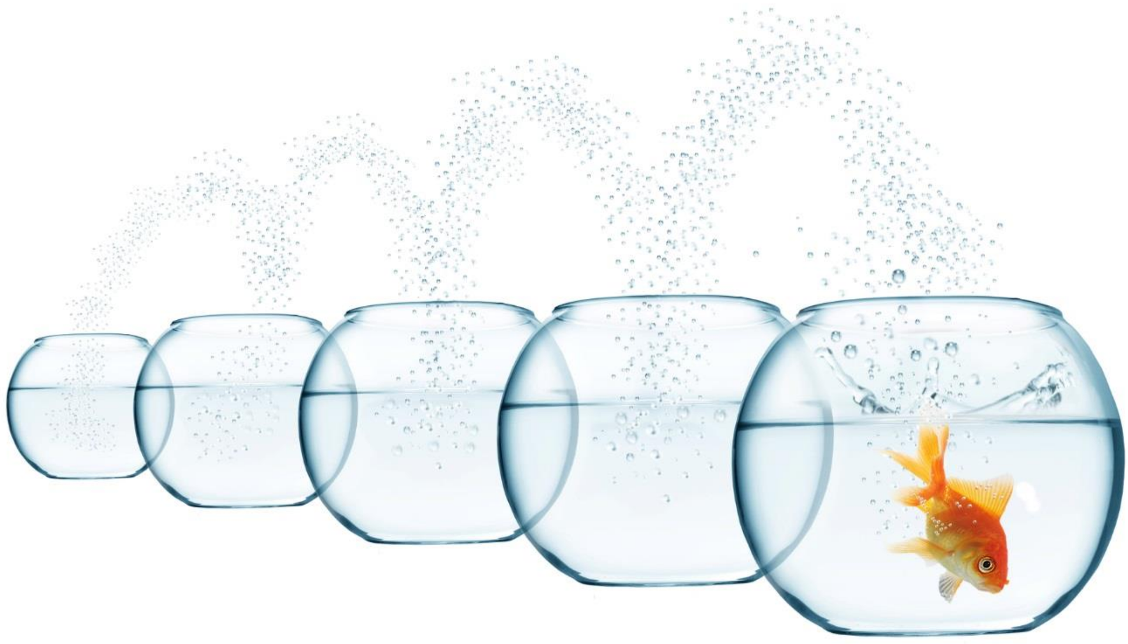
Short-term trend following

How to monetise intraday trading patterns



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Focusing on the short term

"A cloud is made of billows upon billows upon billows that look like clouds. As you come closer to a cloud you don't get something smooth but irregularities at a smaller scale."

A Theory of Roughness, B. Mandelbrot

About 75% of trades in the US equity market are generated by algorithmic trading[1]. Approximately a third of the $3.8trn AUM of US-listed ETFs are labelled as "factor and style ETFs". [2] Total AUM in risk premia funds and indices is estimated to be around the $400bn mark.

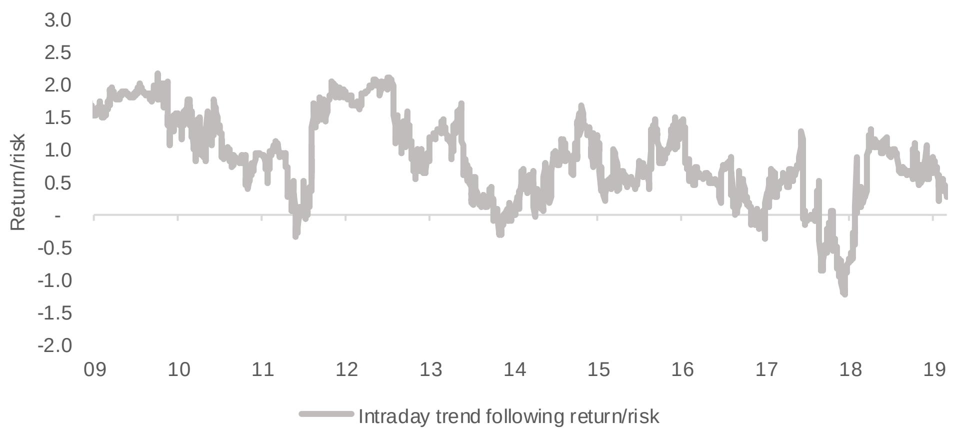
Rule-based trading is now fully integrated into the investment landscape. Many systematic strategies, once the preserve of a few market players, are being commoditized: trend following, equity factor investing, and commodities carry strategies to name just a few.

But so far, commoditized systematic strategies have remained in the field of low-frequency trading with holding periods of between one week to several months. High-frequency trading is still the bread and butter of hedge funds and execution desks. That might change as sophistication increases across the asset management industry.

We focus on day trading and intraday price patterns in this report. We introduce the intraday trend strategy. It follows a simple trading rule. It starts the day with no position at all. It then gradually builds up a position that is proportional to the intraday trend during the trading day. If at any given time in the trading day, the current price is high relative to the previous day's close, then a long position is built. Conversely, if the current price is low, then the rule builds a short position. If the market shows no clear signs of a trend – that is, if the current intraday price is close to the previous day's close – then no position is taken. All remaining positions are unwound at the end of the day.

This strategy applied to the S&P has an attractive return profile over the long run.

The intraday-trend strategy to the S&P, an attractive return profile



Source: SG Cross Asset Research/Cross Asset Quant, SG Trading, Bloomberg

[1] Source Tabb Group, https://www.ft.com/content/fdc1c064-1142-11e9-a581-4ff78404524e

[2] See SG US ETF Directory – 2Q29

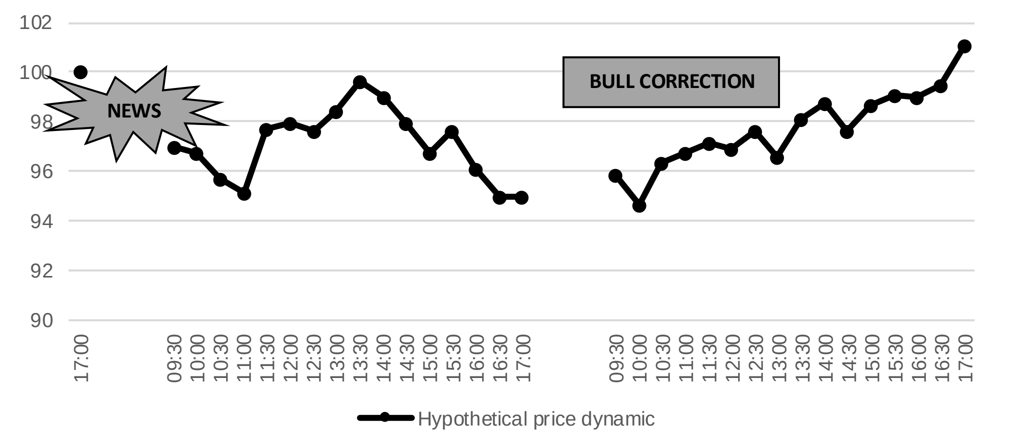
The intraday trend following strategy over one day (S&P on 17 December 2018)[3]

Source: SG Cross Asset Research/Cross Asset Quant

[3] Position (second and third chart above) is a multiple of intraday returns. The strategy is naturally underleveraged and so any gains or losses are likely to be small. Position size needs to be adjusted to achieve a meaningful return. This point will be discussed in part 2 of the report.

The intraday trend following strategy monetises a well-observed behavioural pattern of market participants. When negative news appears outside trading hours, markets drop sharply at the open. The downtrend tends to persist until the close of the session as this new information is analysed. During the next session, prices tend to revert, with the formation again of a new trend during the day. This is the usual bear correction in a bull market or bull correction in a bear market.

Intraday price dynamic in the stock market



Source: SG Cross Asset Research/Cross Asset Quant

The intraday strategy is well equipped to handle such a pattern. The position established on each day is governed by price moves compared to the previous close. Thus, the strategy builds up a short position and closes it at end of day on the first day when there is a sell-off. It does the opposite the next day when the market rallies. Effectively, the strategy gains on both days of this pattern.

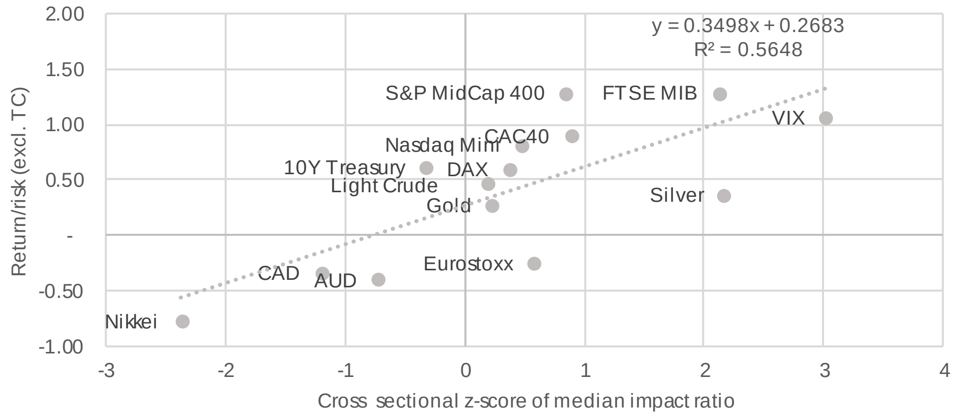
Intraday trend followers can benefit greatly from market turmoil. Passive mutual funds, ETF managers and options hedgers are all forced into trading at the end of the day. This increase in trading activity has several consequences just before the closing bell: more stocks change hands, volatility increases, as do trading costs.

Quantifying these flows is a daunting task. However, their mechanics and qualitative impacts are easier to understand. Leveraged ETF providers chase the market at the close to keep their leverage ratio constant and so add to the buying or selling pressure. This intensifies the trend going into the close. It is no surprise then that in markets where leveraged ETFs AUMs are large, the intraday trend follower fares better.

We use our ETF research team's database of global ETF flows and AUMs to calculate a daily impact ratio, namely the volume of trading due to leveraged ETF rebalancing divided by the trading volume in the related futures market. There is a positive relationship between the risk-adjusted return of the intraday trend strategy and this impact ratio[4].

[4] More detail in part 5 of this document.

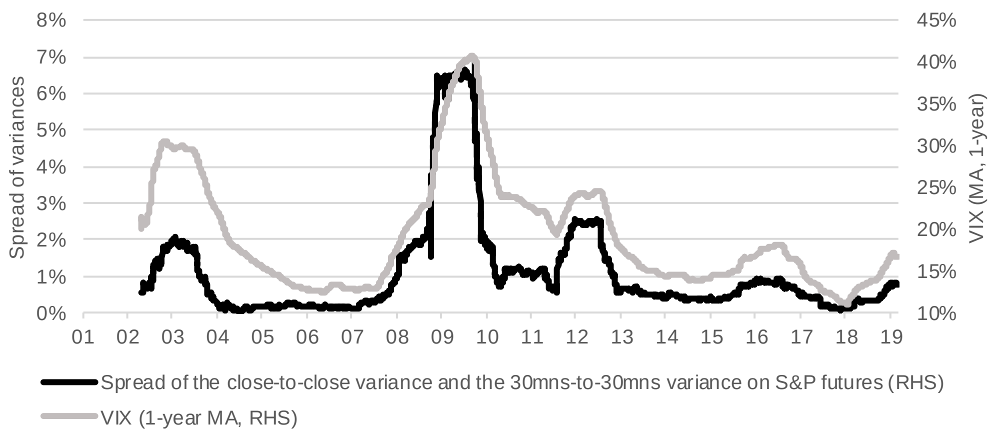
The impact of ETF flows on intraday trend followers



Source: SG Cross Asset Research/Cross Asset Quant, ETF Research, SG Trading, Bloomberg

The intraday trend-following strategy ends up long the daily variance of price returns and short the intraday variance of price returns. Historically, uncertainty has always been greater at the close than intraday, and this spread has always been positive. And the more uncertain the environment, the greater this spread. If this relationship holds, then the intraday trend following strategy should have a defensive profile, gaining more during periods of market turmoil.

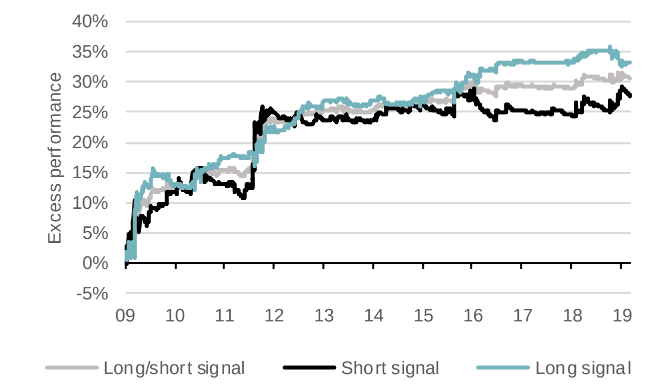
The higher the uncertainty, the better the expected return of the intraday trend strategy



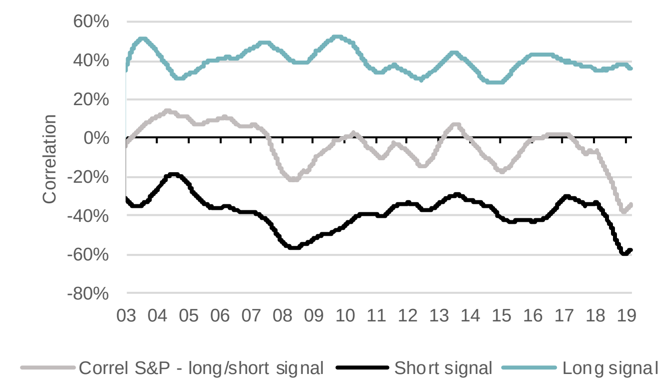
Source: SG Cross Asset Research/Cross Asset Quant, SG Trading, Bloomberg

But this relationship can break down or momentarily disappear. An investor with a long exposure on the broad market and looking for a cost-efficient hedge against market downturns can greatly profit from allocating to intraday trend on the downside. As shown below, implementing only the short side of the signal has a strong negative correlation with the broad market while delivering an attractive risk/return profile.

Asymmetric intraday trend signals…



… lead to a more defensive profile



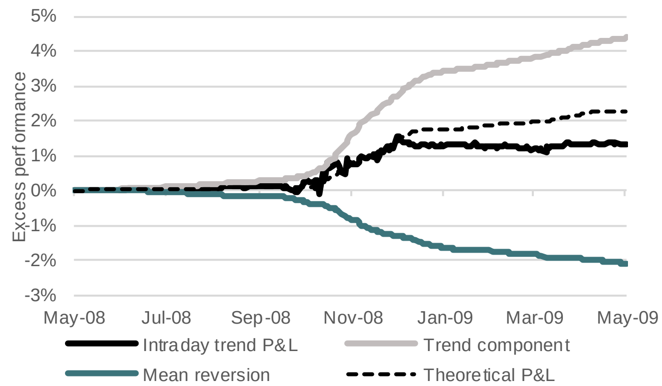
Source: SG Cross Asset Research/Cross Asset Quant

A framework for understanding intraday trend following performance

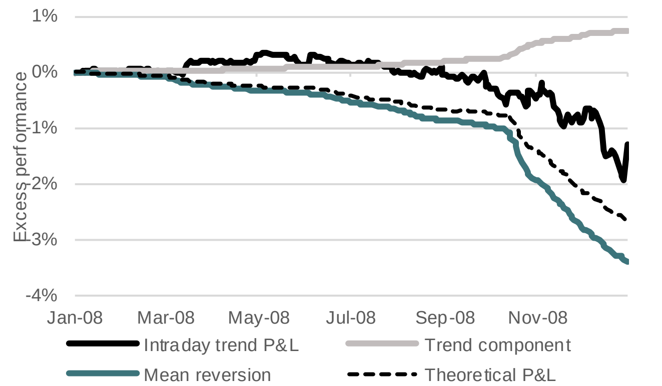
To gain a greater understanding of the performance of the intraday trend following strategy, we developed an analytical framework inspired by our previous work on mean reversion.

We split the performance drivers of the intraday trend following strategy into three parts. The first part benefits from the daily trend, the second part from the uncertainty of this trend, and the last part captures the reversion to the mean of intraday prices. The strategy posts a gain if the market trends from one day to another. The gain is even larger if the market trends in an uncertain manner, but the strategy loses if prices have large oscillations during the day.

S&P gains during the GFC from the trend and its volatility



Brent mean reversion offset any trend gains



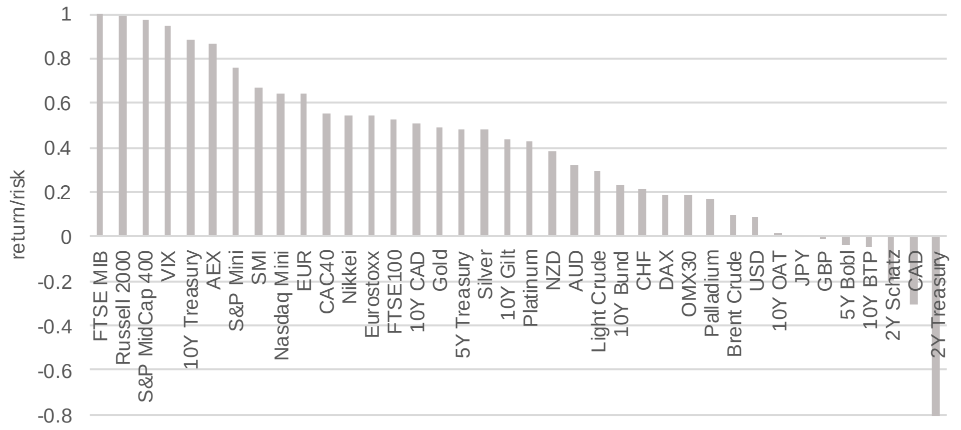
Source: SG Cross Asset Research/Cross Asset Quant

Mean reversion, daily trend, intraday and daily volatilities are the four key parameters of our theoretical performance model. The statistical estimation of those parameters is difficult and we propose an innovative estimation procedure later in this document. Investors can use these parameters to help identify the assets best suited for intraday trend following. They can also use them for allocation or risk management purposes.

Day trading across assets

Before transaction costs, most asset classes are amenable to intraday trend following. Only short-term government bond futures, BTPs and some currency pairs are not profitable over the long run.

Applying the intraday trend following rule across assets (excluding costs)



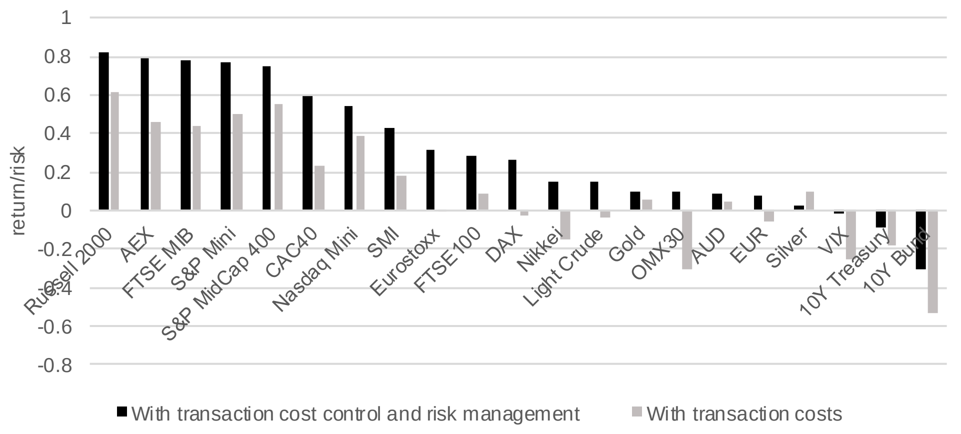
Source: SG Cross Asset Research/Cross Asset Quant, SG Trading, Bloomberg

But following a trend intraday requires many transactions, and therefore execution costs matter a lot. Bid-ask spreads vary greatly across assets and within a single asset class. The most expensive assets to trade are palladium and platinum. Transaction costs for these two metals more than offset strategy gains, even if they trend strongly intraday.

Moreover, execution costs vary during the day. As such execution strategy, risk management and cost control are key to successful implementation and can significantly improve the risk adjusted returns over the long run. In term of the latter, we discuss ideas on how to improve cost control and risk management.

Once all is said and done, the most profitable assets in this trading rule are mainly equity futures over the long run. But diversification can be found across regions and in some liquid commodities such as light crude or gold.

Day trading across assets – fine-tuning the signal



Source: SG Cross Asset Research/Cross Asset Quant, SG Trading, Bloomberg

The rest of this document is organised as follows. The first part shows how intraday trends relate to other risk premia strategies such as short volatility and extra-day mean reversion.

The second part details the intraday trend trading rule. We explain how we split the performance of the strategy into three components: the trend, its volatility and the mean-reversion component.

The third part details how to implement this trading rule efficiently by reducing the number of transactions that need to be done and by risk managing the position.

The fourth part goes one step further and introduces subtleties to the trading signal to make it more defensive or to combine it with a mean-reversion pattern.

The fifth part is a detour in the world of “non-delta one” ETFs in an attempt to explain the return of the strategy via the flows coming from those products.

The technical details, mathematical formulas and assumptions are in the addendum.

A journey in day trading

This journey starts with a story. It is the story of two risk premia strategies: the short volatility strategy and the daily-weekly strategy. These share a common element: the fixing of prices at the close.

The volatility premium conundrum

A close-up view of the option premium

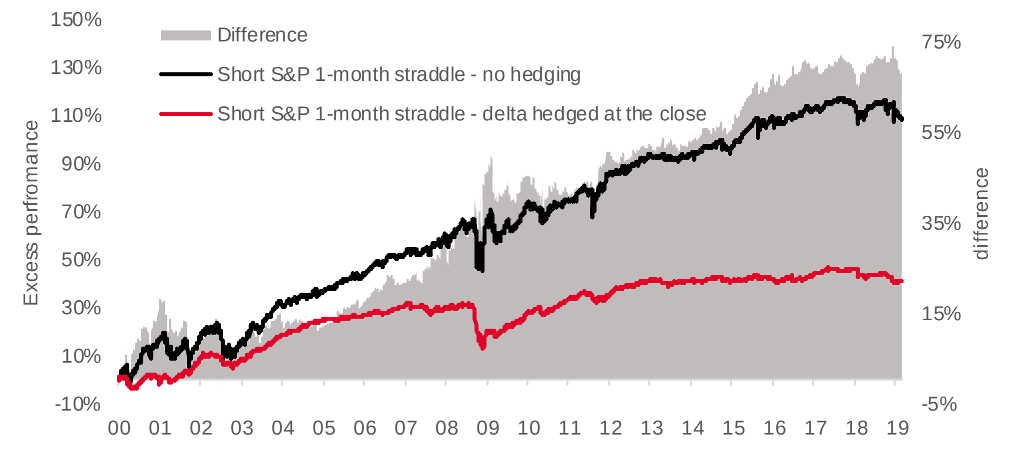
Source: SG Cross Asset Research/Cross Asset Quant

A popular strategy among equity option traders is to collect the volatility premium. There are two approaches. The first consists of selling naked options. Selling naked options is akin to taking insurance risk. The investor sells a form of insurance against a sudden move and receives a premium in exchange for taking that risk.

The investor can also choose to hedge directional risks. This type of strategy is usually pursued by arbitrageurs via the mechanism of delta hedging. Selling options and delta-hedging them is much safer than selling naked straddles. Well, in theory it is.

In practice, in the equity market, this is not necessarily the case. When hedging every day at the close, an investor would have lost 80% in performance over the past 20 years compared to just selling straddles on the S&P, a clear underperformance from a risk-adjusted return standpoint.

The volatility premium conundrum



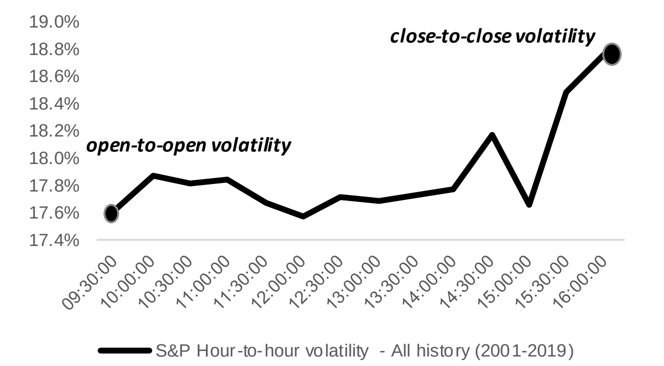
Source: SG Cross Asset Research/Cross Asset Quant, Bloomberg

There is something structural at play here. Selling straddles without any form of risk management is a very risky business. Selling straddles on the main equity indices would have miraculously benefited from the Lehman crisis, thanks entirely to the timely intervention of central banks. But there is no guarantee that in the next major breakdown, central banks will step in. Risk management is key.

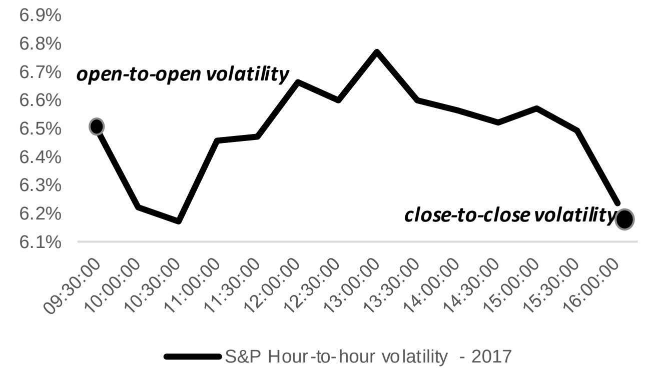
But risk management can be costly. In our report A close up view of the option premium, we explored all possible ways of hedging straddles across markets. When adjusting a hedge, we found some value in trading during the day rather than when the market closes. Volatility is often higher at the close.

Hedging at fixed trading hours is a way to avoid the volatility at the close. But this is not always the case. In 2017, for example, prices at the close were less volatile due to investors massively entering into short volatility strategies hedged at fixed hours during the trading day. We have nonetheless found value in dynamically hedging during the day.

Volatility is often higher at the close



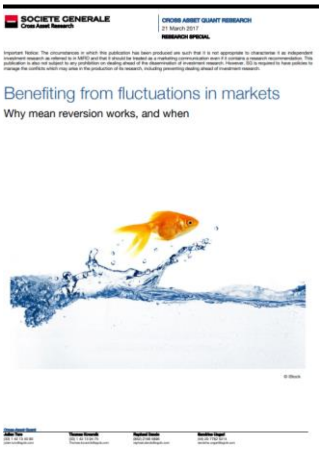
But not always



Source: SG Cross Asset Research/Cross Asset Quant, SG Trading, Bloomberg

Benefiting from market fluctuations

Benefiting from market fluctuations



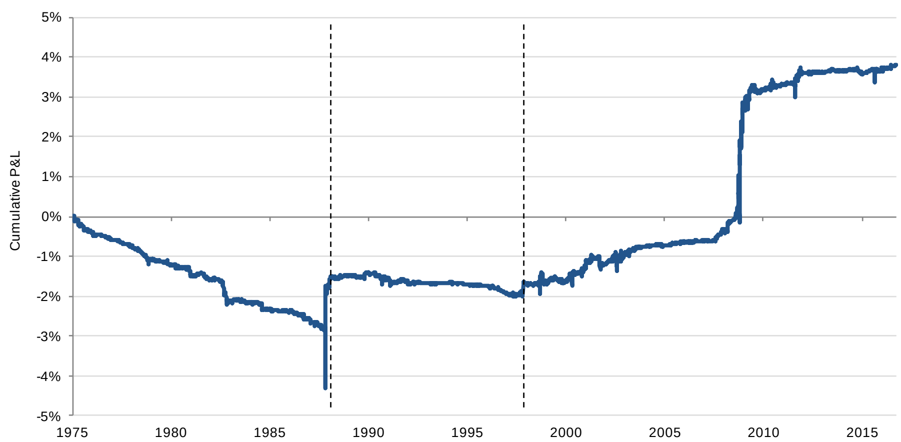
Source: SG Cross Asset Research/Cross Asset Quant

Back early 2010, a systematic strategy gained traction among American investors, the daily-weekly strategy. This strategy builds up contrarian positions and unwinds the position at the end of each week. The investor who pursues this strategy must buy according to how much the market fell on the previous day or sell by how much it rose.

The daily-weekly strategy is very simple and does not require the use of options. Simple algebra reveals that the pay-off of this strategy is proportional to the difference between the variance of all daily returns during the week and the variance of weekly returns. A more in-depth analysis is available here.

This strategy monetises the fact that the daily variance in major equity markets tends to be higher than the variance measured on a longer time horizon. Historical simulations suggest that this has been the case since the crash of 1987 for reasons that are linked to the microstructure of the market, such as the introduction of the circuit breakers or the development of the option market.

40 years of mean reversion



Source: SG Cross Asset Research/Cross Asset Quant, Bloomberg

The intraday traveler

While designing cross-asset volatility premium strategies and cross-asset mean-reversion strategies, we learned two very important lessons.

First, mean reversion – or trend following – and volatility arbitrage are very closely related. In a mean-reverting market, there will be more variance over the short run than over the long run. A strategy selling short-term variance and buying long-term variance stands a good chance of being profitable – and vice-versa in a trend-following market.

Second, there is value in trading during the day rather than trading at the close for hedging a short volatility strategy, and we established that in a mean-reverting market, one should hedge less frequently than in a trend-following market.

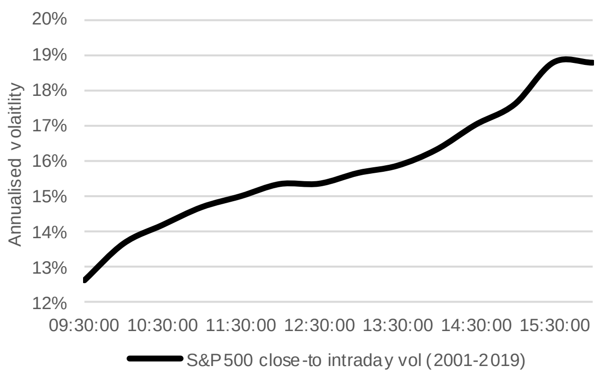
Looking more closely at numbers on the S&P, it appears that the market trends on a close-to-intraday basis and reverts to an average value over a horizon greater than a day and less than a month.

When there is overnight news, markets typically move sharply up or down. The trend up or down tends to persist until the close of the day, as new information is analysed by market participants. The day after a big move on the market, prices tend to revert. This is the usual bear correction in a bull market or bull correction in a bear market.

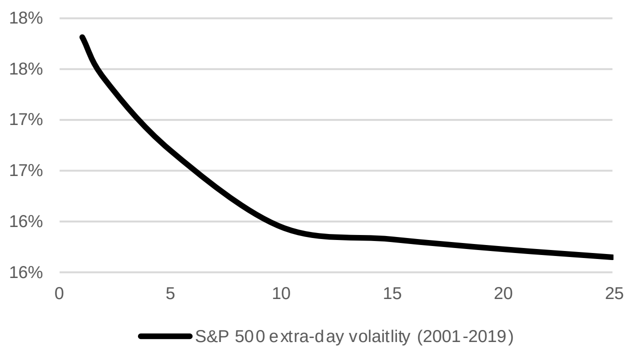
The realised volatility of prices illustrates this effect: when prices are trending, realised volatility tends to increase with time. When prices revert to the mean, realised volatility decreases as the time span on which returns are measured decreases[5].

In the below-left graph, S&P prices can be seen trending intraday, when compared to the previous close. Early afternoon in the New York session, the trend even accelerates before slowing in the last half hour. In the graph on the right, after a large move, the market correction occurs over a 5-10 days horizon.

Intraday trend following



Extra-day mean reversion



Source: SG Cross Asset Research/Cross Asset Quant, SG Trading, Bloomberg

[5] For a technical discussion on the relationship between the term structure of realised volatility and the dynamic of the underlying asset, please refer to Addendum 4

How to benefit from intraday trends

Intraday trends and extra-day mean reversion appear to be a persistent feature of the equity market. Can the investor use a trading rule to monetise that statistical bias? What are the drivers of performance? And how can the investor measure and monitor them?

A simple rule for the day trader

We introduce a very simple trading rule similar the daily-weekly strategy but applied on a smaller time scale: the intraday trend strategy.

Investors start the trading day with no positions in the portfolio. After 30 minutes of trading, they compare the price of the market to the close on the previous day. If the market fell by 1% overnight, they sell the market for an amount equivalent to 1% of the nominal attributed to this strategy. If prices fall by another 1% after the next 30 minutes, the position is doubled down. The investor carries on like this and unwinds the portfolio at the close of the day, leaving no open position.

In real life, an algorithmic trader would not execute the entire position on the same tick price but would smooth it using some VWAP or TWAP execution model. The exact execution strategy is beyond the scope of this paper. To be on the conservative side, we assume that there is a five-minute lag between the calculation of the signal and its execution.

Starting the day with nothing in the portfolio, positions gradually build up in relation to intraday returns. The value of the portfolio then fluctuates with the market.

When the portfolio is unwound, the investor receives or pays an amount of money that is proportional to the average of the cross products of consecutive 30-minute by 30-minute returns. This means that if consecutive returns tend to be positively correlated, the strategy will have a positive outcome. In the long run, returns are positively correlated if there are intraday trends.

The performance profile of the strategy

At each time step, we take a position of the same magnitude and direction as the return within the intraday time interval. For instance, at the end of the second time interval, the position is $R_{0,1} + R_{1,2}$ and the mark-to-market PnL is $R_{0,1}R_{1,2}$. By the end of the day, the PnL is the sum of all MtM PnLs:

$$PnL = \sum_{j=1}^{N}\left(\sum_{i=1}^{j-1} R_{i-1,i}\right)R_{j-1,j} = \sum_{1\leq i<j\leq N} R_{i-1,i}R_{j-1,j}$$

The key drivers of performance

As in previous work on extra-day mean reversion, we assume that intraday market prices oscillate around a daily trend. This trend itself is not necessarily constant and fluctuates around a long-term average with a certain uncertainty.

Mean reversion with a trend

We assume that the underlying asset follows a process consisting of a mean-reverting process and a trend:

$$dY_t = -aYdt + \sigma dW_t$$

where **a** captures mean reversion and $\boldsymbol{\sigma}$ volatility. Y represents the deviation between the market, in real or log terms, and the long-term trend $\boldsymbol{\mu}$. The price of the market, X, evolves according to:

$$dX_t = dY_t + \mu\, dt$$

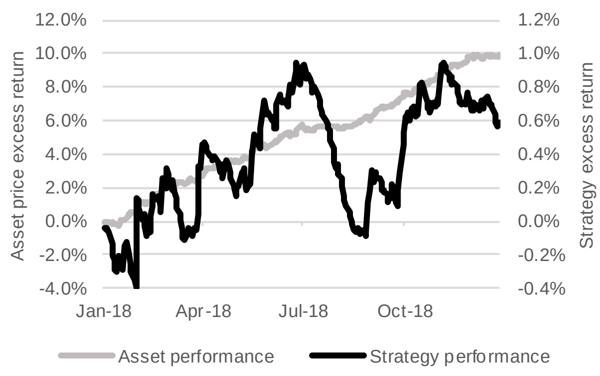
… where the trend $\boldsymbol{\mu}$ is a random variable with mean $\bar{\boldsymbol{\mu}}$ and standard deviation $\boldsymbol{\sigma_\mu}$.

This model involves four parameters:

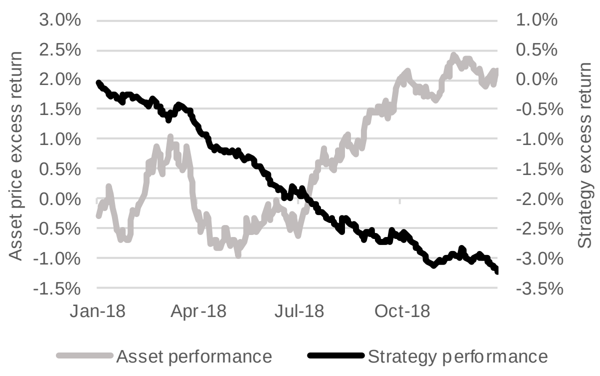
- The mean-reversion parameter controls the speed at which the market will mean revert towards its daily trend.
- The volatility of the return reflects the uncertainty around market prices: the market might stay temporarily off course from its daily trend but will eventually resume its daily trend.
- The average daily trend measures the statistical average at which daily returns are trending.
- The volatility of the trend itself. It reflects the uncertainty of daily prices.

The model can be used to understand the main drivers of our practical trading rule. Unsurprisingly, when the intraday trend in strong, the strategy strives. But when mean reversion is strong or when intraday prices are very volatile, the trend is not enough to compensate for the losses occurred by intraday uncertainty.

When the daily trend is strong, the strategy strives



But mean reversion and uncertainty weigh on performance



Source: SG Cross Asset Research/Cross Asset Quant

Beyond simulations, this model can be used to derive an analytical formula that explains the daily P&L of the strategy. This formula bears striking similarities with the one derived in our work Benefiting from fluctuations in markets.

The key drivers of performance

If we assume that prices follow a mean-reverting process with a trend as above, the expected annualised return of daily-weekly strategy becomes:

$$\Pi_{Intraday\ Trend} = \frac{1}{2}\Delta(\Delta - \delta)\left(\bar{\mu}^2 + \sigma_{\mu}{}^2 - a\sigma^2\right)$$

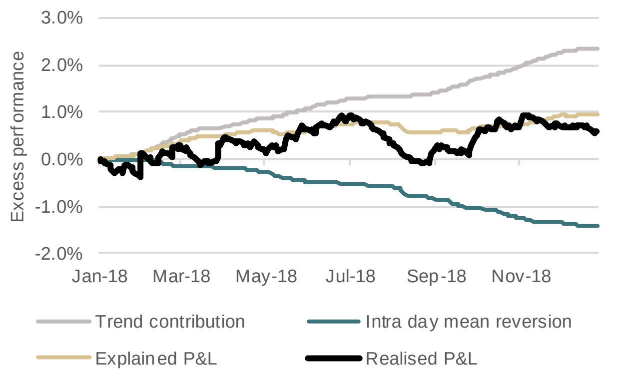
All calculations are detailed in Addendum 2.

This formula also confirms what we observed above for simulated prices: the strategy benefits from daily trends and suffers from mean reversion, even more so when markets fluctuate in a disorderly manner.

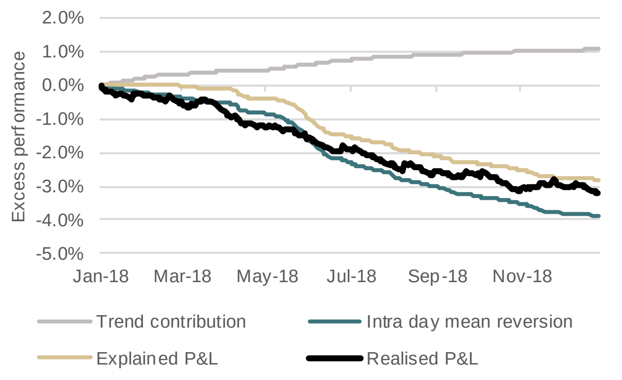
This sheds new light on the return of the strategy. There are two conflicting forces at play here. On the one hand, the strategy suffers from uncertainty during the day through mean reversion. On the other, it benefits from uncertainty from one day to another.

Daily trend and daily volatility need to be strong enough to compensate for the negative impact of mean reversion. If this is not the case, the strategy will suffer from the intraday volatility, compounded by the speed at which assets revert during the day.

When the daily trend outweighs intraday mean reversion



When mean reversion wins the battle



Source: SG Cross Asset Research/Cross Asset Quant

The balance between those two forces determines the success of the strategy. Looking at the P&L through the lens of the model should help investors identify markets that can be effectively traded intraday, i.e. markets that are more volatile on a day-to-day basis and calmer on an intraday basis.

One size fits all

So much for the theory — we now need to relate this model to the reality of financial markets. This is the estimation step. In our case, we need to estimate three parameters: the intraday mean reversion, the average daily trend, and their volatilities.

When dealing with real world data, a certain number of issues arise. The true dynamics of the asset price is of course unknown and is very likely to vary with time. It is therefore important to recalibrate the model frequently.

The choice of the length of the window for an estimation task is a thorny issue in quantitative finance. To reduce the potential biases in the estimation and its uncertainty, longer time windows are usually better. But, parameters are time varying. There is a natural trade-off between the statistical robustness of the estimation and the reactivity of the model. So as a rule of thumb, we use a 20-day rolling window.

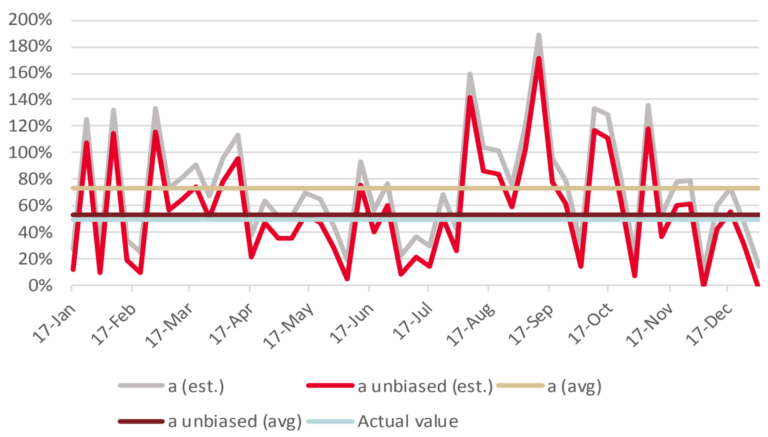
We estimate the parameters of our model on that rolling window using a three-step process:

First, we calculate the slope on the rolling window of the price series over the period, and we remove the constant trend term. We are left with a de-trended series of intraday prices.

Second, we estimate the intraday mean-reversion parameters and volatility on the detrended series. Estimating a mean-reversion parameter is another thorny issue in quantitative finance. Techniques include the simplest ones such as linear regression to the more sophisticated Kalman filtering. Intraday time series are generally large datasets, and the computational burden is a hurdle, so for simplicity purposes, we use here a simple linear regression model.

As a refinement to the estimation procedure, we quantified the bias in the mean-reversion parameter introduced when using a linear regression. This bias is a function of the sampling frequency. We correct our estimation from that bias. For those interested by that discussion, Addendum 3 is an interesting read. For simulated data, we show that this bias correction effectively helps improve the estimation. For real market data, this bias correction significantly improves the accuracy of our model.

Estimates of a both biased and unbiased versus true parameter value



Source: SG Cross Asset Research/Cross Asset Quant

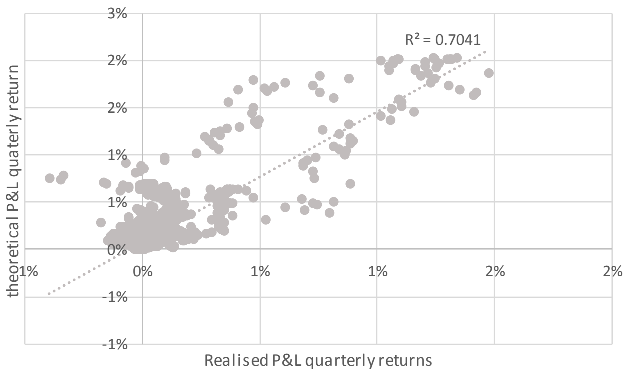
We use this model to understand the return of the intraday trend strategy. Here are a couple of case studies.

When the trend is your friend

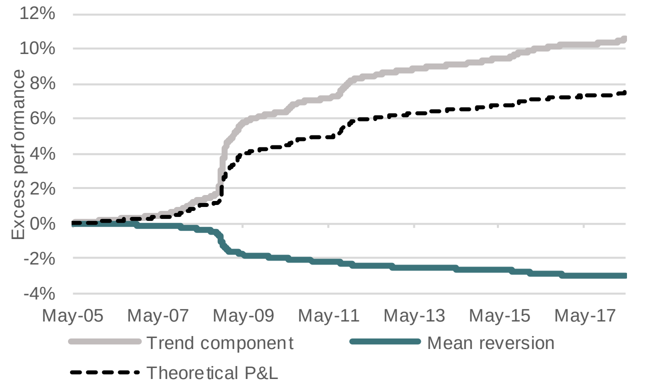
The S&P has been trending intraday over the past 15 years, but most importantly, it has been doing so with major uncertainty. Intraday mean reversion is also quite important, but volatility gains due to the trend largely offset losses to the mean-reversion component.

The model manages to explain the daily returns of the strategy run on the S&P relatively well, with an R-squared of 70%.

Explanation power of our model for the S&P



S&P is more trending than mean reverting intraday

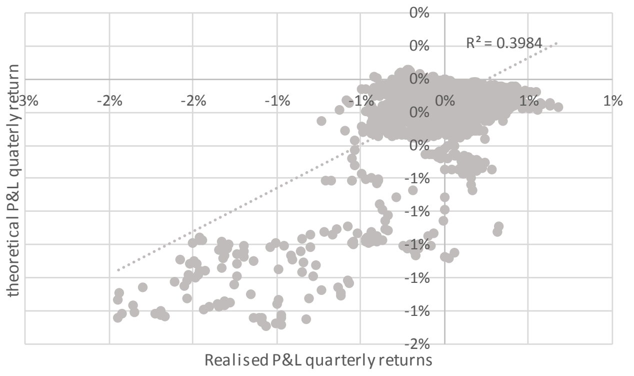


Source: SG Cross Asset Research

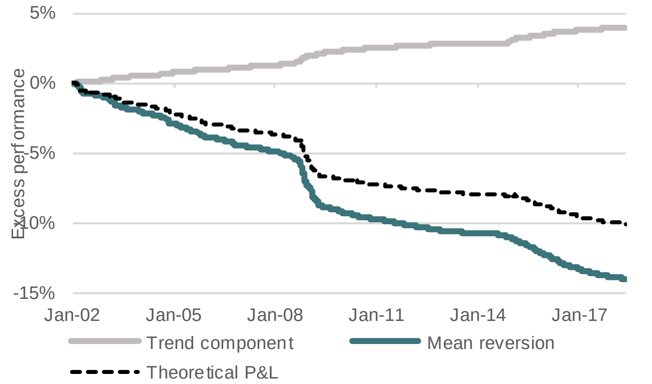
When mean reversion wins

The Brent is quite the opposite of the S&P. Over the past 15 years, the daily mean reversion has completely erased the gains of the trend-following component. The model is not as good for explaining the realised P&L as for the S&P. This is due to the fact that the descriptive model that we are using is probably less realistic for the Brent.

Explanation power of our model for the Brent



Brent is more mean reverting than trending



Source: SG Cross Asset Research

The practical day trader

In the previous sections, we established that, on the stock market, the volatility at the close is higher than the volatility during the day. We also described a practical trading rule that benefits from this statistical bias. We went one step further to understand the dynamics of the strategy and by showing that overall performance is a trade-off between daily trend, intraday mean-reversion and their uncertainty.

In this section, we extend our investigations to a large range of futures markets. We detail the impact of the costs on the strategy and show the importance of cost control and risk management.

Our trading universe

Our study focuses on liquid futures. The universe covers 40 liquid futures spread across five asset classes (equities, commodities, fixed income, FX and volatility) and three regions (US, Europe and Asia).

We are using a database of high-frequency prices. This database contains 15 years of one-minute data for prices, volumes and bid-ask spreads. That minute-by-minute data is sampled from tick data provided by relevant exchanges. The data covers 12 exchanges, with CME, Eurex and ICE being the largest of them.

The data we cover here is not big data as such, but it still requires special caution and tools when being manipulated. It amounts to a total of 15GB, much more than the standard size of data supported by Excel.

An extra difficulty is time-zone management. To avoid spurious time comparisons, all our data is expressed in UTC time. A detailed list of the futures contracts is provided in Addendum 1.

Most liquid futures per asset classes

Asset class	Most liquid contract	Start date
Commodities	Light Crude	03/01/2001
Currency	EUR	02/01/2001
Equities	S&P Mini	02/01/2001
Fixed Income	10Y Treasury	02/01/2001
Volatility	VIX	26/03/2004

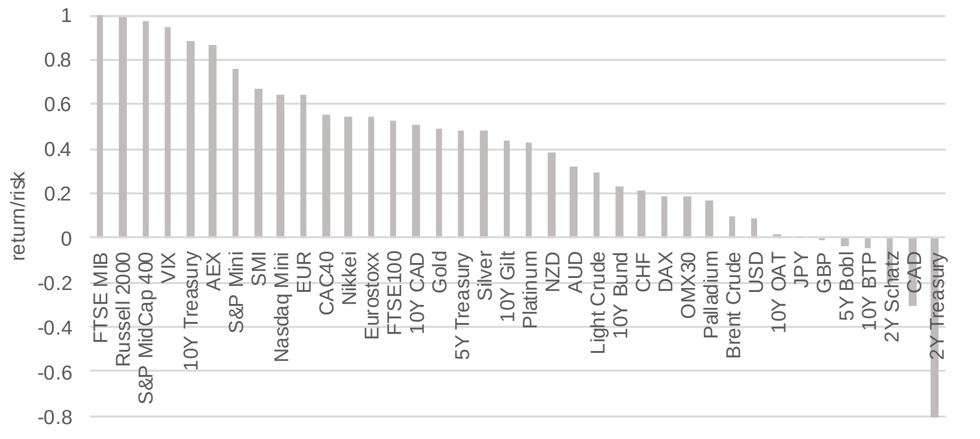
Source: SG Cross Asset Research/Cross Asset Quant

The fabric of intraday trends across assets

We investigate the nature of intraday pattern for a large range of assets. We are interested by identifying if some assets naturally cluster together with respect to their day trading dynamics. For that analysis, we do not take transaction costs into account. Transaction costs will be introduced at a later stage.

The table below gives the risk-adjusted returns for intraday trend performances. The trading period ranges early 2001 until late 2018.

Day trading across assets – long-term risk-adjusted returns



Source: SG Cross Asset Research/Cross Asset Quant, SG Trading, Bloomberg

Most asset classes tend to perform well over the long run when applying our trend-following day trading rule. The best performing assets are US and European-based equity indices, and the VIX futures. We will see in the following that those are futures markets where there are a lot of flows at the close. The S&P market is probably one of the biggest markets for option traders, and the amount of trading flows due to passive funds is very large in the US market, with most risk parity funds referencing one of these indices.

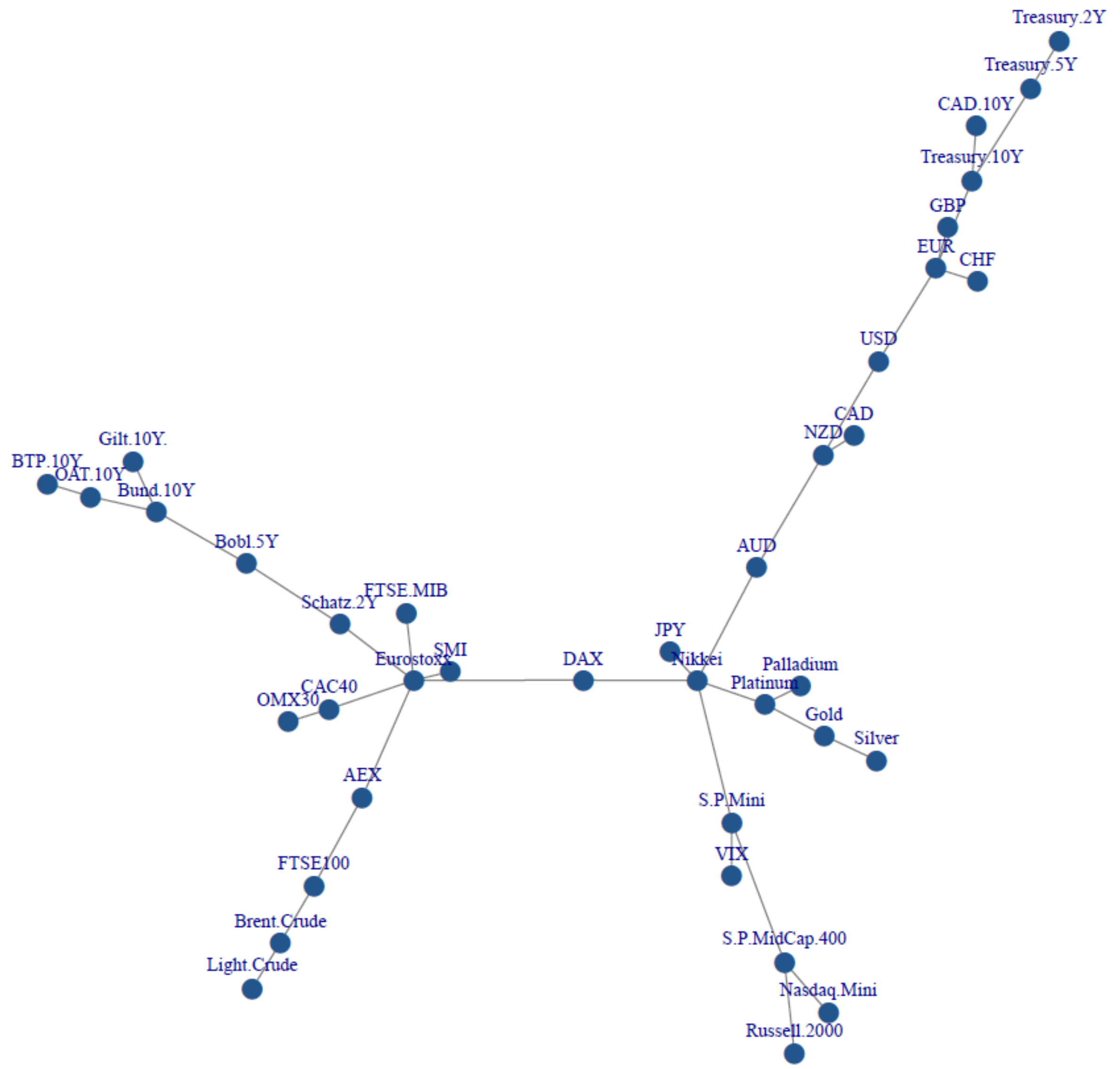
Platinum, Nikkei and 10-year treasuries also seem to trend on an intraday basis. For the first two, the related futures market is relatively small, and we will see in the next section how much of that good performance remains once transaction costs are included.

On the other side of the scale, GBP, CAD, short-term German and US Treasuries futures exhibit a negative performance. This would indicate the presence of mean reversion intraday.

As a second step, we analyse the strategies' performances and attempt to group together assets that exhibit similar performance profiles. Using a simple clustering technique called a minimum spanning tree, we can construct clusters of correlated strategies.

A spanning tree is a relatively simple grouping mechanism. It identifies the strategy the most correlated with the others and puts it in the middle of the graph. It then goes on to build several branches, so that strategies that are highly correlated are next to each other. In our example, Eurostoxx is in the middle of European equities, commodities are on their own branch, and US equities and the VIX cluster together.

Spanning tree for intraday trend strategies



Source: SG Cross Asset Research/Cross Asset Quant, SG Trading, Bloomberg

There is no unique way to cluster a set of data. Using the spanning tree and other hierarchical clustering algorithms as a guideline, we identified seven groups of assets. Cluster composition is strongly related to asset classes as well as risk/return profile:

Clusters of correlated strategies

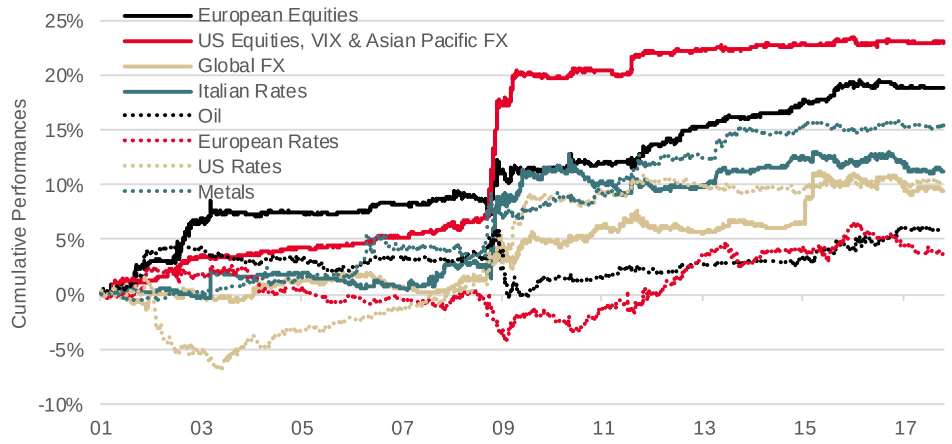
Cluster ID	Characteristics	Components
1	Euro Equities	SMI, DAX, Eurostoxx, CAC40, FTSE100, FTSE MIB, AEX
2	US Equities & Nikkei	Nikkei, Nasdaq Mini, Russell 2000, S&P Mini, S&P MidCap 400
3	Euro Rates	10Y Bund, 10Y OAT, 10Y Gilt, 10Y BTP, 2Y Schatz, 5Y Bobl
4	US Rates	10Y CAD, 10Y Treasury, 2Y Treasury, 5Y Treasury
5	Oil	Brent Crude, Light Crude, OMX30
6	VIX & Asian Pacific FX	VIX, AUD, CAD, JPY, NZD
7	Metals	Gold, Platinum, Silver, Palladium
8	Global FX	CHF, EUR, GBP, USD

Source: SG Cross Asset Research/Cross Asset Quant

The next two graphs show the cumulative performance for each cluster for the entire history and zooming in on the past 10 years.

The first and the second clusters contain European equities, US equities, VIX and some FX pairs. These two clusters are also the best performing over the long run.

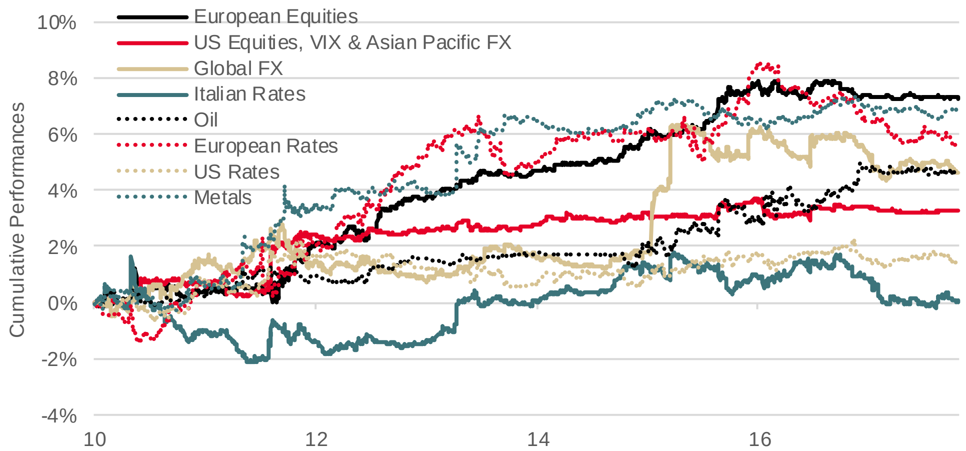
Equities lead the pack



Source: SG Cross Asset Research/Cross Asset Quant

Zooming in on the most recent history and excluding 2008 gives a different finding: European equities and European rates lead the pack. There is an overall sense of performance compression. Does it mean that there is less alpha? That more people are accessing the source of return and suppressing the arbitrage opportunity? We think not.

Performance compression?



Source: SG Cross Asset Research/Cross Asset Quant

The potential gain of that strategy is a function of the difference between the daily volatility and the intraday volatility. Low volatility means a narrow spread and a lower gain potential. We will also demonstrate that with the appropriate risk control and cost control, intraday strategies remain attractive for a large set of assets.

But before getting there, let us bring in the cost component. So far, the analysis has remained purely qualitative. Our simple trading rule still needs to stand the test of reality, with the inclusion of trading costs, risk management and some control of turnover. This is the focus of the next section.

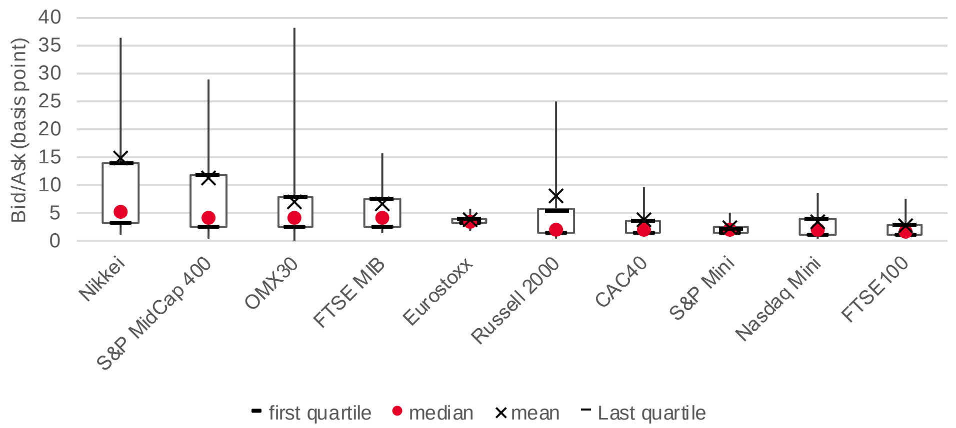
The devil is in the execution

The intraday trend strategy is a relatively high turnover strategy. Transaction costs matter a lot.

In the following, we model transaction costs using intraday historical bid-ask spreads. When buying a clip of futures, we assume that the trade is executed at the ask price (higher than the mid), and when selling, we assume that the trade is executed at the bid price (lower than the mid).

Bid-ask spreads vary greatly across assets and within a single asset class. For example, in the equity futures universe, the median spread is the smallest for the S&P mini at two basis points and the highest for the Nikkei at five basis points. But historically, the bid-ask fluctuates much more on the Nikkei, with a value above 14 basis points 75% of the time. Any intraday strategy with a high turnover will most likely be very costly for that market.

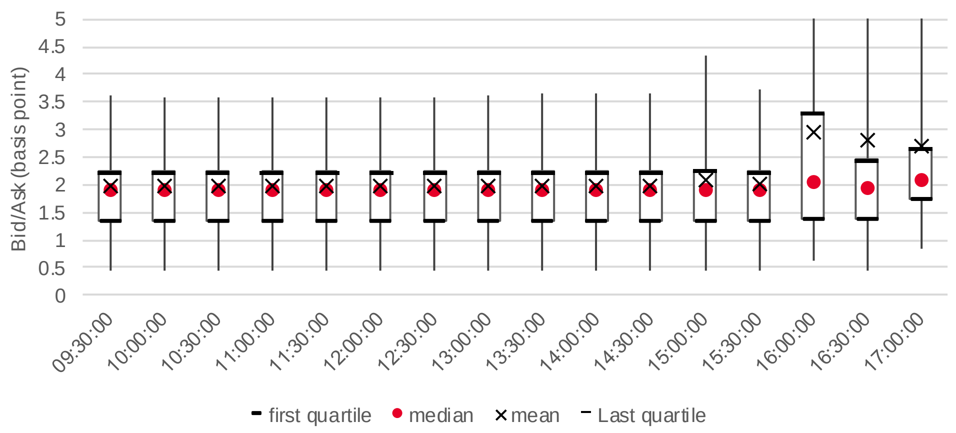
Beware the costs on less liquid markets



Source: SG Cross Asset Research/Cross Asset Quant

Bid-ask spreads are usually not constant during the day. When markets are volatile, bid-ask spreads tend to widen and execution is costlier. On the contrary, when markets are calm, bid-ask spreads narrow and execution is cheaper.

Transaction costs vary greatly across the trading day – S&P

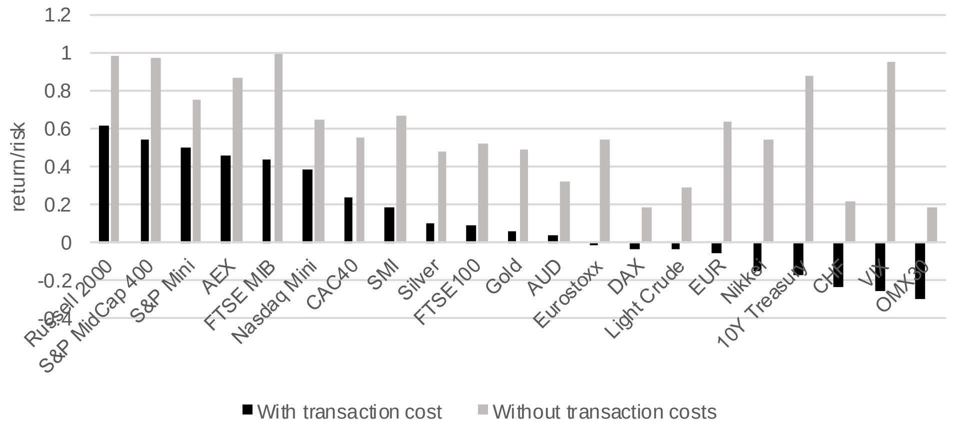


Source: SG Cross Asset Research/Cross Asset Quant

Logically, some intraday trend strategies do not stand the test of execution costs, as all the performance vanishes in trading costs. According to our simulations, this is the case for commodities futures except gold and silver, some equity futures such a Nikkei and Treasuries futures.

Treasuries futures are an interesting case. This is a market where bid-ask spreads are relatively narrow on an absolute basis but are relatively large compared with the realised volatility. Remember that the P&L of that strategy arises mainly from the difference between the daily volatility and the intraday volatility. Low volatility means a narrow spread and a lower gain potential.

Day trading across assets – long-term risk-adjusted returns



Source: SG Cross Asset Research/Cross Asset Quant, SG Trading, Bloomberg

The performances of metals and currencies are strongly affected by the inclusion of transaction costs. On average, unwinding the intraday position on platinum costs five times the end-of-day PnL and can cost as much as 25 times it on days of high volatility. Metals are an extreme case, and other strategies are less affected by transaction costs.

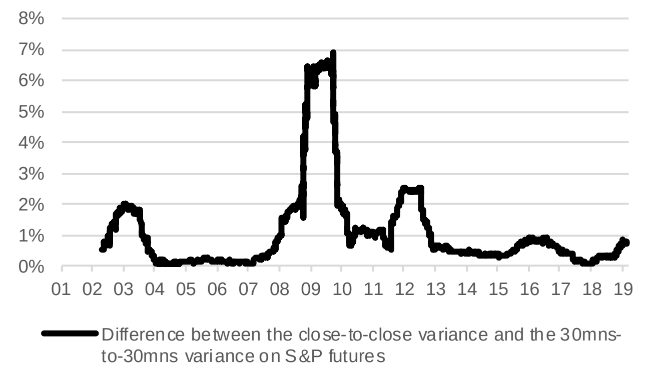
How to control for costs and fine-tune the signal

While the topic of this paper is not about optimal execution, there are a few refinements that can be made to control costs and risk manage the strategy.

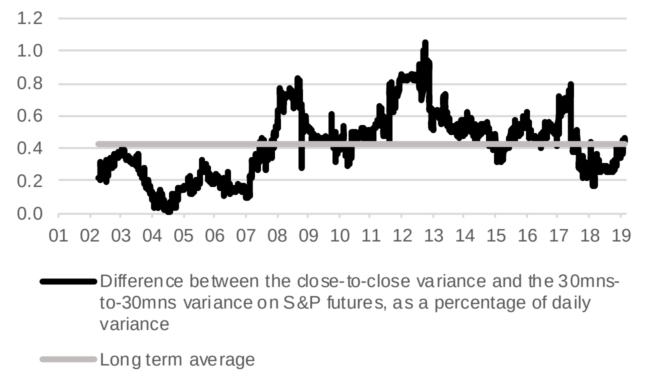
Intuitively, low intraday volatility decreases the adverse effect of mean reversion and increases the contribution of the trend and its volatility to the performance. A low-volatility environment is favourable. But when intraday volatility is low, daily volatility tends also to be low, and the potential gain of the strategy, defined as the difference between the daily volatility and the intraday volatility, reduces.

The graphs below illustrate that effect. The difference between the daily variance and the intraday variance measures the potential P&L associated with the intraday trend strategy. It varies greatly across time, tending to be large in volatile times and low in quiet times. Conversely, this difference as a percentage of the daily variance is much more stable historically. The potential gain of the strategy is proportional to the volatility of the markets.

Potential gains evolve across time



Gains are proportional to the level of volatility



Source: SG Cross Asset Research/Cross Asset Quant

A first idea is to scale the position by the volatility of the market. The volatility that we use at any point in time to scale the signal is the rolling one-year volatility measured between the close and the time at which the signal is calculated.

Trend-following signals can be costly when price fluctuations are not large enough even though the asset is slightly trending. Another simple idea is to add a trigger level from which the strategy starts to trade: we cut the exposure to zero if the return is below some volatility threshold. We also start trading only if the returns are significantly more positive or negative than the historical one-year volatility.

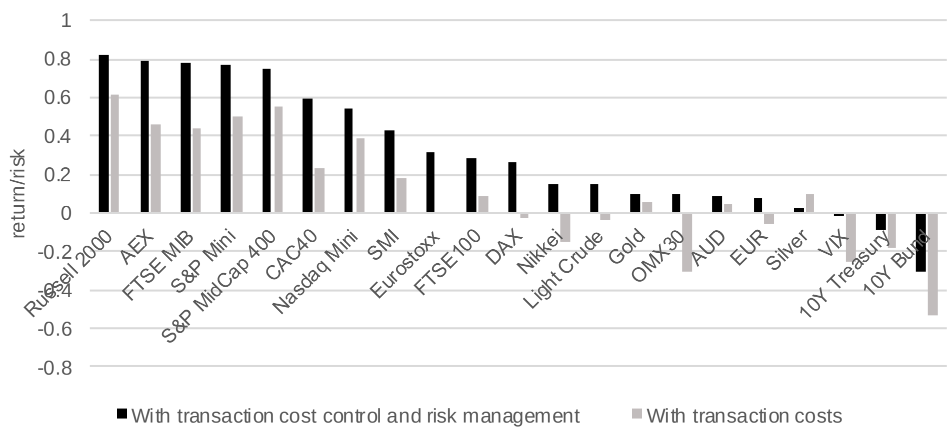
Risk management and cost control

The final signal we use for our intraday strategy across assets is the following:

$$w(t_i, T) = \begin{cases} R(t_i, T) - B\sigma(t_i, T, M), & B\sigma(t_i, T, M) < R(t_i, T) \\ R(t_i, T) + B\sigma(t_i, T, M), & R(t_i, T) < -B\sigma(t_i, T, M) \\ 0, & |R(t_i, T)| < B\sigma(t_i, T, M) \end{cases}$$

Those refinements help to mitigate the impact of the transaction costs and improve the risk-adjusted performance for all asset classes.

Day trading across assets – fine-tuning the signal



Source: SG Cross Asset Research/Cross Asset Quant, SG Trading, Bloomberg

Once all transaction costs are considered, equity futures are the top performers over the long run. The table below sums up the performances of the top six performers since 2005.

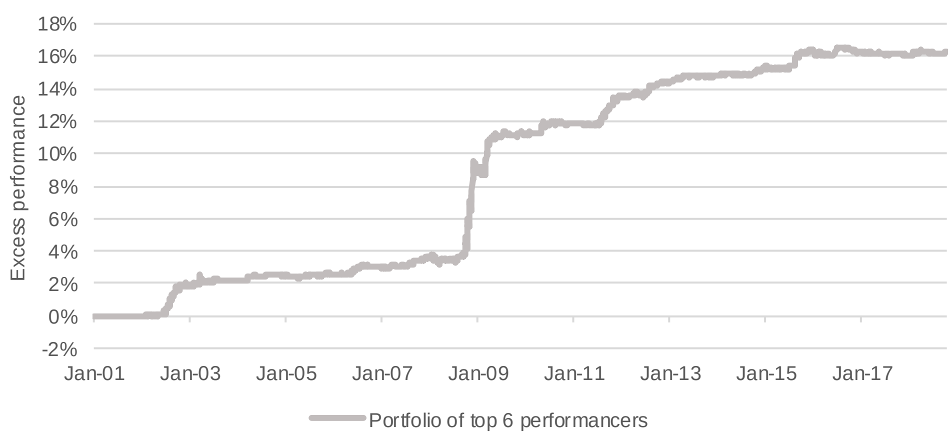
Top six performers (since 2005)

	Ann. return	Ann. vol	Ann. Sharpe	Max drawdown
Russell 2000	1.2%	1.4%	0.82	-1.3%
AEX	1.1%	1.4%	0.79	-2.0%
FTSE MIB	1.0%	1.3%	0.78	-2.6%
S&P Mini	0.8%	1.0%	0.76	-1.0%
S&P MidCap 400	0.9%	1.2%	0.75	-1.5%
CAC40	0.7%	1.2%	0.59	-2.0%
Portfolio	0.9%	0.9%	1.01	-0.9%

Source: SG Cross Asset Research

The correlation between these top six strategies is relatively low, and combining them results in a portfolio with a smoother performance profile:

Zooming in on the top performers

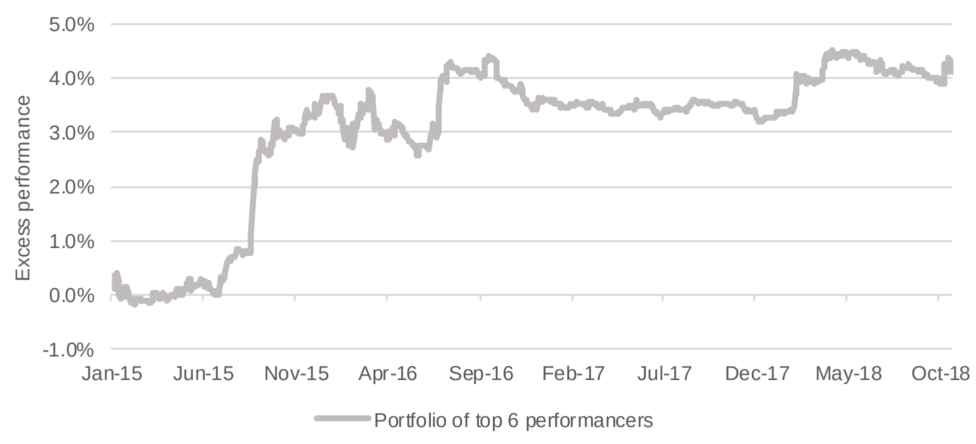


Source: SG Cross Asset Research/Cross Asset Quant

When zooming in on the most recent history, it seems that returns are less positive than in the more distant past. As illustrated above, this strategy monetises the slope of the realised volatility term structure. And that slope is proportional to the level of uncertainty in the market. The period 2016-2017 was exceptional, with central banks supressing uncertainty in financial markets across the globe. The performance of such strategies stalled.

Last year, uncertainty rose quite significantly, with two major bear markets in February and November-December. The environment has been somewhat better for those types of intraday trend strategies.

A defensive strategy?



Source: SG Cross Asset Research/Cross Asset Quant

The return profile of this intraday trend strategy is very similar to a ‘defensive’ strategy, namely, a strategy that fares well when the equity market tends to sell off. Is that really the case? The following section addresses this question.

Possible variations around the same theme

So far, we have applied a simple trading rule to monetise intraday mean reversion, or equivalently, the high volatility at the close versus the lower volatility intraday. There are many other ways to trading this pattern. In the following, we explore two of them.

First, we show how to turn an intraday strategy into a truly defensive strategy. We will use the S&P as our case study.

Second, we investigate the relationship between intraday trend following and extra-day mean reversion across assets. If pursuing the goal of constructing an effective overlay strategy, investors should consider diversifying the various trading patterns that they monetise.

The case for defensiveness

As mentioned in the previous section, the intraday trend-following strategy has a defensive profile: it tends to perform well in bear equity markets. A closer investigation showed that the P&L of the strategy is proportional to the slope of the realised volatility term structure, which is itself proportional to the level of uncertainty in the market.

However, this is true only if the intraday trend following pattern persists in the market. In an environment where there is more uncertainty during the day than overnight, this strategy might finish in negative territory.

There is a way to avoid negative returns in a downside market: only short the market. In this case, the investor is guaranteed to gain from his trading if stocks are selling off. This is very easy to implement by adding a cap to the signal.

Trading only the short signals

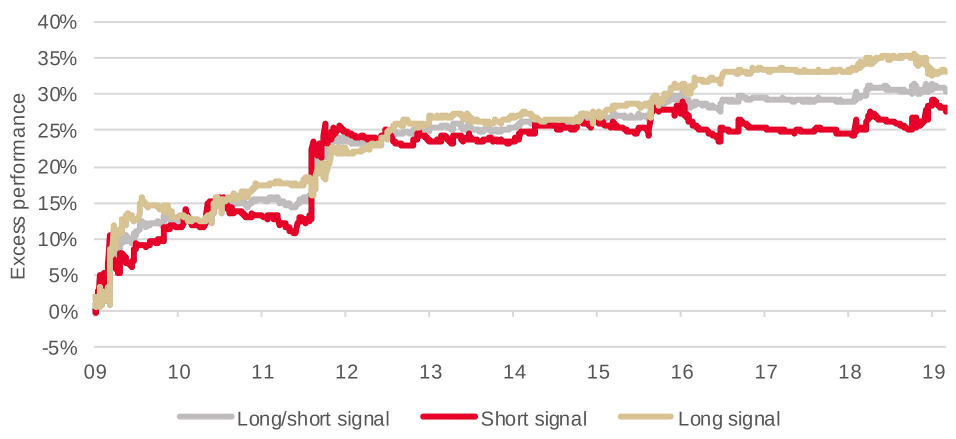
$$w(t_i,T) = \begin{cases} R(t_i,T) + B\sigma(t_i,T,M), & R(t_i,T) < -B\sigma(t_i,T,M) \\ 0, & R(t_i,T) > 0 \end{cases}$$

The short only strategy consists of trading only the short signal.

When applying this signal to the S&P, the strategy becomes much more negatively correlated with the S&P, with an average long-term correlation of -40%. By comparison, the correlation between the S&P and the long only signal oscillates around +40%. The net strategy, i.e. the one implementing the long and the short signal, is not correlated with the S&P.

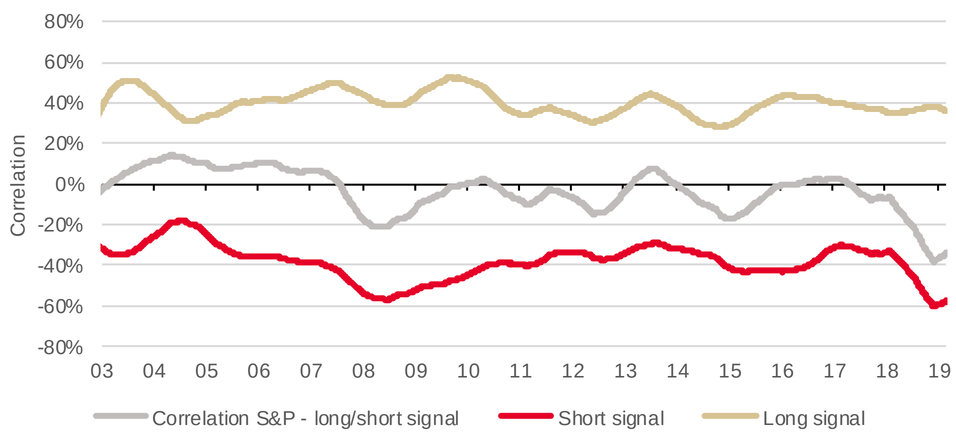
Interestingly, in recent history, the short signal became even more defensive, with a greater negative correlation in 2018-2019.

How to build a truly defensive strategy on the S&P



Source: SG Cross Asset Research/Cross Asset Quant

Long-term correlation with the S&P

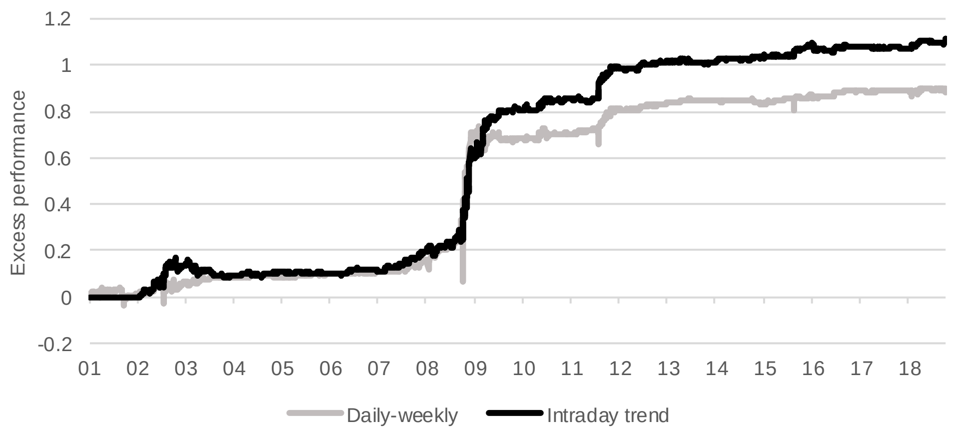


Source: SG Cross Asset Research/Cross Asset Quant

Trend following intraday or mean reversion extra day: two sides of the same coin

Daily weekly and intraday trend are very similar. For example, on the S&P:

Two sides of the same coin



Source: SG Cross Asset Research/Cross Asset Quant

As shown in addendum 1, under certain theoretical conditions the intraday trend signal exhibits the same behaviour as the daily-weekly mean-reverting signal that rebalances once a day.

Mean reversion and intraday trend: two sides of the same coin

The P&L of the intraday trend strategy is proportional to the difference between the daily variance and the 30-to-30 minute variance:

$$Daily\ Var - Intraday\ Var = 2\Pi_{Intraday\ Trend}$$

We showed in the past that the P&L of the daily-weekly is proportional to the difference between the daily variance and the weekly variance:

$$2\ \Pi_{Daily\ Weekly} = \text{Daily var} - \text{Weekly var}$$

So, if the weekly variance is equal to the intraday variance, then the two strategies have the same performance profile:

$$Weekly\ var\ \approx Intraday\ Var\ \Leftrightarrow \Pi_{Daily\ Weekly} \approx \Pi_{Intraday\ Trend}$$

Therefore, it is tempting to investigate if certain strategies that perform poorly on the intraday signal (after costs) can show a positive performance on the daily-weekly signal. In the table below, we calculated the Sharpe ratios (after transaction costs) of the daily-weekly signal that rebalances once a day at the close.

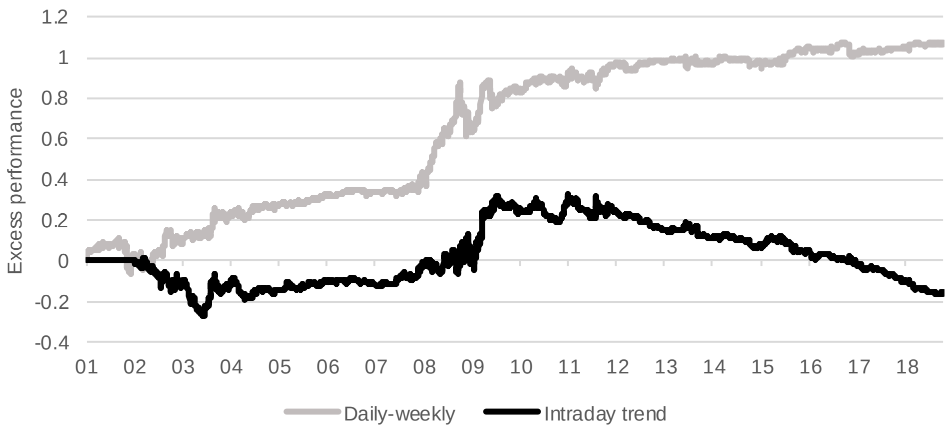
Sharpe ratios of intraday trend signal versus daily-weekly signal

	Intraday trend	Daily weekly
S&P Mini	0.78	0.49
Russell 2000	0.82	0.31
CAC40	0.55	0.47
Nasdaq Mini	0.59	0.40
S&P MidCap 400	0.79	0.18
FTSE MIB	0.75	0.14
FTSE100	0.29	0.54
AEX	0.76	0.01
10Y Treasury	0.03	0.58
Eurostoxx	0.14	0.46
VIX	-0.08	0.67
SMI	0.42	0.16
Light Crude	0.10	0.48
Silver	0.31	0.01
Nikkei	0.07	0.16
DAX	0.10	0.14
Gold	0.27	-0.05
EUR	0.09	0.06
OMX30	-0.30	0.43
AUD	0.15	-0.02
CHF	-0.02	0.03
5Y Treasury	-0.57	0.54
USD	-0.63	0.27

Source: SG Cross Asset Research

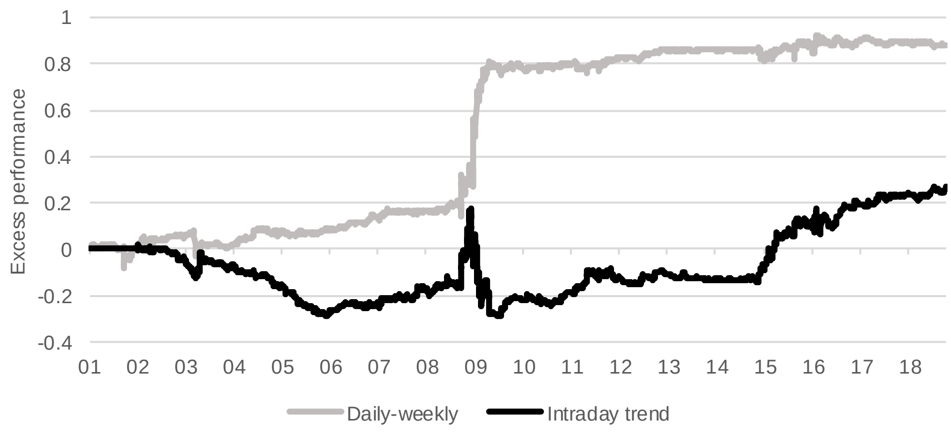
Mean-reversion signals exhibit interesting profiles on 10Y treasuries, VIX and light crude futures. The graphs below compare the intraday trend signals and the daily-weekly signal after transaction costs. Under certain regimes, performance profiles are quite similar and daily-weekly turns out to be a cost-effective substitute for the intraday trend signal.

Intraday trend versus daily-weekly signal cumulative performance for 10Y Treasury futures



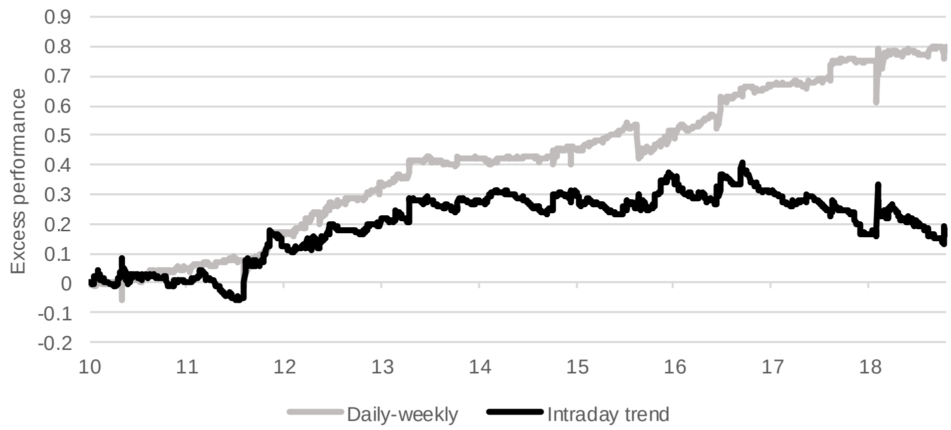
Source: SG Cross Asset Research/Cross Asset Quant

Intraday trend versus daily-weekly signal cumulative performance for light crude



Source: SG Cross Asset Research/Cross Asset Quant

Intraday trend versus daily-weekly signal cumulative performance for the VIX



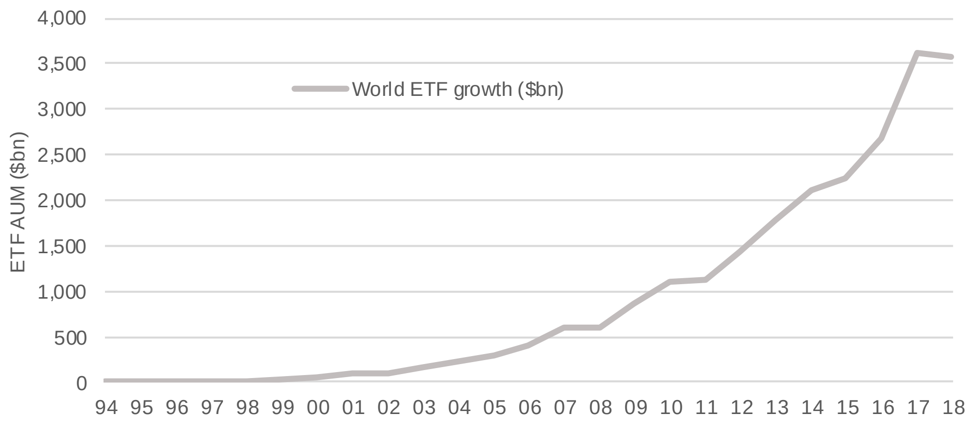
Source: SG Cross Asset Research/Cross Asset Quant

So the logical next step is a combination of intraday trend following and extra-day mean reversion. We will leave that for further research.

A detour into the world of ETFs

Exchange Traded Funds (ETFs) have developed massively over the past decade to become one of the most successful investment vehicles. Assets invested in these low-cost trackers have grown to over $3.5trn globally, up from less than $700bn before the financial crisis. Their systematic impact on the volumes of the underlying market is potentially very big. This is a topic that has been discussed in the past by our ETF team (see here).

The incredible success story of ETFs



Source: SG Cross Asset Research/ETF

ETFs may hold futures contracts in several situations:

- ‘Non-delta one’ ETFs are ETFs that aim to deliver the underlying index’s daily percentage performance times a leverage ratio. The leverage ratio can be 2x or 3x for “leveraged ETFs” or -1x, -2x or -3x for “Inverse ETFs”. These structures achieve their objectives by investing in unfunded derivatives contracts such as futures contracts or OTC swaps. Due to the compounding of daily returns, the returns of ‘non-delta one’ ETFs over periods greater than one day are likely to differ in amount and possibly direction from the target return for the same period.

- ETFs may track indices of futures contracts. This is typically the case in the commodity space. As a result, commodity ETFs generally invest in futures contracts. A notable exception includes physical gold and other precious-metal ETFs that own gold bullion instead.

- All equity ETFs using a physical replication hold futures contracts. This is because there is generally a lag between ex-dates and effective stock dividend payment dates that varies by stock geographies (typically, the lag is large in the case of Japanese and EM stocks, and shorter with US and European stocks). ETFs must invest in unfunded derivatives contracts (typically futures) to remain fully exposed to index total returns and alleviate deviation risk during these periods.

In the following, we focus on ‘non-delta one’ ETFs. To achieve a constant leverage ratio, the ETF manager must rebalance its position daily. Our assumption is that these rebalancings affect the intraday volatility profile of certain futures contracts and in turn might explain the returns of the intraday trend strategy. In this section, we aim at quantifying this effect.

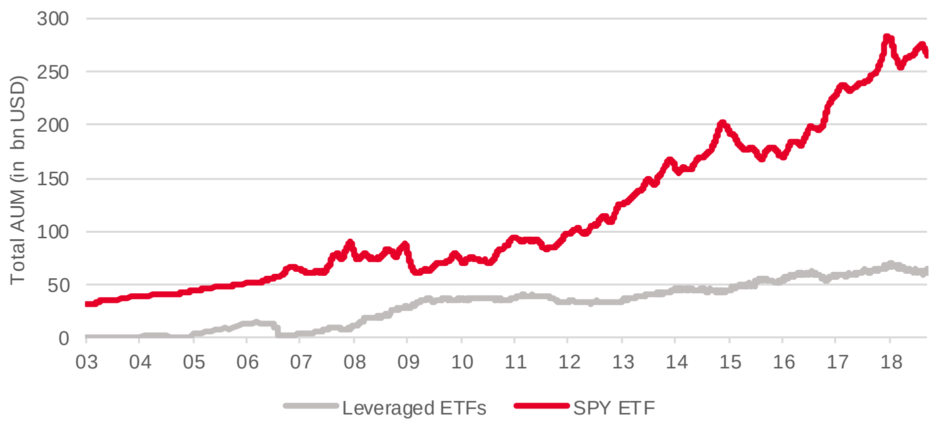
A few facts on the 'non-delta one' ETF market

Our ETF research team has collected a unique database of ETFs flows and AUMs globally. This is a great source of information on the ETF market that can be accessed through their ETF screener.

They gathered data on over 1,300 'non-delta one' ETFs across various countries and asset classes. This dataset describes the individual characteristics of each fund: the name of the fund and of the manager; some characteristics of the underlying index such as the name, the asset class and the geographical focus; the amount of the leverage ratio targeted by the ETF provider; and the direction (long or short).

The 'non-delta one' ETF market seems to be mainly driven by retail flows. In terms of total AUM, it is relatively small compared to the global ETF market. For a quick comparison, the current AUM on the SPY ETF is around $250bn, over four times the size of the global 'non-delta one' ETF market.

'Non-delta one' ETF AUM is small compared to global ETF market



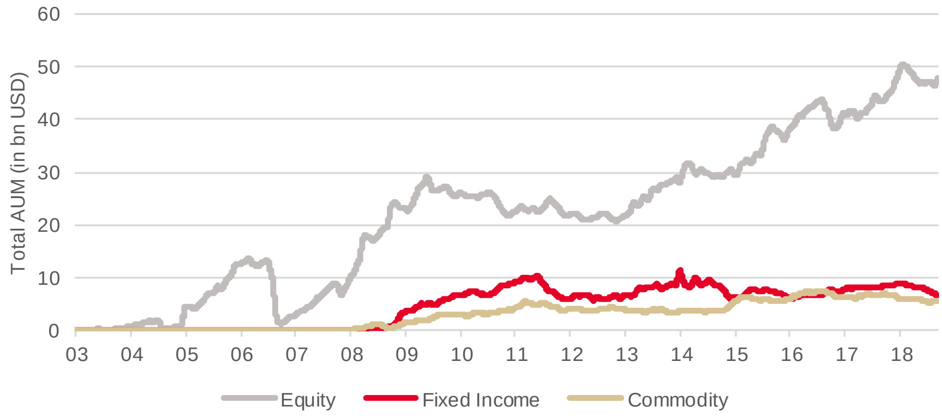
Source: SG Cross Asset Research/Cross Asset Quant, Bloomberg, SG ETF Screener

Most of the 'non-delta one' ETFs can be found in the equity market and in the US. The most common leverage ratios used by ETF providers are 2x and 3x.

'Non-delta one' ETFs can be used to gain access to long or short exposure on the market. The short ETFs, also known as inverse ETFs, are used by investors to benefit from a potential decline of markets. One of the main advantages of inverse ETFs compared to short selling is that they do not require the investor to hold a margin account. This justifies their relative success over the past few years.

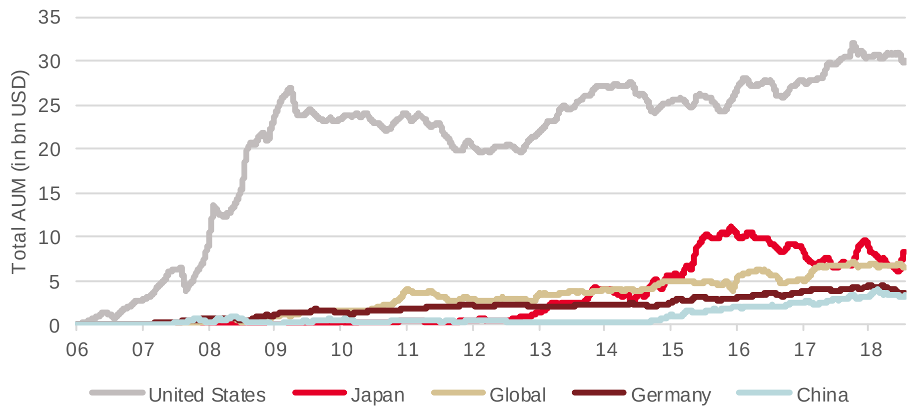
'Non-delta one' ETFs are the most popular in equity markets and in the US. Short ETF popularity increased between 2006 and 2010 and has been declining since 2017. Long leveraged ETFs became popular more recently, and their AUM is now above the AUM of inverse ETFs.

Equities attract most of the AUM...



Source: SG Cross Asset Research/Cross Asset Quant, Bloomberg, SG ETF Screener

... as well as US-related assets



Source: SG Cross Asset Research/Cross Asset Quant, Bloomberg, SG ETF Screener

Shorts funds dominated during the post 2008-era; the trend is now inverted

Source: SG Cross Asset Research Cross Asset Quant, Bloomberg, SG ETF Screener

Assessing the impact of 'non delta-one' ETFs on futures markets

This section covers our approach for mapping an ETF to an underlying futures market and for measuring the impact that ETF rebalancing has on the underlying futures market.

The first difficulty is to associate an ETF with a future, as that mapping is not easily available from the ETF providers. To solve this issue, we calculate the correlation between the ETFs' daily returns and the returns of the futures contracts in our universe. We map each fund with the future contracts that meet the two following criteria:

- The daily correlation between the fund and the futures contract is maximal
- The maximum daily correlation always points to the same contract across time

With this mapping, we can easily estimate the global ETF AUM related to a futures market. The following table gives the overview of the average and maximum ETF AUM related to each futures market. Note that there are not all futures markets have an active 'non delta-one' ETF.

Mapped 'non delta-one' ETF to futures contracts

	Average AUM (bn USD)	Max AUM (bn USD)
S&P Mini	3.92	8.74
10Y Treasury	2.57	9.53
Nasdaq Mini	1.88	8.17
Russell 2000	0.71	2.98
Light Crude	0.57	3.19
Silver	0.42	2.36
Nikkei	0.39	3.18
Eurostoxx	0.33	3.41
OMX30	0.32	0.90
VIX	0.29	1.90
DAX	0.25	0.66
Gold	0.24	0.90
EUR	0.24	1.10
CAC40	0.21	0.74
S&P MidCap 400	0.21	1.90
FTSE MIB	0.16	0.46
JPY	0.14	0.58
Brent Crude	0.09	0.29
FTSE100	0.04	0.14
SMI	0.02	0.09
AUD	0.01	0.03
CAD	0.01	0.04
2Y Treasury	0.01	0.02

Source: SG Cross Asset Research/Cross Asset Quant, Bloomberg, SG ETF Screener

Not surprisingly, 'non delta-one' ETFs are the largest on US equities futures and US Treasuries futures, but also on commodities futures and Nikkei futures. This might be a significant element for the latter two, as the liquidity for those futures is not as abundant as for US equity and Treasuries futures.

The second difficulty is to assess the actual impact of the ETFs on the futures market. For that purpose, we need to relate the AUM of the ETFs to the liquidity of each future. We have developed a simple yet robust indicator, the 'non delta-one' ETF impact indicator.

Every day, we calculate the 'non delta-one' ETF impact indicator for a given future as the ratio between:

- The sum of the "signed" AUM of ETFs related to this future multiplied by the absolute value of the ETF daily return – "signed" in this context means positive for long ETFs and negative for short ETFs,

- And the end-of-day dollar volume of each futures market. The dollar volume is defined as the number of contracts exchanged during the trading day times the point value of the contract times the level of the future.

The daily ETF returns are proportional to the leverage ratio maintained by the ETF provider. Empirically, the leverage ratio of an ETF is not exactly equal to the one targeted by the ETF provider. Trading circumstances may force ETF managers to adjust leverage. Addendum 1 delves into this issue and offers a methodology to calculate implicitly the leverage ratio from ETFs and futures returns. Using ETF daily returns in our analysis alleviates this issue.

The AUM of an ETF multiplied by the absolute value of its daily return gives a good proxy of the amount of rebalancing that will take place at the end of the day. Summing up all these quantities across all ETFs related to a future will in turn give an aggregate view of the amount of daily rebalancing on that market.

Another interesting indicator to look at is an ETF crowdedness indicator. This is simply the same as previously, but rather than summing up the "signed" AUMs, it consists of summing up the "unsigned" AUMs. This gives an indication on how much the ETF rebalancing is weighting on the volumes of the associated future.

Quant box: calculating an ETF impact indicator and an ETF crowdedness indicator

For a given futures market, denoted by F, let $\mathcal{M}(F)$ denote the set of 'non delta-one' ETFs that map to F. For a given ETF fund $f \in \mathcal{M}(F)$ let $\widetilde{AUM}(f,t)$ denote its total "signed" AUM and $AUM(f,t)$ its total "unsigned" AUM at time t, R_t^f its daily return. Let $Volume(F,t)$ denote the end of day volume of the market F at time t.

The ETF impact indicator for the futures market F at time t is given by:

$$I(F,t) = \frac{1}{Volume(F,t)} \sum_{f \in \mathcal{M}(F)} \widetilde{AUM}(f,t) \times \left|R_t^f\right|$$

$$C(F,t) = \frac{1}{Volume(F,t)} \sum_{f \in \mathcal{M}(F)} AUM(f,t) \times \left|R_t^f\right|$$

In other words, the ETF impact indicator measures if the daily flows from the 'non delta-one' ETF market are net long or short. The higher this ratio, the more flows will be executed at the close. A net positive exposure should force ETF providers to act as intraday trend followers: they are buying more of the underlying future at the close, when markets are going up on a close-to-close basis. Conversely, a net short exposure should force ETF providers to behave as intraday mean reverters.

The ETF crowdedness indicator measures how much of the futures volume comes from the 'non delta-one' ETF funds. The higher that ratio, the more flows are related to leveraged ETFs.

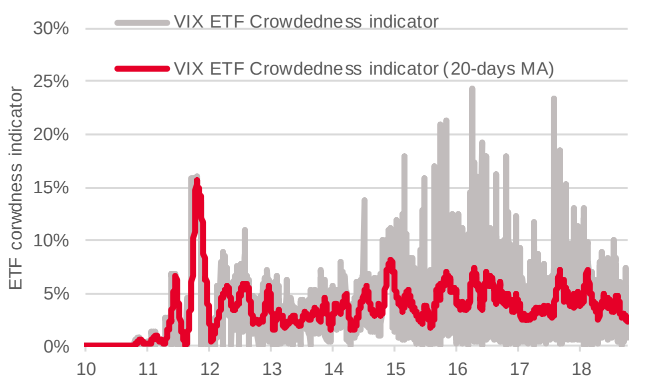
Those two indicators give some interesting highlights on the state of the leveraged and inverse ETFs on the VIX market, especially after some of those made the headlines in 2018.

First, the VIX ETF crowdedness indicator shows that the amount of flows from 'non delta-one' ETFs can be as high as 25% of the daily volume, with a 20-day average oscillating between 4% and 6%). This is a substantial fraction of the trading happening on a given day.

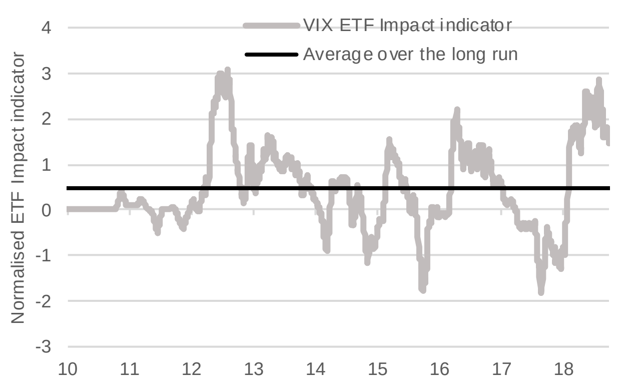
Second, the amount of flows increased in 2017 and decreased by about the same amount in February 2018, when some VIX ETFs were redeemed. Interestingly, although the story on VIX ETNs sent shock waves across the market, the amount of AUMs in VIX ETFs did not collapse completely.

Third, the net positioning of 'non delta-one' ETFs was negative early 2018 due to the massive inflow from speculative money at the time. After February 2018, the net positioning returned to positive territory, well above its average over the long run.

Contribution of 'non delta-one' ETFs to VIX futures volumes



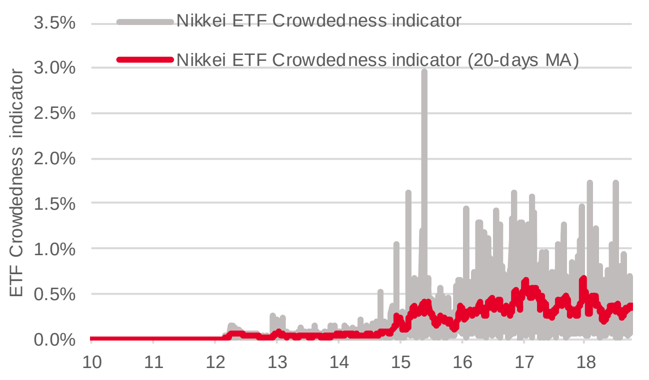
Net impact of ETFs on the VIX futures market



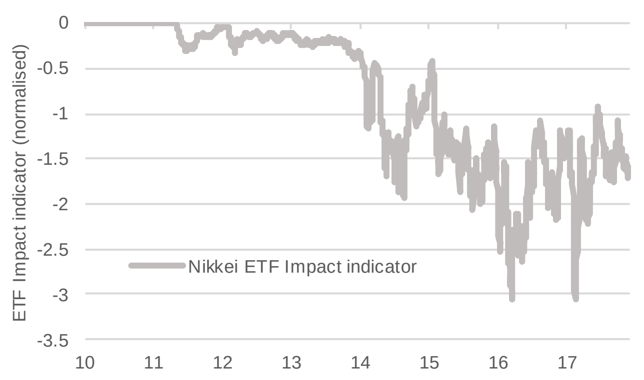
Source: SG Cross Asset Research/Cross Asset Quant

ETFs on Nikkei are also an interesting example. 'Non delta-one' ETFs on Nikkei are mainly inverse ETFs. They have a relatively small contribution in terms of net volume in the underlying futures market, but that net contribution should have a mean-reverting effect on the market. This seems to be confirmed by the performance of our trading signal on Nikkei futures.

Contribution of 'non delta-one' ETFs to Nikkei futures



Net impact of ETFs on Nikkei futures



Source: SG Cross Asset Research/Cross Asset Quant

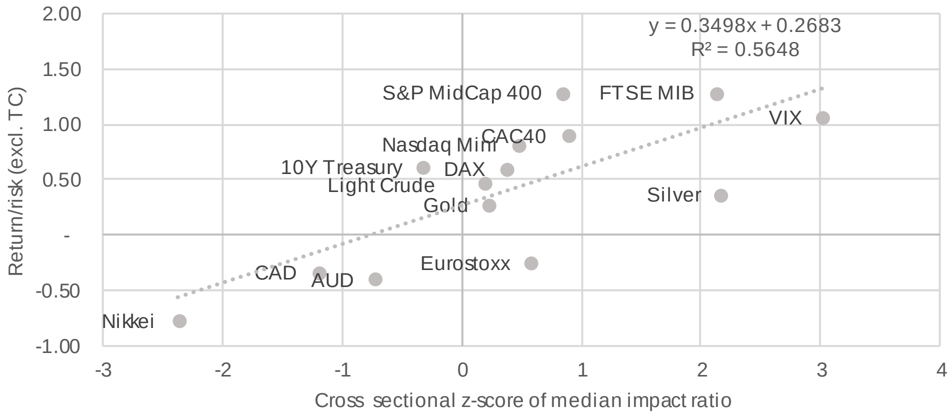
Can ETF rebalancing explain the intraday trading pattern?

Trying to measure all the directional flows linked to a particular rebalancing activity is a daunting task. Here, we spent quite some time gathering data on 'non delta-one' ETFs, which are a natural suspect for explaining intraday trading patterns. We are clearly missing out on the potential impact from other segments of the ETF universe.

When a particular future is trending upwards at the end of the trading day, long leveraged ETF providers needs to buy a fraction of the position to keep at a constant leverage. The ETF provider is "chasing the money". If there are a lot of volumes to be executed relative to the usual volume executed on the underlying market, the ETF provider will add to the buying pressure on the underlying market, thus nurturing the trend. Conversely, short leveraged ETF providers will have to sell a fraction of the position in an upward-trending market. They will contribute to opposing the trend.

As a result, we can compare the performance of our intraday trend following strategy with the median of the impact ratio measured on the same time span. There seems to be a positive relationship between our intraday strategy and the impact indicator. The least liquid futures, with a significantly positive impact ratio, tend to perform well in our algorithm: VIX, FTSE MIB, silver. The least liquid futures, with a significant negative impact ratio, will tend to underperform in our trading rule.

ETF rebalancing can help in understanding trading patterns



Source: SG Cross Asset Research/Cross Asset Quant

But there are other factors potentially influencing the price dynamics, in particular in the largest markets such as the S&P mini. For example, the development of short-term options in the S&P mini futures market could have a much larger impact than the leveraged ETFs. Short-term expiry options tend to have large fluctuations in their hedging ratio when they are close to the money.

In a market where investors are natural buyers of put options, market makers have a short position in those options and have to hedge them by selling or buying the related future instrument. In a bear market, the hedge ratio of the puts changes in such a way that market makers have to sell more of the underlying instrument to adjust their position. This increases the overall selling pressure on prices. The reverse happens in a bull market.

This type of flow is relatively complicated to measure, but the good performance of our trend-following strategy tends to confirm that this type of flow is significant on the S&P Mini.

Addendum

Addendum 1: The universe of futures

This table shows the futures that are being used in this paper, with the median bid-ask. The spread between the annual variance and the intraday variance is a rough estimate of the potential return of the strategy, not including execution costs. For some assets, like the VIX, the potential return is quite high, but the transaction costs are also massive. Thus, the strategy when applied to the VIX struggles once costs are factored in.

The universe of futures

Name	Start date	Annual return	Annual vol	Intraday vol (30 mins annualized)	Spread : annual variance vs. intraday variance	Median bid-ask (bps)
VIX	29/03/2004	34.1%	84.7%	40.9%	55.0%	38.0
Light Crude	04/01/2001	11.3%	36.4%	18.9%	9.7%	4.1
Silver	04/01/2006	8.9%	32.5%	16.1%	8.0%	5.2
Palladium	04/01/2001	6.0%	31.9%	17.2%	7.2%	33.6
Brent Crude	03/01/2001	11.3%	31.6%	16.8%	7.1%	5.3
Nasdaq Mini	03/01/2001	9.3%	24.7%	11.3%	4.8%	2.5
Nikkei	25/02/2004	7.7%	24.6%	12.4%	4.5%	18.7
FTSE MIB	23/03/2004	0.5%	23.1%	11.7%	4.0%	5.8
DAX	03/01/2001	5.7%	22.7%	11.8%	3.7%	1.6
Eurostoxx	03/01/2001	0.3%	22.6%	12.2%	3.6%	3.5
OMX30	13/03/2001	5.2%	21.7%	10.4%	3.6%	5.4
Russell 2000	26/10/2001	9.4%	21.8%	11.0%	3.5%	8.4
Platinum	03/01/2001	4.1%	21.9%	11.4%	3.5%	24.0
CAC40	03/01/2001	1.5%	21.8%	11.6%	3.4%	2.7
AEX	03/01/2001	1.1%	21.5%	11.0%	3.4%	3.1
S&P MidCap 400	29/01/2002	9.5%	20.8%	10.3%	3.3%	12.0
S&P Mini	03/01/2001	5.7%	18.7%	9.4%	2.6%	2.0
FTSE100	14/11/2001	3.3%	18.4%	9.8%	2.4%	2.0
SMI	04/01/2001	2.0%	18.1%	9.3%	2.4%	3.1
Gold	31/01/2001	10.0%	17.7%	9.1%	2.3%	2.9
NZD	04/01/2006	0.6%	13.5%	7.4%	1.3%	4.9
CHF	10/02/2005	2.1%	11.9%	5.9%	1.1%	2.1
USD	05/02/2001	-0.4%	10.8%	5.3%	0.9%	3.0
JPY	03/01/2001	0.6%	10.1%	5.3%	0.7%	1.5
EUR	03/01/2001	1.5%	9.8%	5.0%	0.7%	1.1
CAD	10/02/2005	0.1%	9.5%	5.1%	0.6%	1.8
10Y BTP	15/09/2009	0.9%	9.4%	5.0%	0.6%	3.2
10Y Gilt	14/11/2001	0.4%	7.1%	4.1%	0.3%	2.0
10Y Treasury	03/01/2001	0.8%	6.3%	3.2%	0.3%	1.3
10Y CAD	03/01/2001	1.5%	5.8%	3.2%	0.2%	4.1
10Y OAT	24/04/2012	3.1%	5.6%	3.1%	0.2%	1.7
10Y Bund	03/01/2001	2.2%	5.5%	3.0%	0.2%	0.8
5Y Treasury	03/01/2001	0.5%	4.2%	2.2%	0.1%	1.0
5Y Bobl	03/01/2001	1.2%	3.5%	2.0%	0.1%	0.9
2Y Treasury	04/01/2001	0.2%	1.8%	1.2%	0.0%	1.3
2Y Schatz	03/01/2001	0.5%	1.2%	0.7%	0.0%	0.6
AUD	04/01/2001	2.1%	12.9%	39.4%	-13.9%	2.7
GBP	03/01/2001	-0.4%	9.2%	45.8%	-20.1%	1.4

Source: SG Cross Asset Research

Addendum 2: Intraday trading signal and performance analysis

The trading signal in details

In our simple trading signal, we assume that no overnight positions are being held. We subdivide a trading day into N time intervals of equal length (e.g. 16 intervals of 30 minutes in an eight-hour trading day). Let $R_{t-1,t}$ denote the intraday returns in the time interval $(t-1,t)$.

At each time step, we take a position in the same magnitude and direction as the return within the intraday time interval. For instance, at the end of the second-time interval, the position is $R_{0,1} + R_{1,2}$ and the mark-to-market PnL is $R_{0,1}R_{1,2}$. By the end of the day, the PnL is the sum of all MtM PnLs:

$$PnL = \sum_{j=1}^{N}\sum_{i=1}^{j-1} R_{i-1,i}R_{j-1,j} = \sum_{1 \leq i<j \leq N} R_{i-1,i}R_{j-1,j}$$

We denote by Π the annualized expected PnL of that trading rule:

$$\Pi = \delta^2 \sum_{1 \leq i<j \leq N} E(R_{i-1,i}R_{j-1,j)}$$

and δ denotes the time horizon of an intraday interval in annual terms (for instance, 1/16th of 1/250 in the case of 30-minute time intervals.

A simple model of intraday price dynamics

As in our previous research, we model the intraday price dynamics using a trend and mean-reverting process around this trend using a Ornstein-Uhlenbeck process.

$$\mathrm{dY_t = -aYdt + \sigma dW_t}$$

The parameter *a* captures the speed of mean reversion and σ is the volatility. Y represents the deviation between the market, in real or log terms, and the long-term trend µ. The price of the market, X, evolves according to:

$$\mathrm{dX_t = dY_t + \mu\, dt}$$

Deriving an analytical formula for the expected PnL

We let δ denote the time horizon of an intraday interval in annual terms (for instance 1/16th of 1/250 in the case of 30-minute time intervals). The intraday returns are expressed as log differences of prices X:

$$R_{t+i:t+i+1} = \ln\left(\frac{\mathrm{X_{t+i+1}}}{X_{\mathrm{t+i}}}\right)$$

The daily return can be broken down into the sum of intraday returns:

$$R_{t:t+N} = \sum_{i=1}^{N-1} R_{t+i:t+i+1}$$

In turn, the daily variance can be broken down into the sum of intraday variances and the expectation of cross-product daily returns:

$$E(R_{t:t+N}^2) = \sum_{i=1}^{N-1} E(R_{t+i:t+i+1}^2) + 2 \sum_{1 \leq i<j \leq N} E(R_{i-1,i}R_{j-1,j})$$

In the last term of the expression above, we recognise the cross products of returns that define the expected PnL (denoted by Π) of the intraday trend strategy. The equation above can be simplified as:

$$Daily\ Var - Intraday\ Var = 2\Pi_{Intraday\ Trend}$$

A clear analogy can be drawn with PnL decomposition from the daily-weekly strategy:

$$2\ \Pi_{Daily\ Weekly} = \text{Daily var} - \text{ Weekly var}$$

In turn, we can see that the expected PnL of each strategy is close under the condition that the intraday variance and the weekly variance are of comparable levels:

$$Weekly\ var\ \approx Intraday\ Var\ \Leftrightarrow \Pi_{Daily\ Weekly} \approx \Pi_{Intraday\ Trend}$$

From the equations above, we can derive a closed formula for the expected PnL of the trend strategy. Let Δ denote the daily time horizon (that is $N\delta = \Delta$). The daily variance, which is equal to $E[(X_{t+\Delta} - X_t)^2]$, can be further expressed as (see addendum for details):

$$E[(X_{t+\Delta} - X_t)^2] = (\mu\Delta)^2 + \frac{\sigma^2}{2a}\left(1 - e^{-2a\Delta}\right)$$

The intraday variance over a trading day is the sum of intraday quadratic differences:

$$\sum_{k=0}^{N-1} \mathrm{E}[(\mathrm{X}_{k\delta+\delta} - \mathrm{X}_{k\delta})^2]$$

The sum above can be further expressed as (see addendum for details):

$$\sum_{k=0}^{N-1} \mathrm{E}[(\mathrm{X}_{k\delta+\delta} - \mathrm{X}_{k\delta})^2] = \mu^2(\mathrm{N}\delta^2) + \frac{\sigma^2}{2a}\left[\left(1 - e^{-a\delta}\right)^2\left(\frac{\Delta}{\delta} - \frac{1 - e^{-2a\Delta}}{1 - e^{-2a\delta}}\right) + \frac{\Delta}{\delta}\left(1 - e^{-2a\delta}\right)\right]$$

Under the assumption that the terms $a\Delta$ and $a\delta$ are small, we can linearize the expressions above and derive a simple closed formula for the expected PnL:

$$\Pi_{Intraday\ Trend} = \frac{1}{2}\Delta(\Delta - \delta)(\mu^2 - a\sigma^2)$$

In the model above, the trend parameter $\boldsymbol{\mu}$ is deterministic. We can account for additional uncertainty around the trend by assuming that the trend is a Gaussian random variable with mean $\bar{\boldsymbol{\mu}}$ and standard deviation $\boldsymbol{\sigma_\mu}$. Under this assumption, the formula for the expected PnL becomes:

$$\Pi_{Intraday\ Trend} = \frac{1}{2}\Delta(\Delta - \delta)\left(\bar{\mu}^2 + {\sigma_\mu}^2 - a\sigma^2\right)$$

The formula above shows that the trend strategy returns is the sum of two components:

- An intraday volatility term that makes a negative contribution to the performance
- A daily trend term that has a positive contribution to the performance

Adding risk management and cost control to the trading signal

On a given trading day T let $P^{(T)}$denote the price of the asset at the close. The intraday trading session is divided into N time intervals of equal size (e.g. 30 minutes). Let t_i denote the time at the end of the i-th time interval. We denote by $P(t_i,T)$ the price of the asset at time t_i on day T, hence $P(t_N,T) = P^{(T)}$. We denote by $R(t_i,T)$ the price return at time t_i to the previous day's close:

$$R(t_i,T) = \frac{P(t_i,T)}{P^{(T-1)}} - 1$$

The core idea behind the signal is to build up an intraday position that is proportional to the cumulated intraday returns. We also want to reduce exposure to the intraday trend when intraday volatility is high. We denote by $\sigma(t_i,T,M)$ the rolling standard deviation of $R(t_i,T)$ for the time interval that ends at t_i with a window of size M:

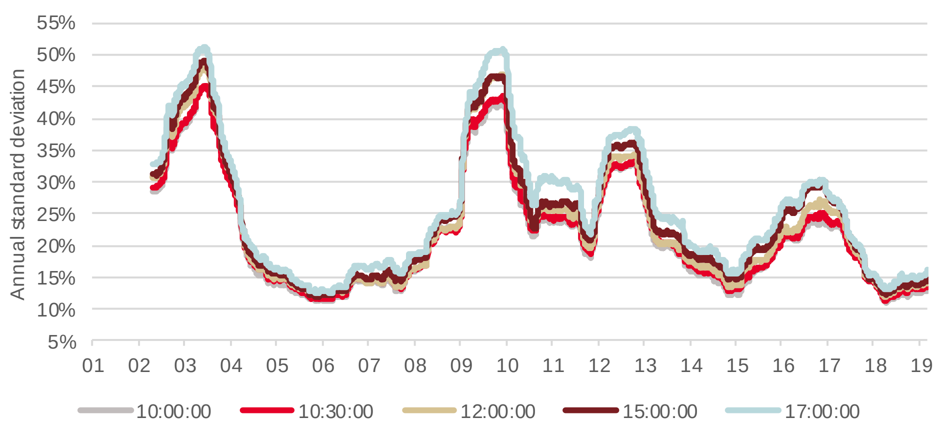
$$\sigma^2(t_i,T,M) = \frac{1}{M-1} \sum_{\tau=T-M-1}^{T} R(t_i,\tau)^2$$

…where

$$\overline{R}(t_i,T) = \frac{1}{M} \sum_{\tau=T-M-1}^{T} R(t_i,\tau)\,.$$

We interpret $\sigma(t_i,T,M)$ as the volatility at time t_i measured in the past M trading days. If $\sigma(t_i,T,M)$ is high, then the intraday exposure should be reduced. If $\sigma(t_i,T,M)$ is low, our confidence in the trend is stronger and we should therefore increase exposure. In practice, the time window M is set to be one year. The graph below shows the rolling one-year intraday volatility of Eurostoxx. We can observe that volatility increases as we approach the end of the trading session, hence reducing the intraday trend exposure.

Intraday one-year rolling volatility for Eurostoxx futures



Source: SG Cross Asset Research/Cross Asset Quant

Trend-following signals can be costly in terms of execution when price fluctuations are not large enough even though the asset is slightly trending. Therefore, we add an extra constraint whereby we cut the exposure to zero if the return is below a certain volatility threshold. All in all, the instant exposure at time t_i is given by:

$$w(t_i,T)=\begin{cases} R(t_i,T)-B\sigma^2(t_i,T,M), & B\sigma^2(t_i,T,M)<R(t_i,T) \\ R(t_i,T)+B\sigma^2(t_i,T,M), & R(t_i,T)<-B\sigma^2(t_i,T,M) \\ 0, & |R(t_i,T)|<\ B\sigma^2(t_i,T,M) \end{cases}$$

where B is a volatility threshold parameter that has to be adjusted. In practise, we set it to 50%. Some additional volatility cap on the exposure might be applied too.

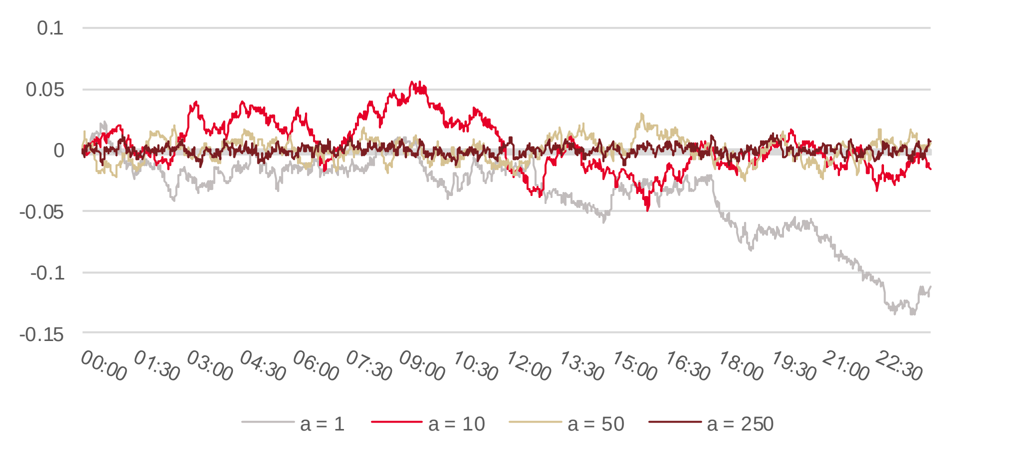
Addendum 3: Resolving the estimation conundrum

In this section, we come up with an estimation procedure for the price model parameters. Recall that the price model is the sum of a trend term and an oscillating diffusion process:

$$dY_t = -aYdt + \sigma dW_t$$

Two parameters govern that diffusion. The first parameter (denoted by a) is the speed of mean reversion around the trend. The greater this parameter, the faster the trajectories mean revert to zero, as can be seen in the graph below:

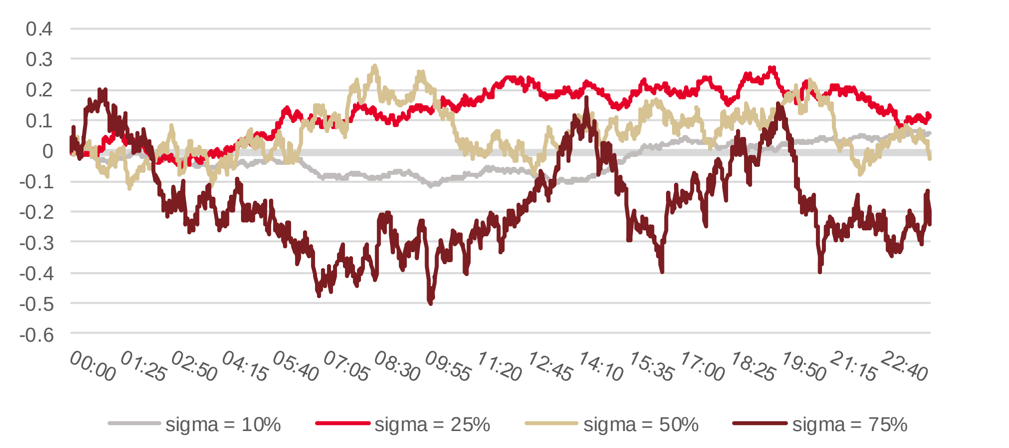
Intraday mean reverting simulations for various values of *a*



Source: SG Cross Asset Research/Cross Asset Quant

The second parameter, σ, is a volatility parameter. The greater this parameter, the wider the fluctuations will be.

Intraday mean reverting simulations for various values of σ



Source: SG Cross Asset Research/Cross Asset Quant

There are various approaches for estimating these two parameters. For the sake of simplicity and to avoid heavy numerical computations, we chose an estimation procedure based on linear regressions. It works as follows. For a given window of size T, we regress the observed values of Y_t against its lagged values Y_{t-1}:

$$Y_t = \varphi Y_{t-1} + \varepsilon_t$$

By integrating the continuous diffusion equation, we can come up with a discretised version of the dynamics:

$$Y_{t+\Delta t} = e^{-a\Delta t} Y_t + \sigma \sqrt{\frac{1 - e^{-2a\Delta t}}{2a}} N$$

… where N is a random variable that follows a standard normal distribution. By identification, we can in turn express a and σ as functions of φ and the standard deviation of the residuals ε_t:

$$a = -\frac{\ln(\varphi)}{\Delta t}$$

$$\sigma = \sqrt{\frac{2a}{1 - e^{-2a\Delta t}}} \operatorname{std}(\varepsilon_t)$$

Choosing a proper size for the estimation window is not an easy task. Under the assumption that the model's parameters are constant, one can show that the larger the window size, the smaller the estimators' variance and bias. Of course, real prices dynamics do not follow the constant parameter assumption, and an optimal window size must satisfy some bias/variance trade-off. As a rule of thumb, the estimation window must be comparable to the intraday horizon.

Linear regression-based estimates also have inherent bias. Academic research shows that the OLS estimators for a have a systematic bias that is a function of the sampling parameters. In [JY09], the authors show that the second order bias is given by:

$$\frac{1}{2T}\left(3 + e^{2a\Delta t}\right) - \frac{2\left(1 - e^{-2an\Delta t}\right)}{Tn\left(1 - e^{-2a\Delta t}\right)}$$

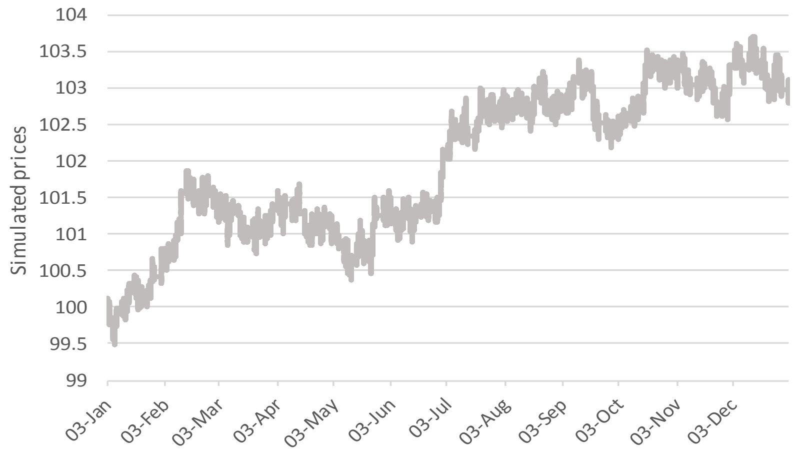
We can therefore construct a robust estimator by subtracting the above quantity in the estimate:

$$\hat{a}_{\text{no bias}} = \hat{a} - \frac{1}{2T}\left(3 + e^{2\hat{a}\Delta t}\right) + \frac{2\left(1 - e^{-2\hat{a}n\Delta t}\right)}{Tn\left(1 - e^{-2\hat{a}\Delta t}\right)}$$

This approach is useful in the case of intraday data, as it allows for the construction of estimators with low bias using simple linear regression techniques.

To verify these theoretical results numerically, we simulate intraday trajectories over the course of a year, with a constant positive trend and verifying the dynamic above.

Simulated intraday trajectory with slight upward trend, $a = 50\%$ and $\sigma = 20\%$



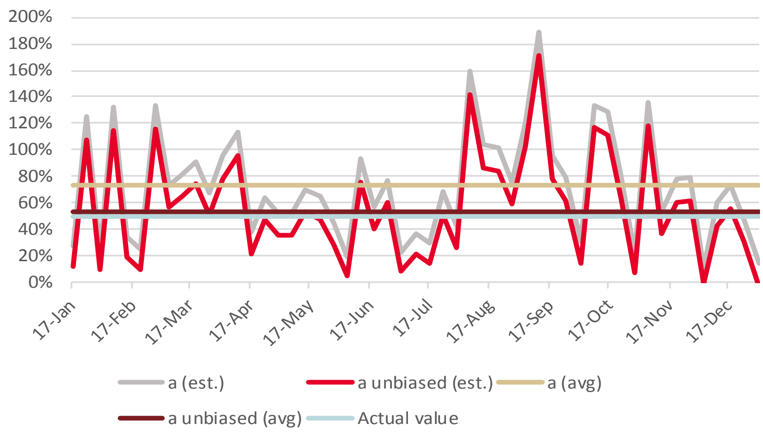
Source: SG Cross Asset Research/Cross Asset Quant

We estimate the model's parameters on a rolling window of size T (10 days in this example). Let $(t, t+T)$ denote the bounds of the time window. We first detrend the data by calculating the price slope on the window:

$$Slope(t, t+T) = \frac{Y(t+T) - Y(t)}{T}.$$

We then estimate the parameters a and σ on the detrended intraday series using both the biased OLS estimator and the unbiased one. The graphs below show the rolling estimates values as well as their mean (across time) and true parameter values.

Estimates of a both biased and unbiased versus true parameter value



Source: SG Cross Asset Research/Cross Asset Quant

The unbiased version of the estimator reduces the bias and is on average much closer to the actual parameter's value.

Addendum 4: Parametric form of a mean-reverting process

The Ornstein-Uhlenbeck process is the traditional process used to model mean reversion. It is named after Leonard Ornstein and George Uhlenbeck, two mathematicians of Dutch origin from the first half of the 20th century.

This process can be written in this form:

$$dX_t = -aX_t dt + \sigma dW_t$$

… where *a* is classically negative and measures the speed of the mean reversion and *σ* is the volatility of the process. If *a* is positive, then the process is explosive and is similar to a trend-following process.

The Ornstein-Uhlenbeck process leads to closed-form formulas for the underlying process:

$$X_t = X_0 e^{-at} + \int_0^t \sigma e^{a(s-t)} dW_s$$

This equation states that the price follows a normal distribution with mean and variance:

$$E(X_t) = X_0 e^{-at}$$

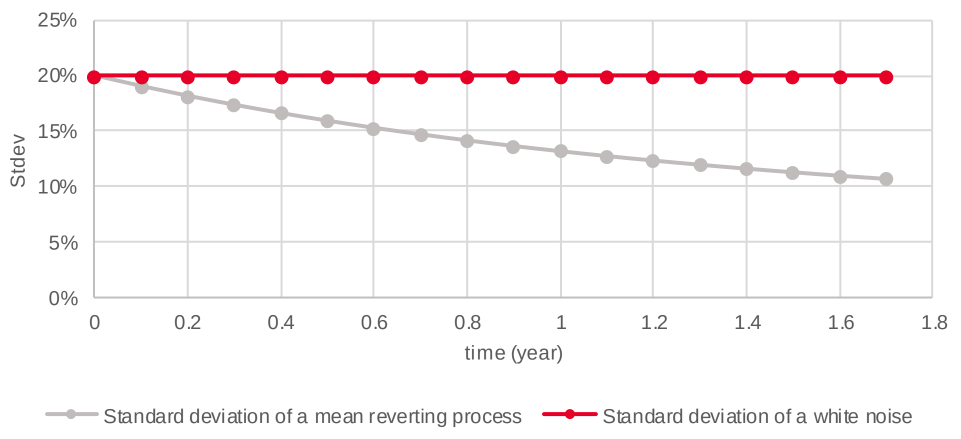
$$\mathrm{Var}(X_t) = \frac{\sigma^2}{2a}\left(1 - e^{-2at}\right)$$

Therefore, the annualised volatility measured between two time periods is given by:

$$\sigma(X_{t+h} - X_t) = \sigma\sqrt{\frac{(1 - e^{-2ah})}{2ah}}$$

If *a* is negative, the process is mean reverting and the volatility is strictly decreasing. If *a* is positive, the process follows a trend and the volatility is strictly increasing.

Parametric form of the variance in an Ornstein-Uhlenbeck process



Source: SG Cross Asset Research/Cross Asset Quant

Addendum 5: Performance results of our intraday strategy

Intraday trend-followers performance (execution at the mid)

	Ann. return	Ann. vol	Ann. Return/Vol	Max drawdown
Russell 2000	1.15%	1.08%	1.07	-1.54%
S&P Mini	0.83%	0.79%	1.05	-1.28%
S&P MidCap 400	0.99%	0.95%	1.04	-1.21%
VIX	8.17%	9.24%	0.88	-13.59%
Platinum	0.48%	0.55%	0.88	-1.41%
10Y Treasury	0.04%	0.05%	0.81	-0.10%
Nasdaq Mini	0.69%	0.97%	0.71	-2.15%
AUD	0.21%	0.31%	0.68	-0.62%
Nikkei	0.66%	0.98%	0.67	-2.01%
EUR	0.06%	0.11%	0.58	-0.33%
OMX30	0.34%	0.71%	0.48	-1.34%
USD	0.03%	0.07%	0.46	-0.19%
Palladium	0.50%	1.10%	0.46	-2.71%
5Y Treasury	0.01%	0.02%	0.45	-0.06%
Light Crude	0.88%	1.94%	0.45	-4.72%
Gold	0.22%	0.48%	0.45	-1.34%
Silver	0.55%	1.41%	0.39	-4.83%
NZD	0.08%	0.24%	0.31	-0.87%
10Y CAD	0.01%	0.04%	0.28	-0.11%
CHF	0.04%	0.14%	0.26	-0.47%
FTSE100	0.14%	0.68%	0.21	-1.66%
10Y Gilt	0.00%	0.05%	0.07	-0.16%
FTSE MIB	0.04%	0.71%	0.06	-2.94%
JPY	0.01%	0.12%	0.06	-0.86%
AEX	0.01%	0.86%	0.01	-3.80%
SMI	-0.01%	0.48%	-0.03	-2.03%
CAD	-0.01%	0.10%	-0.14	-0.93%
10Y OAT	0.00%	0.02%	-0.14	-0.14%
CAC40	-0.17%	0.74%	-0.22	-5.49%
DAX	-0.21%	0.85%	-0.24	-5.63%
GBP	-0.03%	0.10%	-0.26	-0.68%
Eurostoxx	-0.23%	0.84%	-0.28	-6.14%
Brent Crude	-0.62%	1.78%	-0.35	-12.24%
10Y Bund	-0.02%	0.04%	-0.36	-0.52%
2Y Treasury	0.00%	0.01%	-0.45	-0.05%
10Y BTP	-0.05%	0.11%	-0.46	-0.96%
2Y Schatz	0.00%	0.00%	-0.58	-0.04%
5Y Schatz	-0.01%	0.02%	-0.62	-0.24%

Source: SG Cross Asset Research/Cross Asset Quant

Addendum 6: How to measure the leverage ratio in a leveraged ETF

Each of the leveraged ETFs in our dataset reports its target leverage ratio. In real world settings, various factors may force the ETF manager to adjust leverage in a non-linear fashion. For example, if liquidity is drying out on the underlying futures market, the ETF manager might be momentarily forced to reduce leverage. In the following, we try to assess actual leverage using a dynamic approach.

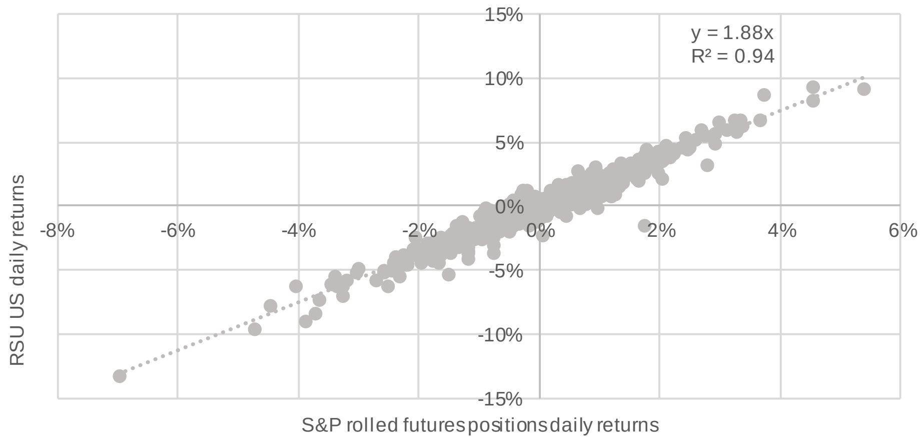
For the sake of clarity, we denote by r_t^{ETF} and $r_t^{Futures}$ the respective returns of the ETF and the futures at time at t. The leverage ratio L_t can be estimated using a linear model:

$$r_t^{ETF} = L_t \times r_t^{Futures} + \epsilon_t$$

… where ϵ_t is an error term. There are various statistical approaches to compute an estimate of the leverage ratio. As an example, we consider a leveraged ETF tracking the S&P 500 (RSU US Equity), with a reported leverage ratio of 2x. This ETF was launched in 2010 and is now delisted. We look at calculating its leverage over the three years it was active.

The first approach consists of using a linear regression on the whole period as per the graph below. The model is very good, with an R squared well above 90%, and the slope is statistically significant, with an estimated value of 1.88x. This value is below the target leverage of 2x, which is an indication that the ETF manager is generally underleveraged.

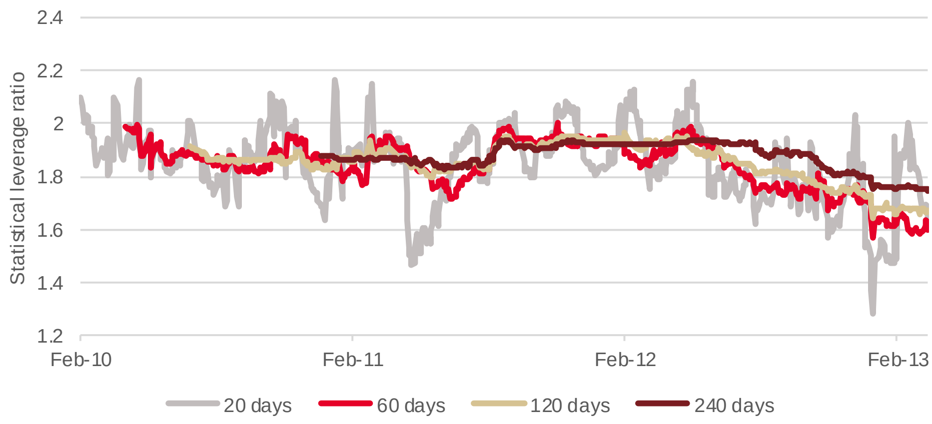
Leveraged ETF returns versus futures returns



Source: SG Cross Asset Research/Cross Asset Quant, Bloomberg, SG ETF Screener

The second approach is to calculate the linear regression on a rolling window. The graph below shows the time varying values of the estimated leverage ratio for different window sizes.

Time varying leverage ratio for various time windows



Source: SG Cross Asset Research/Cross Asset Quant, Bloomberg, SG ETF Screener

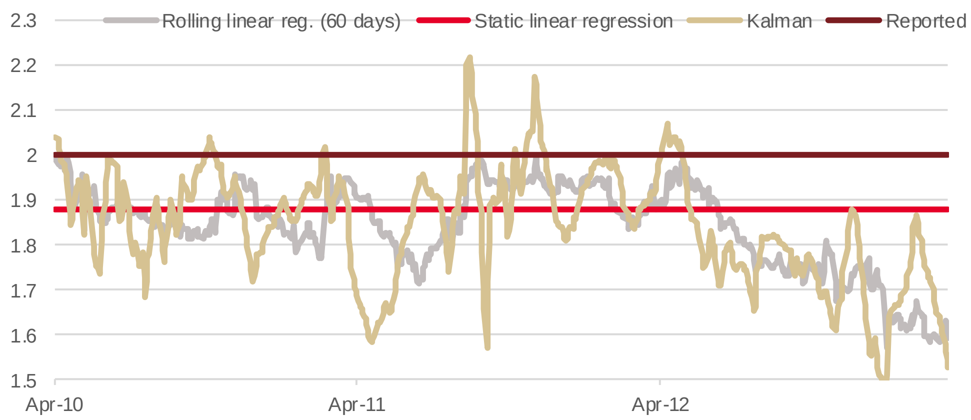
Choosing an optimal value for the window is not an easy task, as the leverage ratio is not observable. One can find a suitable window under some constraints on the variance of estimated leverage or by ensuring that the estimate passes some stationarity tests.

Another approach is to use a statistical filtering technique such as Kalman filtering. The Kalman filter is a state space model that allows for estimating a model and the associated error in an iterative way. In such a setting, the leverage ratio is assumed to have a normally distributed error term:

$$L_t = L_{t-1} + \eta_t.$$

There is no single best approach to estimating the leverage ratio. Kalman has the desirable property of being robust to missing data (which is often the case for ETF funds that do not report regularly), but it is more computationally intensive. The graph below summarises the different estimates as well as the reported leverage ratio.

Various leverage ratio estimates versus reported leverage



Source: SG Cross Asset Research/Cross Asset Quant

In this example, the statistical leverage ratio is less than the reported leverage ratio.

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