6.47%	0.73	20.4%	3.7x	2.21%
2010-2019	2.99%	0.54	17.1%	3.3x	1.86%
2019-2024	3.31%	0.31	22.6%	3.7x	2.11%
2021-2024	6.98%	0.41	12.6%	3.7x	2.14%
2023-2024	2.56%	0.98	11.6%	3.7x	2.18%

Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2020-03-09	2021-07-26	2022-06-08	23.0%	821 days
2007-11-28	2008-10-10	2009-08-28	20.0%	639 days
2011-02-04	2012-06-25	2014-05-14	17.0%	1195 days
2002-10-18	2005-05-20	2007-02-26	12.0%	1592 days
2023-08-09	2024-01-26	2024-11-15	12.0%	464 days
2022-06-08	2022-07-21	2022-10-19	11.0%	133 days



2.8 Earnings Growth

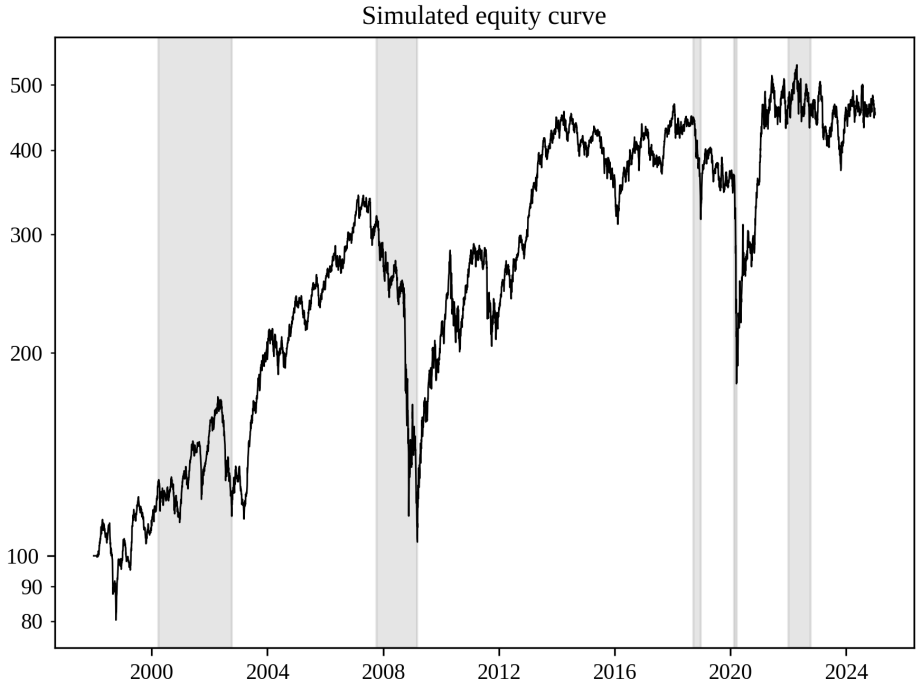
Earnings growth is like the revenue growth factor except it measures growth in earnings.

In the following simulations, the long-only portfolio buys the 60 companies with the highest earnings growth, and the short-only portfolio shorts the 60 companies with the lowest earnings growth. The long-short strategy holds the top 30 companies from each strategy long and short, respectively.

2.8.1 Earnings growth: Long-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	5.93%	0.41	69.4%	4.7x	2.68%
2000-2009	6.64%	0.34	69.4%	4.7x	2.78%
2010-2019	5.58%	0.59	32.6%	4.6x	2.57%
2019-2024	4.92%	0.2	55.4%	4.5x	2.51%
2021-2024	6.11%	0.73	30.3%	4.4x	2.52%
2023-2024	1.88%	-0.04	26.2%	4.5x	2.69%

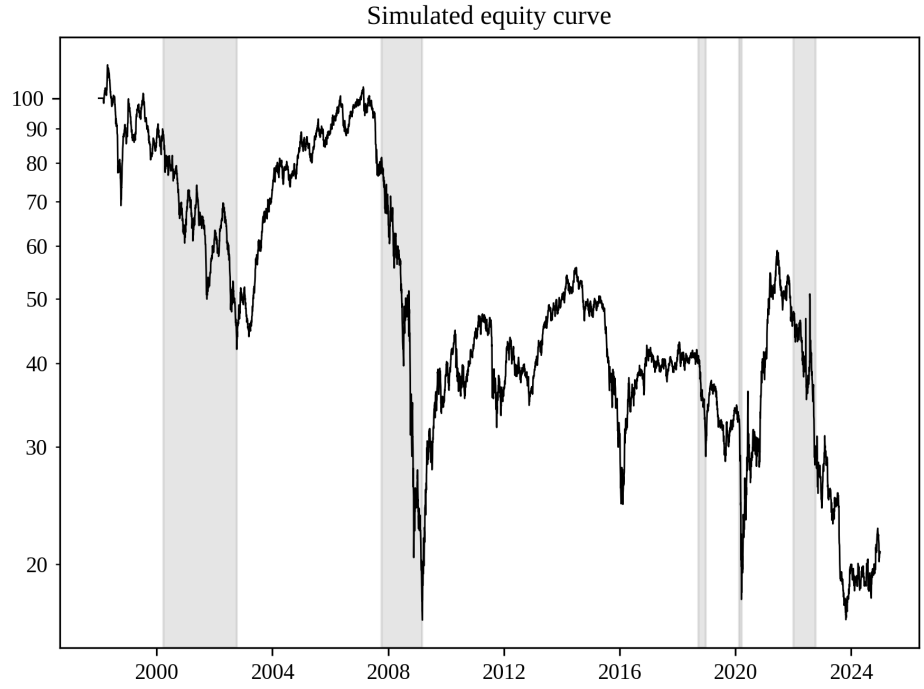
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-02-22	2009-03-09	2013-02-14	69.0%	2184 days
2018-01-23	2020-03-18	2021-03-11	62.0%	1143 days
2002-04-16	2003-03-12	2003-08-21	34.0%	492 days
2014-04-02	2016-02-11	2018-01-08	32.0%	1377 days
2022-04-20	2023-10-27	2024-12-31	30.0%	Ongoing
1998-04-21	1998-10-08	1999-05-11	29.0%	385 days



2.8.2 Earnings growth: Short-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-5.55%	-0.05	84.1%	4.9x	2.82%
2000-2009	-7.95%	-0.23	84.1%	5.0x	2.96%
2010-2019	-1.43%	0.2	55.9%	4.7x	2.65%
2019-2024	-6.65%	-0.12	72.0%	4.8x	2.71%
2021-2024	-13.85%	0	72.0%	4.9x	2.77%
2023-2024	-9.27%	-1.15	47.0%	5.0x	2.93%

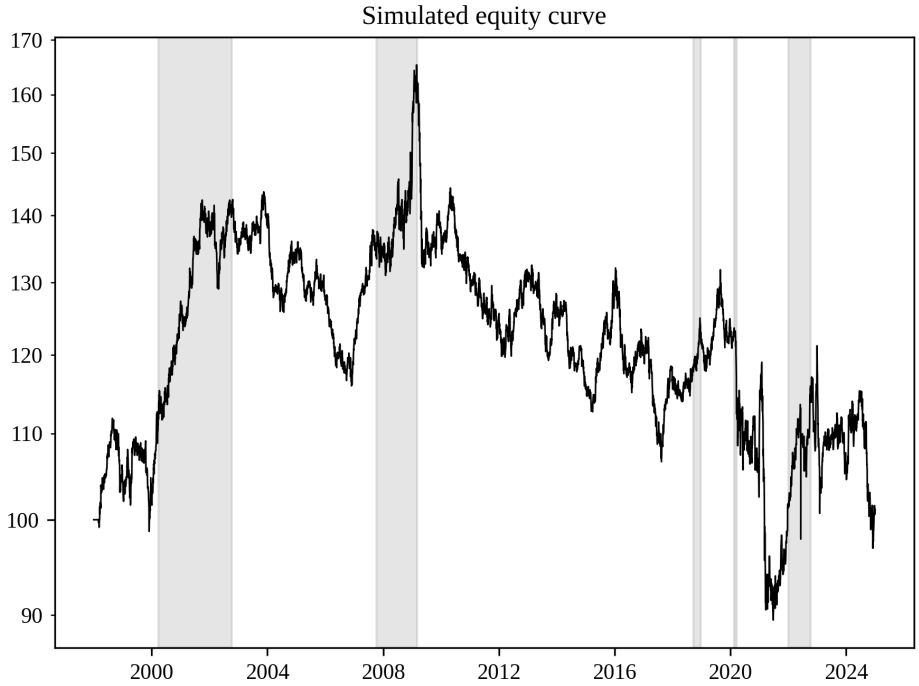
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
1998-04-22	2009-03-09	2024-12-31	85.0%	Ongoing
1998-03-24	1998-04-07	1998-04-14	2.0%	21 days
1997-12-31	1998-03-05	1998-03-10	2.0%	69 days
1998-03-16	1998-03-17	1998-03-18	1.0%	2 days
1998-03-19	1998-03-23	1998-03-24	1.0%	5 days
1998-03-11	1998-03-11	1998-03-12	0.0%	1 days



2.8.3 Earnings growth: Long-short portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-0.14%	0.05	45.9%	5.2x	3.07%
2000-2009	3.03%	0.41	20.1%	5.2x	3.15%
2010-2019	-0.95%	-0.18	26.1%	5.1x	2.95%
2019-2024	-3.13%	-0.06	32.1%	5.1x	2.96%
2021-2024	-2.88%	-0.02	24.8%	5.1x	3.01%
2023-2024	-7.49%	-0.04	17.6%	5.0x	3.09%

Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2009-02-27	2021-06-25	2024-12-31	46.0%	Ongoing
2003-11-17	2006-11-29	2008-07-03	19.0%	1690 days
1998-08-24	1999-11-30	2000-03-03	12.0%	557 days
2001-10-01	2002-04-25	2002-10-21	9.0%	385 days
2008-07-15	2008-09-18	2008-12-10	7.0%	148 days
2002-10-21	2002-12-26	2003-10-27	6.0%	371 days



2.9 Free Cash Flow Growth

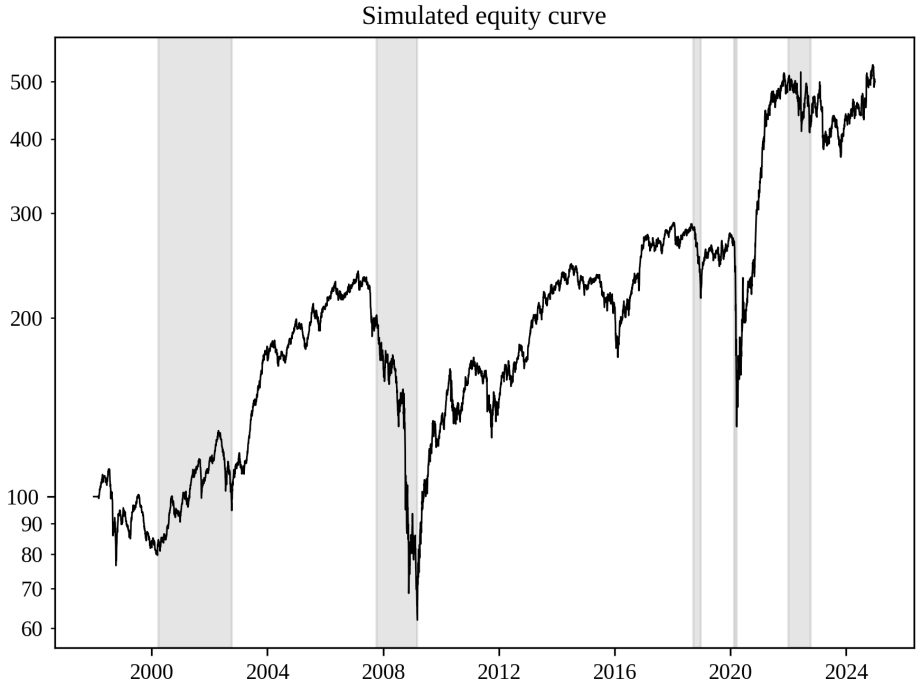
Free cash flow growth is like the revenue growth factor except it measures growth in free cash flow.

In the following simulations, the long-only portfolio buys the 60 companies with the highest free cash flow growth, and the short-only portfolio shorts the 60 companies with the lowest free cash flow growth. The long-short strategy holds the top 30 companies from each strategy long and short, respectively.

2.9.1 Free Cash Flow Growth: Long-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	6.67%	0.48	74.1%	4.3x	2.52%
2000-2009	4.83%	0.22	74.1%	4.3x	2.66%
2010-2019	7.48%	0.78	30.4%	4.1x	2.36%
2019-2024	13.86%	0.61	52.8%	4.3x	2.43%
2021-2024	11.36%	1.43	28.1%	4.3x	2.48%
2023-2024	5.39%	0.05	25.3%	4.5x	2.70%

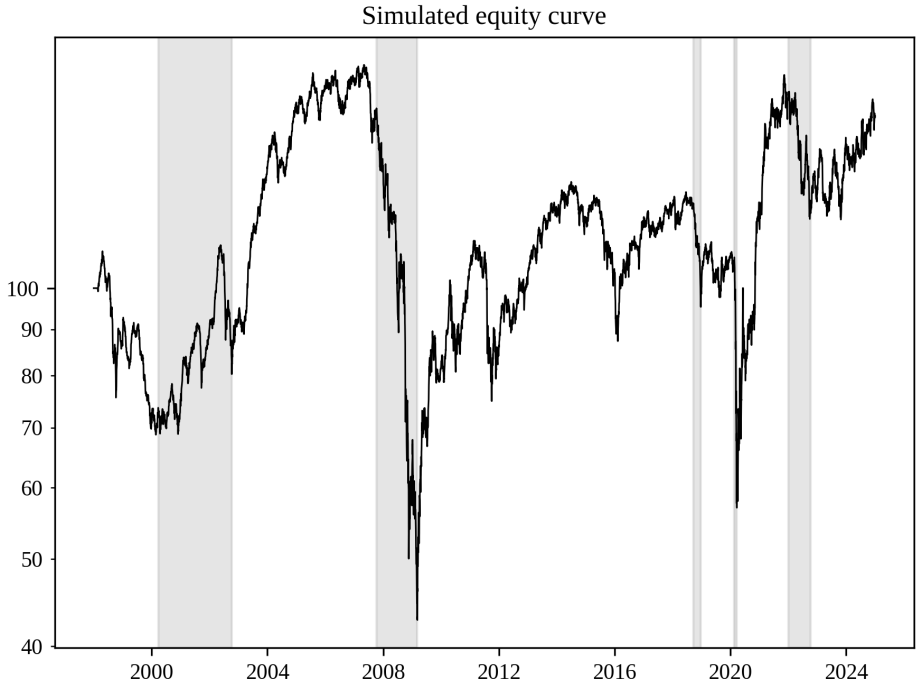
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-02-20	2009-03-09	2014-06-05	74.0%	2662 days
2018-01-12	2020-03-23	2020-11-23	55.0%	1046 days
1998-07-16	1998-10-08	2001-07-13	31.0%	1093 days
2014-07-03	2016-02-11	2016-11-18	30.0%	869 days
2022-06-08	2023-10-27	2024-11-11	28.0%	887 days
2002-04-24	2002-10-09	2003-05-28	27.0%	399 days



2.9.2 Free Cash Flow Growth: Short-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	2.14%	0.23	75.8%	4.3x	2.52%
2000-2009	1.25%	0.09	75.8%	4.4x	2.69%
2010-2019	2.74%	0.37	33.7%	4.0x	2.31%
2019-2024	7.57%	0.3	49.3%	4.3x	2.42%
2021-2024	7.55%	0.98	30.9%	4.2x	2.37%
2023-2024	10.39%	0.15	16.5%	4.2x	2.42%

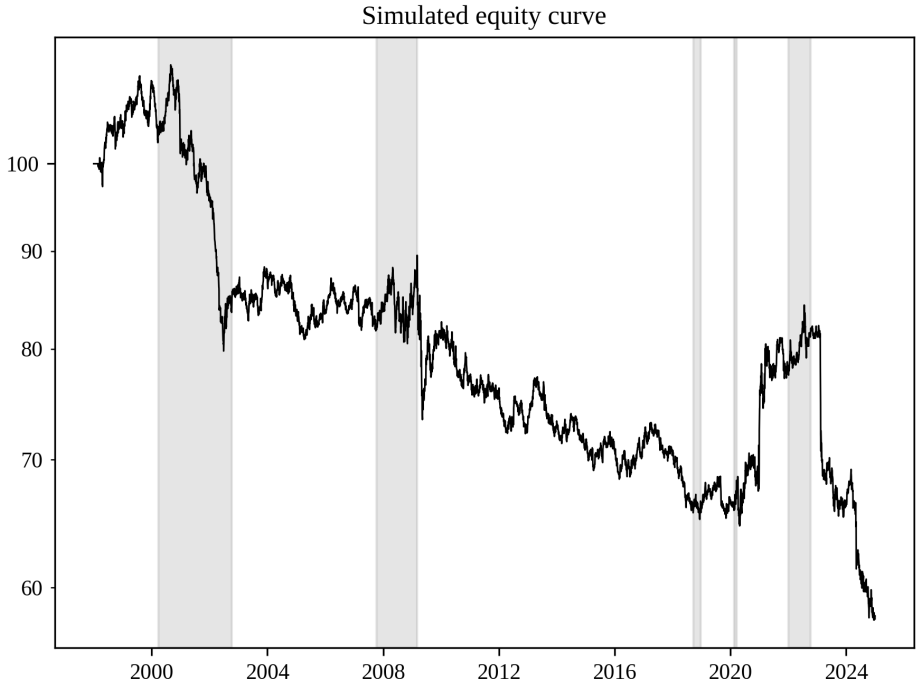
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-05-04	2009-03-09	2024-12-31	76.0%	Ongoing
1998-04-21	2000-02-24	2002-05-02	37.0%	1472 days
2002-05-23	2002-10-09	2003-06-04	28.0%	377 days
2004-04-01	2004-05-17	2004-11-04	12.0%	217 days
2005-07-28	2005-10-27	2006-05-05	11.0%	281 days
2006-05-09	2006-08-14	2007-02-06	11.0%	273 days



2.9.3 Free Cash Flow Growth: Long-short portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-2.24%	-0.24	48.8%	4.5x	2.73%
2000-2009	-3.01%	-0.36	34.8%	4.7x	2.94%
2010-2019	-1.98%	-0.37	21.2%	4.2x	2.49%
2019-2024	-2.25%	-0.09	31.6%	4.6x	2.69%
2021-2024	-6.16%	-0.16	31.6%	4.6x	2.69%
2023-2024	-15.70%	-1.29	29.9%	4.6x	2.82%

Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2000-08-29	2024-12-20	2024-12-31	49.0%	Ongoing
1999-08-05	2000-03-20	2000-08-18	8.0%	379 days
1998-09-21	1998-09-30	1998-12-07	4.0%	77 days
1998-03-17	1998-04-22	1998-05-12	3.0%	56 days
1998-12-07	1999-01-06	1999-02-02	3.0%	57 days
1999-03-31	1999-04-26	1999-07-02	2.0%	93 days



2.10 Gross Profit to Assets (Profitability)

Gross Profits to Assets is one of the big five factors from literature. It is often referred to as just *profitability*. Researchers believe that controlling for profitability improves the performance of value strategies. It is calculated as follows.

$$\text{Gross Profits} = \text{Revenue} - \text{Cost of Goods Sold}$$

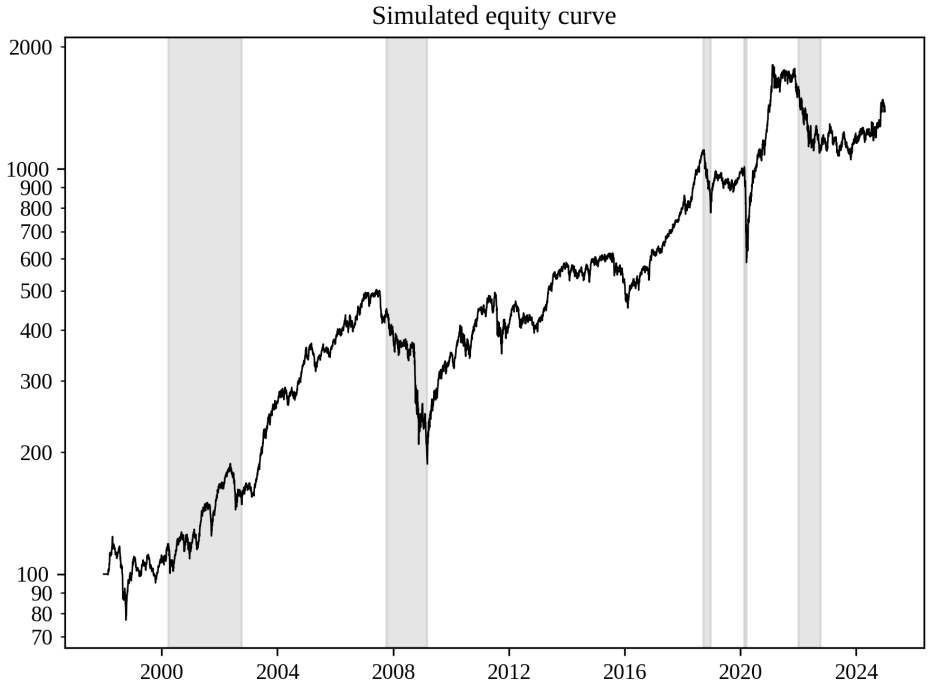
$$\text{Profitability} = \frac{\text{Gross Profits}}{\text{Assets}}$$

In the following simulations, the long-only portfolio buys the 60 companies with the highest profitability, and the short-only portfolio shorts the 60 companies with the lowest profitability. The long-short strategy holds the top 30 companies from each strategy long and short, respectively.

2.10.1 Gross Profit to Assets: Long-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	10.40%	0.64	62.9%	0.9x	0.53%
2000-2009	12.22%	0.65	62.9%	1.0x	0.59%
2010-2019	10.83%	0.85	30.0%	0.8x	0.44%
2019-2024	8.63%	0.4	41.9%	1.0x	0.55%
2021-2024	0.11%	0.55	41.6%	1.0x	0.59%
2023-2024	11.15%	0.07	18.4%	0.8x	0.57%

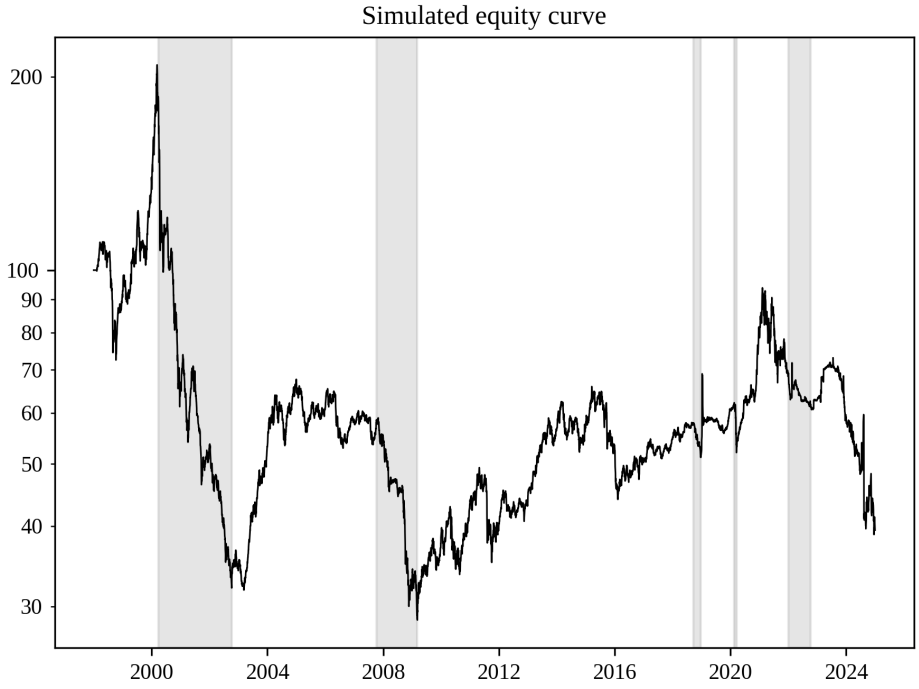
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-06-04	2009-03-09	2013-05-14	63.0%	2171 days
2018-09-28	2020-03-18	2020-08-25	47.0%	697 days
2021-02-16	2023-10-26	2024-12-31	42.0%	Ongoing
1998-04-22	1998-10-08	2000-08-29	38.0%	860 days
2015-08-05	2016-02-11	2016-12-08	27.0%	491 days
2002-05-17	2002-07-23	2003-05-27	23.0%	375 days



2.10.2 Gross Profit to Assets: Short-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-3.24%	0.03	86.3%	1.8x	1.05%
2000-2009	-11.97%	-0.28	86.3%	1.9x	1.15%
2010-2019	4.50%	0.39	33.2%	1.5x	0.91%
2019-2024	-4.62%	0	58.7%	1.7x	1.01%
2021-2024	-15.86%	-0.1	58.7%	1.9x	1.11%
2023-2024	-20.93%	-0.31	46.9%	1.3x	0.93%

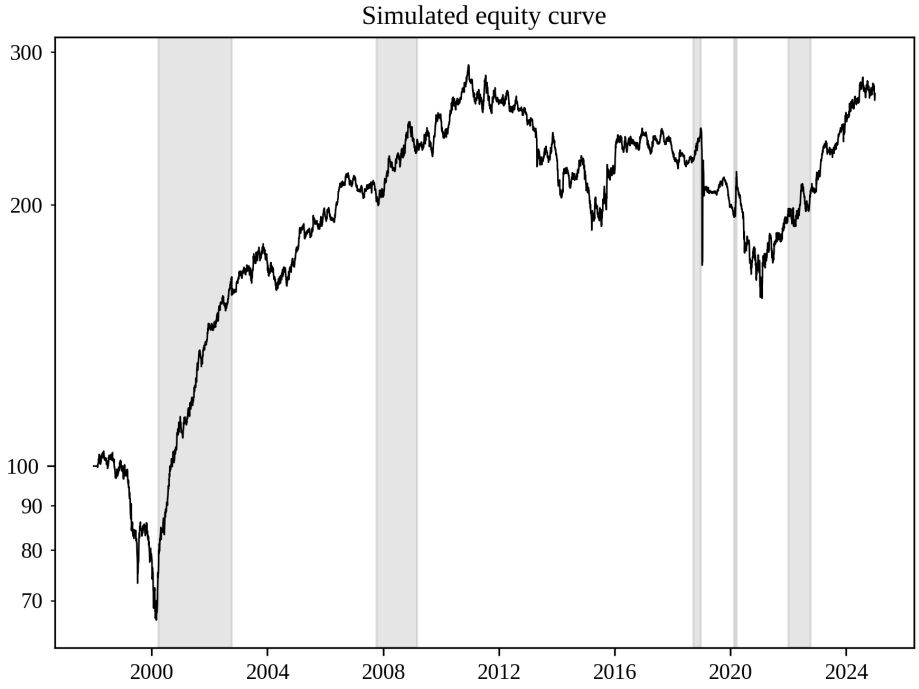
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2000-03-10	2009-03-09	2024-12-31	86.0%	Ongoing
1998-05-08	1998-10-08	1999-06-29	34.0%	417 days
1999-07-14	1999-10-18	1999-12-03	18.0%	142 days
2000-01-25	2000-01-31	2000-02-07	6.0%	13 days
1998-04-22	1998-04-27	1998-05-08	4.0%	16 days
1999-12-31	2000-01-04	2000-01-07	4.0%	7 days



2.10.3 Gross Profit to Assets: Long-short portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	3.89%	0.42	46.2%	2.0x	1.20%
2000-2009	12.34%	1.3	14.9%	2.0x	1.22%
2010-2019	-2.25%	-0.08	41.2%	1.6x	0.98%
2019-2024	1.74%	0.21	35.5%	2.5x	1.46%
2021-2024	11.74%	0.93	9.5%	2.9x	1.67%
2023-2024	11.62%	1.7	5.9%	3.8x	2.30%

Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2010-12-14	2021-02-04	2024-12-31	46.0%	Ongoing
1998-05-07	2000-02-29	2000-10-18	36.0%	895 days
2003-11-10	2004-04-26	2005-01-31	12.0%	448 days
2008-12-02	2009-09-16	2009-10-29	9.0%	331 days
2006-10-16	2007-10-31	2008-02-19	8.0%	491 days
2009-11-25	2010-02-02	2010-04-27	6.0%	153 days



2.11 Return on Equity (Quality)

Return on Equity (ROE) is one of the big five factors from literature. It is often referred to as just *quality*, which is shorthand for *earnings quality*. Researchers believe that controlling for quality improves the performance of value strategies. It is calculated as follows.

$$\text{Shareholder's Equity} = \text{Assets} - \text{Liabilities}$$

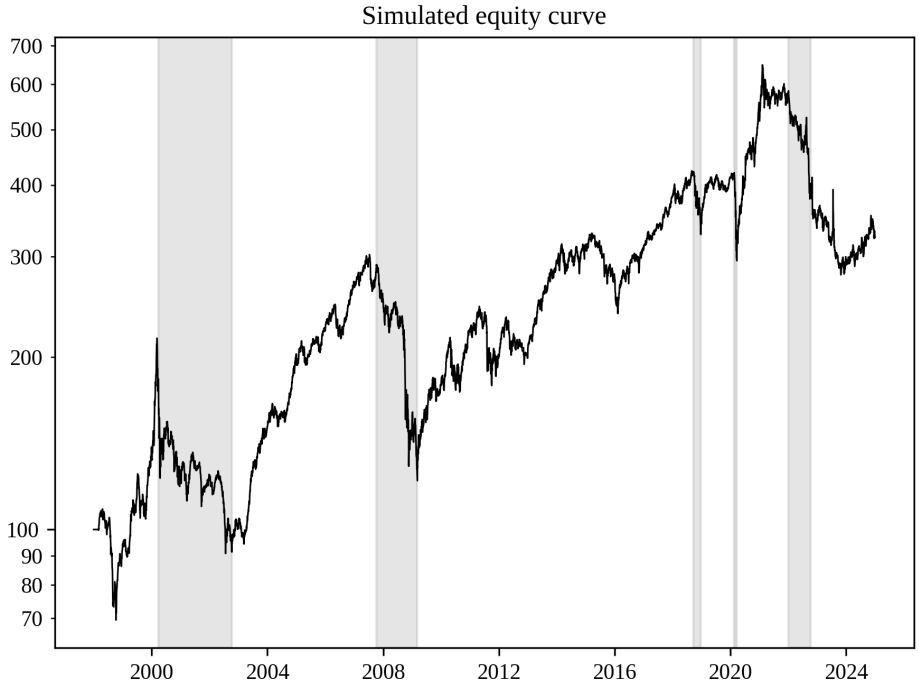
$$\text{Quality} = \frac{\text{Net Income}}{\text{Shareholder's Equity}}$$

In the following simulations, the long-only portfolio buys the 60 companies with the highest quality, and the short-only portfolio shorts the 60 companies with the lowest quality. The long-short strategy holds the top 30 companies from each strategy long and short, respectively.

2.11.1 Quality: Long-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	4.89%	0.39	59.7%	1.9x	1.00%
2000-2009	2.73%	0.37	59.7%	1.7x	0.94%
2010-2019	8.51%	0.67	27.6%	1.8x	0.88%
2019-2024	-1.13%	-0.03	57.0%	2.5x	1.28%
2021-2024	-11.07%	-0.15	57.0%	2.6x	1.35%
2023-2024	-3.33%	-0.85	29.0%	2.0x	1.10%

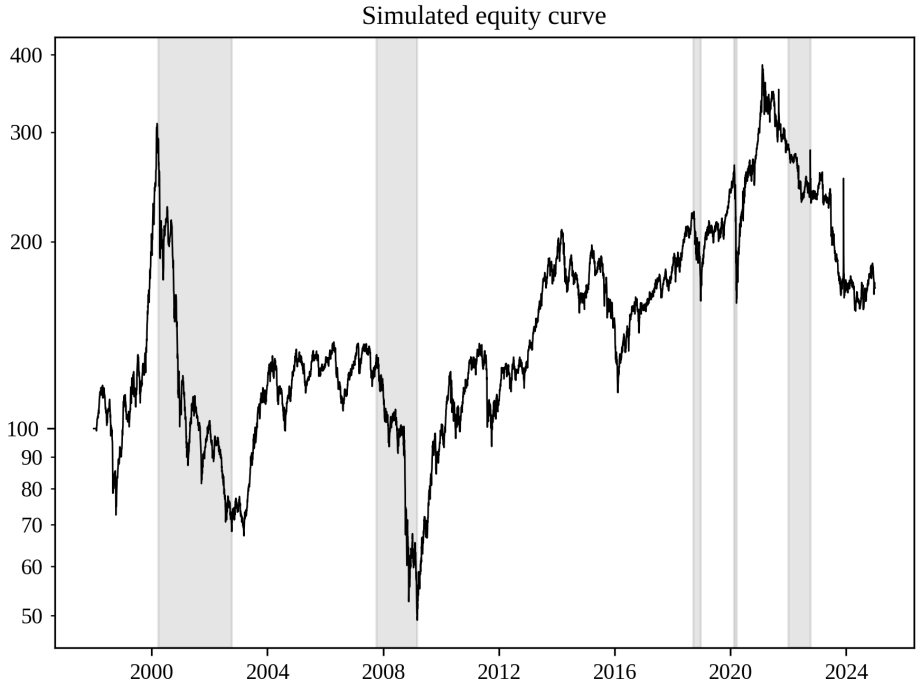
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-07-13	2009-03-09	2014-01-22	60.0%	2385 days
2000-03-09	2002-07-23	2005-09-07	58.0%	2008 days
2021-02-09	2023-10-27	2024-12-31	57.0%	Ongoing
1998-04-22	1998-10-08	1999-04-29	36.0%	372 days
2018-09-04	2020-03-23	2020-07-09	30.0%	674 days
2015-03-20	2016-02-11	2017-02-21	28.0%	704 days



2.11.2 Quality: Short-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	2.00%	0.28	84.1%	2.4x	1.36%
2000-2009	-7.03%	0.09	84.1%	2.5x	1.44%
2010-2019	9.29%	0.68	45.3%	2.1x	1.15%
2019-2024	-0.48%	0.01	59.8%	2.7x	1.46%
2021-2024	-13.43%	-0.18	59.8%	2.8x	1.54%
2023-2024	-15.87%	-0.52	40.3%	2.2x	1.27%

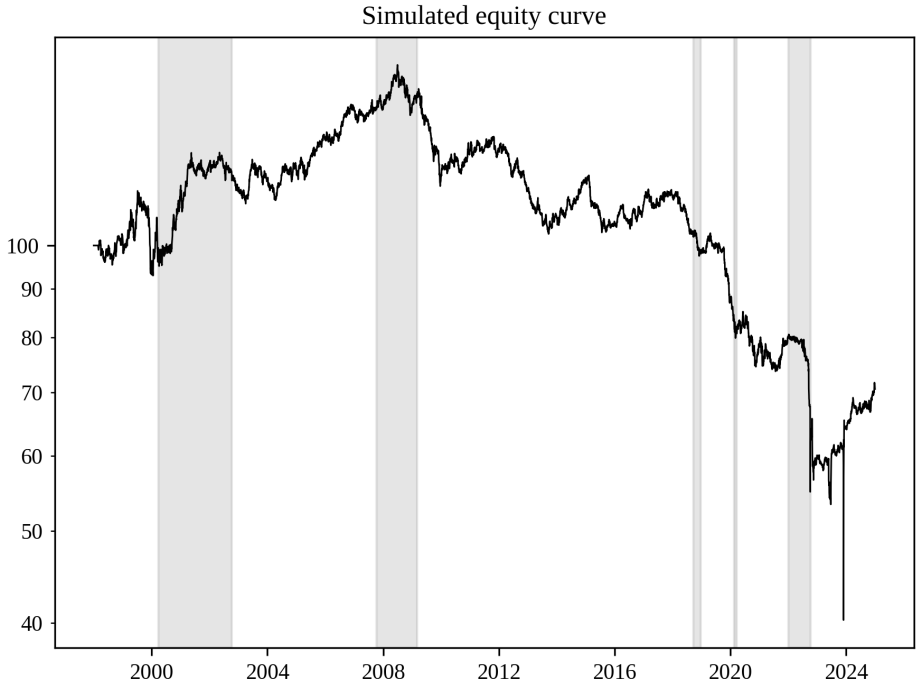
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2000-03-10	2009-03-09	2021-01-07	84.0%	7608 days
2021-02-08	2024-04-30	2024-12-31	60.0%	Ongoing
1998-04-22	1998-10-08	1999-04-26	38.0%	369 days
1999-07-12	1999-08-10	1999-10-11	16.0%	91 days
1999-05-20	1999-06-15	1999-07-02	12.0%	43 days
1999-12-31	2000-01-06	2000-01-13	8.0%	13 days



2.11.3 Quality: Long-short portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-1.36%	-0.08	74.0%	2.8x	1.48%
2000-2009	2.33%	0.35	25.5%	2.6x	1.46%
2010-2019	-2.99%	-0.46	33.2%	2.4x	1.27%
2019-2024	-5.40%	-0.27	60.9%	3.3x	1.73%
2021-2024	-2.52%	-0.12	50.0%	3.7x	1.88%
2023-2024	8.53%	-0.06	35.0%	3.2x	1.69%

Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2008-07-01	2023-11-29	2024-12-31	74.0%	Ongoing
1999-07-08	2000-01-19	2000-12-28	19.0%	539 days
2002-05-07	2003-04-03	2005-07-28	12.0%	1178 days
1999-04-13	1999-06-01	1999-07-01	7.0%	79 days
2001-01-03	2001-01-19	2001-03-05	6.0%	61 days
2001-05-16	2001-11-14	2002-05-07	6.0%	356 days



2.12 Size (Market capitalization)

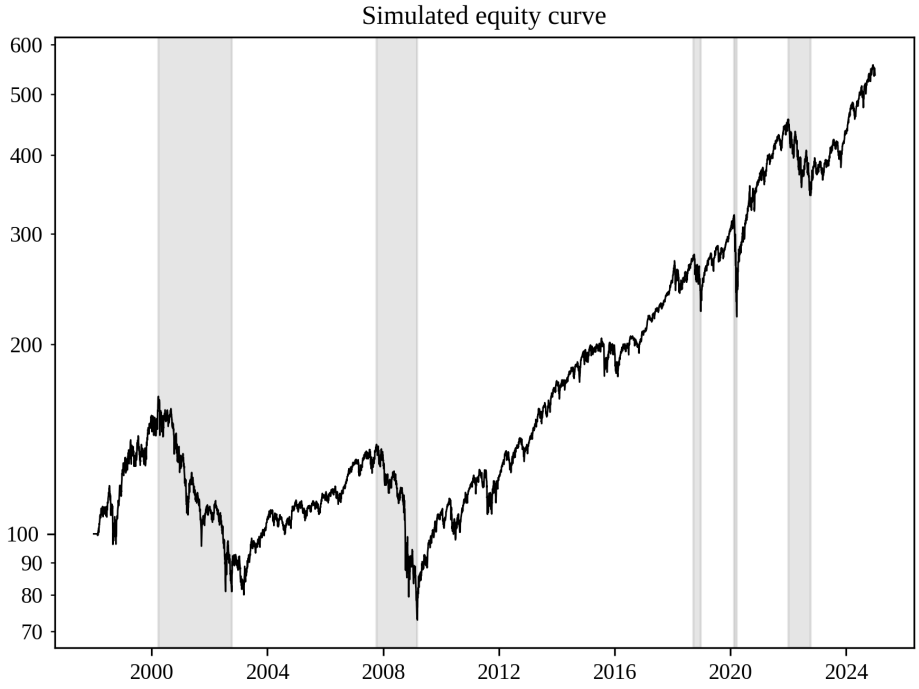
The size factor is measured as the market capitalization. It is one of the original three factors from Fama-French. It is traditionally believed that small market cap stocks outperform large market cap stocks because small businesses are more nimble and have more room to grow. Post-2008 data challenges this belief.

In the following simulations, we show the performance of portfolios constructed from the largest companies and the smallest companies. Unlike others in this book, the following simulations assume we do not know the sign of the underlying factor coefficient. The long-only portfolios buy the largest or smallest 60 stocks, and the long-short portfolios hold 30 stocks in each direction. There are no short-only portfolios presented because here because there is no theoretical justification for a short-only portfolio based on this factor.

2.12.1 Highest Market cap: Long-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	5.78%	0.41	55.9%	0.4x	0.10%
2000-2009	-3.56%	-0.12	55.9%	0.5x	0.13%
2010-2019	10.83%	0.85	18.8%	0.3x	0.08%
2019-2024	14.21%	0.66	31.1%	0.4x	0.09%
2021-2024	10.17%	0.91	24.3%	0.4x	0.10%
2023-2024	19.66%	1.15	9.7%	0.4x	0.12%

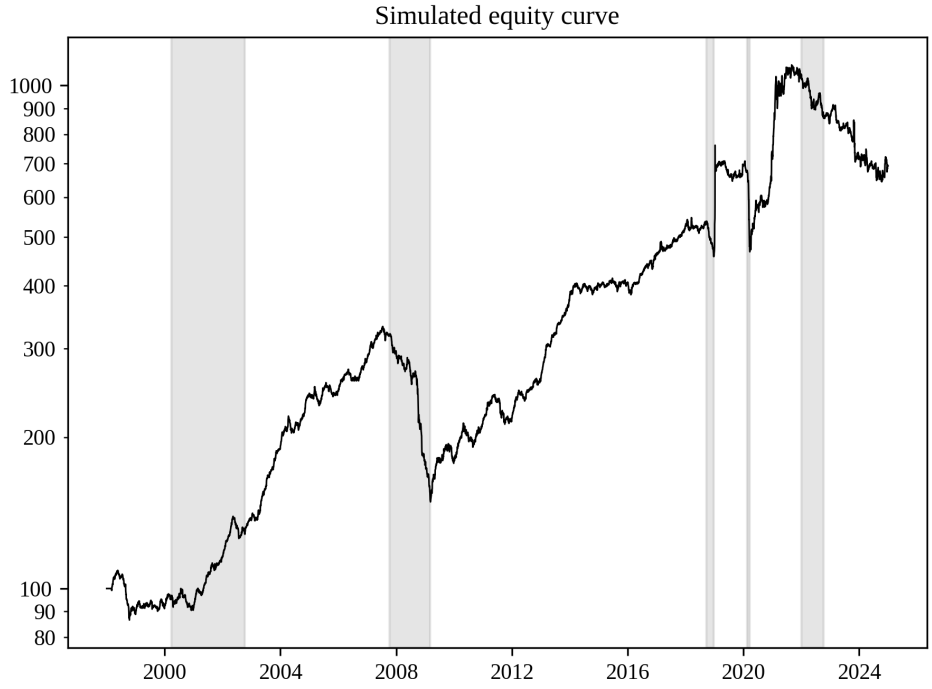
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2000-03-27	2009-03-09	2013-10-24	56.0%	4959 days
2020-02-19	2020-03-23	2020-07-22	31.0%	154 days
2022-01-03	2022-10-12	2024-01-30	24.0%	757 days
1998-07-17	1998-08-31	1998-11-27	19.0%	133 days
2018-10-01	2018-12-24	2019-04-26	19.0%	207 days
2015-07-20	2016-02-11	2016-07-14	13.0%	360 days



2.12.2 Lowest Market cap: Long-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	8.17%	0.79	55.2%	2.1x	1.59%
2000-2009	6.93%	1.01	55.2%	2.0x	1.56%
2010-2019	14.37%	1.17	16.3%	1.8x	1.34%
2019-2024	6.43%	0.44	41.4%	2.8x	2.06%
2021-2024	-0.78%	0.56	41.4%	2.9x	2.20%
2023-2024	-10.74%	-0.82	29.7%	3.0x	2.36%

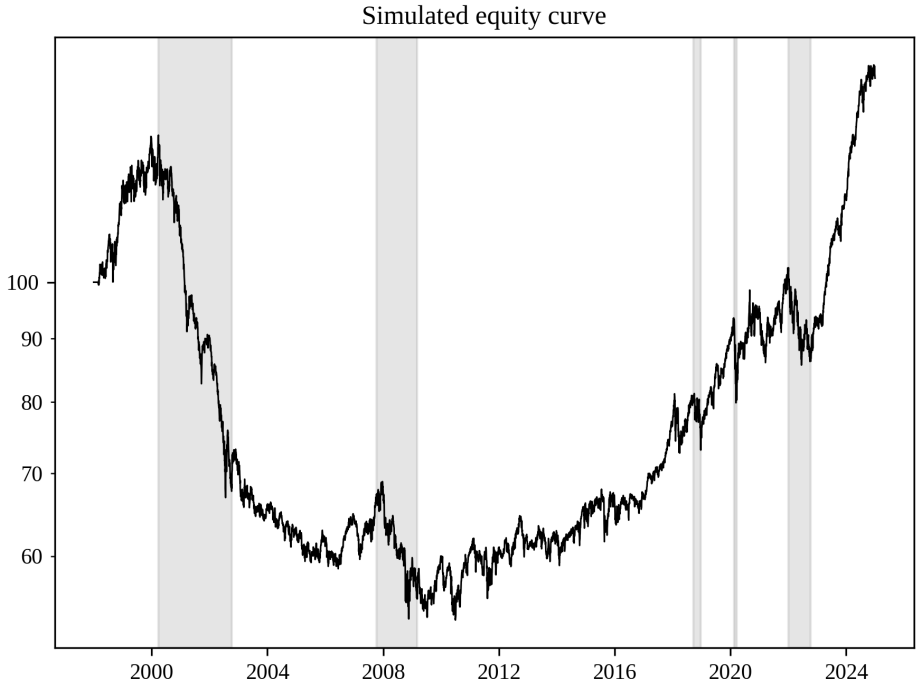
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-07-17	2009-03-10	2013-07-24	55.0%	2199 days
2021-09-02	2024-10-15	2024-12-31	41.0%	Ongoing
2019-01-09	2020-03-23	2021-01-08	39.0%	730 days
1998-05-21	1998-10-14	2001-08-07	20.0%	1174 days
2018-03-16	2018-12-24	2019-01-08	16.0%	298 days
2021-02-16	2021-03-05	2021-05-03	14.0%	76 days



2.12.3 Market cap: Long-short Highest-lowest

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	0.80%	0.14	59.5%	1.0x	0.63%
2000-2009	-7.49%	-0.57	59.4%	1.1x	0.72%
2010-2019	4.13%	0.4	11.2%	0.8x	0.47%
2019-2024	11.49%	0.81	16.6%	1.2x	0.67%
2021-2024	11.67%	1.03	16.6%	1.2x	0.70%
2023-2024	25.70%	2.48	5.9%	1.4x	0.83%

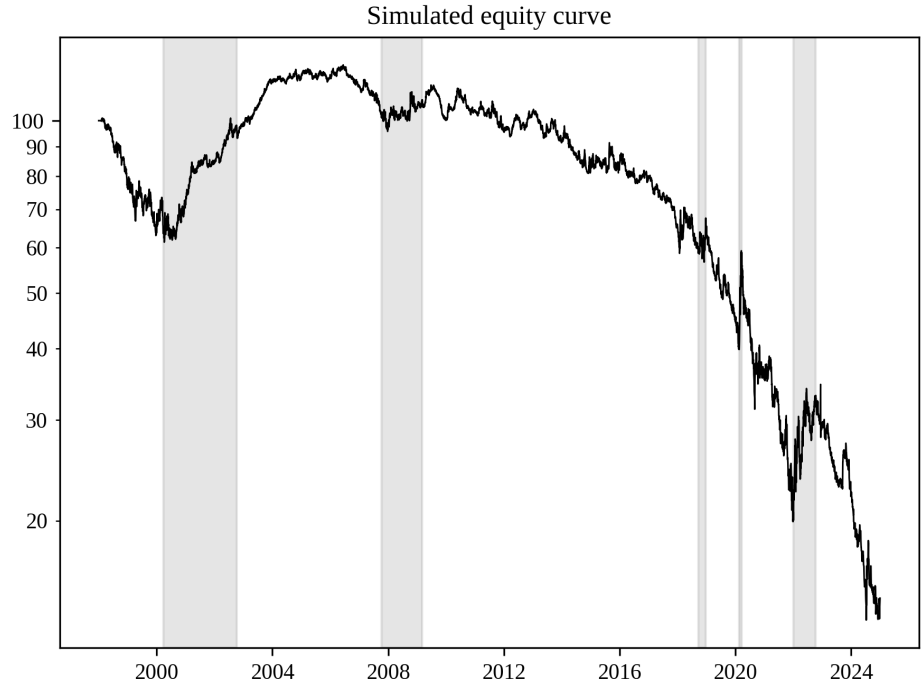
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2000-03-27	2010-07-02	2024-03-27	60.0%	8766 days
1999-12-23	2000-02-18	2000-03-24	9.0%	92 days
1998-07-20	1998-08-31	1998-11-02	9.0%	105 days
1999-04-26	1999-05-25	1999-07-15	6.0%	80 days
1999-04-09	1999-04-19	1999-04-26	6.0%	17 days
1999-08-25	1999-10-15	1999-12-03	6.0%	100 days



2.12.4 Market cap: Long-short Lowest-highest

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-6.19%	-0.25	89.3%	4.0x	2.46%
2000-2009	4.71%	0.39	23.5%	4.5x	2.77%
2010-2019	-7.64%	-0.48	60.6%	3.0x	1.85%
2019-2024	-21.59%	-0.52	79.5%	4.3x	2.65%
2021-2024	-20.16%	-0.52	65.4%	4.6x	2.81%
2023-2024	-29.50%	-0.83	55.4%	4.0x	2.61%

Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2006-06-13	2024-07-10	2024-12-31	89.0%	Ongoing
1998-02-17	2000-04-07	2003-01-27	39.0%	1805 days
2005-03-22	2005-11-25	2006-02-06	5.0%	321 days
2004-10-22	2004-11-12	2005-03-22	4.0%	151 days
2003-03-04	2003-03-21	2003-04-25	3.0%	52 days
2006-02-07	2006-03-20	2006-04-11	3.0%	63 days



2.13 Volatility

The volatility factor is measured as the trailing standard deviation of log returns on the underlying asset. The volatility factor is highly inversely correlated to the size factor because small cap stocks tend to be more volatile and large cap stocks tend to be less volatile.

Given a stock price, p_t at time t, volatility with a lookback window of k is measured as follows. We use a window length of $k = 252$ in our simulations to represent TTM volatility.

$$y_t = \log p_t$$

$$r_t = y_t - y_{t-1}$$

$$\bar{r_t} = \frac{1}{k}\sum_{i=0}^{k-1} r_{t-i}$$

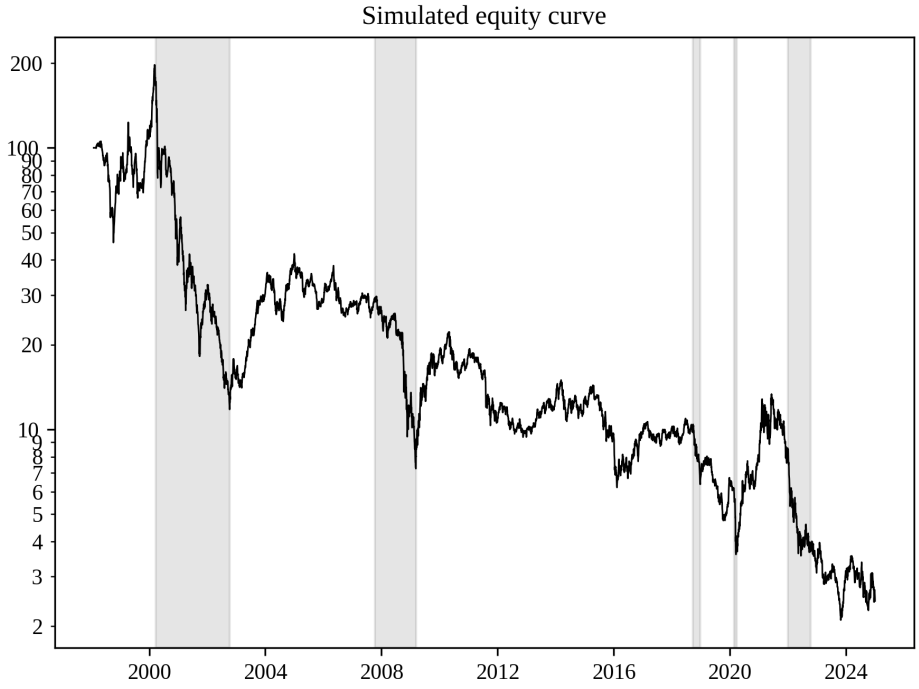
$$\sigma_t = \sqrt{\frac{\sum_{i=0}^{k-1}(r_{t-i} - \bar{r}_t)^2}{k-1}}$$

In the following simulations, we show the performance of portfolios constructed from the most and least volatile companies. Unlike others in this book, the following simulations assume we do not know the sign of the underlying factor coefficient. The long-only portfolios buy the most or least volatile 60 stocks, and the long-short portfolios hold 30 stocks in each direction. There are no short-only portfolios presented because here because there is no theoretical justification for a short-only portfolio based on this factor.

2.13.1 Highest volatility: Long-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-12.45%	-0.11	98.9%	3.0x	1.86%
2000-2009	-16.77%	-0.17	96.3%	3.1x	1.95%
2010-2019	-10.01%	-0.12	78.6%	2.8x	1.72%
2019-2024	-16.01%	-0.17	84.2%	3.1x	1.91%
2021-2024	-24.81%	-0.06	84.2%	3.0x	1.86%
2023-2024	-14.08%	-0.46	46.9%	3.1x	2.04%

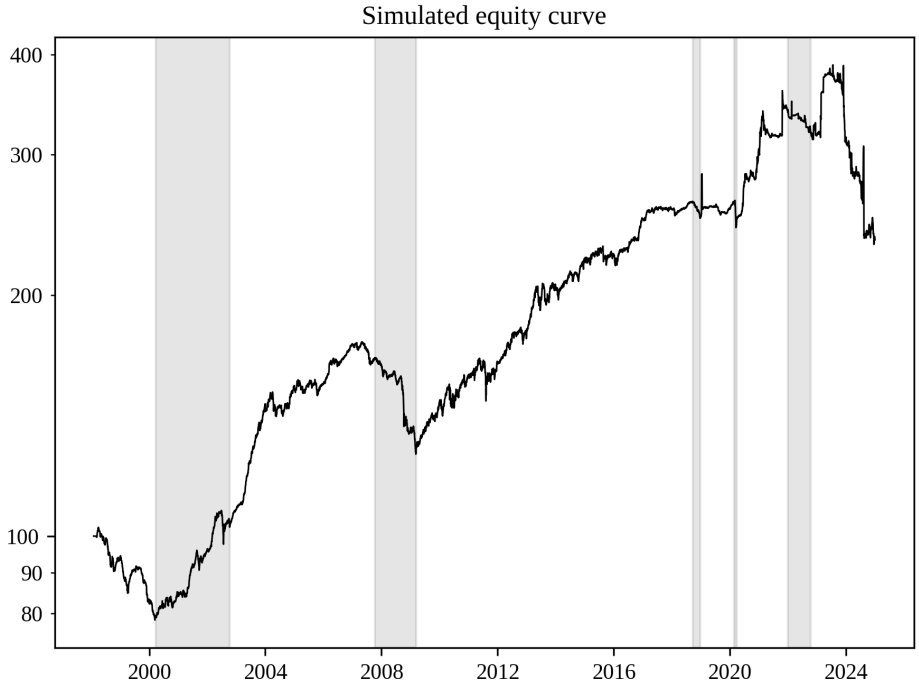
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2000-03-09	2023-10-27	2024-12-31	99.0%	Ongoing
1998-05-04	1998-10-08	1999-04-09	56.0%	340 days
1999-04-13	1999-08-10	2000-01-24	46.0%	286 days
2000-01-27	2000-01-31	2000-02-03	5.0%	7 days
1998-04-21	1998-04-27	1998-05-04	4.0%	13 days
2000-02-14	2000-02-16	2000-02-18	3.0%	4 days



2.13.2 Lowest volatility: Long-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	3.57%	0.5	40.4%	1.9x	1.04%
2000-2009	5.93%	0.9	27.6%	1.9x	1.11%
2010-2019	5.66%	0.88	11.5%	1.7x	0.88%
2019-2024	-1.11%	0.13	40.4%	1.9x	1.14%
2021-2024	-5.95%	0.09	40.4%	1.9x	1.11%
2023-2024	-14.13%	-0.32	40.4%	1.3x	0.79%

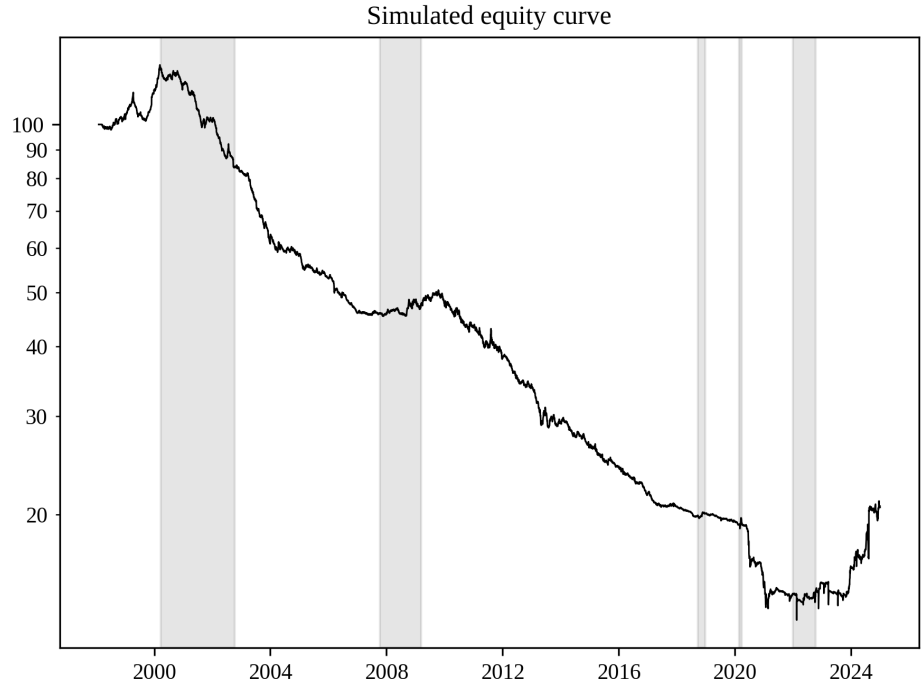
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2023-07-20	2024-12-18	2024-12-31	40.0%	Ongoing
2007-04-25	2009-03-09	2012-06-14	28.0%	1877 days
1998-04-02	2000-03-13	2002-03-27	23.0%	1455 days
2019-01-15	2020-03-18	2020-07-23	14.0%	555 days
2021-10-22	2022-11-10	2023-03-22	13.0%	516 days
2002-06-28	2002-07-24	2002-12-23	9.0%	178 days



2.13.3 Volatility: Long-short Highest-lowest

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-5.99%	-0.69	89.9%	2.4x	1.42%
2000-2009	-8.52%	-1.33	64.5%	2.3x	1.42%
2010-2019	-8.50%	-1.48	59.8%	2.1x	1.20%
2019-2024	0.42%	-0.05	35.7%	2.9x	1.72%
2021-2024	8.12%	0.13	14.6%	2.9x	1.70%
2023-2024	16.90%	0.69	13.2%	2.3x	1.30%

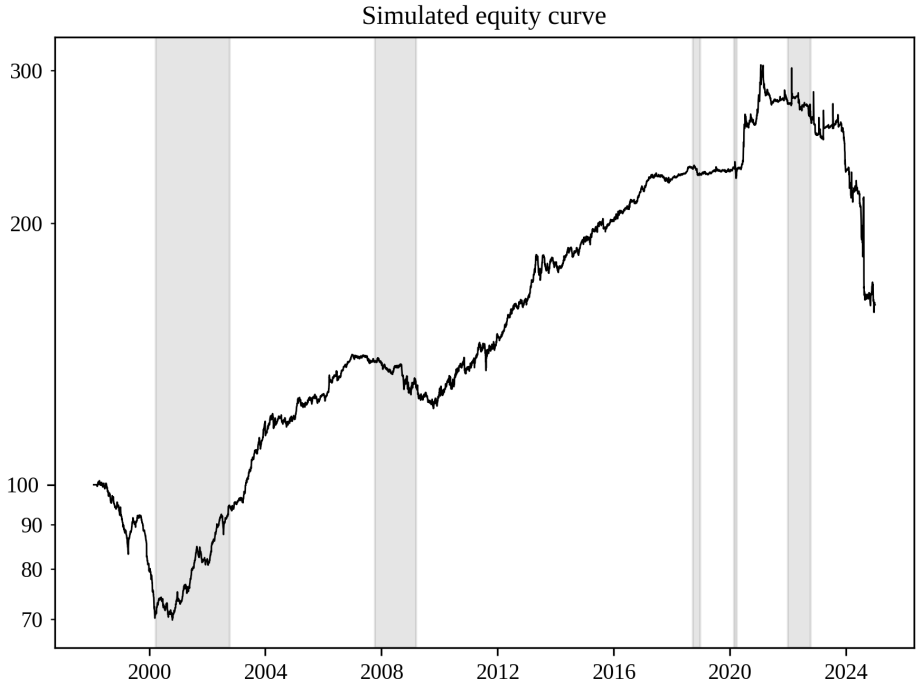
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2000-03-13	2022-02-17	2024-12-31	90.0%	Ongoing
1999-04-13	1999-09-16	1999-12-28	11.0%	259 days
1998-02-02	1998-07-07	1998-08-05	2.0%	184 days
1998-09-11	1998-09-23	1998-10-26	2.0%	45 days
1998-12-28	1999-01-05	1999-01-11	2.0%	14 days
1998-11-10	1998-11-24	1998-12-21	2.0%	41 days



2.13.4 Volatility: Long-short Lowest-highest

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	2.10%	0.39	48.1%	2.4x	1.39%
2000-2009	4.93%	0.85	13.3%	2.3x	1.39%
2010-2019	5.93%	1.2	7.1%	2.1x	1.17%
2019-2024	-5.60%	-0.11	48.1%	2.8x	1.68%
2021-2024	-12.74%	-0.26	48.1%	2.7x	1.65%
2023-2024	-20.23%	-0.66	42.5%	1.9x	1.21%

Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2021-01-25	2024-12-18	2024-12-31	48.0%	Ongoing
1998-04-15	2000-10-19	2003-05-08	31.0%	1849 days
2006-12-27	2009-10-16	2011-04-15	13.0%	1570 days
2011-05-19	2011-08-08	2011-11-11	7.0%	176 days
2013-04-30	2013-06-20	2014-05-16	7.0%	381 days
2020-03-04	2020-03-19	2020-06-10	4.0%	98 days



2.14 Momentum

Momentum is one of the big five factors from literature. It is the most popular traditional factor that uses solely price history data. The theory behind momentum states that momentum is persistent over approximately a year, but stocks have a negative auto-correlation on a monthly time horizon. Therefore, momentum is the difference between the price one month ago and the price one year ago. In our simulations, we use log prices and standardize momentum by volatility.

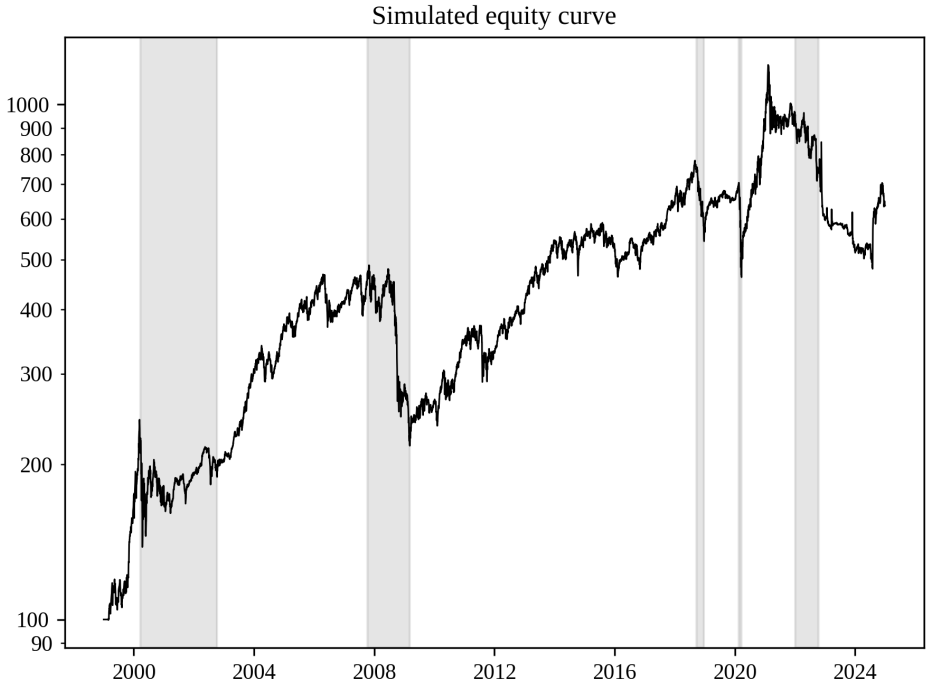
$$\text{Momentum}_t = \frac{y_{t-21} - y_{t-252}}{\sigma_{t-21}}$$

In the following simulations, the long-only portfolio buys the 60 companies with the highest momentum, and the short-only portfolio shorts the 60 companies with the lowest momentum. The long-short strategy holds the top 30 companies from each strategy long and short, respectively.

2.14.1 Highest Momentum: Long-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	7.38%	0.41	59.8%	5.2x	2.58%
2000-2009	4.15%	0.5	55.4%	5.2x	2.78%
2010-2019	9.43%	0.62	30.3%	5.4x	2.50%
2019-2024	1.69%	0.01	59.8%	5.2x	2.48%
2021-2024	-8.12%	0.01	59.8%	5.0x	2.34%
2023-2024	3.35%	-0.74	23.9%	4.0x	1.99%

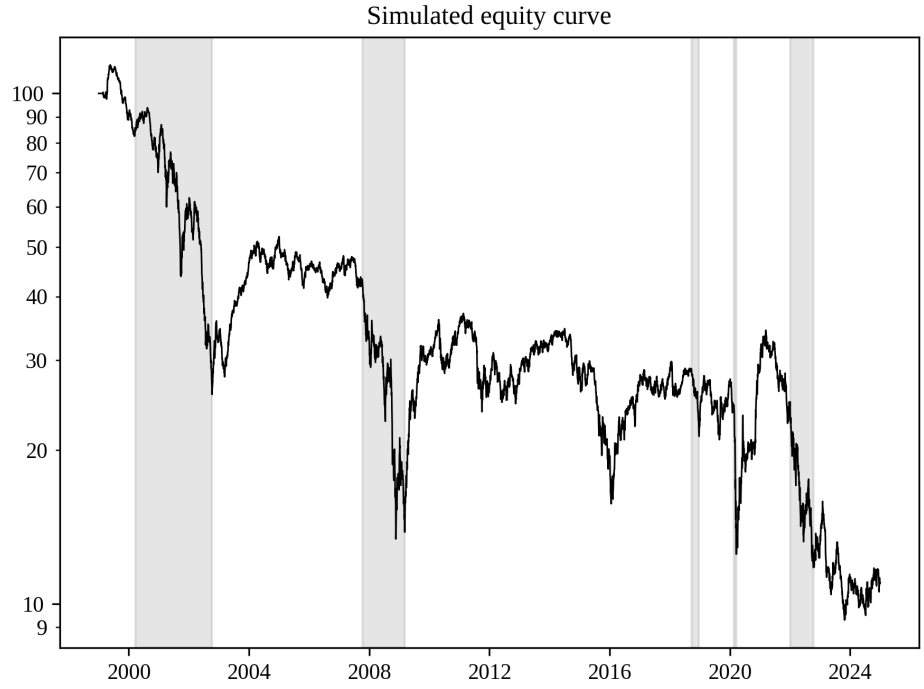
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2021-02-09	2024-08-02	2024-12-31	60.0%	Ongoing
2007-10-29	2009-03-09	2013-08-01	55.0%	2103 days
2000-03-10	2000-04-14	2003-08-21	43.0%	1259 days
2018-09-04	2020-03-23	2020-10-09	41.0%	766 days
2015-08-05	2016-02-09	2017-07-26	21.0%	721 days
2006-04-19	2006-06-13	2007-10-10	21.0%	539 days



2.14.2 Lowest Momentum: Long-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-8.14%	-0.18	91.8%	5.9x	3.31%
2000-2009	-10.31%	-0.38	85.7%	6.1x	3.56%
2010-2019	-1.49%	0.14	57.6%	5.8x	3.13%
2019-2024	-11.62%	-0.27	72.9%	6.1x	3.27%
2021-2024	-21.51%	-0.26	72.9%	6.0x	3.22%
2023-2024	-8.36%	-0.68	41.4%	5.6x	3.09%

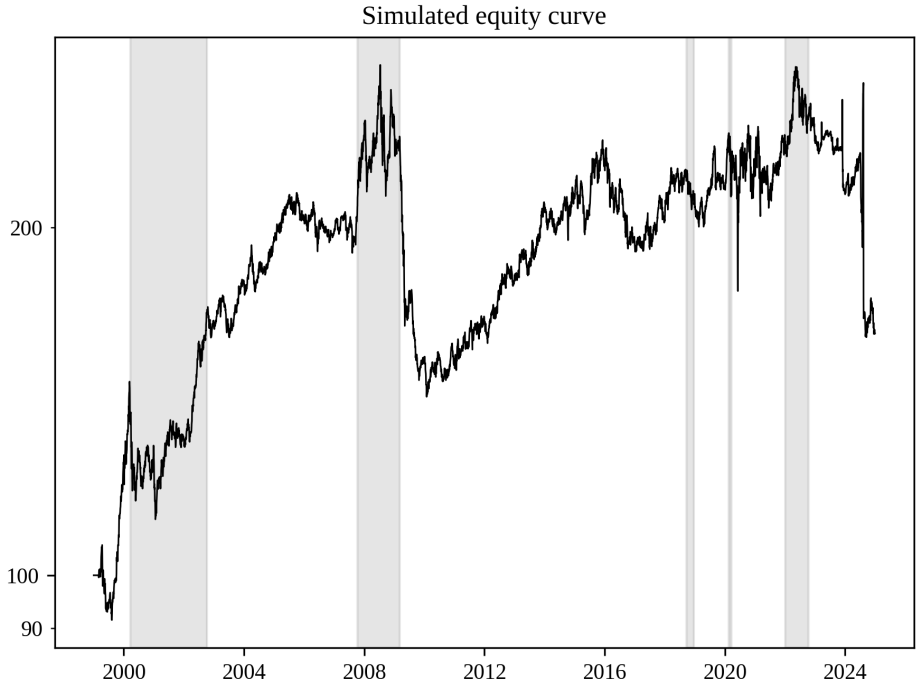
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
1999-05-21	2023-10-27	2024-12-31	92.0%	Ongoing
1999-03-29	1999-04-07	1999-04-14	3.0%	16 days
1999-02-23	1999-03-23	1999-03-29	2.0%	34 days
1999-05-11	1999-05-18	1999-05-21	1.0%	10 days
1999-04-19	1999-04-20	1999-04-21	1.0%	2 days
1998-12-31	1999-02-18	1999-02-19	0.0%	50 days



2.14.3 Momentum: Long-short highest-lowest portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	1.87%	0.23	48.4%	5.9x	3.10%
2000-2009	1.88%	0.6	46.7%	6.0x	3.43%
2010-2019	3.51%	0.24	19.9%	5.9x	2.93%
2019-2024	-4.22%	-0.04	41.7%	5.9x	2.96%
2021-2024	-7.82%	-0.08	41.7%	5.7x	2.84%
2023-2024	-17.58%	-0.29	39.8%	4.6x	2.46%

Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2008-07-14	2010-01-29	2024-12-31	48.0%	Ongoing
2000-03-10	2001-01-19	2002-05-29	24.0%	810 days
1999-04-13	1999-08-09	1999-10-25	14.0%	195 days
2008-01-14	2008-02-01	2008-06-09	13.0%	147 days
2005-10-03	2007-08-09	2007-10-16	11.0%	743 days
2004-04-01	2004-05-17	2004-12-20	9.0%	263 days



Chapter 3

Technical strategies

This chapter will detail the most popular technical indicator strategies and their simulated historical performance.

3.1 The Relative Strength Index (RSI)

The Relative Strength Index (RSI) is a popular oscillator bounded between zero and one hundred. When the RSI is below 30, it is a bullish reversal signal. When the RSI is above 70, it is a bearish reversal signal. In our simulations, we use these bullish and bearish signals as entry and exit signals in a logical way to achieve long-only, short-only, and long-short strategies.

Given the stock price p_t, the RSI_t is calculated as follows.

$$y_t = \log p_t$$

$$r_t = y_t - y_{t-1}$$

$$r_t^+ = \begin{cases} r_{t-i} & \text{for } r_t > 0 \\ 0 & \text{for } r_t \leq 0 \end{cases}$$

$$r_t^- = \begin{cases} r_{t-i} & \text{for } r_t < 0 \\ 0 & \text{for } r_t \geq 0 \end{cases}$$

$$G_t = \sum_{i=0}^{k} r_{t-k}^+$$

$$L_t = \sum_{i=0}^{k} r_{t-k}^-$$

$$\bar{G_t} = \frac{1}{n} G_t + \frac{n-1}{n} \bar{G}_{t-1}$$

$$\bar{L_t} = \frac{1}{n} L_t + \frac{n-1}{n} \bar{L}_{t-1}$$

$$\mathrm{RS}_t = \bar{G_t} / \bar{L_t}$$

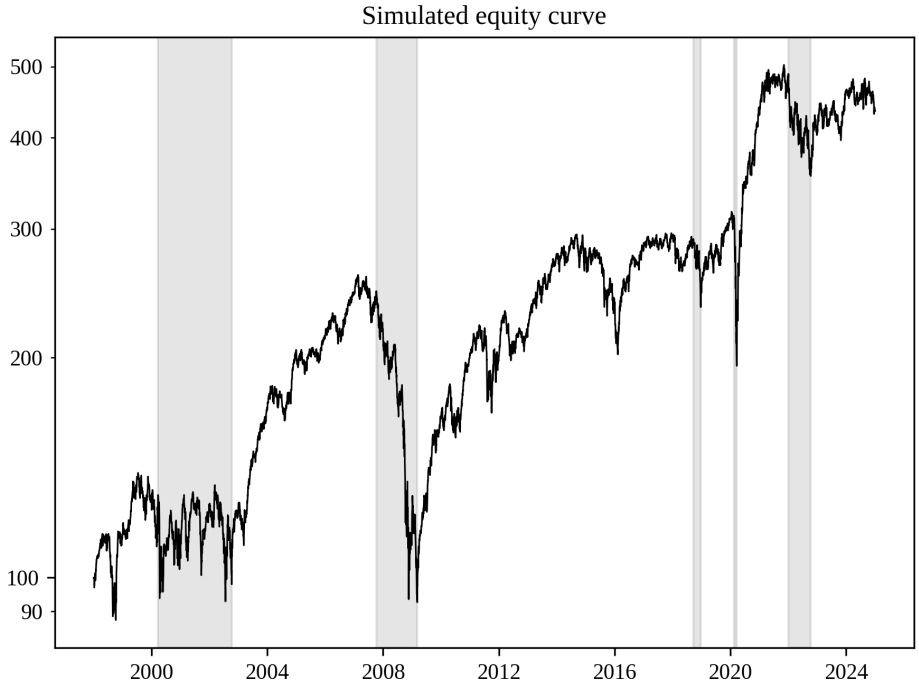
$$\mathrm{RSI}_t = 100 - \frac{100}{(1 + \mathrm{RS}_t)}$$

In our simulation, we use a window length of $k = 21$.

3.1.1 RSI: Long-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	5.24%	0.39	64.3%	12.4x	4.45%
2000-2009	2.66%	0.13	64.3%	12.3x	4.68%
2010-2019	6.40%	0.57	31.5%	12.4x	4.39%
2019-2024	9.70%	0.53	38.4%	12.4x	4.10%
2021-2024	0.35%	0.62	29.5%	12.2x	3.80%
2023-2024	3.64%	0.44	11.7%	12.0x	3.77%

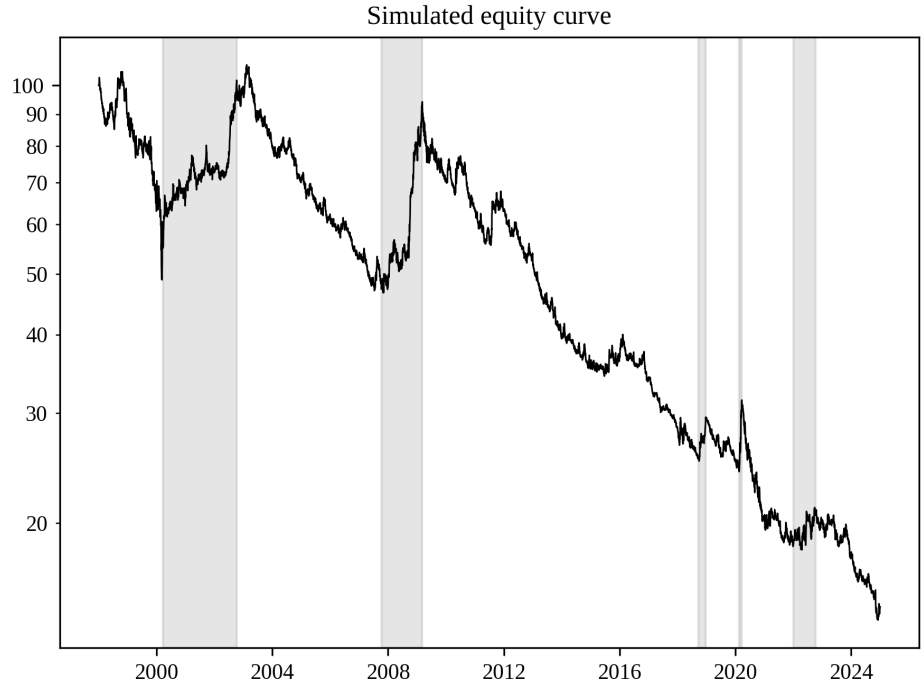
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-02-20	2009-03-09	2013-08-02	64.0%	2355 days
2020-01-17	2020-03-23	2020-05-27	38.0%	131 days
1999-07-16	2002-07-23	2003-05-30	33.0%	1414 days
2014-09-11	2016-02-11	2017-10-04	31.0%	1119 days
2021-11-08	2022-10-12	2024-12-31	30.0%	Ongoing
1998-07-08	1998-10-08	1998-11-05	24.0%	120 days



3.1.2 RSI: Short-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-6.72%	-0.35	87.0%	11.9x	3.94%
2000-2009	1.17%	0.13	56.7%	12.0x	4.34%
2010-2019	-9.72%	-0.81	67.4%	11.8x	3.79%
2019-2024	-10.87%	-0.54	55.4%	11.8x	3.43%
2021-2024	-8.13%	-0.71	33.8%	11.7x	3.27%
2023-2024	-14.79%	-0.8	32.3%	11.4x	3.06%

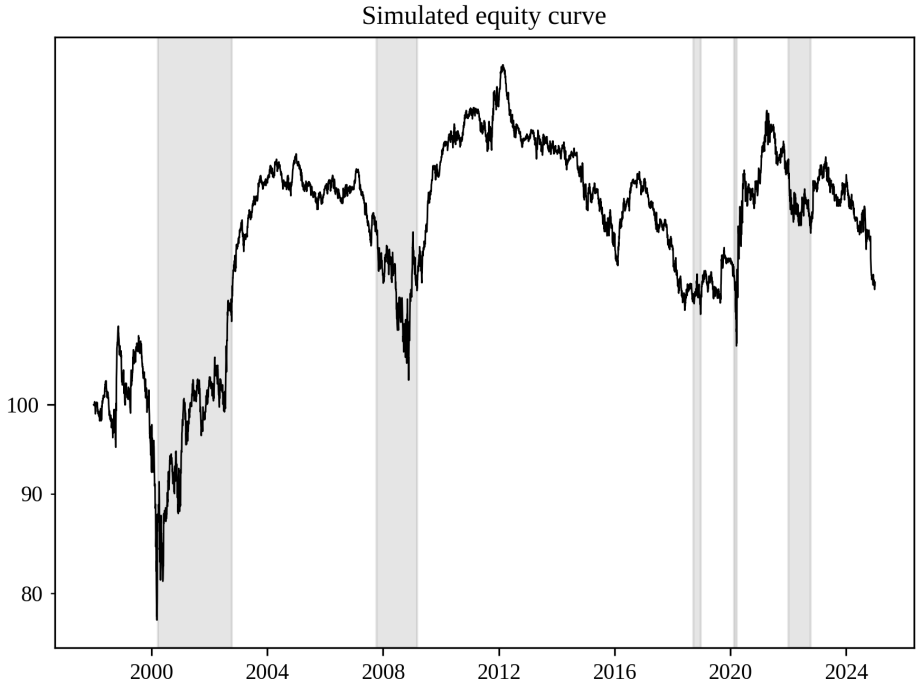
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2003-02-13	2024-12-06	2024-12-31	87.0%	Ongoing
1998-10-27	2000-03-10	2003-02-05	53.0%	1562 days
1998-01-09	1998-07-17	1998-10-09	17.0%	273 days
1998-10-12	1998-10-15	1998-10-27	4.0%	15 days
2003-02-07	2003-02-10	2003-02-12	1.0%	5 days
1998-01-02	1998-01-05	1998-01-06	0.0%	4 days



3.1.3 RSI: Long-short portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	0.41%	0.15	28.6%	12.1x	4.20%
2000-2009	3.75%	0.27	23.5%	12.2x	4.52%
2010-2019	-1.15%	-0.1	25.5%	12.1x	4.10%
2019-2024	0.18%	0.18	19.1%	12.1x	3.77%
2021-2024	-3.16%	0.01	19.1%	12.0x	3.54%
2023-2024	-5.34%	-0.2	14.5%	11.7x	3.43%

Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
1998-11-09	2000-03-10	2002-08-15	29.0%	1375 days
2012-02-23	2020-03-18	2024-12-31	28.0%	Ongoing
2004-12-31	2008-11-20	2010-01-12	23.0%	1838 days
1998-06-08	1998-10-08	1998-10-16	8.0%	130 days
2011-02-22	2011-08-10	2011-10-27	5.0%	247 days
2004-04-28	2004-10-25	2004-12-14	4.0%	230 days



3.2 Moving Average Convergence Divergence Oscillator (MACD)

The Moving Average Convergence Divergence Oscillator (MACD) is a simple oscillator based on the difference between two moving averages of different lengths. When the MACD crosses zero from below, it is a bullish signal. When it crosses zero from above, it is a bearish signal. In our simulations, we use these bullish and bearish crosses as entry and exit signals in a logical way to achieve long-only, short-only, and long-short strategies.

Given the stock price p_t, the $MACD_t$ is calculated as follows.

$$y_t = \log p_t$$

$$SMA_{t,k} = \frac{1}{k} \sum_{i=0}^{k-1} y_{t-i}$$

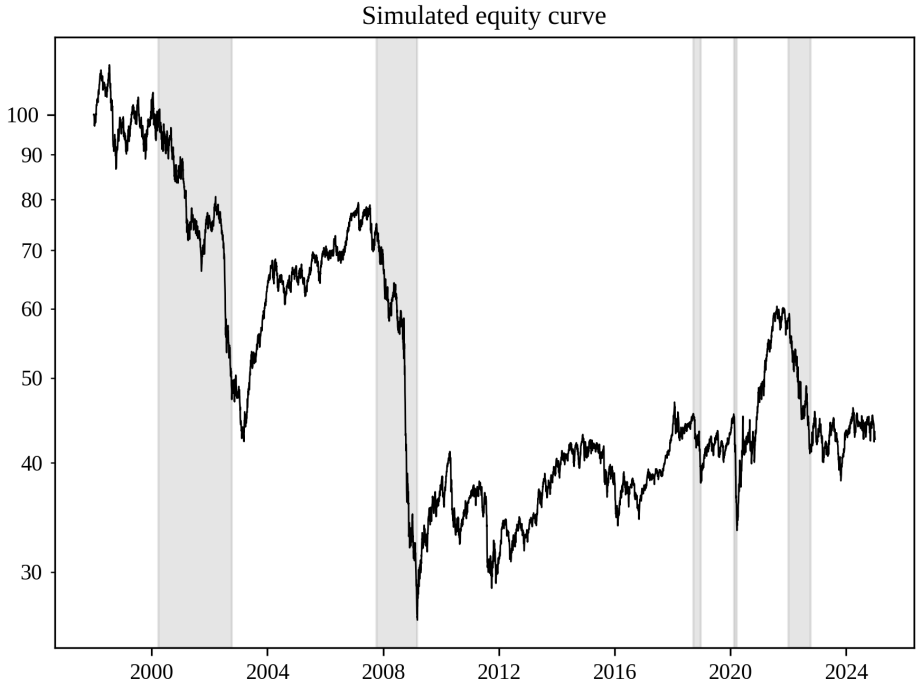
$$\text{MACD}_t = SMA_{t,k_1} - SMA_{t,k_2}$$

In our simulation, we use moving averages with $k_1 = 12$ and $k_2 = 26$.

3.2.1 MACD: Long-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-3.15%	-0.09	75.1%	17.7x	6.53%
2000-2009	-9.57%	-0.43	75.1%	17.7x	6.89%
2010-2019	1.35%	0.23	30.2%	17.5x	6.38%
2019-2024	1.50%	0.11	36.8%	17.8x	5.99%
2021-2024	-2.40%	0.25	36.8%	18.0x	5.95%
2023-2024	0.38%	-0.27	15.3%	18.0x	5.86%

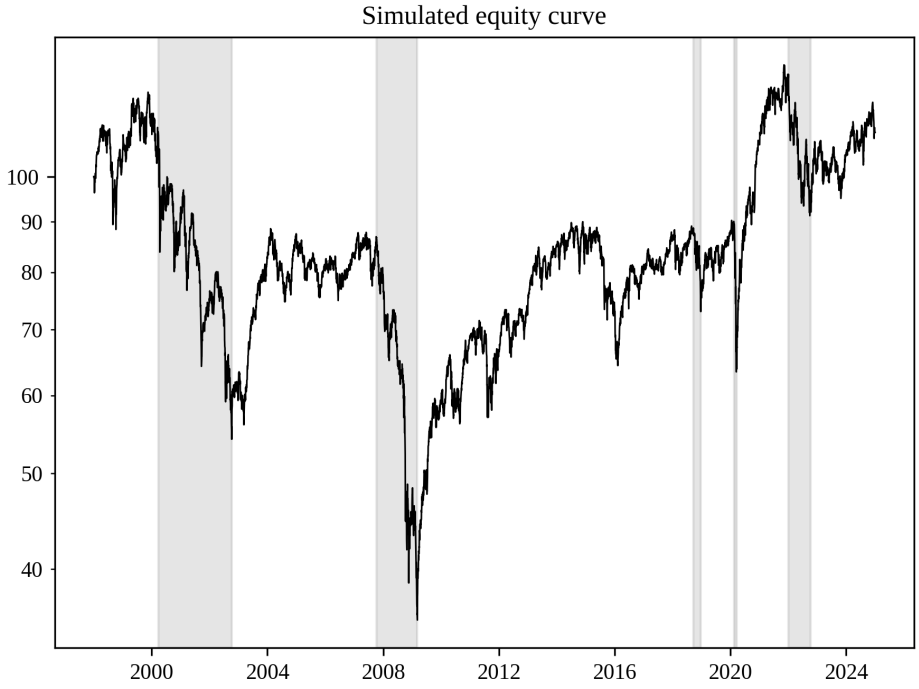
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
1998-07-17	2009-03-09	2024-12-31	77.0%	Ongoing
1998-04-02	1998-06-15	1998-07-14	7.0%	103 days
1998-01-05	1998-01-12	1998-01-29	3.0%	24 days
1998-03-03	1998-03-05	1998-03-09	1.0%	6 days
1998-03-24	1998-03-30	1998-04-01	1.0%	8 days
1998-02-18	1998-02-24	1998-02-25	1.0%	7 days



3.2.2 MACD: Short-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	0.12%	0.1	70.8%	19.4x	7.15%
2000-2009	-6.41%	-0.29	69.4%	19.3x	7.47%
2010-2019	3.91%	0.41	28.5%	19.6x	7.19%
2019-2024	6.36%	0.33	29.8%	19.6x	6.53%
2021-2024	0.72%	0.45	29.7%	19.1x	6.18%
2023-2024	4.34%	0.24	12.6%	18.9x	6.06%

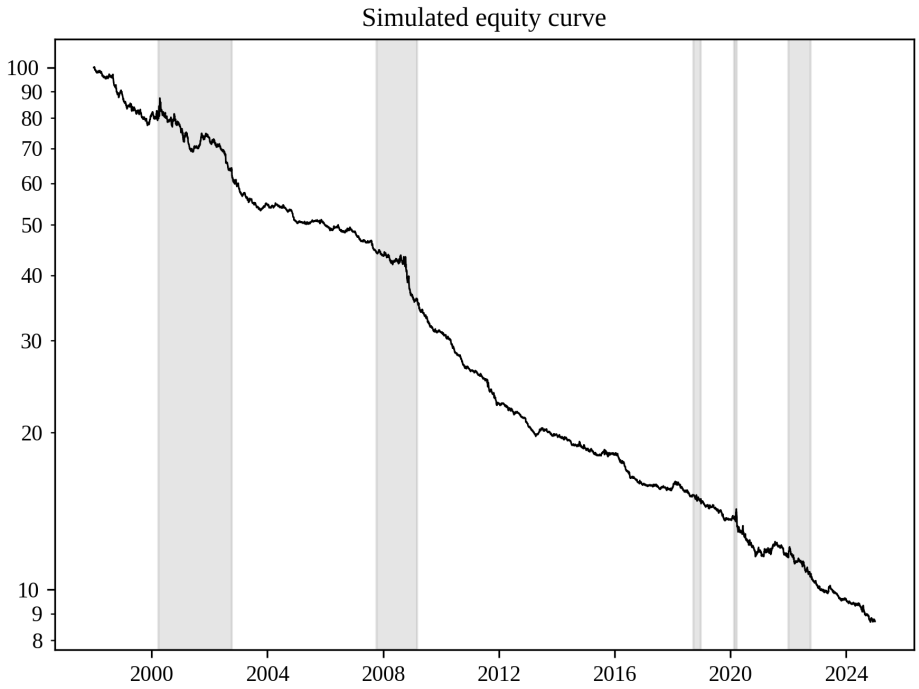
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
1999-11-17	2009-03-09	2021-04-28	71.0%	7833 days
2021-11-08	2022-09-30	2024-12-31	30.0%	Ongoing
1998-04-17	1998-10-08	1999-04-21	22.0%	369 days
1999-07-15	1999-10-18	1999-11-15	10.0%	123 days
2021-05-28	2021-07-19	2021-10-20	6.0%	145 days
1999-05-13	1999-05-25	1999-07-15	5.0%	63 days



3.2.3 MACD: Long-short portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-8.50%	-1.57	90.1%	18.2x	6.73%
2000-2009	-9.15%	-1.4	64.5%	18.1x	7.05%
2010-2019	-7.93%	-2.1	56.5%	18.2x	6.70%
2019-2024	-8.46%	-1.33	41.3%	18.3x	6.16%
2021-2024	-7.39%	-1.45	29.9%	18.2x	5.96%
2023-2024	-7.65%	-2.13	14.9%	18.1x	5.88%

Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
1998-01-09	2024-11-04	2024-12-31	91.0%	Ongoing
1998-01-05	1998-01-07	1998-01-09	0.0%	4 days
1997-12-31	1998-01-02	1998-01-05	0.0%	5 days



3.3 Bollinger Bands

Bollinger Bands are a day-trading system with many nuances and interpretations. In our simulations, we will be calculating the Bollinger Z-score and using it as a reversal signal. When the Bollinger Z-score is below -2, it is a bullish reversal. When it is above +2, it is a bearish reversal. We use these bullish and bearish reversals as entry and exit signals in a logical way to achieve long-only, short-only, and long-short strategies.

Given the stock price p_t and a lookback window k, the Bollinger Z-score is calculated as follows. We use a lookback window of $k = 20$ in our simulations.

$$y_t = \log p_t$$

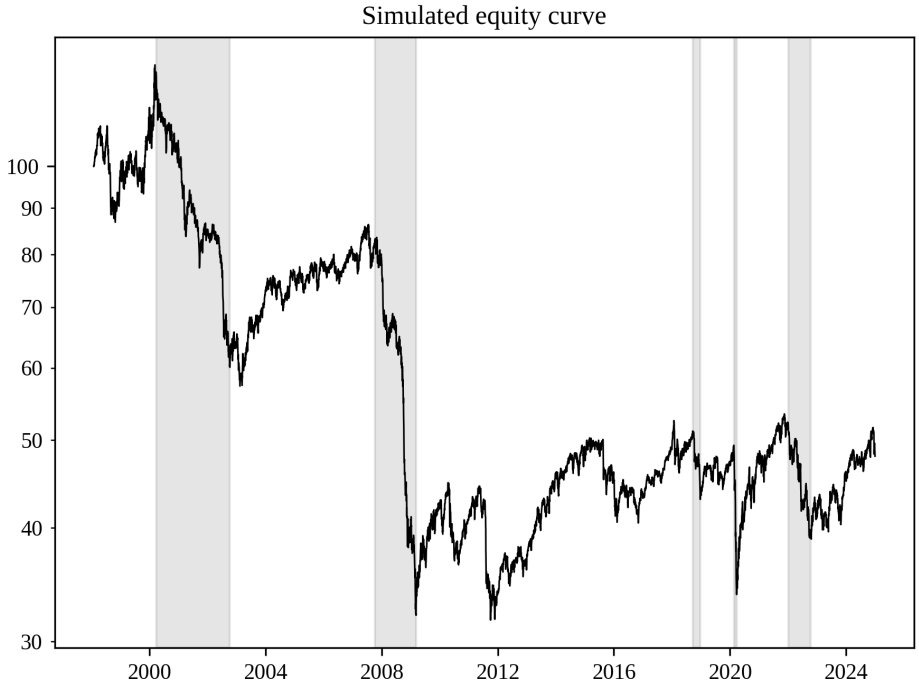
$$\text{Bandwidth}_{t,k} = \sqrt{\frac{\sum_{i=0}^{k-1} (y_{t-i} - \text{SMA}_{t,k})^2}{k-1}}$$

$$\text{Bollinger Z}_{t,k} = \frac{y_t - \text{SMA}_{t,k}}{\text{Bandwidth}_{t,k}}$$

3.3.1 Bollinger: Long-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-2.70%	-0.1	75.5%	12.8x	4.16%
2000-2009	-9.59%	-0.44	75.2%	12.8x	4.43%
2010-2019	0.99%	0.19	29.4%	12.9x	4.11%
2019-2024	1.50%	0.04	31.5%	12.9x	3.74%
2021-2024	0.51%	0.27	27.2%	12.8x	3.57%
2023-2024	8.00%	0.39	9.7%	12.7x	3.41%

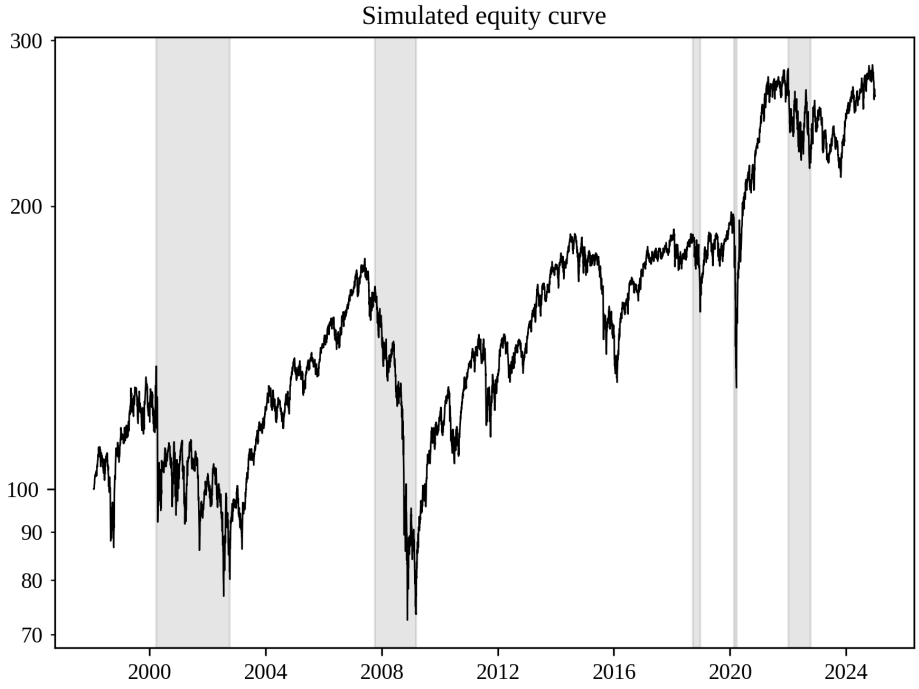
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2000-03-10	2011-10-03	2024-12-31	76.0%	Ongoing
1998-07-17	1998-10-28	1999-12-21	22.0%	522 days
1999-12-31	2000-01-28	2000-02-24	10.0%	55 days
1998-04-22	1998-06-15	1998-07-17	9.0%	86 days
2000-03-06	2000-03-07	2000-03-09	2.0%	3 days
1998-04-03	1998-04-08	1998-04-15	2.0%	12 days



3.3.2 Bollinger: Short-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	3.26%	0.26	58.7%	13.1x	4.39%
2000-2009	-0.28%	-0	58.7%	13.0x	4.60%
2010-2019	4.82%	0.47	30.5%	13.1x	4.37%
2019-2024	8.15%	0.41	34.9%	13.2x	4.02%
2021-2024	2.87%	0.55	23.3%	13.0x	3.80%
2023-2024	3.99%	0.37	15.7%	12.9x	3.77%

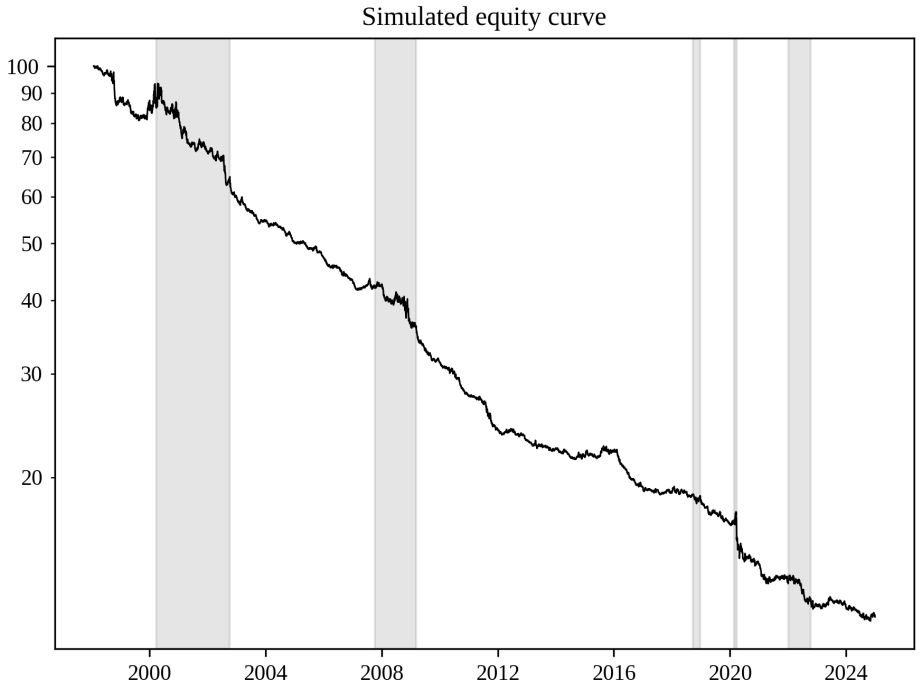
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-06-04	2008-11-20	2014-03-04	59.0%	2465 days
2000-03-27	2002-07-23	2004-12-13	43.0%	1722 days
2020-01-17	2020-03-23	2020-06-05	35.0%	140 days
2014-08-27	2016-02-11	2018-01-22	30.0%	1244 days
2022-01-03	2023-10-27	2024-10-15	23.0%	1016 days
1998-04-15	1998-10-08	1998-11-25	22.0%	224 days



3.3.3 Bollinger: Long-short portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-7.48%	-1.25	87.8%	12.9x	4.27%
2000-2009	-9.76%	-1.2	66.5%	12.8x	4.50%
2010-2019	-6.13%	-1.58	46.9%	12.9x	4.24%
2019-2024	-7.29%	-1.11	37.7%	12.9x	3.87%
2021-2024	-4.94%	-1.09	19.7%	12.8x	3.66%
2023-2024	-2.14%	-0.92	9.0%	12.7x	3.57%

Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
1998-02-03	2024-11-04	2024-12-31	89.0%	Ongoing
1998-01-29	1998-02-02	1998-02-03	0.0%	5 days



3.4 Aroon Oscillator

The Aroon Oscillator is theorized to represent the strength of a trend in the price history of a stock. It consists of two indicators, the Aroon-Up and the Aroon-Down, each bounded between -100 and +100. It produces a bullish signal when the Aroon-Up crosses above the Aroon-Down, and it produces a bearish signal when the Aroon-Down crosses above the Aroon-Up. In our simulations, we use the bullish and bearish crosses as entry and exit signals in a logical way to achieve long-only, short-only, and long-short strategies.

Given a vector of closing prices represented as $p(t)$, the Aroon Oscillator is calculated as follows.

$$\text{Days since high}_t = t - \underset{t-k<i\leq t}{\text{argmax}}(p(i))$$

$$\text{Days since low}_t = t - \underset{t-k<i\leq t}{\text{argmin}}(p(i))$$

$$\text{Aroon}_t^+ = 100 \times \left(1 - \frac{\text{Days since high}_t}{k}\right)$$

$$\text{Aroon}_t^- = 100 \times \left(1 - \frac{\text{Days since low}_t}{k}\right)$$

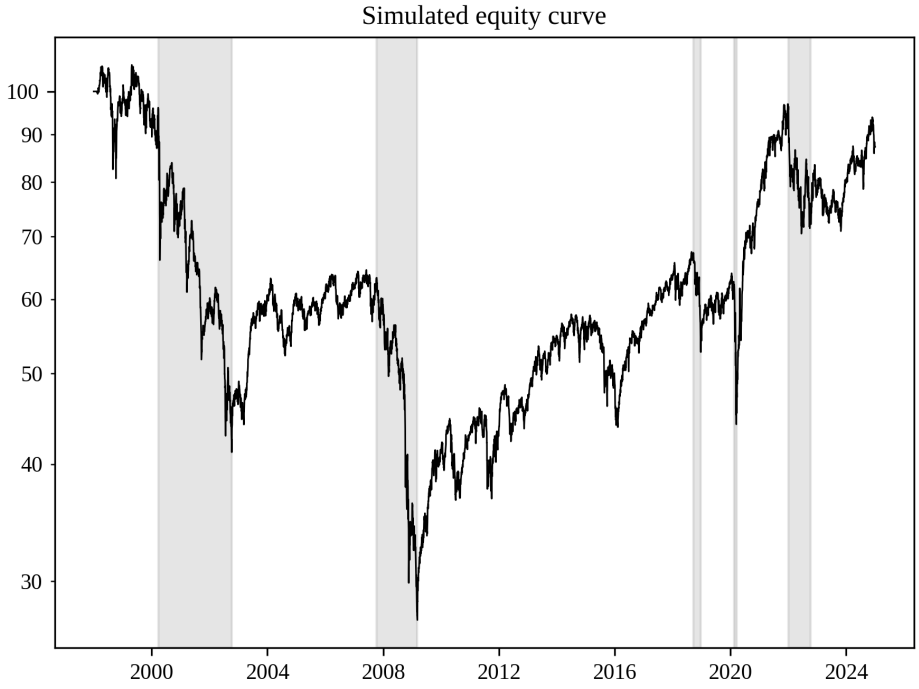
$$\text{Aroon Oscillator}_t = \text{Aroon}_t^+ - \text{Aroon}_t^-$$

In our simulations, we set $k = 25$.

3.4.1 Aroon: Long-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-0.47%	0.05	74.5%	17.8x	6.26%
2000-2009	-7.77%	-0.4	71.6%	17.6x	6.53%
2010-2019	4.17%	0.41	24.2%	18.0x	6.32%
2019-2024	7.85%	0.36	31.0%	17.9x	5.71%
2021-2024	3.61%	0.55	27.3%	17.5x	5.33%
2023-2024	5.72%	0.35	12.3%	17.5x	5.29%

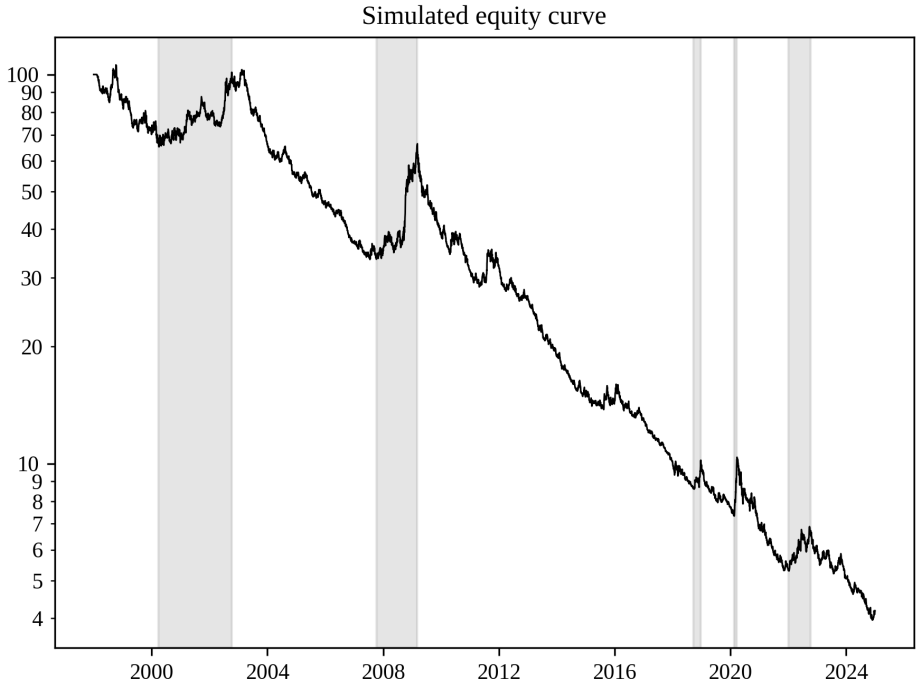
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
1999-04-26	2009-03-09	2024-12-31	74.0%	Ongoing
1998-04-15	1998-10-08	1999-04-26	24.0%	376 days
1998-04-02	1998-04-08	1998-04-15	2.0%	13 days
1998-02-26	1998-03-05	1998-03-06	1.0%	8 days
1998-03-26	1998-03-30	1998-03-31	1.0%	5 days
1997-12-31	1998-02-19	1998-02-25	1.0%	56 days



3.4.2 Aroon: Short-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-10.89%	-0.61	96.2%	16.6x	5.88%
2000-2009	-5.87%	-0.13	67.5%	16.7x	6.23%
2010-2019	-14.87%	-1.22	81.1%	16.3x	5.73%
2019-2024	-13.19%	-0.64	61.8%	16.6x	5.39%
2021-2024	-12.01%	-0.86	43.8%	16.8x	5.24%
2023-2024	-16.68%	-1.1	34.2%	16.3x	4.94%

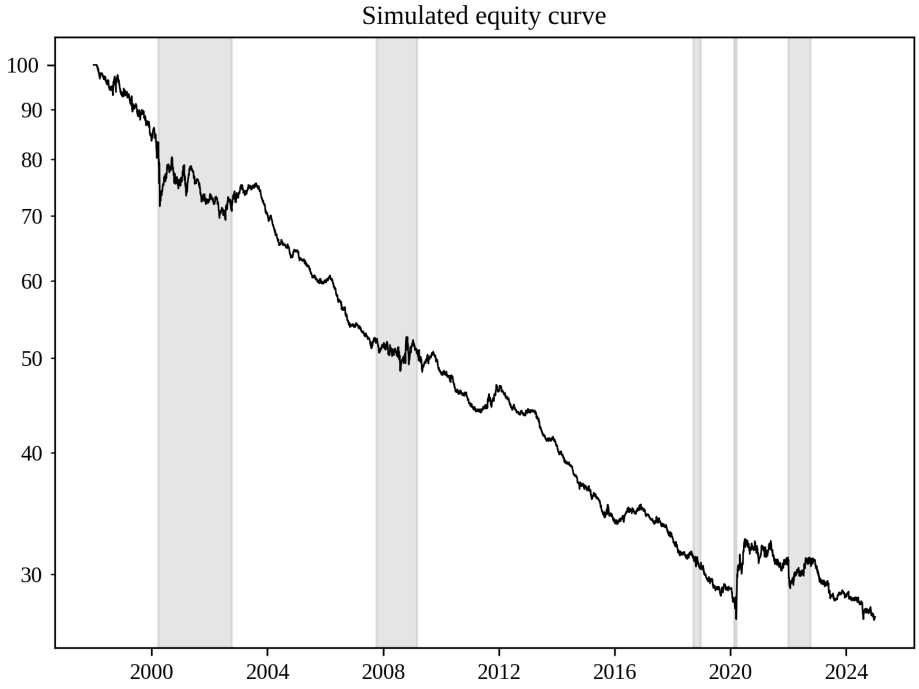
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
1998-10-08	2024-11-29	2024-12-31	96.0%	Ongoing
1997-12-31	1998-07-17	1998-08-31	15.0%	243 days
1998-09-03	1998-09-23	1998-10-08	5.0%	35 days
1998-08-31	1998-09-01	1998-09-02	0.0%	2 days
1998-09-02	1998-09-02	1998-09-03	0.0%	1 days



3.4.3 Aroon: Long-short portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-4.64%	-0.86	71.5%	17.2x	6.08%
2000-2009	-5.40%	-0.91	44.0%	17.2x	6.39%
2010-2019	-4.98%	-1.48	41.3%	17.2x	6.03%
2019-2024	-1.93%	-0.31	17.4%	17.3x	5.56%
2021-2024	-3.45%	-0.45	17.1%	17.2x	5.29%
2023-2024	-5.46%	-0.99	11.3%	17.0x	5.12%

Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
1997-12-31	2024-12-18	2024-12-31	73.0%	Ongoing



3.5 Average Directional Index (ADX)

The Average Directional Index (ADX) is theorized to represent the strength of a trend in the price history of a stock. ADX is a trading system that consists of three indicators, the DI^+, the DI^-, and the ADX itself. If the DI^+ crosses above DI^- while the ADX is above 20, it is considered a bullish momentum signal. If the DI^- crosses below DI^+ while the ADX is above 20, it is considered a bearish momentum signal. In our simulations, we use the bullish and bearish crosses as entry and exit signals in a logical way to achieve long-only, short-only, and long-short strategies.

Given closing prices p_t, daily highs h_t, and daily lows l_t, the ADX is calculated as follows. We use a window length of $k = 14$ in our calculations.

$$\mu(x)_t = \frac{1}{k}\sum_{i=0}^{k-1} x_{t-i}$$

$$\mathrm{TR}_t = \max\left(h_t - l_t, \left|h_t - p_{t-1}\right|, \left|l_t - p_{t-1}\right|\right)$$

$$\mathrm{DM}_t^+ = \begin{cases} h_t - h_{t-1}, & \text{if } h_t - h_{t-1} > l_{t-1} - l_t \text{ and } h_t - h_{t-1} > 0 \\ 0, & \text{otherwise} \end{cases}$$

$$\mathrm{DM}_t^- = \begin{cases} l_{t-1} - l_t, & \text{if } l_{t-1} - l_t > h_t - h_{t-1} \text{ and } l_{t-1} - l_t > 0 \\ 0, & \text{otherwise} \end{cases}$$

$$\mathrm{DI}_t^+ = 100 \times \frac{\mu(\mathrm{DM})_t^+}{\mu(\mathrm{TR})_t}$$

$$\mathrm{DI}_t^- = 100 \times \frac{\mu(\mathrm{DM})_t^-}{\mu(\mathrm{TR})_t}$$

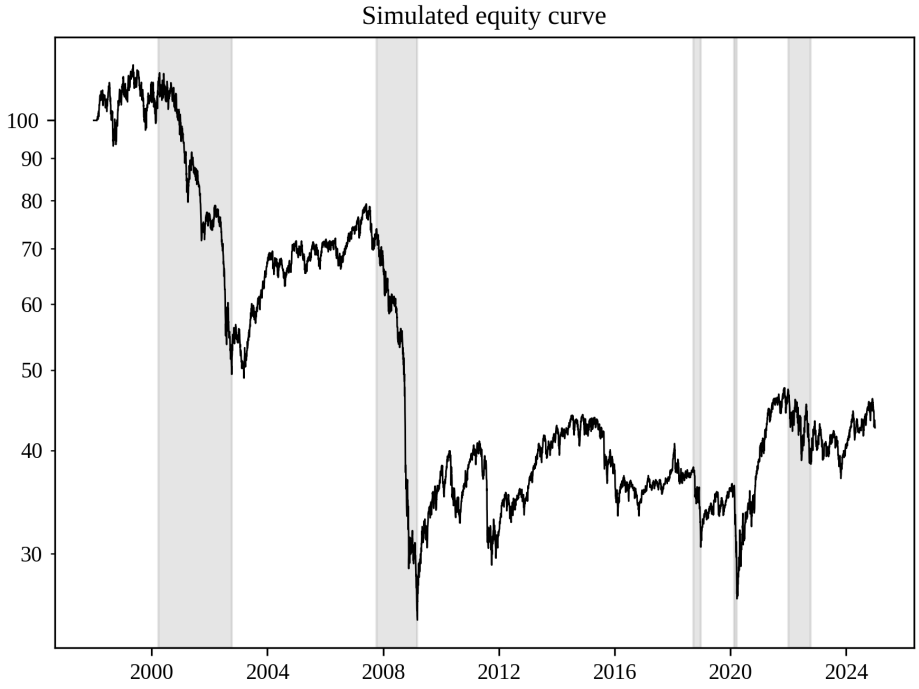
$$\mathrm{DX}_t = 100 \times \frac{\left|\mathrm{DI}_t^+ - \mathrm{DI}_t^-\right|}{\mathrm{DI}_t^+ + \mathrm{DI}_t^-}$$

$$\mathrm{ADX}_t = \mu(\mathrm{DX})_t$$

3.5.1 ADX: Long-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-3.58%	-0.1	78.6%	22.2x	7.48%
2000-2009	-10.19%	-0.5	78.1%	22.5x	8.04%
2010-2019	-0.50%	0.09	30.7%	21.9x	7.32%
2019-2024	5.18%	0.24	27.4%	22.0x	6.56%
2021-2024	2.35%	0.56	22.2%	22.3x	6.43%
2023-2024	2.79%	0.09	14.1%	22.4x	6.25%

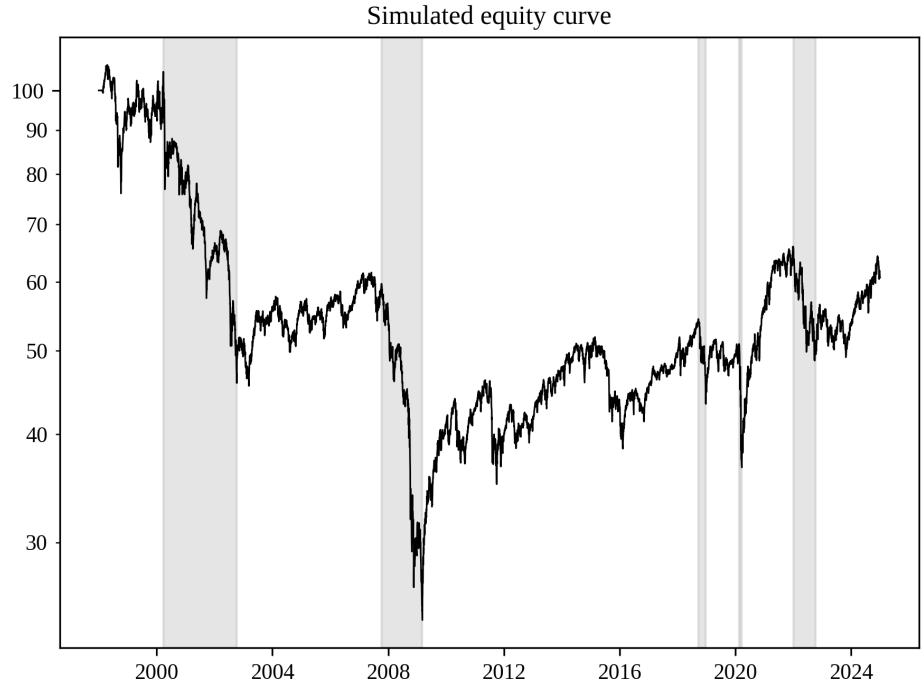
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
1999-05-13	2009-03-09	2024-12-31	79.0%	Ongoing
1998-07-16	1998-09-03	1999-01-06	16.0%	174 days
1999-01-08	1999-03-03	1999-03-15	7.0%	66 days
1998-04-22	1998-06-15	1998-07-06	6.0%	75 days
1999-03-15	1999-03-23	1999-04-09	4.0%	25 days
1998-04-03	1998-04-08	1998-04-21	2.0%	18 days



3.5.2 ADX: Short-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-1.73%	-0.04	76.8%	23.5x	7.82%
2000-2009	-8.22%	-0.41	76.8%	23.4x	8.26%
2010-2019	1.80%	0.3	25.7%	23.6x	7.76%
2019-2024	5.10%	0.21	28.9%	24.0x	7.13%
2021-2024	2.32%	0.42	26.2%	23.1x	6.50%
2023-2024	6.19%	0.25	12.1%	23.4x	6.50%

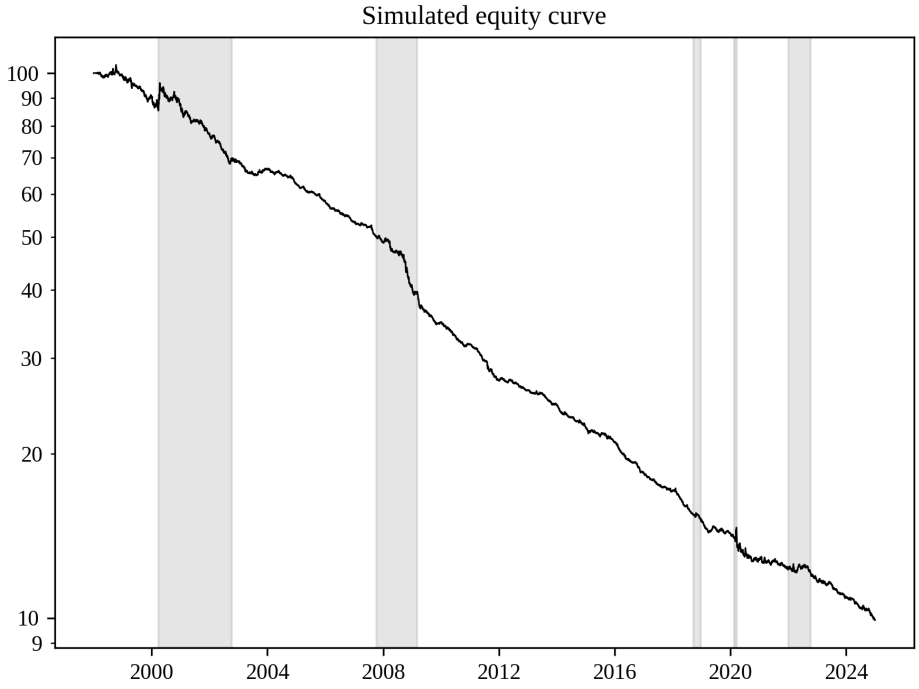
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
1998-04-17	2009-03-09	2024-12-31	77.0%	Ongoing
1998-04-02	1998-04-08	1998-04-15	1.0%	13 days
1998-04-15	1998-04-16	1998-04-17	1.0%	2 days
1998-02-12	1998-02-24	1998-02-25	1.0%	13 days
1998-03-03	1998-03-05	1998-03-06	1.0%	3 days
1998-03-26	1998-03-30	1998-03-31	1.0%	5 days



3.5.3 ADX: Long-short portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-8.44%	-2.01	90.0%	22.6x	7.58%
2000-2009	-9.09%	-1.91	64.0%	22.6x	8.06%
2010-2019	-8.51%	-3.17	59.1%	22.5x	7.49%
2019-2024	-6.82%	-1.47	34.5%	22.7x	6.80%
2021-2024	-6.23%	-1.52	23.5%	22.4x	6.41%
2023-2024	-7.85%	-2.22	16.1%	22.6x	6.34%

Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
1998-10-08	2024-12-31	2024-12-31	90.0%	Ongoing
1998-08-31	1998-09-22	1998-10-06	2.0%	36 days
1998-02-18	1998-04-30	1998-08-04	2.0%	167 days
1998-08-04	1998-08-20	1998-08-28	1.0%	24 days
1997-12-31	1998-02-13	1998-02-17	0.0%	48 days
1998-08-28	1998-08-28	1998-08-31	0.0%	3 days



3.6 Stochastic Oscillator

Given the closing prices p_t, daily highs h_t, and daily lows l_t of a stock, the Stochastic Oscillator is calculated as follows. In our simulations, we use a lookback window of $k = 14$.

$$h_t^+ = \max_{t-k<i\leq t}(h_i)$$

$$l_t^+ = \min_{t-k<i\leq t}(l_i)$$

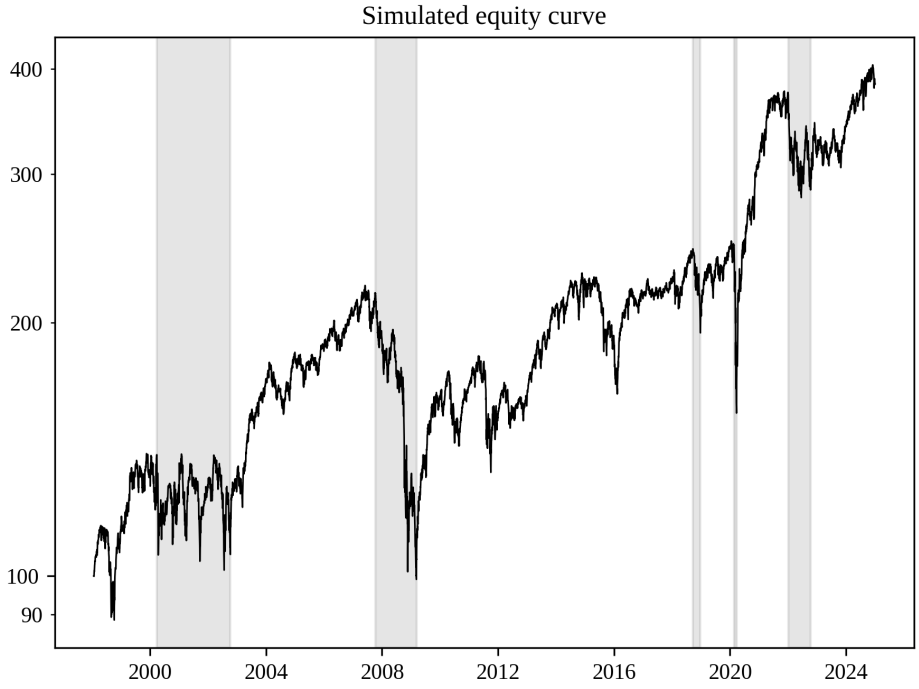
$$\text{Stochastic Oscillator}_t = 100 \times \frac{p_t - l_t^+}{h_t^+ - l_t^+}$$

Any value below 20 is considered a bullish reversal signal and any value above 80 is considered a bearish reversal signal. In our simulations, we use these bullish and bearish crosses as entry and exit signals in a logical way to achieve long-only, short-only, and long-short strategies.

3.6.1 Stochastic Oscillator: Long-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	4.74%	0.32	55.2%	18.5x	5.66%
2000-2009	2.08%	0.1	55.2%	18.2x	5.94%
2010-2019	4.13%	0.4	28.1%	18.8x	5.76%
2019-2024	10.82%	0.51	37.5%	18.6x	5.00%
2021-2024	5.49%	0.75	25.2%	18.0x	4.64%
2023-2024	9.73%	0.73	10.0%	18.2x	4.59%

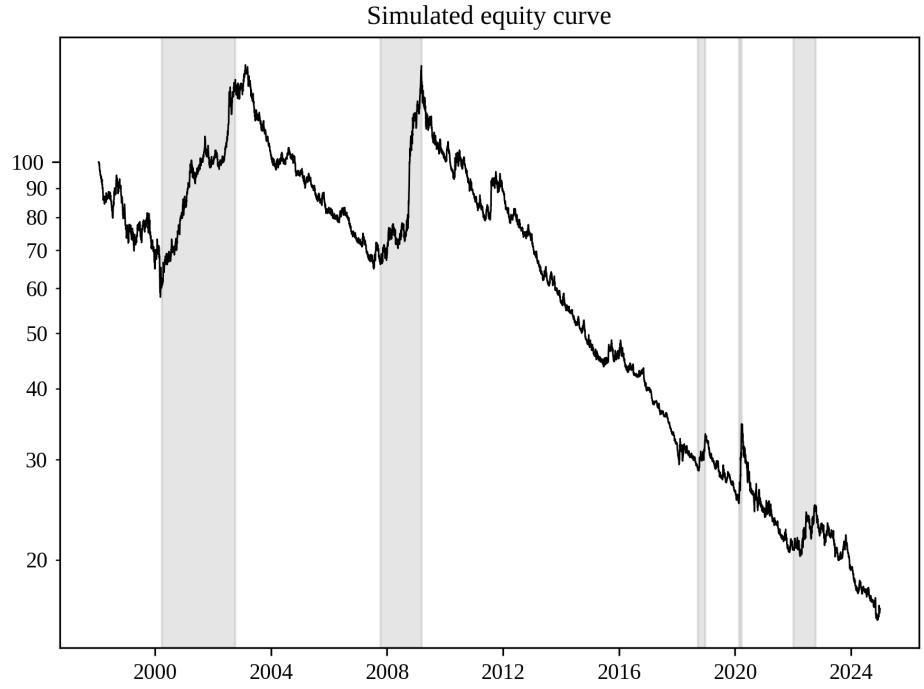
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-06-01	2009-03-09	2014-06-30	55.0%	2586 days
2020-01-17	2020-03-23	2020-06-22	38.0%	157 days
2014-11-24	2016-02-11	2018-01-23	28.0%	1156 days
1999-11-18	2002-07-23	2003-04-23	27.0%	1252 days
2021-11-15	2022-06-16	2024-06-24	25.0%	952 days
1998-04-22	1998-10-08	1999-01-04	23.0%	257 days



3.6.2 Stochastic Oscillator: Short-only portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	-5.77%	-0.28	89.4%	16.5x	4.89%
2000-2009	4.56%	0.43	56.2%	17.0x	5.37%
2010-2019	-12.53%	-1.07	75.7%	15.9x	4.63%
2019-2024	-10.90%	-0.56	54.8%	16.4x	4.28%
2021-2024	-9.70%	-0.71	38.3%	16.5x	4.17%
2023-2024	-15.70%	-0.96	32.5%	16.3x	3.98%

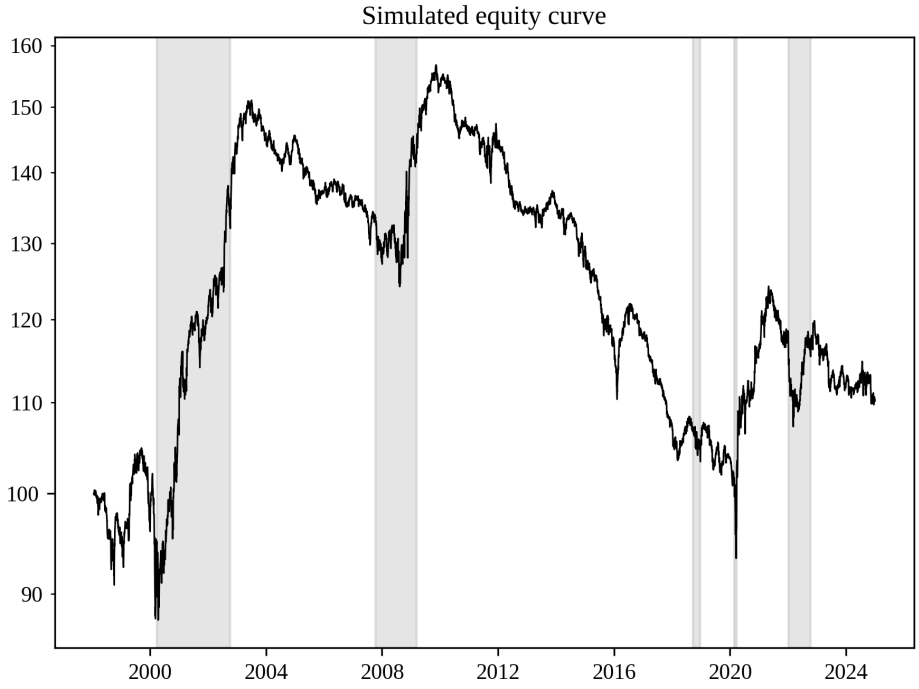
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2003-02-13	2024-11-26	2024-12-31	89.0%	Ongoing
1998-01-26	2000-03-09	2001-04-03	42.0%	1163 days
2001-09-21	2002-03-19	2002-07-02	12.0%	284 days
2002-08-05	2002-08-22	2002-09-23	10.0%	49 days
2001-04-04	2001-05-21	2001-07-24	9.0%	111 days
2002-10-09	2002-11-27	2003-01-22	8.0%	105 days



3.6.3 Stochastic Oscillator: Long-short portfolio

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	0.54%	0.13	40.4%	17.6x	5.30%
2000-2009	4.81%	0.62	17.8%	17.7x	5.69%
2010-2019	-3.83%	-0.79	34.3%	17.4x	5.22%
2019-2024	0.70%	0.16	13.7%	17.6x	4.67%
2021-2024	-1.39%	0.17	13.7%	17.4x	4.44%
2023-2024	-3.14%	-0.18	7.1%	17.3x	4.31%

Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2009-11-11	2020-03-18	2024-12-31	40.0%	Ongoing
2003-07-03	2008-08-11	2009-06-23	18.0%	2182 days
1999-09-15	2000-04-14	2000-11-15	17.0%	427 days
1998-01-30	1998-10-08	1999-04-22	9.0%	447 days
2001-08-10	2001-09-20	2002-01-02	6.0%	145 days
2001-02-15	2001-03-12	2001-04-12	5.0%	56 days



Chapter 4

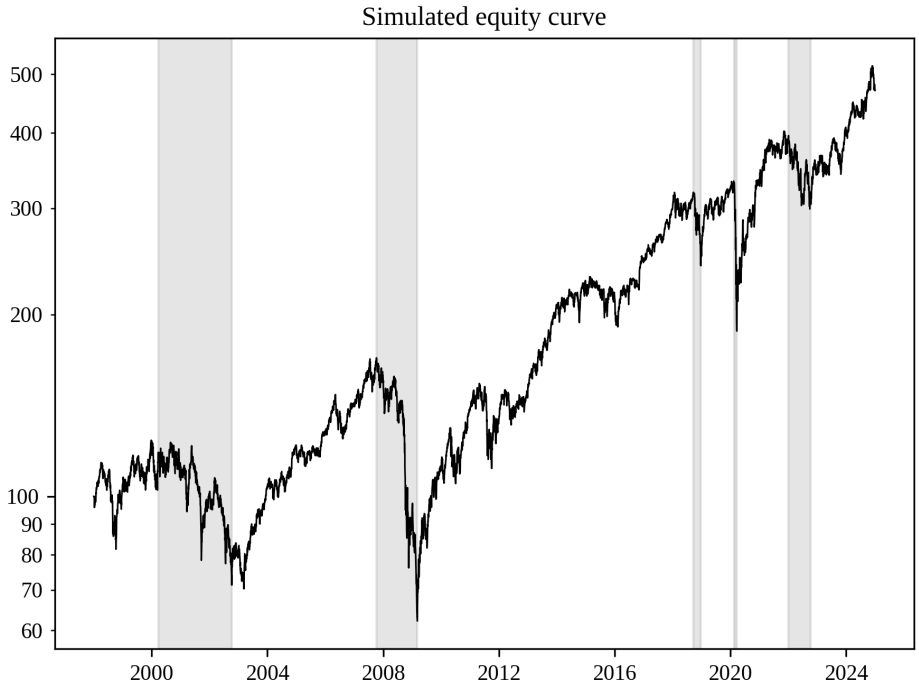
Sector strategies

This chapter will show the performance of equal-weighted and cap-weighted long-only strategies in various sectors. Equal-weighted strategies allocate the same dollar amount to all companies in a given sector on a monthly basis. Cap-weighted strategies allocate capital in proportion to the market capitalization of each company in a given sector on a monthly basis.

4.1 Industrials: Capitalization weighted

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	5.97%	0.36	63.3%	0.3x	0.11%
2000-2009	-0.95%	0.02	63.3%	0.3x	0.11%
2010-2019	11.08%	0.78	27.7%	0.2x	0.09%
2019-2024	10.53%	0.38	43.5%	0.3x	0.12%
2021-2024	9.56%	0.78	25.7%	0.3x	0.13%
2023-2024	16.94%	0.96	12.9%	0.3x	0.16%

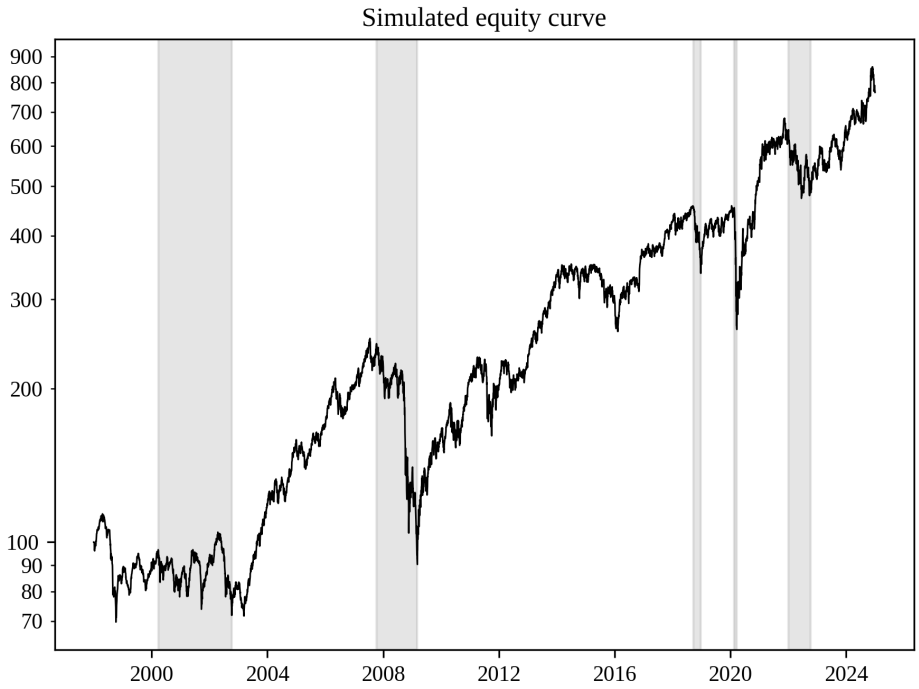
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-10-09	2009-03-09	2013-05-10	63.0%	2040 days
2020-02-12	2020-03-23	2020-11-24	44.0%	286 days
1999-12-27	2003-03-11	2005-11-17	43.0%	2152 days
1998-04-02	1998-10-08	1999-04-23	28.0%	386 days
2021-11-08	2022-09-30	2023-12-19	26.0%	771 days
2018-09-21	2018-12-24	2019-11-05	24.0%	410 days



4.2 Industrials: Equal weighted

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	8.66%	0.47	64.0%	0.2x	0.14%
2000-2009	5.93%	0.32	64.0%	0.3x	0.17%
2010-2019	10.46%	0.7	29.9%	0.2x	0.09%
2019-2024	13.39%	0.46	42.8%	0.2x	0.14%
2021-2024	10.72%	0.86	30.4%	0.2x	0.16%
2023-2024	20.70%	0.8	14.8%	0.2x	0.20%

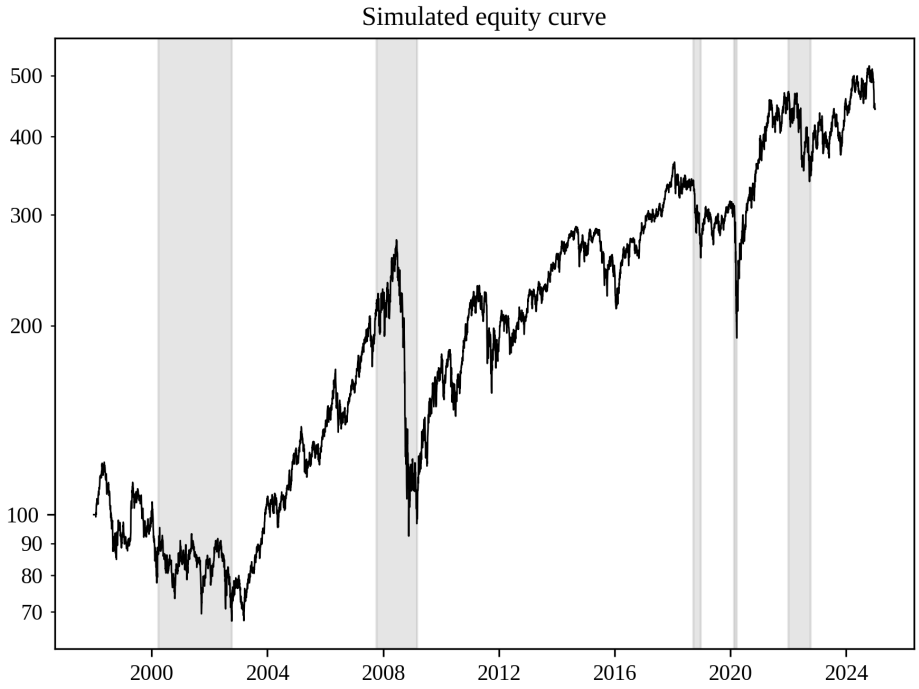
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-07-19	2009-03-09	2013-02-19	64.0%	2042 days
2020-01-16	2020-03-23	2020-11-09	43.0%	298 days
1998-04-21	1998-10-08	2003-12-01	39.0%	2050 days
2021-11-16	2022-06-16	2024-03-01	30.0%	836 days
2014-07-03	2016-02-11	2016-11-17	26.0%	868 days
2018-09-14	2018-12-24	2020-01-16	26.0%	489 days



4.3 Basic Materials: Capitalization weighted

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	6.15%	0.33	66.2%	0.4x	0.15%
2000-2009	5.37%	0.23	66.2%	0.4x	0.17%
2010-2019	6.15%	0.47	32.6%	0.3x	0.12%
2019-2024	8.27%	0.35	39.4%	0.4x	0.15%
2021-2024	4.74%	0.67	28.1%	0.3x	0.16%
2023-2024	7.37%	0.5	15.6%	0.3x	0.19%

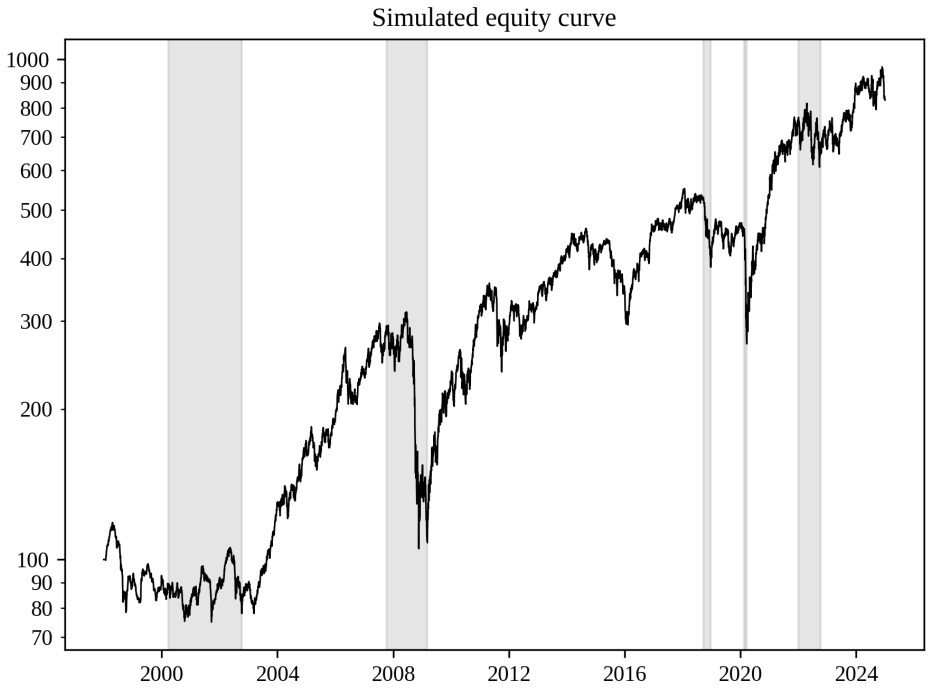
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2008-06-18	2008-11-20	2014-05-29	66.0%	2171 days
2018-01-26	2020-03-23	2020-12-17	48.0%	1056 days
1998-05-13	2002-10-09	2004-11-12	44.0%	2375 days
2022-01-04	2022-09-26	2024-03-07	28.0%	793 days
2014-08-29	2016-01-20	2016-12-07	26.0%	831 days
2006-05-10	2006-06-13	2007-02-01	21.0%	267 days



4.4 Basic Materials: Equal weighted

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	8.84%	0.48	66.4%	0.2x	0.14%
2000-2009	9.38%	0.38	66.4%	0.3x	0.18%
2010-2019	7.39%	0.61	35.8%	0.2x	0.10%
2019-2024	12.48%	0.47	43.7%	0.2x	0.14%
2021-2024	11.73%	0.97	25.5%	0.1x	0.13%
2023-2024	11.92%	0.59	15.3%	0.1x	0.18%

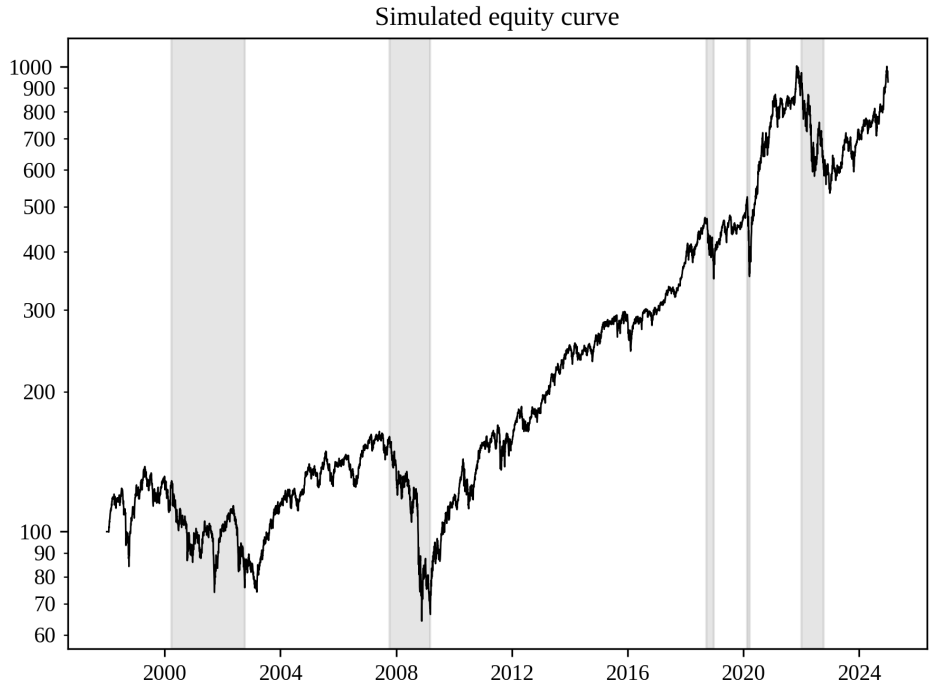
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2008-06-18	2008-11-20	2010-12-21	66.0%	916 days
2018-01-26	2020-03-23	2021-01-06	51.0%	1076 days
1998-04-22	2001-09-21	2003-12-01	37.0%	2049 days
2014-09-02	2016-02-11	2016-12-07	36.0%	827 days
2011-04-29	2011-10-03	2013-03-14	34.0%	685 days
2022-04-20	2022-09-26	2023-12-14	25.0%	603 days



4.5 Consumer Cyclical: Capitalization weighted

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	8.20%	0.45	60.9%	0.4x	0.13%
2000-2009	-1.05%	-0.02	60.9%	0.4x	0.17%
2010-2019	14.89%	0.98	26.2%	0.3x	0.10%
2019-2024	15.84%	0.55	46.7%	0.4x	0.10%
2021-2024	4.31%	0.5	46.7%	0.4x	0.11%
2023-2024	30.99%	0.44	17.5%	0.3x	0.12%

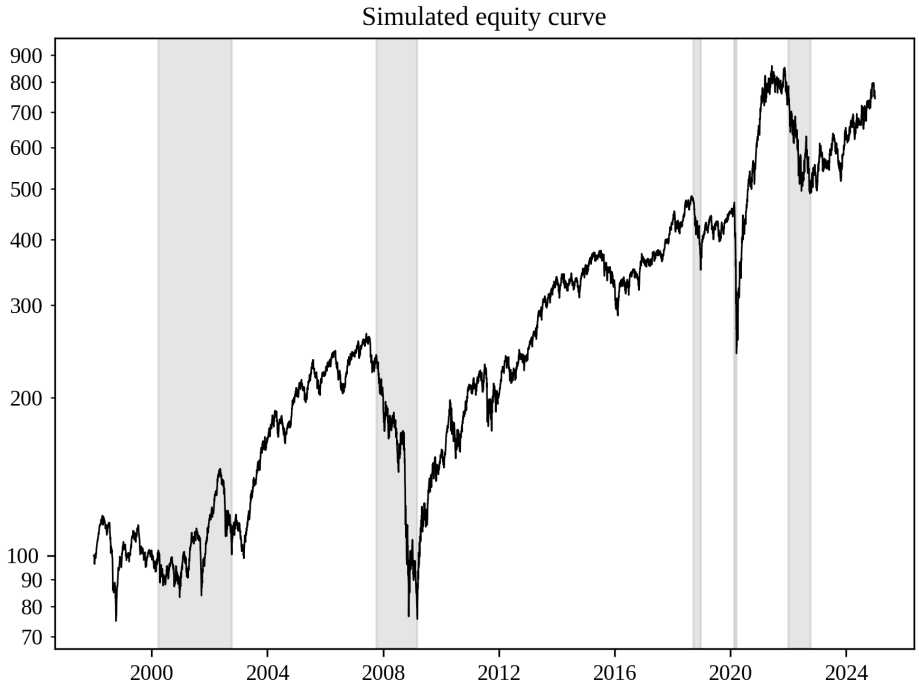
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-06-04	2008-11-20	2011-05-10	61.0%	1436 days
2021-11-05	2022-12-28	2024-12-31	47.0%	Ongoing
1999-04-27	2001-09-21	2004-12-28	46.0%	2072 days
2020-02-19	2020-03-18	2020-06-03	33.0%	105 days
1998-07-08	1998-10-08	1999-01-06	32.0%	182 days
2018-09-04	2018-12-24	2019-07-12	26.0%	311 days



4.6 Consumer Cyclical: Equal weighted

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	7.88%	0.48	71.4%	0.2x	0.15%
2000-2009	4.25%	0.22	71.4%	0.3x	0.19%
2010-2019	11.22%	0.81	27.7%	0.2x	0.10%
2019-2024	12.03%	0.48	48.5%	0.2x	0.14%
2021-2024	4.11%	0.73	42.9%	0.2x	0.14%
2023-2024	21.18%	0.5	18.9%	0.1x	0.18%

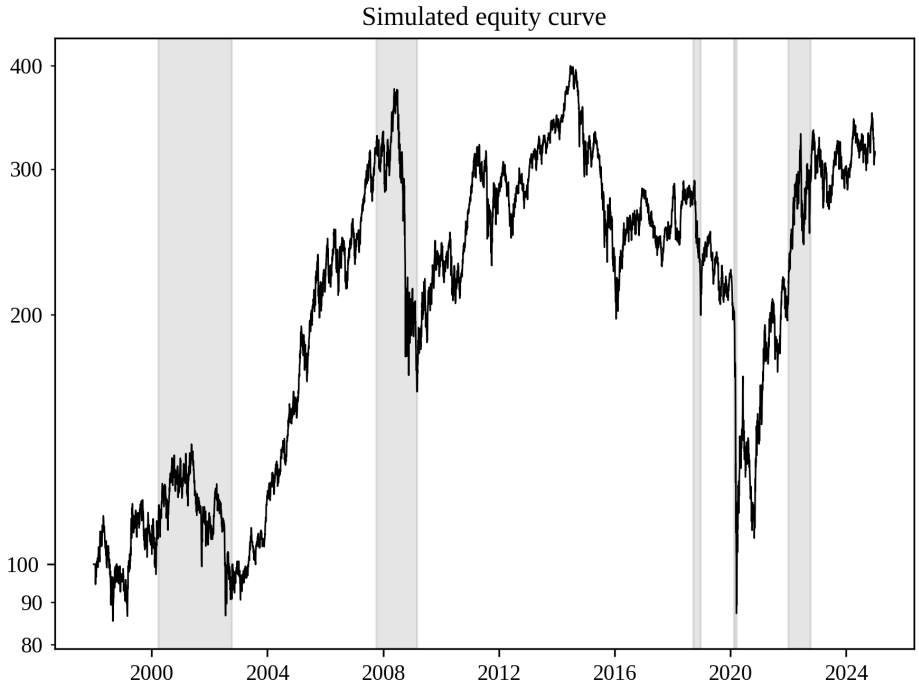
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-06-04	2009-03-09	2013-03-13	71.0%	2109 days
2018-08-29	2020-03-18	2020-08-04	50.0%	706 days
2021-06-08	2022-09-30	2024-12-31	43.0%	Ongoing
1998-04-21	1998-10-08	2002-01-08	37.0%	1358 days
2002-05-15	2003-03-12	2003-08-28	32.0%	470 days
2015-07-14	2016-02-11	2017-07-03	25.0%	720 days



4.7 Energy: Capitalization weighted

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	4.67%	0.27	78.2%	0.3x	0.11%
2000-2009	8.32%	0.33	56.9%	0.3x	0.10%
2010-2019	-0.70%	0.11	50.5%	0.3x	0.10%
2019-2024	6.39%	0.26	65.4%	0.3x	0.12%
2021-2024	22.28%	0.96	26.5%	0.3x	0.12%
2023-2024	2.97%	0.37	18.1%	0.3x	0.14%

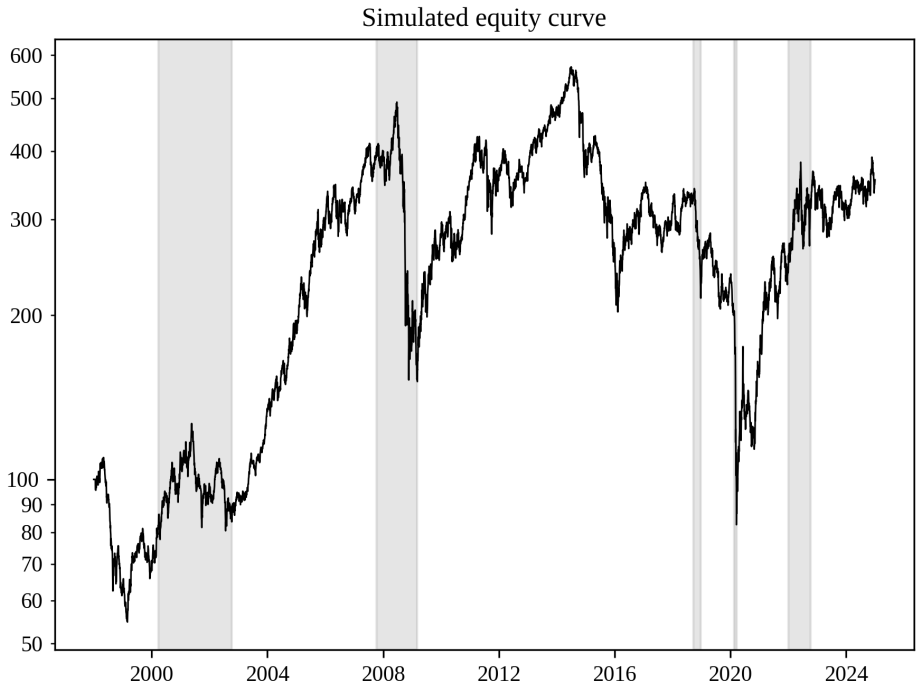
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2014-06-23	2020-03-18	2024-12-31	78.0%	Ongoing
2008-05-20	2009-03-05	2014-05-07	57.0%	2178 days
2001-05-18	2002-07-23	2004-07-16	38.0%	1155 days
1998-05-01	1998-08-31	1999-04-29	25.0%	363 days
1999-09-09	2000-02-25	2000-05-11	19.0%	245 days
2006-04-21	2006-06-13	2006-11-29	17.0%	222 days



4.8 Energy: Equal weighted

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	6.79%	0.36	85.5%	0.3x	0.19%
2000-2009	14.95%	0.59	69.3%	0.3x	0.18%
2010-2019	-2.14%	0.16	64.5%	0.3x	0.15%
2019-2024	7.04%	0.25	70.8%	0.4x	0.25%
2021-2024	22.51%	0.95	30.6%	0.3x	0.20%
2023-2024	6.25%	0.23	19.6%	0.2x	0.21%

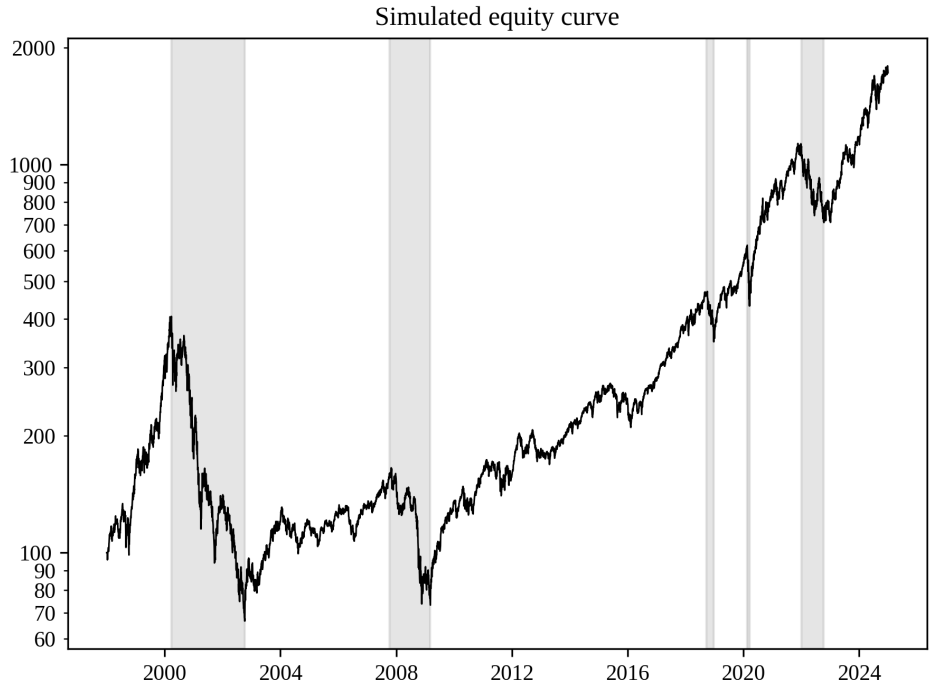
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2014-07-01	2020-03-18	2024-12-31	86.0%	Ongoing
2008-06-23	2009-03-09	2014-02-24	69.0%	2072 days
1998-05-05	1999-03-02	2000-12-27	50.0%	967 days
2001-05-21	2002-07-23	2003-12-17	36.0%	940 days
2006-05-10	2006-06-13	2007-03-22	20.0%	316 days
2005-10-03	2005-10-20	2006-01-13	16.0%	102 days



4.9 Technology: Capitalization weighted

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	9.57%	0.53	83.6%	0.3x	0.11%
2000-2009	-8.40%	0.02	83.6%	0.4x	0.15%
2010-2019	15.00%	0.91	25.8%	0.3x	0.09%
2019-2024	28.92%	0.93	37.4%	0.3x	0.07%
2021-2024	20.02%	1	37.4%	0.3x	0.07%
2023-2024	54.34%	1.51	18.1%	0.3x	0.07%

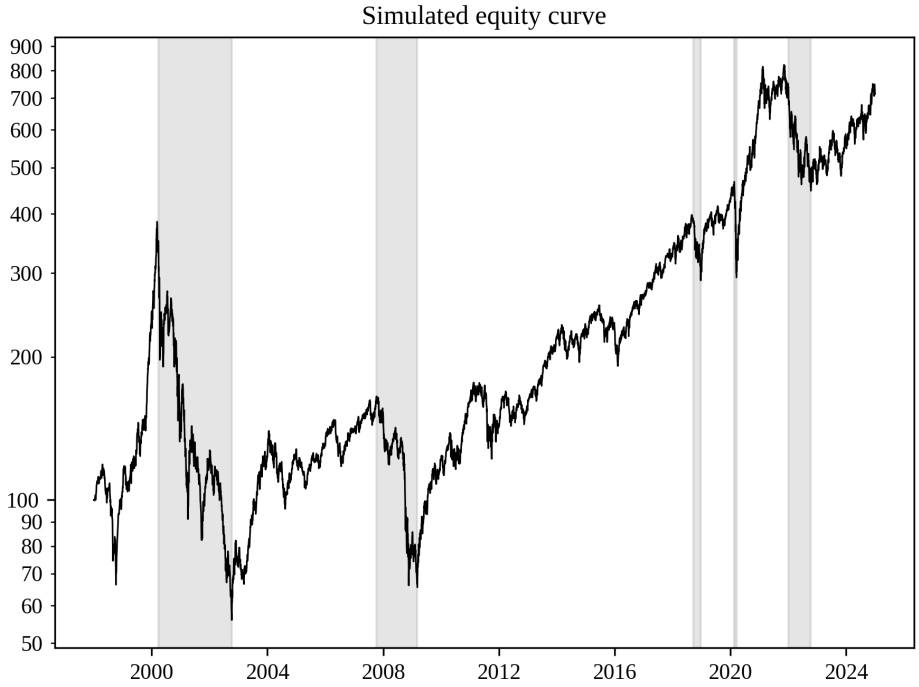
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2000-03-27	2002-10-09	2018-02-26	84.0%	6545 days
2021-11-19	2022-10-14	2023-11-20	37.0%	731 days
2020-02-19	2020-03-16	2020-06-05	30.0%	107 days
1998-07-20	1998-10-08	1998-11-19	26.0%	122 days
2018-10-03	2018-12-24	2019-04-12	26.0%	191 days
2024-07-10	2024-08-07	2024-10-21	18.0%	103 days



4.10 Technology: Equal weighted

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	7.61%	0.47	85.5%	0.4x	0.22%
2000-2009	-7.00%	0.17	85.5%	0.5x	0.29%
2010-2019	13.15%	0.81	30.9%	0.3x	0.16%
2019-2024	14.76%	0.49	45.6%	0.3x	0.17%
2021-2024	1.70%	0.45	45.6%	0.2x	0.16%
2023-2024	22.94%	0.43	19.7%	0.2x	0.18%

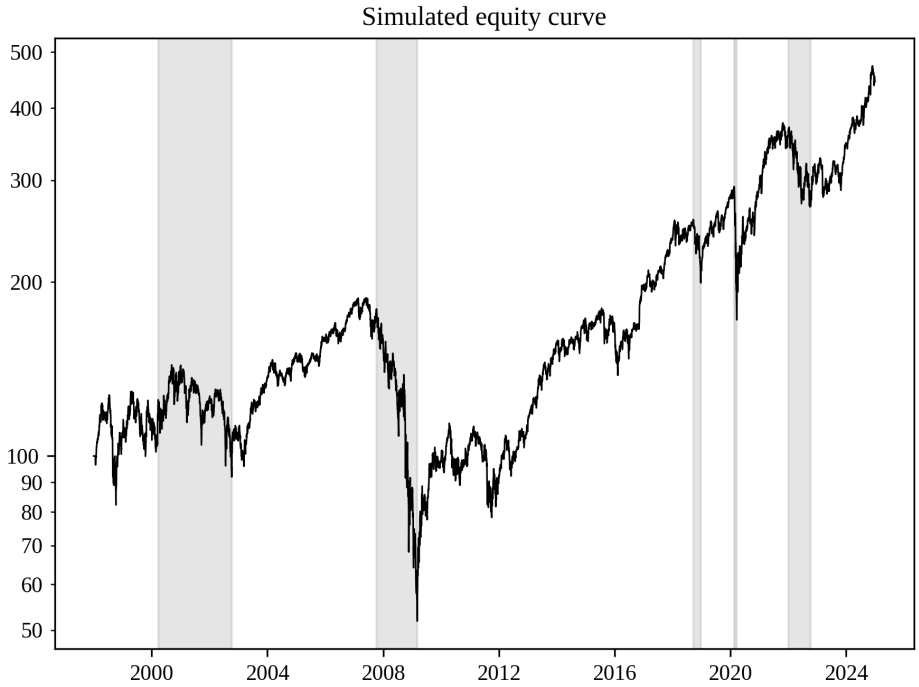
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2000-03-10	2002-10-09	2018-08-23	85.0%	6740 days
2021-11-08	2022-10-14	2024-12-31	46.0%	Ongoing
1998-04-21	1998-10-08	1999-04-26	44.0%	370 days
2020-02-20	2020-03-18	2020-06-08	37.0%	109 days
2018-09-04	2018-12-24	2019-04-24	27.0%	232 days
2021-02-12	2021-05-13	2021-11-08	22.0%	269 days



4.11 Financial Services: Capitalization weighted

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	5.51%	0.28	72.4%	0.3x	0.09%
2000-2009	-1.33%	-0.03	72.4%	0.3x	0.11%
2010-2019	10.93%	0.66	31.3%	0.2x	0.07%
2019-2024	12.87%	0.44	41.2%	0.2x	0.09%
2021-2024	11.12%	0.77	28.5%	0.2x	0.10%
2023-2024	21.27%	0.89	14.5%	0.2x	0.12%

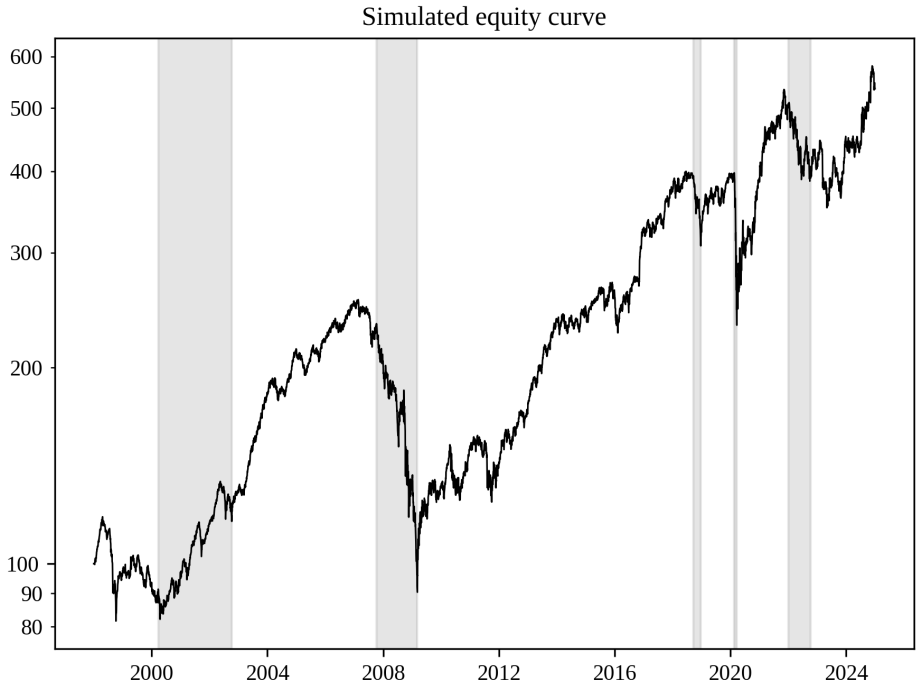
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-06-01	2009-03-09	2016-11-25	72.0%	3465 days
2020-02-19	2020-03-23	2020-12-31	41.0%	316 days
2000-09-11	2002-10-09	2004-02-11	36.0%	1248 days
1998-07-14	1998-10-08	1999-04-12	35.0%	272 days
2021-10-25	2022-09-30	2024-03-20	28.0%	877 days
1999-04-27	1999-10-15	2000-08-03	23.0%	464 days



4.12 Financial Services: Equal weighted

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	6.77%	0.44	64.4%	0.2x	0.10%
2000-2009	3.53%	0.26	64.4%	0.2x	0.11%
2010-2019	11.56%	0.87	23.1%	0.1x	0.09%
2019-2024	8.60%	0.27	41.6%	0.1x	0.09%
2021-2024	8.59%	0.67	34.1%	0.1x	0.10%
2023-2024	14.51%	0.31	21.1%	0.1x	0.16%

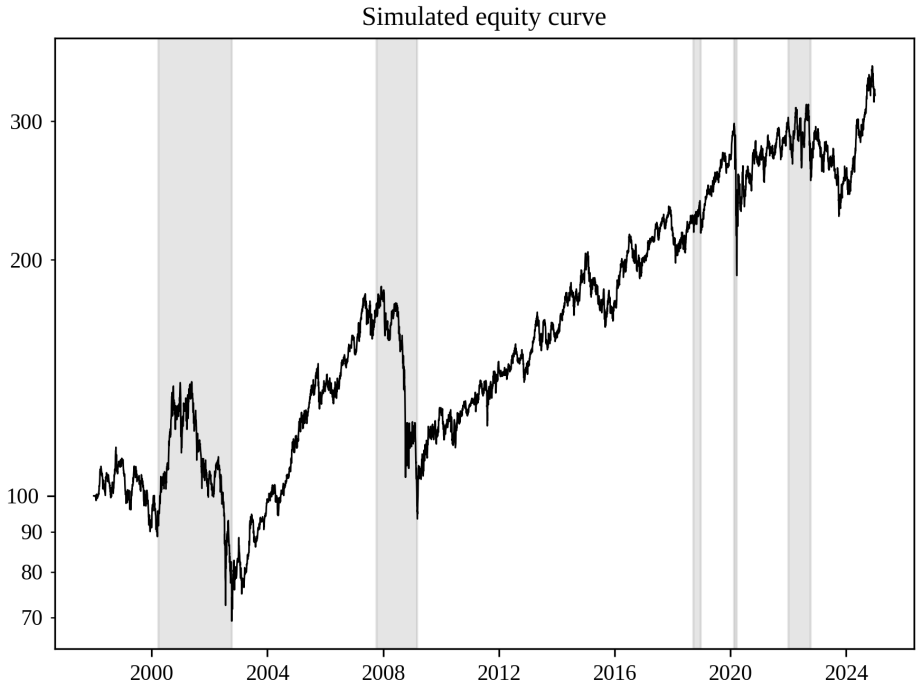
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-02-22	2009-03-09	2015-04-24	64.0%	2983 days
2018-06-20	2020-03-23	2021-01-06	42.0%	931 days
2021-11-08	2023-05-04	2024-11-06	34.0%	1094 days
1998-04-22	1998-10-08	2002-01-31	31.0%	1380 days
2015-12-01	2016-02-11	2016-08-23	16.0%	266 days
2002-05-17	2002-10-09	2003-04-07	13.0%	325 days



4.13 Utilities: Capitalization weighted

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	4.20%	0.28	50.4%	0.2x	0.09%
2000-2009	3.42%	0.17	50.4%	0.3x	0.11%
2010-2019	7.83%	0.61	19.8%	0.2x	0.06%
2019-2024	6.82%	0.27	36.0%	0.2x	0.09%
2021-2024	5.23%	0.23	28.0%	0.2x	0.11%
2023-2024	6.30%	0.13	22.6%	0.2x	0.14%

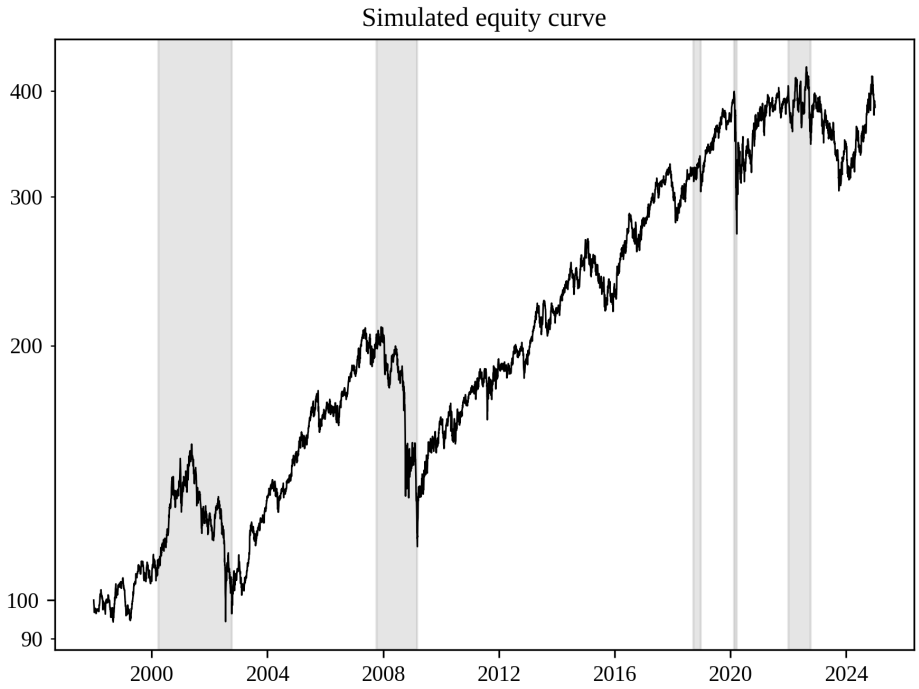
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2001-05-21	2002-10-09	2005-08-02	50.0%	1534 days
2007-12-10	2009-03-09	2014-06-26	49.0%	2390 days
2020-02-18	2020-03-23	2021-12-16	36.0%	667 days
2022-09-12	2023-10-02	2024-09-13	28.0%	732 days
1998-10-08	2000-03-14	2000-08-07	23.0%	669 days
2015-01-29	2015-09-04	2016-06-09	20.0%	497 days



4.14 Utilities: Equal weighted

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	5.05%	0.35	45.0%	0.1x	0.06%
2000-2009	4.41%	0.28	45.0%	0.1x	0.07%
2010-2019	8.68%	0.71	17.9%	0.1x	0.04%
2019-2024	3.62%	0.15	32.1%	0.1x	0.07%
2021-2024	0.92%	0.08	28.6%	0.1x	0.09%
2023-2024	0.16%	-0.22	22.6%	0.1x	0.14%

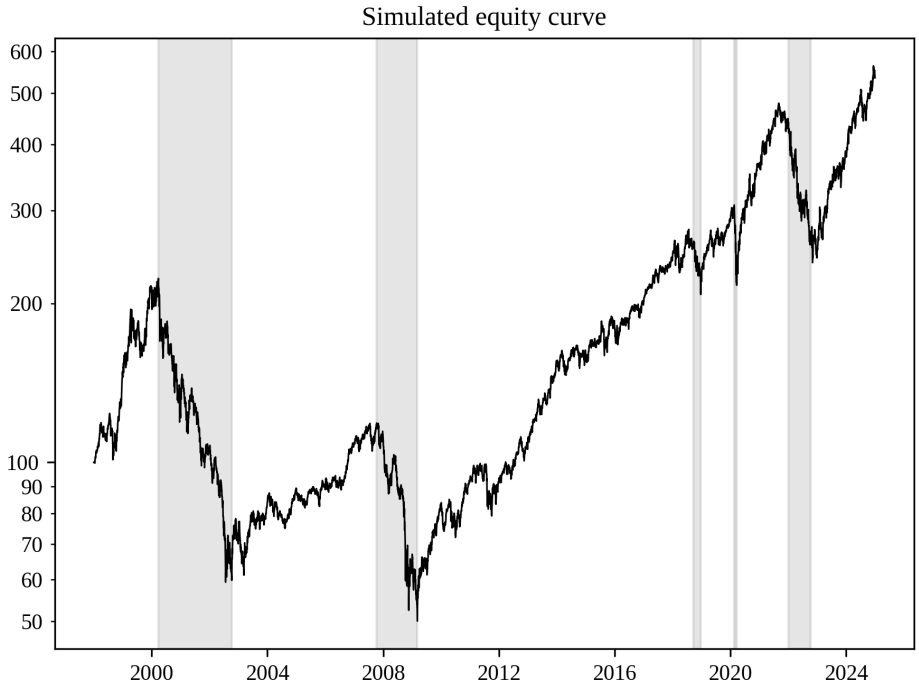
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-12-07	2009-03-09	2013-03-15	45.0%	1925 days
2001-05-21	2002-07-23	2005-02-04	38.0%	1355 days
2020-02-18	2020-03-23	2021-09-01	32.0%	561 days
2022-08-18	2023-10-02	2024-12-31	29.0%	Ongoing
2015-01-29	2015-12-11	2016-06-03	18.0%	491 days
2017-11-30	2018-02-08	2018-11-19	15.0%	354 days



4.15 Communication Services: Capitalization weighted

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	5.15%	0.38	77.5%	0.3x	0.10%
2000-2009	-9.08%	-0.25	77.5%	0.4x	0.14%
2010-2019	13.07%	0.92	24.7%	0.3x	0.08%
2019-2024	15.66%	0.59	50.1%	0.3x	0.07%
2021-2024	10.29%	0.69	50.1%	0.3x	0.07%
2023-2024	45.68%	1.17	13.1%	0.3x	0.08%

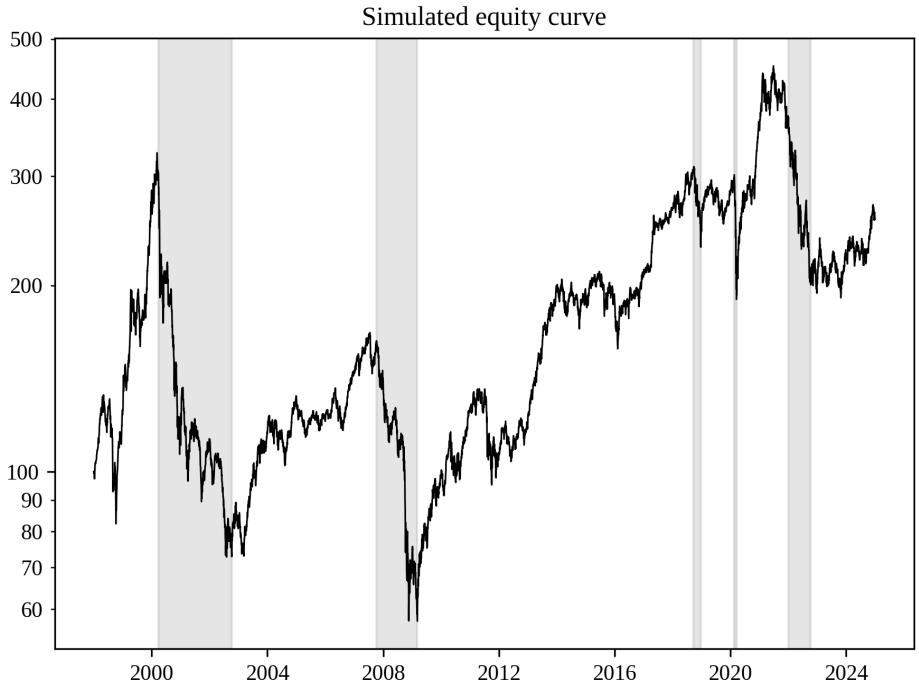
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2000-03-27	2009-03-09	2017-04-27	78.0%	6240 days
2021-09-01	2022-11-03	2024-06-12	50.0%	1015 days
2020-02-19	2020-03-20	2020-07-08	30.0%	140 days
2018-07-25	2018-12-24	2019-07-26	25.0%	366 days
1999-04-12	1999-08-10	1999-11-12	19.0%	214 days
1998-07-20	1998-08-31	1998-11-19	18.0%	122 days



4.16 Communication Services: Equal weighted

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	2.78%	0.31	82.5%	0.4x	0.22%
2000-2009	-10.15%	-0.09	82.5%	0.4x	0.24%
2010-2019	10.87%	0.79	30.0%	0.3x	0.18%
2019-2024	0.52%	0.04	57.8%	0.4x	0.24%
2021-2024	-7.95%	0.06	57.8%	0.4x	0.24%
2023-2024	12.71%	-0.17	19.9%	0.3x	0.27%

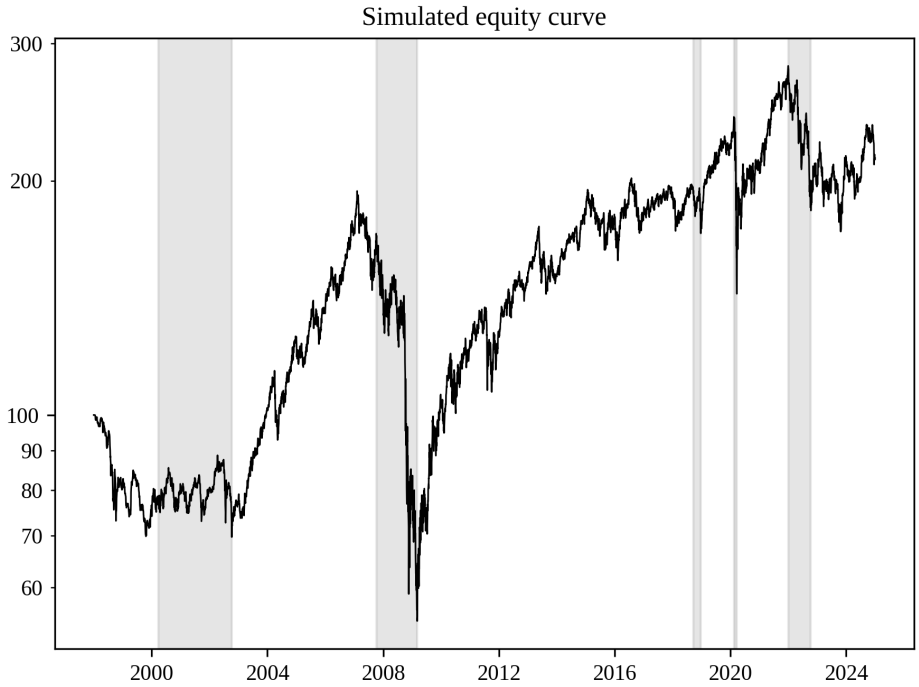
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2000-03-10	2009-03-09	2020-11-25	82.0%	7565 days
2021-06-28	2023-10-27	2024-12-31	58.0%	Ongoing
1998-05-04	1998-10-08	1999-01-08	38.0%	249 days
1999-07-15	1999-08-10	1999-11-01	19.0%	109 days
1999-04-13	1999-06-15	1999-07-15	15.0%	93 days
2021-02-12	2021-05-12	2021-06-14	14.0%	122 days



4.17 Real Estate: Capitalization weighted

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	3.74%	0.22	72.0%	0.3x	0.13%
2000-2009	3.20%	0.11	72.0%	0.3x	0.15%
2010-2019	8.04%	0.65	22.2%	0.2x	0.09%
2019-2024	3.55%	0.15	40.7%	0.3x	0.12%
2021-2024	1.15%	0.15	38.7%	0.3x	0.13%
2023-2024	3.73%	-0.13	23.3%	0.2x	0.17%

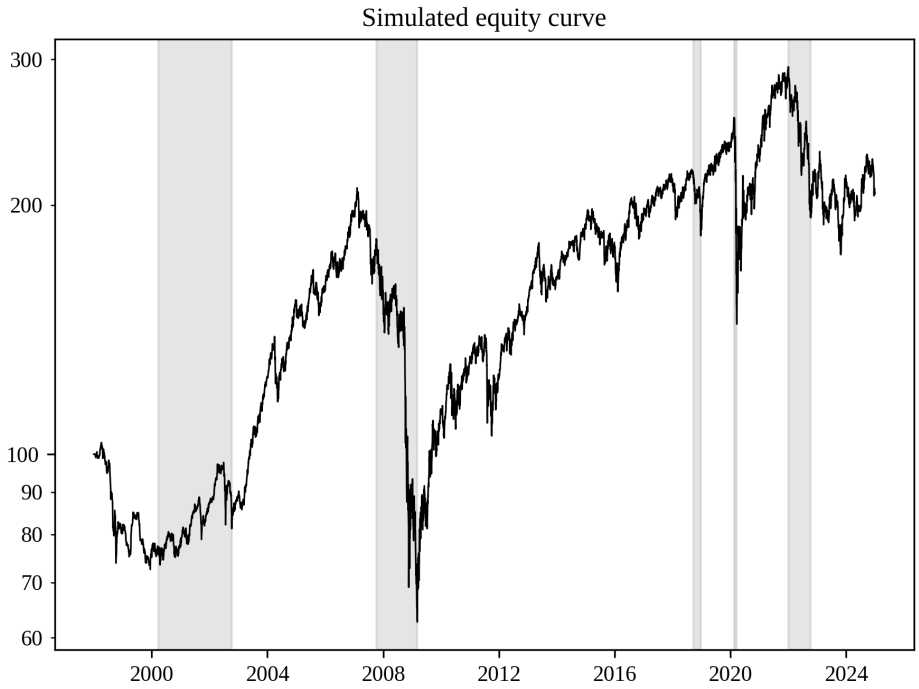
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-02-07	2009-03-06	2015-01-26	72.0%	2910 days
2020-02-14	2020-03-23	2021-06-01	41.0%	473 days
2021-12-31	2023-10-25	2024-12-31	39.0%	Ongoing
1997-12-31	2002-10-09	2003-12-12	30.0%	2172 days
2015-01-26	2016-02-11	2016-07-05	19.0%	526 days
2004-04-01	2004-05-10	2004-10-06	19.0%	188 days



4.18 Real Estate: Equal weighted

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	3.63%	0.24	70.1%	0.2x	0.11%
2000-2009	3.96%	0.17	70.1%	0.2x	0.12%
2010-2019	7.83%	0.67	24.5%	0.2x	0.08%
2019-2024	1.70%	0.08	43.7%	0.2x	0.14%
2021-2024	-2.19%	0.14	40.7%	0.2x	0.16%
2023-2024	0.27%	-0.31	24.9%	0.2x	0.22%

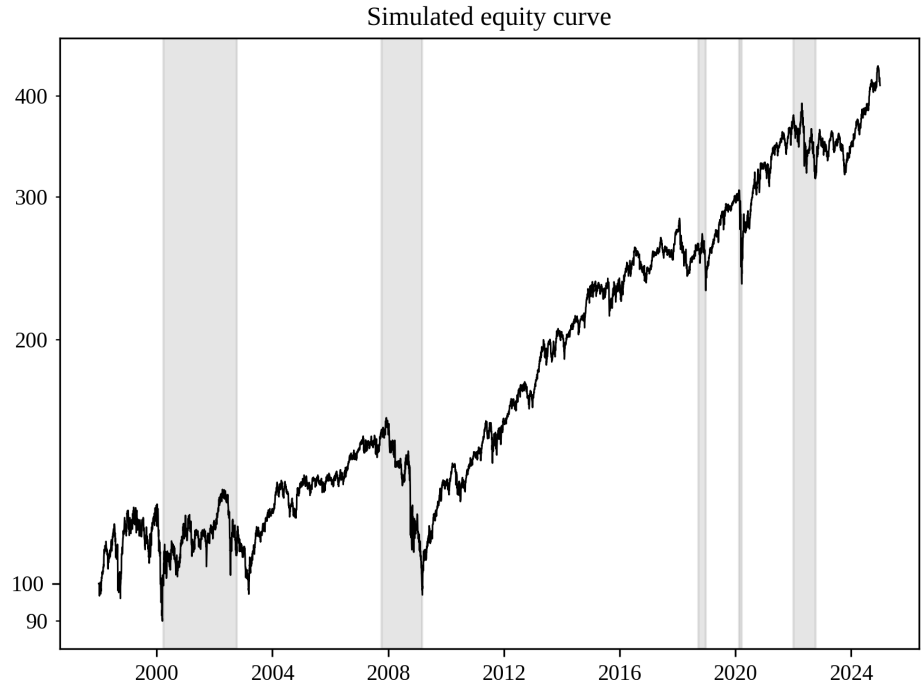
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-02-07	2009-03-09	2017-06-26	70.0%	3792 days
2020-02-21	2020-03-23	2021-02-12	44.0%	357 days
2021-12-31	2023-10-25	2024-12-31	41.0%	Ongoing
1998-04-07	1999-12-15	2003-06-10	30.0%	1890 days
2018-08-31	2018-12-24	2019-04-01	17.0%	213 days
2004-04-01	2004-05-10	2004-10-18	17.0%	200 days



4.19 Consumer Defensive: Capitalization weighted

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	4.83%	0.36	39.6%	0.3x	0.08%
2000-2009	0.83%	0.04	39.6%	0.3x	0.09%
2010-2019	8.45%	0.78	18.5%	0.2x	0.07%
2019-2024	9.41%	0.47	23.4%	0.2x	0.08%
2021-2024	5.89%	0.56	19.3%	0.2x	0.08%
2023-2024	8.95%	0.52	11.7%	0.2x	0.10%

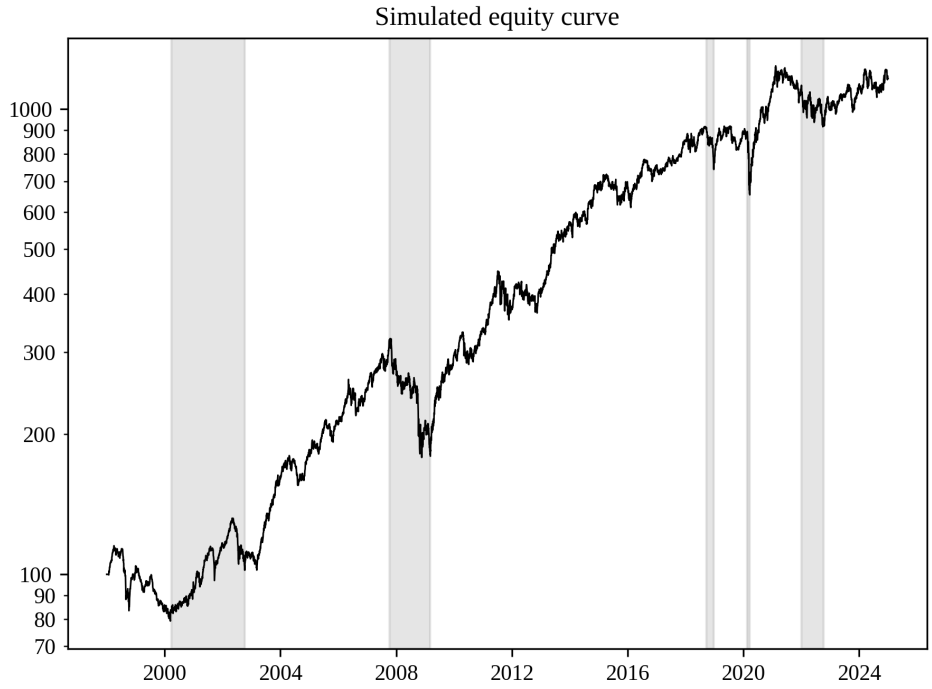
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-12-10	2009-03-09	2012-02-09	40.0%	1522 days
2000-01-07	2000-03-14	2002-02-25	28.0%	780 days
2002-04-10	2003-03-10	2004-02-20	26.0%	681 days
2020-02-14	2020-03-23	2020-08-12	23.0%	180 days
2022-04-20	2022-10-07	2024-08-14	19.0%	847 days
1998-07-16	1998-10-01	1998-11-20	19.0%	127 days



4.20 Consumer Defensive: Equal weighted

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	9.76%	0.64	44.5%	0.2x	0.12%
2000-2009	13.30%	0.67	44.5%	0.2x	0.13%
2010-2019	11.60%	0.89	21.5%	0.2x	0.11%
2019-2024	7.08%	0.32	28.8%	0.2x	0.12%
2021-2024	1.66%	0.44	26.0%	0.1x	0.13%
2023-2024	8.19%	0.45	13.0%	0.1x	0.17%

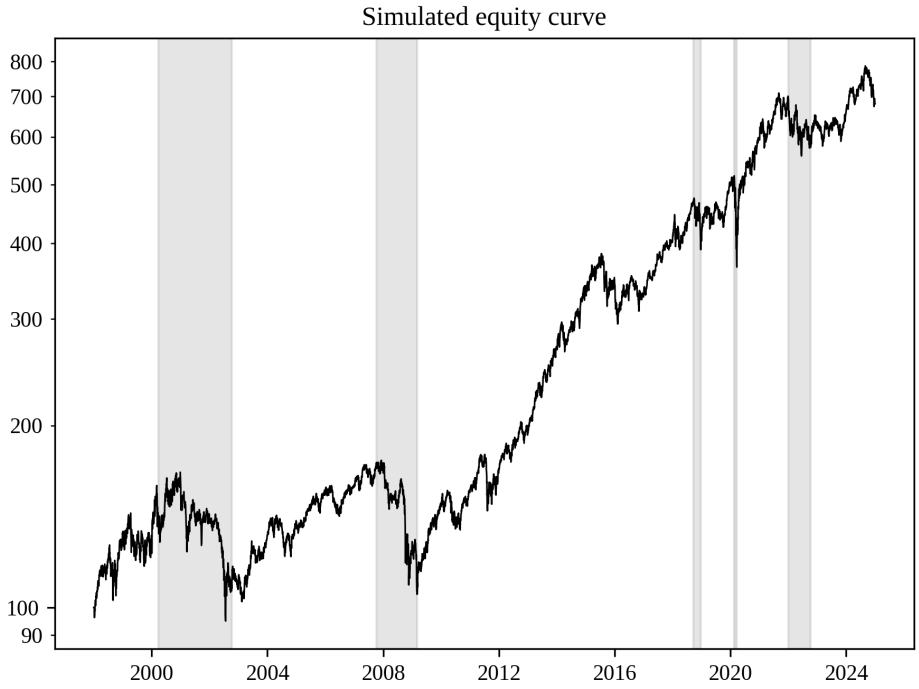
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-10-18	2008-11-20	2010-03-17	44.0%	881 days
1998-04-02	2000-03-14	2001-12-21	31.0%	1359 days
2019-07-16	2020-03-23	2020-07-15	29.0%	365 days
2021-02-12	2022-09-30	2024-12-31	26.0%	Ongoing
2002-05-03	2002-10-09	2003-07-08	23.0%	431 days
2011-07-08	2011-11-25	2013-03-20	21.0%	621 days



4.21 Healthcare: Capitalization weighted

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	6.51%	0.45	43.3%	0.3x	0.12%
2000-2009	1.27%	0.06	43.3%	0.4x	0.14%
2010-2019	12.93%	0.89	23.4%	0.3x	0.10%
2019-2024	8.63%	0.51	29.4%	0.3x	0.12%
2021-2024	3.52%	0.63	21.3%	0.3x	0.12%
2023-2024	3.84%	0.69	14.3%	0.3x	0.14%

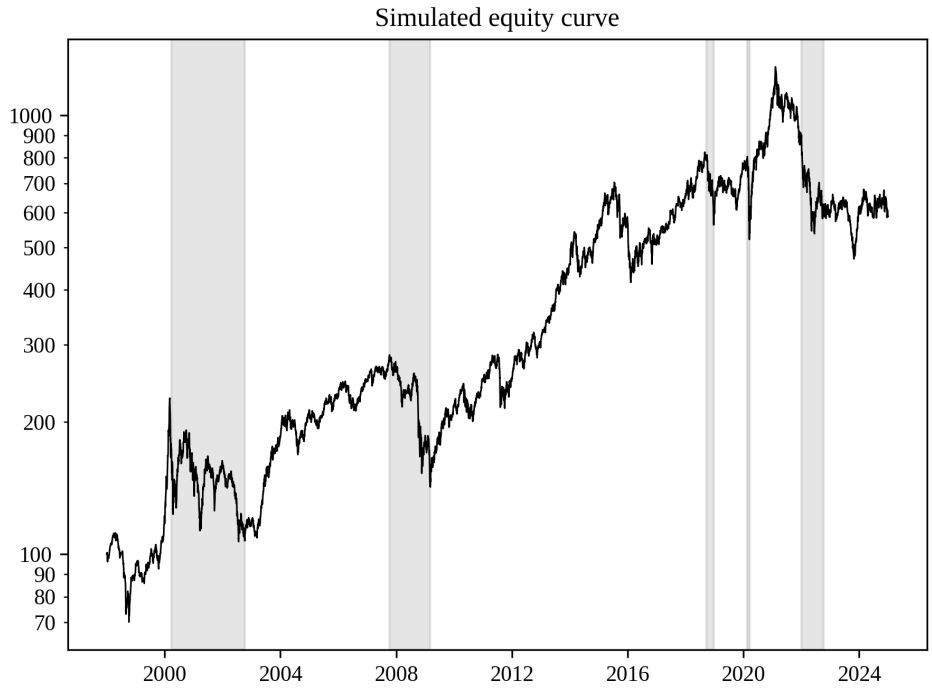
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2000-12-28	2002-07-23	2007-04-16	43.0%	2300 days
2007-12-10	2009-03-05	2011-04-28	40.0%	1235 days
2020-02-19	2020-03-23	2020-07-02	29.0%	134 days
2015-07-20	2016-02-08	2017-07-19	23.0%	730 days
2021-09-03	2022-06-16	2024-02-15	21.0%	895 days
2000-03-06	2000-04-14	2000-07-05	19.0%	121 days



4.22 Healthcare: Equal weighted

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	7.31%	0.45	63.5%	0.4x	0.27%
2000-2009	5.88%	0.45	52.9%	0.4x	0.27%
2010-2019	13.28%	0.73	40.8%	0.4x	0.24%
2019-2024	-0.69%	0.05	63.5%	0.5x	0.33%
2021-2024	-13.32%	-0.07	63.5%	0.5x	0.34%
2023-2024	-0.94%	-0.04	28.8%	0.5x	0.41%

Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2021-02-09	2023-10-27	2024-12-31	63.0%	Ongoing
2000-03-06	2002-07-23	2005-09-06	53.0%	2010 days
2007-10-10	2009-03-09	2011-07-07	50.0%	1366 days
2015-07-17	2016-02-11	2018-01-25	41.0%	923 days
1998-04-21	1998-10-08	1999-12-22	37.0%	610 days
2018-08-31	2020-03-18	2020-06-22	37.0%	661 days



Chapter 5

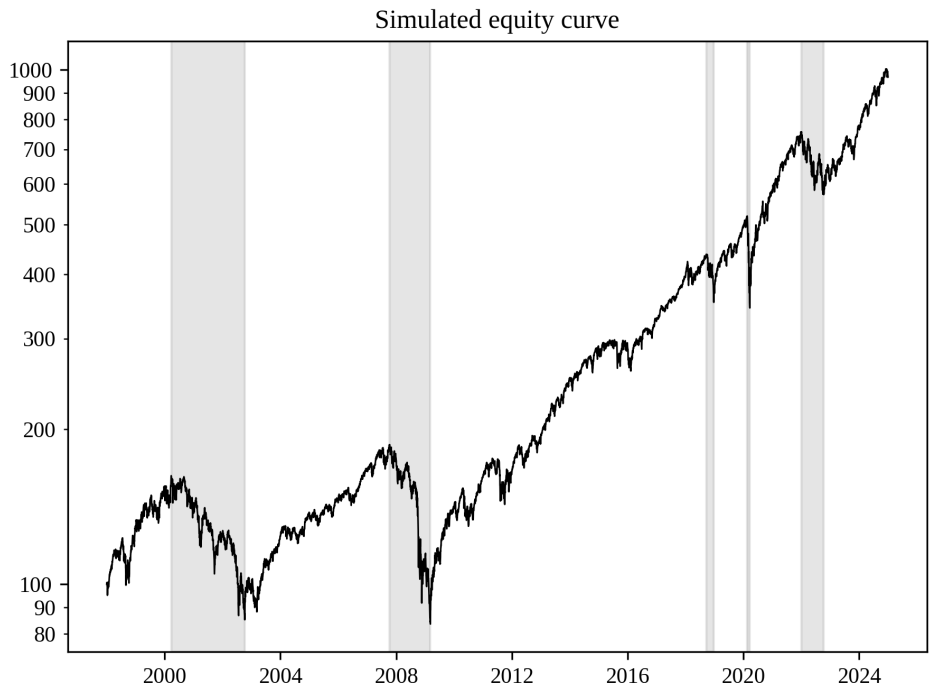
Benchmark strategies

This chapter will show the performance of common benchmarks in the framework of our other simulations for comparison purposes.

5.1 The S&P 500

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	8.08%	0.5	55.2%	0.0x	0.00%
2000-2009	-0.91%	0	55.2%	0.0x	0.00%
2010-2019	13.26%	1	19.3%	0.0x	0.00%
2019-2024	17.03%	0.76	33.7%	0.0x	0.00%
2021-2024	13.85%	1.05	24.5%	0.0x	0.00%
2023-2024	25.69%	1.39	10.0%	0.0x	0.00%

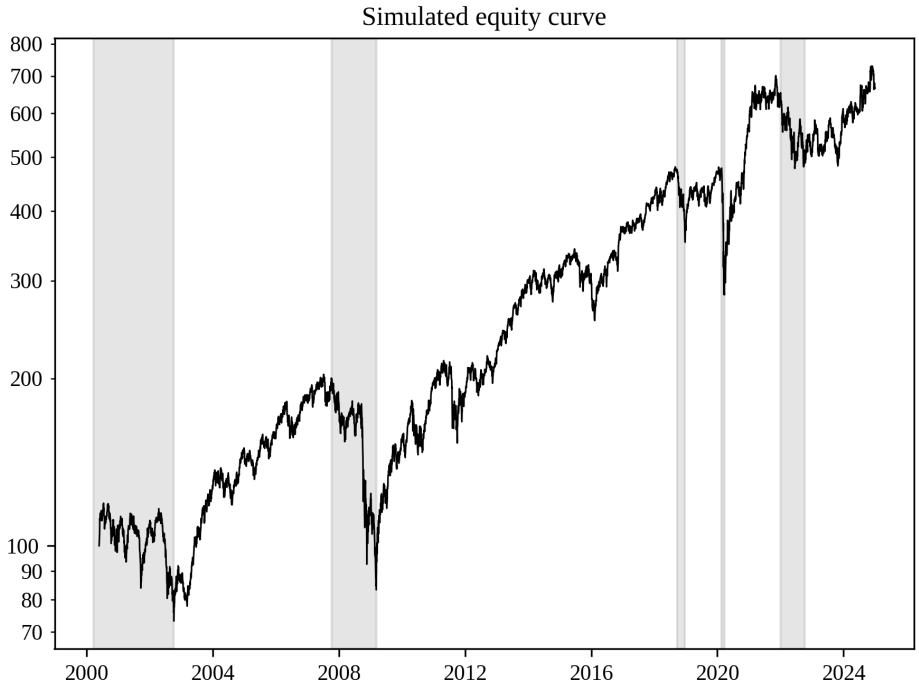
Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-10-09	2009-03-09	2012-08-16	55.0%	1773 days
2000-03-24	2002-10-09	2006-10-26	48.0%	2407 days
2020-02-19	2020-03-23	2020-08-10	34.0%	173 days
2022-01-03	2022-10-12	2023-12-13	24.0%	709 days
2018-09-20	2018-12-24	2019-04-12	19.0%	204 days
1998-07-17	1998-08-31	1998-11-23	19.0%	129 days



5.2 The Russel 2000

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	8.01%	0.41	59.0%	0.0x	0.00%
2000-2009	4.55%	0.16	59.0%	0.1x	0.00%
2010-2019	11.57%	0.74	28.9%	0.0x	0.00%
2019-2024	9.98%	0.34	41.1%	0.0x	0.00%
2021-2024	4.62%	0.59	31.9%	0.0x	0.00%
2023-2024	14.28%	0.42	18.0%	0.0x	0.00%

Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2007-07-09	2009-03-09	2011-02-11	59.0%	1313 days
2018-08-31	2020-03-23	2020-11-09	41.0%	801 days
2000-07-17	2002-10-09	2003-10-13	39.0%	1183 days
2021-11-08	2022-06-16	2024-11-06	32.0%	1094 days
2011-04-29	2011-10-03	2012-09-13	29.0%	503 days
2015-06-23	2016-02-11	2016-11-11	26.0%	507 days



5.3 The NASDAQ Index

Summary statistics	CAGR	Sharpe	Max Drawdown	Turnover	Fee impact
1999-2024	10.03%	0.47	83.0%	0.0x	0.00%
2000-2009	-6.76%	0.01	83.0%	0.0x	0.00%
2010-2019	17.69%	1.13	22.8%	0.0x	0.00%
2019-2024	22.83%	0.88	35.1%	0.0x	0.00%
2021-2024	14.09%	0.93	35.1%	0.0x	0.00%
2023-2024	39.97%	1.41	13.6%	0.0x	0.00%

Drawdown start	Trough	End	Max drawdown	Peak-to-peak days
2000-03-27	2002-10-09	2015-02-20	83.0%	5443 days
2021-12-27	2022-11-03	2023-12-13	35.0%	716 days
2020-02-19	2020-03-16	2020-06-03	29.0%	105 days
2018-08-29	2018-12-24	2019-04-12	23.0%	226 days
2015-12-01	2016-02-09	2016-07-27	16.0%	239 days
2000-01-03	2000-01-06	2000-01-19	15.0%	16 days