



# Investing in mean reversion works, but the devil is in the detail

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- Momentum and mean reversion on the stock market are phenomena that have preoccupied researchers for decades.
- Mean reversion can occur as a cross-sectional mean reversion (reversal of the relative performance) and as time series mean reversion (absolute reversal to the mean of individual assets).
- The two forms of mean reversion have led to various absolute return-orientated, truly uncorrelated strategies such as pairs trading or long-short investing on indices.
- In this article, we focus on mean reversion in time series and examine the possible causes of the observed mean-reverting behaviour in major equity markets since the turn of the century. Lastly, our article shows how Amadeus harvests the associated returns.

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**S**ince the early days of modern financial analysis, investors have tried to recognise patterns in seemingly random and unpredictable price movements. At the centre of this, of course, is the question of whether a trend observable in the rear-view mirror will continue or reverse. As we have been systematically and successfully investing in mean reversion for some time, this article examines the possible reasons why it has dominated market behaviour over the last 24 years and highlights the obstacles to exploiting it.

## 1 What is mean reversion?

Mean reversion in finance is a theory that posits that asset prices, historical returns or fundamentals such as profit margins or returns on investments eventually revert to their long-term mean or average level. The concept is based on the idea that significant deviations of values from the mean statistically tend to be anomalies that will be corrected over time. The idea finds direct application among investors in dedicated strategies or the analysis of asset prices and their trajectory, providing valuable insights for informed investment decisions. It also has indirect use, for instance when assuming mean reverting behaviour of valuation multiples or companies' operating performance in competitive markets.

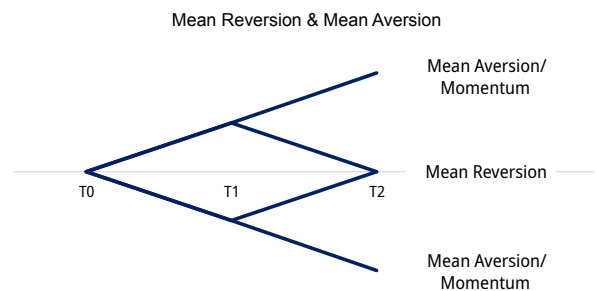
Broadly speaking, there are two ways investors typically exploit mean reversion.

- **Cross-sectional:** The concept of mean reversion

can be applied in the cross-section of asset returns, for instance, through pairs trading, where the investor or trader assumes that the relative out- or underperformance of a security against a comparable asset will eventually revert. This concept is opposed to the momentum effect (mean aversion) that assumes that relative out- or underperformance will continue.

- **Time-series:** In time series mean reversion, the investor focuses exclusively on the respective asset's performance, ignoring other assets' returns and behaviour. Again, the approach is opposed to the concept of momentum. While time series momentum assumes that positive returns will be followed by positive returns, and vice versa, mean reversion assumes the contrary. Figure 1 demonstrates this using a stylized example.

Some market observers have argued that both forms of

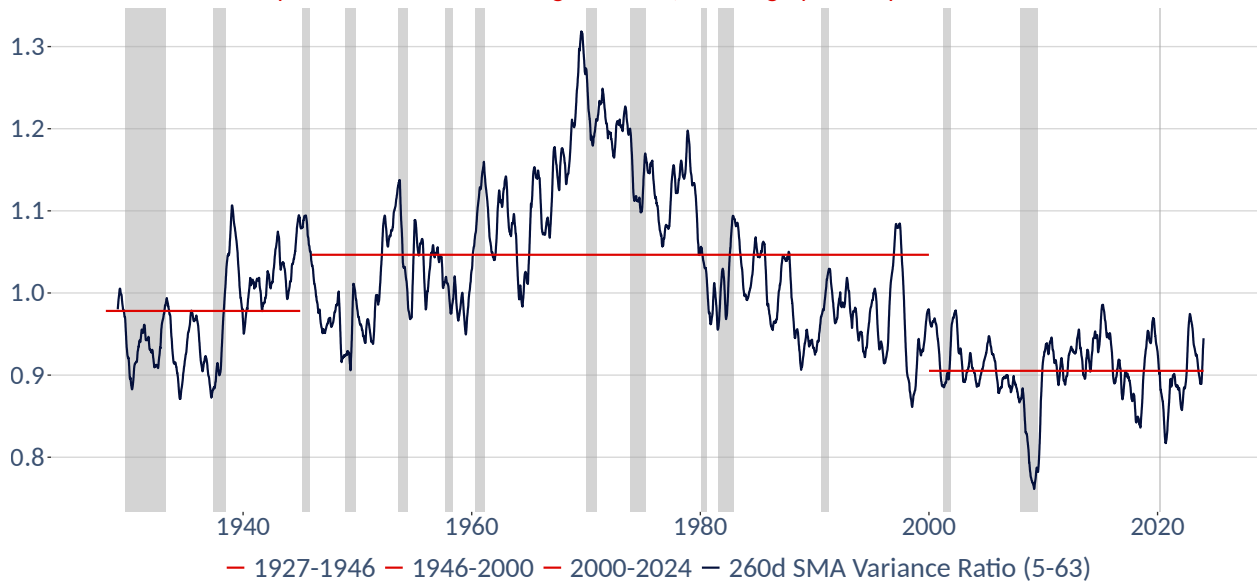


Source: Source: Amadeus Capital

Figure 1: Stylized mean averting and reverting behaviour

### Variance ratio S&P 500

Values of < 1 indicate presence of mean reverting behaviour, shaded grey areas represent NBER-recessions



Source: Bloomberg, FRED, Amadeus Capital

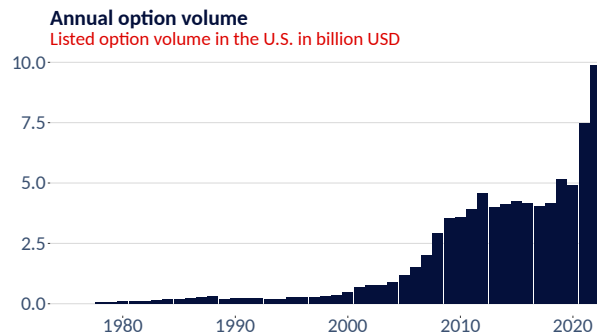
**Figure 2:** The variance ratio describes the relation between the return volatility calculated over a longer return interval and the daily return volatility. It is a commonly used indicator of an asset's trending (momentum/mean averting) or mean reverting behaviour. If the former is higher than the latter, markets are trending and vice versa.

mean reversion and momentum principally violate the efficient market hypothesis, which states that returns (particularly in the stock market) are unpredictable [1]. Based on this assumption, markets are typically modelled as a random walk, where each day's return resembles a flip of a coin whose outcome depends in no way on previous outcomes. On the other hand, researchers have pointed out that the discussed phenomena may represent a form of risk premia. In other words, traders who profitably engage in momentum or mean reversion strategy are rewarded for a particular risk. An example of this approach is given for instance by the Carhart four-factor model [2], stating that single stock returns can be explained by their sensitivity to movements of the overall stock market as well as their exposure to a given set of additional risk factors, namely size (small outperforms large), value (cheap outperforms expensive) and momentum (past outperformers outperform past underperformers). In the case of momentum strategies in stock selection, the unique risk that is taken can, for example, stem from so-called 'momentum crashes', which are often observed in connection with market regime changes [3].

While there is a substantial and growing body of literature on momentum and mean reversion in the cross-section of returns, this article delves into the phenomenon of time series mean reversion (there are overlaps with the topic of cross-sectional mean reversion, though, when it comes to identifying the possible drivers of the phenomenon). Academics have been using simple tests to determine the presence of mean reversion in a time series in principle. The most com-

monly used one is the calculation of the so-called variance ratio.

The variance ratio divides the volatility of returns over a longer interval (e.g. weekly or monthly returns) by the volatility of daily returns multiplied by the number of days in the interval. Both calculations should yield the same result in a perfectly random time series that experiences neither momentum nor mean reversion. In the presence of mean reversion, the volatility calculated over a longer interval adjusted for its length will be lower (variance ratio < 1). In contrast, an interval



Source: Source: Amadeus Capital

**Figure 3:** Trading volume in liquid options increased massively over the past 25 years and surged again since the COVID-19 crash. Index options still only represent a fairly small share of the overall pool, but it can't be ruled out that increased options trading in single stocks indirectly increases mean-reverting tendencies at the macro level through dealer's hedging activity.

Source: Source: Amadeus Capital  
Figure 4

variance higher than the daily variance multiplied by the number of days in the interval signals the presence of momentum or mean aversion (variance ratio  $> 1$ ). Figure 2 displays the 260-day moving average of this ratio estimated for the S&P 500 based on 5-day return intervals (one week) and a rolling variance lookback window of 63 days (approximately 3 months). Furthermore, we calculated the average ratio over three periods, namely the pre-World War II period from 1927 to the end of 1945, the period between the war and the turn of the millennium and the last 24 years since 2000. As can be seen, the S&P 500 tended to show slight mean-reverting characteristics during the pre-war phase. It then turned into a momentum-driven market over the second half of the century while mean reversion dominated again following the dot-com bubble. This phenomenon leads to some interesting observations concerning the half-life of academic research. A 1991 paper in the *Review of Economic Studies*, for instance, concluded that mean-reverting behaviour in stock prices was "entirely a pre-war phenomenon", attributing this to fundamental changes in the "stock returns process" and the resolution of the uncertainties of the 1930's and 1940's" [4].

Nevertheless, the (this time stronger) reoccurrence of time series mean-reverting behaviour, not only in the S&P 500 but also, for instance, in the Nasdaq, the DAX, the CAC 40 or the FTSE since the turn of the century, raises the question, why it is consistently present. As Micaletti 2023 [5] pointed out, two popular theories attempt to explain the phenomenon.

### 1.1 The behavioral case

Most active investors would probably agree that they frequently feel that markets exaggerate in either direction, driven by the fear and greed of the swarm. Can a single macroeconomic announcement, combined with a compelling narrative, reduce the present value of all future cash flows of a company or an entire market by a mid-single digit amount?

Source: Source: Amadeus Capital  
Figure 5

It is hence not surprising that much academic research has covered reversal effects. As Micalette 2023 critically noted, the question remains though, as to why mean-reverting behaviour at the broad market level became particularly prevalent around the turn of the century?

A possible explanation lies in the advent of new technology, namely the internet, and a broader and more accessible offering of financial services enabled by it. The presence of mean-reverting behaviour in stock market indices coincides with the dawn of index futures in the 1980s [6] and the development of electronic trading at scale during the 1990s [7]. In fact, running mean reverse strategies like ours would have been impossible before the launch of the S&P 500 futures contract in 1982. Beyond that, the 2000s brought the advance of Exchange Traded Funds (ETFs), faster information dissemination through all kinds of online news channels, as well as algorithmic trading and no-frills brokerage. As shown in Figure 3, options trading volume has also risen sharply since the turn of the century, and as the CBOE pointed out in a 2022 article, retail brokers like Robin Hood enjoy substantial market share [8].

These points may be relevant for several reasons. First of all, the rise in ETFs and inverse (short) ETFs, alongside faster dissemination of news and algorithmic trading, favour the timely pricing of information both at a single stock and a market-wide level. Bhojraj et al. (2020), for instance, found that a high share of sector-ETF ownership is associated with "increased earnings response coefficients and responsiveness to industry and idiosyncratic components of earnings" and "reduced post-earnings announcement drift". While the cause of this effect is not entirely clear, one hypothesis presented is the role of sector ETF in efficiently transmitting industry-level information into stock prices and reducing drift and thus momentum effects.

At the same time, the impact of the rise in low-cost retail brokers is not entirely clear. Some researchers argue that retail traders may be more prone to overre-

Source: Bloomberg, Amadeus Capital

Figure 6: The graphic provides an extract from our backtest of a complex time series mean reversion strategy. The strategy utilizes multiple signals to detect relatively extreme up- or down-moves in the market that are likely to result in substantial reversals and size positions according to the derived confidence level.

acting to news, punching the market below justifiable levels during bear markets and bidding them up to unsustainable levels after positive events, thus causing reversal effects (e.g. Barber and Odean (2013)[9]). On the other hand, a 2022 working paper by the Chicago Fed [10] argued that retail investors at the single stock level tend to act as contrarians, thus tending to induce momentum effects. Similarly, Hüfner et al. (2021)[11] find that high retail ownership tends to improve liquidity and stabilize stocks during market crashes. This could favour drift behaviour. On the other hand, it could also speak for mean reversion if retail traders systematically react to drops in share prices by buying the dip - potentially with a lag.

## 1.2 The liquidity provision case

Aside from the somewhat idiosyncratic behavioural case, positive returns from mean reversion strategies could be the reward for the strategy providing liquidity in crucial moments. Analysing emerging market equities, Butt et al. 2021, for instance, showed that returns from mean reversion strategies tend to be highest during times of elevated volatility and in stocks that witness higher investor exits [12].

The effect could also be linked to the observed surge in options trading since the turn of the century. Listed options are sold by market makers, who typically delta-hedge their position. In other words, a market maker who sells a put option to an investor seeking to protect their portfolio will short-sell the underlying to avoid

exposure to a falling price. Given the embedded convexity in option contracts, this delta hedge, however, becomes inaccurate the moment the underlying drops (delta decreases in the case of a put and increases in the case of a call). The market maker, therefore, needs to increase their short positions to readjust the hedge.

As several market observers pointed out, retail investors effectively deployed this mechanism during the GameStop saga when they tactically caused a gamma squeeze. By buying call options and, contemporaneously bidding up the stock, they forced market makers into buying ever more shares, thus driving prices up even further [13]. It is easy to imagine that, especially in the presence of increasingly popular 0-day options at a market-wide level, this effect could exacerbate short-term exaggerations that set the stage for later reversals.

## 2 Capturing mean reversion returns

As outlined, the reasons for the presence of time series mean reversion at index level since the turn of the century are not completely clear. In the end, the effect may be caused by a combination of factors, with the rise of the internet, ETFs, retail brokerage accounts and deeper derivatives markets, all being possible explanatory variables. In the absence of a regime shift, this also implies that the described behaviour is probably here to stay.

This prompts the question of how investors can benefit

Source: Source: Amadeus Capital  
Figure 7

from the limited predictability of short-term returns that is inherent in the existence of mean-reversion patterns. After all, as many market observers have pointed out, it may be one of the few genuinely market-neutral strategies and opportunities to generate uncorrelated returns that are typically highly sought after. However, reaping these returns is not as straightforward as it may seem at first sight.

In Figure 4 and Figure 5, we simulated the returns of a naïve mean reversion strategy that buys the S&P 500 if the return on the previous day was negative and shorts the market if the return at the last close was positive. Setting aside that in this simulation, we are ignoring transaction costs, this simple strategy would have generated quite impressive returns. Moreover, as Figure 5 indicates, it would have produced gains exactly when markets dropped sharply and vice versa. It is hence a strategy with attractive diversification characteristics. However, on its own, this strategy would have also experienced drawdowns similar to those in the underlying index and suffered from equally high volatility. Moreover, periods of strong returns, such as the Great Financial Crisis, were followed by extended periods of sideways movement and significant drawdowns, which could have led investors to question the strategy's overall viability. Importantly, as Micaletti (2023) pointed out, the same approach would have led to abysmally poor performance before the turn of the century, particularly during the 70s. Lastly, despite the changes in market structure discussed earlier, there is little economic rationale for a mean reversion strategy as simplistic as the one simulated in Figure 4.

### 3 Developing a robust strategy

Over the years, we have, therefore, developed a significantly more complex approach that seeks to capture only instances where factors like irrational greed and fear, algorithmic trading or gamma hedging are likely to have caused short-term movements that can reasonably be considered exaggerated. This approach combines a range of technical indicators and sizes po-

Source: Source: Amadeus Capital  
Figure 8

sitions according to the level of confidence obtained. Furthermore, we implement the strategy across several (currently four) indices and restrict it to the most efficient markets (US, Europe, UK). To further mitigate risks, the strategy switches to cash if there are not sufficiently strong signals and also refrains from trading if the markets are trending too strongly (as in March 2020).

Figure 6 shows an example of this in practice. Some buy signals are typically generated at the onset of a drawdown in the underlying. If the price decline continues and picks up speed, the number of counter-signals multiplies and the strategy expands its long positions. Eventually, the index hits the bottom, and volatility decreases, triggering the strategy to stay out of the market. Figure 7 compares the risk-return profile of the strategy's backtest and its performance since 2021 with the long-only performance of the S&P 500 and the naïve mean-reversion strategy illustrated earlier. Interestingly, despite its low correlation, the naïve mean reversion strategy generated the same returns and volatility as the index itself.

We, however, believe that the more robust strategy we have put in place offers a significantly better risk-return trade-off. Figure 8 illustrates this by plotting the life performance of the complex strategy against the simulated performance of the naïve mean reversion strategy since we started trading in 2021. While both strategies have fared well in a challenging environment characterized by a severe bond market crash and a prolonged equity bear market in 2022, the enhanced strategy evidently generated more consistent returns while providing better diversification benefits in 2022.

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