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Systematic short gamma strategies to trade Euro rates vol

Rule based short gamma strategies based on macro and technical signals outperform outright short gamma

Rates Strategy
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- A substantial literature shows systematic signals utilizing momentum and value work both within and across different asset classes
- Given the natural bias towards short gamma positions to monetize the premium of implied volatility over delivered volatility, a simple strategy generally employed by investors is to sell outright gamma in a systematic way. We use this as a benchmark strategy for comparison with the performance of other rule based strategies
- We present here a set of macro and technical signals to trade interest rate gamma and back test these signals since Euro inception in January 1999. Our main indicators are:
- 1) **Momentum in vol returns** – go long volatility if the cumulative P&L from systematically selling vol over the past 1M is negative; otherwise stay short
- 2) **Carry** – go long vol when risk-adjusted-carry in the underlying swap rate is below 30th percentile, relative to long term history, and rising over a 1M lookback; otherwise stay short
- 3) **Macro shock** – go long vol when the 3M change in PMI is more than 1SD below the cumulative average of 3M changes; otherwise stay short
- 4) **Liquidity** – we use the Hui-Heubel ratio to measure liquidity (lower number indicate more liquid conditions). Turn neutral on vol if the HH ratio is above 0.02; otherwise stay short
- **Combining the above macro signals** and applying equal weights on each of them produces results which are better than the individual strategies
- 5) **ECB Regime** – Empirical analysis shows that selling volatility has been profitable during ECB on-hold and hiking regimes. Buying vol is profitable during ECB rates easing regime. Long vol positions have been profitable during the ECB QE regime but a large part of this outperformance comes from the Bund VaR shock episode
- 6) **Ratio of implied to delivered volatility** – go short if the ratio of implied to 1M delivered volatility is above 125% and go long if the ratio is below 66%. There has been a marked improvement in the performance of this strategy over the past four years
- 7) **Fading extremes in implieds** – fading the valuation extremes (measured in terms of 1Y Z-score) does not outperform our benchmark strategy of outright short gamma
- 8) **Fading extremes in implieds conditional on ECB regime** – Fading the extremes in implieds conditional on ECB regime vastly improves the performance of (7)

See page 19 for analyst certification and important disclosures.

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Introduction

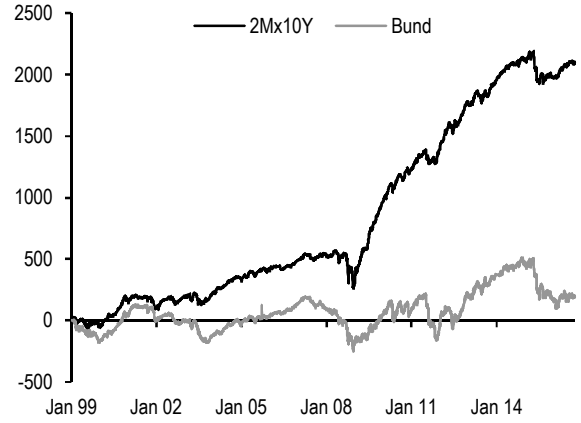
A substantial literature shows that systematic signals utilising momentum and value work both within and across different asset classes.[1] Several market participants also look for similar rule-based strategies in trading interest rate gamma. Given the natural bias towards short gamma positions to monetize the premium of implied volatility over delivered volatility, a simple strategy generally employed by investors is to sell gamma in a systematic way (see below). Indeed, a simple strategy like this would have generated positive returns over time (**Exhibit 1**). Conceptually, this could be seen as somewhat similar to holding long duration exposure over time as a way to monetize term premia, or the fact that yields on 10Y bonds have historically tended to be higher than expectations of future short rates over the same horizon.

In this research note, **we extend our duration analysis to discuss several systematic rule based investment strategies in trading gamma in EUR rates market**. In this analysis of gamma, we use a simple strategy of selling gamma in a systematic way as a benchmark for comparison of various strategies. We back test each of these strategies using J.P.Morgan volatility indices since Euro inception. These indices are constructed using the assumption of daily delta-hedging and zero transaction costs (we also look at the impact of trading costs in our analysis below). We keep the option maturity dates and strikes fixed for an entire month and then re-strike these options into a new ATMF option with original expiry. Readers can find these indices on Dataquery ®.

Exhibit 2 summarizes the various indicators that we have used along with the information ratio of these strategies. We split our indicators into two broad categories: *a)* Macro indicators and *b)* Technical indicators. Under macro indicators, we consider strategies that are based on macro conditions such as global PMI, ECB regime, etc. Here, we present our main conclusions. Intuition and detailed working of these strategies can be found in the relevant sections. Specifically, we look at:

[1] For instance, in the *Overview* section of the *Global Fixed Income Markets weekly*, we regularly update the performance of our systematic signals to trade outright and cross-market fixed income.

Exhibit 1: A simple strategy to sell gamma on a regular basis to monetize the typical premium of implied volatility over delivered volatility is profitable over the long run
Cumulative delta-hedged return from selling 2Mx10Y EUR swaption and Bund straddles; since 1 Jan 1999; bp of notional



1) **Momentum in vol returns** – go long volatility if the cumulative P&L from systematically selling vol over the past 1M is negative; otherwise stay short

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3) **Macro shock** – go long vol when the 3M change in PMI is more than 1SD below the cumulative average of 3M changes; otherwise stay short

4) **Liquidity** – we use the Hui-Heubel ratio to measure liquidity (lower number indicate more liquid conditions). Turn neutral on vol if the HH ratio is above 0.02; otherwise stay short

Combining the above macro signals and applying equal weights on each of them produces results which are better than the individual strategies

5) **ECB Regime** – Empirical analysis shows that selling volatility has been profitable during ECB on-hold and hiking regimes. Buying vol is profitable during ECB rates easing regime. Long vol positions have been profitable during the ECB QE regime but a large part of this outperformance comes from the Bund VaR shock episode

6) **Ratio of implied to delivered volatility** – go short if the ratio of implied to 1M delivered volatility is above 125% and go long if the ratio is below 66%. There has been a marked improvement in the performance of this strategy over the past four years

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Exhibit 2: We develop various signals for rule based trading in vol, which when applied have generally outperformed an outright short gamma strategy. Our macro indicators currently point towards a short gamma bias whereas the technical indicators point towards a neutral bias

Summary of various trading signals with a brief description and their information ratios;

	Strategy	Rule	Ann inf ratio	Success ratio	Current positioning
	Benchmark	Always sell vol	0.6	64%	-
1	Momentum in vol returns	Go long vol if 1M momentum in return from selling vol is negative; otherwise stay short	2	60%	Long
2	Carry	Go long vol when swap RAC is below 30th percentile and rising; otherwise stay short	1.7	65%	Short
3	Macro shock	Go long vol if 3M change in PMI is more than 1SD below average of changes; otherwise stay short	1.6	69%	Neutral
4	Liquidity	Turn neutral on vol if the HH ratio is above 0.02; otherwise short vol	1.3	61%	Short
	Combining 1 - 4	Apply equal weights to each strategy	1.8	65%	Short
5	ECB regime	Buy vol during easing regimes; sell vol during on-hold and hiking regimes; requires ex-ante knowledge of ECB regime	0.9	67%	Short
6	Ratio of implied to delivered volatility	Go long vol if ratio <66%; go short if ratio > 125%; otherwise stay neutral	0.75	61%	Neutral
7	Fading extremes in implied	Buy vol when z-score below -1.5; sell when 1Y Zscore is above 1.5; otherwise stay neutral	-0.5	42%	Neutral
8	Combining 6) and 8)	Only buy low (sell high) when in an easing (on-hold/hiking) regime and Zscore < -1.5 (> 1.5)	0.7	66%	Neutral

7) **Fading extremes in implieds** – fading the valuation extremes (measured in terms of 1Y Z-score) does not outperform our benchmark strategy of outright short gamma

8) **Fading extremes in implieds conditional on ECB regime** – Fading the extremes in implieds conditional on ECB regime vastly improves the performance of (7).

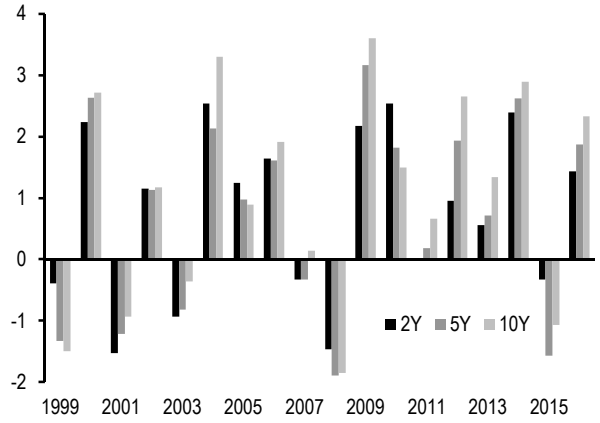
Finally, we also show in Exhibit 2 the current positioning as shown by these indicators.

Natural bias towards short gamma positions

A program selling strategy that systematically sells gamma on a daily basis would have yielded positive delta-hedged returns on a cumulative basis since Euro inception (Exhibit 1). Looking closely, we identify the following: **First**, returns have followed the expected path – mixed returns prior to 2005 as it was a combination of hiking (1999 – 2000) and easing (2001 – 2003) cycle, positive returns during the 2005-2007 low vol cycle, a sharp drop in returns around the Lehman crisis of 2008 and then a broad upward trend in short gamma returns since then. In line with our intuition, short gamma strategies experienced drops during the peripheral crisis, Fed's taper tantrum, and the Bund VaR shock episodes. In retrospect, these drops have been more violent in Bunds compared to OTC swaptions (see below), especially during periods of crisis. Analysis of monthly returns on a yearly basis shows similar results. **Exhibit 3**

Exhibit 3: 2009 was the best year to sell volatility as implieds retraced sharply from their post-Lehman highs under the pressure of ultra-accommodative monetary policy and markedly lower yields

Annualized information ratios of 1M returns from selling 3Mx2Y, 3Mx5Y, and 3Mx10Y EUR gamma; unitless



shows the information ratio (average of rolling 1M returns divided by standard deviation of these rolling 1M returns, expressed in annualized terms) from selling 3Mx2Y, 3Mx5Y, and 3Mx10Y OTC gamma since Euro inception. 2009 was the best year to sell vol – implieds declined sharply from their post-Lehman highs as the global economy started to recover and the central banks took interest rates to hitherto unprecedented lows. Selling gamma in 2015 would have resulted in a loss – the loss at the front-end of the curve was primarily during 4Q15 when market started to price further aggressive ECB easing while the loss at the long-end was

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due to the Bund VaR shock episode during late spring / early summer of 2015. Selling gamma in 2016 has been generally profitable across all tails.

Second, returns from selling OTC and listed options followed broadly similar pattern until early 2008. Since the financial crisis, returns have diverged with short gamma in OTC outperforming short gamma in listed options. Empirical analysis shows that OTC swaptions generally price a higher premium relative to delivered volatility compared to Bunds. **Exhibit 4** shows the cumulative difference of swaption implied/delivered differential and Bund implied/delivered volatility[2]. While the discrepancy between OTC and listed options implied/delivered existed prior to the subprime crisis, this divergence has become more prominent over the last few years[3]. This is primarily due to the change in swap-spread directionality. Prior to the crisis, directionality of German swap spreads to Bund yields were broadly mixed. However, it has been distinctly negative over the past few years – swap spreads have widened (narrowed) in a rally (sell-off). During flight-to-quality episodes, this directionality becomes even more negative leading to further underperformance of short Bund gamma versus OTC gamma, due to a combination of repricing of implieds and losses from delivereds. A corollary of this analysis is that Bund implieds are generally fairly priced versus delivered volatility, at least when compared to swaptions. Therefore, from a systematic strategy point of view, we find risk-reward more attractive to setting up these systematic short gamma strategies using OTC options.

In setting systematic short gamma strategies, we find that selling shorter expiry gamma options has, on average, outperformed longer maturity gamma options. **Exhibit 5** shows various statistics including the annualized information ratio of rolling monthly returns from selling various expiry options for 2Y, 5Y, and 10Y tails. Indeed, shorter maturity options have higher gamma exposure and are thus more effective in monetizing the implied/delivered differential.

We next develop a series of macro and technical indicators and back-test gamma strategies around these indicators since Euro inception in January 1999. We highlight that using 1M options may not be best suited for all the strategies that we test (some involving less frequent rebalancing of signals) and therefore we compare the performance against returns from a strategy of selling 3M expiry options.

Exhibit 4: Historically, OTC swaptions appears to be consistently mispriced with respect to delivered volatility compared to their listed counterparts, a phenomenon that has accelerated since the financial crisis

Cumulative (Ex-ante 3Mx10Y implied vol – subsequent 1M delivered vol of 10Y swaps) minus (ex-ante front Bund volatility – subsequent Bund CTD delivered vol); non-overlapping series since 1 Jan 1999; bp/day

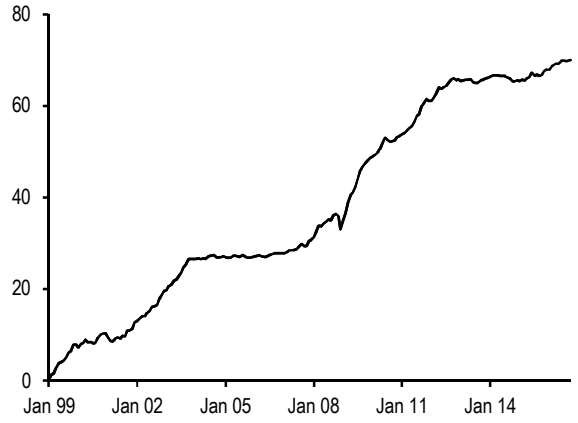

Exhibit 5: In setting systematic short gamma strategies, we find that selling shorter expiry options have generated higher information ratios compared to longer expiries

Statistics of rolling monthly returns from selling various options since Jan 1999; Average and SD in bp of notional; Inf ratio is unitless

	1M	3M	6M
Average			
2Y	3.5	0.9	-0.2
5Y	8.2	2.3	-0.2
10Y	15.6	6.7	2.5
Standard Deviation			
2Y	8.2	9.0	9.9
5Y	18.8	18.9	20.4
10Y	34.2	36.4	38.8
Annualized Information ratio			
2Y	1.5	0.4	-0.1
5Y	1.5	0.4	0.0
10Y	1.6	0.6	0.2

We roll options every two weeks for 1M expiry options and monthly for 3M and 6M options.

[2] Defined as cumulative (ex-ante 3Mx10Y implied volatility – subsequent 1M delivered volatility of 10Y swaps) - (ex-ante Bund implied volatility – subsequent 1M delivered volatility of Bund CTD forward yield).

3 Negative swap spread directionality implies that for a given level of implied volatility for Bund and swaptions, swaps are likely to deliver lower volatility and hence short gamma in OTC would potentially outperform short gamma in listed space.

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Macro indicators

In this section, we outline the intuition behind, and the performance of, a set of macro indicators that we have found to be successful signals for trading volatility. We apply these signals to trading 3Mx10Y swaption volatility, and show in the Appendix below how the signals perform when applied to Bunds.

1. Momentum

Momentum strategies have been well documented across different asset classes and on a cross-asset basis both in our *Investment Strategies*[4] series as well as academic literature.[5] In various guises, the underlying rationale for price momentum is essentially that investors may initially underreact to 'news', as they need subsequent confirmation to verify whether the new information is signal or noise, and perhaps later overreact, with factors such as hedging pressure potentially contributing further[6]. Put another way, momentum strategies seek to exploit positive serial correlation in returns. Interactions between price and macroeconomic momentum can also be mutually reinforcing, as an improvement in financial conditions can contribute to improved macroeconomic conditions. Another source of momentum, particularly relevant in fixed income instruments, is shifts in monetary policy, which historically have been very persistent as central banks have typically hiked by more than initially expected in tightening cycles and cut by more than expected in easing cycles.

In our systematic signals for trading duration[7], we use price momentum signals as a key component of the overall combined signal. For trading volatility, however, price momentum in the underlying bonds or swaps is less meaningful, as the directionality of vol to changes in rates can vary significantly over time. Indeed, looking at a simple chart of rolling 1Y betas between changes in swaption implied volatility and changes in swap rates (**Exhibit 6**) shows that after the Euro area crisis the directionality has generally been positive. Before this, however, there were sharp swings between 2008 and 2012, and pre-crisis the relationship was much less clear-cut. Vol typically increases as an economy slows down, equities decline and central banks cut rates. However,

Exhibit 6: For trading volatility, price momentum in underlying bonds or swaps is less meaningful, as the directionality of volatility with respect to changes in rates can vary significantly over time

1Y rolling beta from regressing changes in 3Mx10Y swaption implied volatility and changes in 10Y swap rates

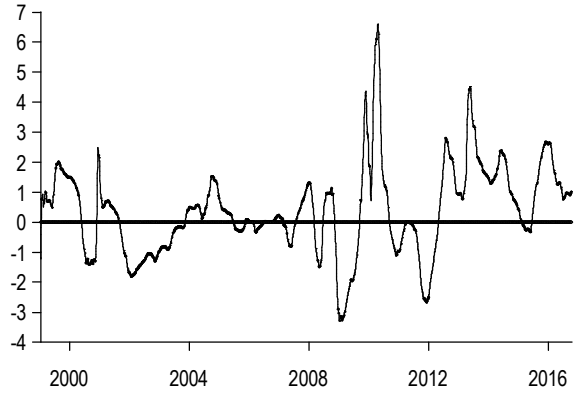
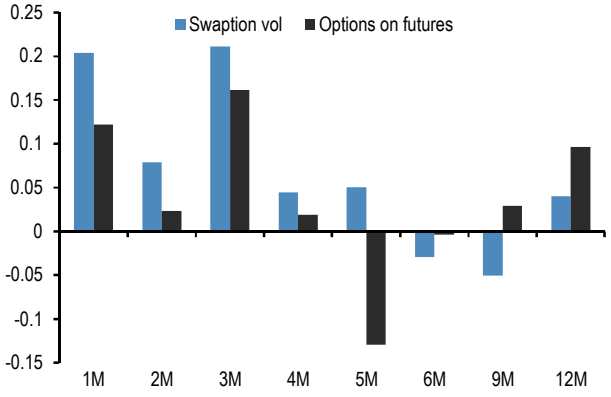


Exhibit 7: Consistent with serial correlation being evident in underlying asset returns and economic indicators, we find that returns on systematically selling volatility tend to exhibit positive serial correlation over time

Serial correlation in monthly returns from selling vol via 3Mx10Y OTC options and listed options on 10Y Bund futures, lags on x-axis



with policy rates at zero, there is a stronger component coming from lognormality.

We focus instead on momentum in returns from systematically selling volatility as a signal for trading vol. Indeed, consistent with serial correlation also being evident in underlying asset returns as well as economic indicators, we find that returns on selling volatility also tend to exhibit positive serial correlation over time (**Exhibit 7**).

We apply a simple momentum signal with varying lookback periods on cumulative returns from continually selling volatility – i.e. when the cumulative P&L over the

[4] E.g. *Exploiting Cross-market Momentum*, Ruy Ribeiro et al, 8 Feb 2006,
[5] See for example *Fact, Fiction and Momentum Investing*, C. Assness et al, 2014, http://ssrn.com/abstract=2435323.
[6] For example, short gamma strategies often imply delta hedging behaviour that can exacerbate price movements in the underlying instrument.
[7] *Overview, GFIMS*, 4 Nov 2016.

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relevant lookback period from selling volatility is positive, the signal stays short volatility, and if the P&L turns negative the signal goes long volatility. In addition, we look at whether using a composite signal of both a shorter and a longer lookback period improves performance, where the signal is short or long vol where both of the sub-signals point in the same direction and neutral otherwise. **Exhibit 8** shows the annualized return-to-risk by look-back period, and disaggregates the signal performance for periods where it is short vol and long vol. This suggests that a relatively short lookback period of around 1M maximises both the overall information ratio as well as the disaggregated performance from the signal holding short and long volatility positions when applied to swaption volatility[8]. We also show the best performing combined signal of using separate lookback periods (1M and 3M) to trade volatility, such that the signal is short or long volatility when both momentum signals point in the same direction and neutral otherwise.

Taken at face value, these results would suggest that a simple momentum signal performs better than a combined signal using a shorter and longer term momentum signal. **Exhibit 9** shows cumulative return systematically selling volatility compared to the 1M momentum strategy, with the shaded areas denoting periods where the momentum signal is long volatility. Over the sample period from 1999 onward, the average holding period for a short and long vol position has been around 25 and 12 days respectively.

2. Carry

Carry is a commonly used value signal for trading fixed income. Indeed, we find that carry has been a reliable indicator for trading bonds on both an outright and as well as a cross-market basis. A steep curve, i.e. high carry, tends to be associated with high term premia. It also generally signals loose monetary policy supporting a weak economy, which essentially means that it also performs the role of a slower-moving cyclical indicator.

However, similar to underlying price momentum in bonds, the impact of carry on vol is less obvious in terms of directionality (**Exhibit 10**). Instead, when we investigate the relationship between carry and vol, we find that there is a degree of level-dependence and asymmetricity whereby **volatility tends to rise in an environment where carry-to-risk is very low and is beginning to rise**, but do not find either rising or

Exhibit 8: A relatively short lookback period of around 1M maximises both the overall information ratio as well as the disaggregated performance from the signal holding short and long volatility positions

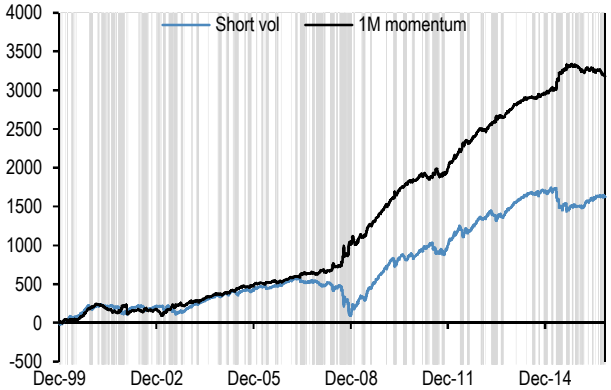
Daily return to risk from a vol momentum strategy* at different lookback periods since the inception of the Euro in 1999 for the overall strategy, broken down to periods where the signal is short and long volatility, and % of time the signal is long

	Performance of signal			Prop of time
	Overall	Short vol	Long vol	long vol
2W	1.7	2.5	0.7	37%
1M	2.0	2.9	1.1	35%
2M	1.4	2.2	0.5	32%
3M	1.2	2.0	0.3	30%
4M	1.2	2.0	0.3	30%
5M	1.3	2.0	0.3	30%
6M	1.2	1.9	0.3	30%
12M	1.0	1.6	0.0	26%
Combined (1M & 3M)	1.8	3.0	1.0	23%

* The strategy is short volatility when the cumulative return from systematically selling volatility is above its average for the relevant lookback period, and long volatility when it is below its average for the same period. The combined signal is short or long when both the 1M and 3M strategy point in the same direction, and is otherwise neutral.

Exhibit 9: A 1M momentum strategy performs well relative to a strategy of always selling volatility, though it implies very frequent trading

Cumulative return from always selling 3Mx10Y volatility and from the 1M momentum strategy; shaded areas denote periods where the momentum strategy is long volatility; bp of notional



declining carry to be a reliable signal when the level of carry is high. Intuitively, our interpretation is that, in a low carry environment fixed income investors can absorb a relatively smaller rise in yields before total returns turn negative. This may trigger investors to hedge or reduce exposures relatively quickly, which in turn can contribute to further rises in yields and further hedging. By contrast, in a higher carry environment, fixed income investors can withstand a larger rise in yields before it turns overall

[8] For trading vol using options on futures, a relatively longer lookback period of around 4M performs better.

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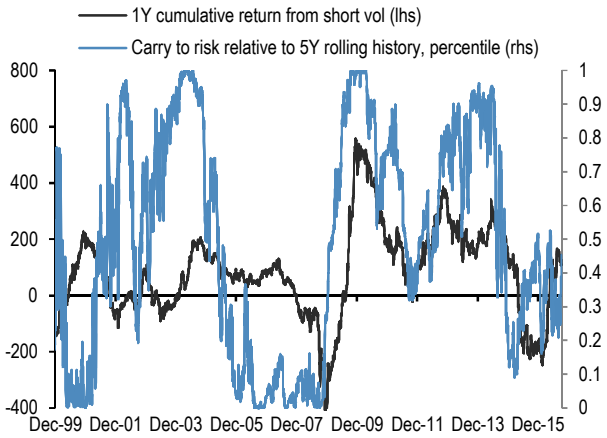
Exhibit 10: We find that there is a degree of asymmetricity in that volatility tends to rise in an environment where carry-to-risk is low and rising, but do not find either rising or declining carry to be a reliable signal when the level of carry is high

1Y rolling returns from a short vol strategy, and the current level of carry-to-risk relative to its 5y rolling history in percentiles



returns negative (indeed, higher carry increases the cost of shorting bonds), while declines in bond yields augment income returns for investors holding bonds.

To define periods where we consider carry to be high or low, we use a framework similar to what we have previously utilised in our duration signals, where we use carry-to-risk relative to its long-term rolling history in percentile terms to signal when it has reached low levels. We then use a change in carry to risk to signal when it is rising. The performance of this conditional signal, i.e. a rise in carry-to-risk conditional on the level of carry-to-risk being low, is shown in **Exhibit 11** for various combinations of percentile thresholds and lookback periods for the change. It suggests that a threshold at the 30th percentile and a short lookback period of 1M edges out other combinations at the margin. **Exhibit 12** shows the performance of this signal when applied to trading swaption vol compared with the strategy of always selling vol, with shaded areas indicating when the signal has turned long vol. The strategy was long volatility during vol spikes in 2008 and 2015.

3. Macro momentum and shocks

We focus here on the Euro area manufacturing purchasing manager index (PMIs). The PMIs are among the timeliest individual indicators of economic conditions, and changes in the J.P. Morgan Global Manufacturing PMI have historically been a good guide to shifts in global GDP as well as a useful signal for

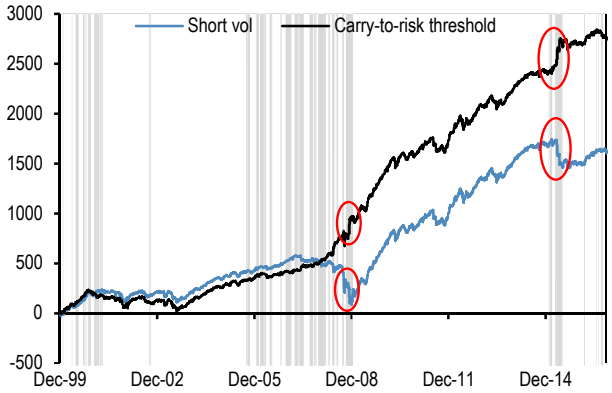
Exhibit 11: The signal produces decent returns across various combinations of lookback periods and thresholds

Daily return to risk from conditional strategy that turns long volatility when RAC is below the relevant percentile thresholds and rising at various lookback periods; overall strategy, and broken down to periods where the signal is short and long volatility, and % of time the signal is long

Percentile threshold	Conditional change	Performance of signal			Proportion of time long vol
		Overall	Short vol	Long vol	
20%	1M	1.7	1.5	2.9	10%
	2M	1.4	1.3	2.4	7%
	3M	1.3	1.3	2.4	7%
	4M	1.3	1.2	2.7	6%
30%	1M	1.7	1.6	2.3	12%
	2M	1.4	1.4	1.9	10%
	3M	1.3	1.3	1.6	9%
	4M	1.4	1.3	1.8	9%
40%	1M	1.6	1.6	1.4	16%
	2M	1.2	1.3	0.7	14%
	3M	1.3	1.4	1.0	13%
	4M	1.3	1.4	1.1	12%

Exhibit 12: Similar to the momentum signal, a conditional carry signal performs well relative to a strategy of always selling volatility

Cumulative return from always selling 3Mx10Y volatility and from a strategy that turns long volatility when RAC is below its 30th percentile and rising, and short vol otherwise; shaded areas denote periods where the momentum strategy is long volatility; bp of notional



market timing in equities, fixed income and commodities[9].

Similar to price momentum, we have found macroeconomic momentum to be a useful signal across different markets. As with price returns, changes in PMIs are strongly serially correlated (**Exhibit 13**), in common with any other activity releases. This would be consistent

[9] See *Using the Global PMI as a trading signal*, N. Panigirtzoglou, Jan 2012.

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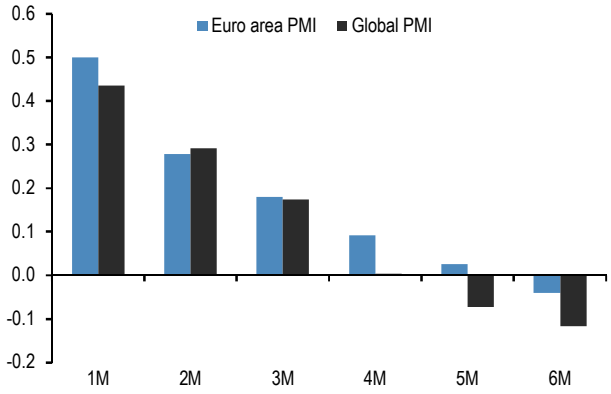
Exhibit 13: As with price returns, changes in PMIs are strongly serially correlated

Serial correlation in Euro area and global PMI at progressively longer lags



with a degree of "anchoring" in investors' expectations as well as economists' forecasts[10]. In turn, this is at least in part driven by the fact that with any piece of 'news' (defined here as a surprise relative to expectations) from 'noisy' indicators requires investors and economists to consider how much of the 'news' constitutes signal rather than noise, which can result in the underreaction to news discussed above. Only over time does it become clear how much of the 'news' represents signal and how much is noise.

However, as with underlying price momentum, when it comes to volatility it is less obvious that simple macroeconomic momentum provides a good framework for trading volatility (**Exhibit 14**). Indeed, focusing first on the PMI, we do not find simple PMI momentum as a compelling signal to trade volatility, as small positive or negative changes can represent relative stability and are as such more likely to be conducive to earning volatility premia rather than attempting to trade the direction of volatility. Indeed, we find that monthly returns from the "always short vol" strategy in months after PMI changes that are either within one standard deviation of their historical average or more than one standard deviation above its average tend to be positive, while returns in months after PMI changes are more than one standard deviation below the average are very negative (**Exhibit 15**).

We thus turn to look at whether larger shocks to the PMI can be useful as a predictor of subsequent rises in volatility, and to profit from periods where a simple 'always short' volatility strategy produces large drawdowns. Here, we find large negative changes in the

Exhibit 14: It is less obvious that simple macro momentum provides a good framework for trading volatility

Rolling 1Y return from always selling volatility and final Euro area Manufacturing PMI; bp of notional and pt

Exhibit 15: We find that monthly returns from always selling volatility in months after PMI changes are particularly negative produce very negative returns

Average monthly return from selling volatility in months after the 3M PMI change is *1)* more than 1 standard deviation above its average; *2)* within 1 standard deviation above and below its average; and *3)* more than 1 standard deviation below its average; bp of notional

Months after 3M PMI change	bp of notional
> avg + 1 s.d.	41.7
within avg ± 1 s.d.	7.5
< avg - 1.s.d.	-43.1

Euro area manufacturing PMI to be a good predictor of subsequent spikes in volatility. We find two simple rules to be useful signals to turn long volatility, with the rules otherwise short volatility:

- When the 3M change in PMI is more than one standard deviation below the cumulative average of the change[11], and look at whether the flash PMI can act as an early predictor of the final PMI to improve the information ratio further.
- When level of the PMI is below 50 (implying that output is contracting) and falling.

When we apply these signals to the data, we find that both signals outperform a simple outright short gamma strategy (**Exhibit 16**). The signal based on large declines in PMI 1) appears to outperform the threshold and decline 2) indicator. This appears to be largely because it performs better during periods when they point to long

[10] Refs to *Which Trade?*, John Normand, Jan 2004 and *Trading on Economic Data Releases*, Seamus Mac Gorain, Mar 2011.

[11] Essentially this assumes that as time goes on we get further information about the "true" sample mean and standard deviation.

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Exhibit 16: We find that a strategy that turns long vol after both a particularly large decline in the PMI, and a PMI below 50 and falling, outperforms the simple 'always short vol' strategy

Daily return to risk from always selling volatility compared to a strategy that turns long when the 3M PMI change is more than one standard deviation below its average, and a strategy that turns long vol when the level of the PMI is below 50 and falling, and % of time the signal is long

	Performance of signal			Proportion of
	Overall	Short vol	Long vol	time long vol
Always short volatility	1.0	1.0		
3M PMI change	1.6	1.6	1.5	13%
PMI < 50 and falling	1.3	1.6	0.5	19%

vol positions, suggesting they have done a better job at picking out periods where of negative macroeconomic shocks that subsequently saw rises in volatility. As a result, we prefer signal 1).

We can further dig into the PMI change signal by varying the lookback period for calculating the changes, as well as the cumulative average and standard deviation. This suggests that 3M lookback periods warrant the highest information ratios, largely due to the performance in periods when the signal turns long volatility (**Exhibit 17**). **Exhibit 18** shows the cumulative performance of the signal over time versus the simple outright short gamma strategy, with shaded areas showing the periods where the PMI signal turns long volatility. The PMI signal performs reasonably well during the early period of the financial crisis, turning long vol in mid-2008 and only turning short again in February 2009, and again during the initial stages of the Euro area sovereign crisis between May and November 2011 and its re-intensification in May/June 2012. The PMI signal does not pick up the most recent sharp rise in volatility in 2Q15 during the Bund VaR, as it did not have a trigger in the form of a macroeconomic growth shock as far as our PMI change signal is concerned. Indeed, an indicator capturing macroeconomic shocks more generally is unlikely to identify a rise in market volatility driven by positioning.

We have also looked at using the J.P. Morgan Forecast Revision Indices as an alternative to PMIs. The results are similar in principle, but have a shorter history (starting in 2002) and with slightly lower IR. In addition, the FRI tends to perform best at very short lookback periods (1-week). Given these factors, we prefer to use the PMI signal in this framework.

4. Liquidity

We have previously used liquidity as a higher frequency systematic signal for trading duration via German Bund

Exhibit 17: 3M lookback periods produce the highest information ratios, largely due to the performance in periods when the signal turns long volatility

Daily return to risk from a strategy that turns long volatility when the change in the PMI over the relevant lookback period is more than 1 standard deviation below its average

a) Flash and final PMIs

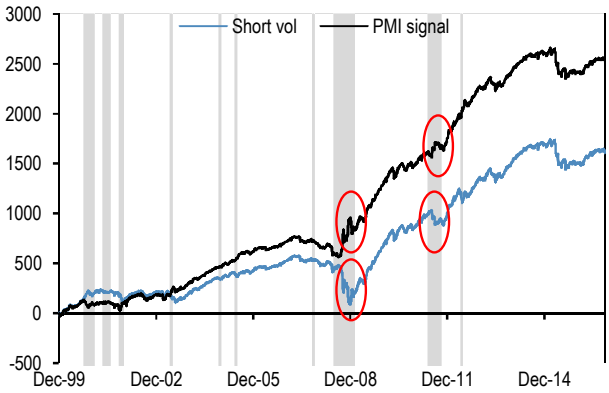
	Performance of signal			Prop of time
	Overall	Short vol	Long vol	long vol
1M	1.0	1.3	0.0	15%
2M	1.4	1.5	1.2	12%
3M	1.6	1.6	1.5	13%
4M	1.3	1.4	0.8	12%
5M	1.2	1.4	0.6	15%
6M	1.2	1.3	0.5	12%
12M	0.9	1.3	-0.1	14%

b) Final PMIs only

	Performance of signal			Prop of time
	Overall	Short vol	Long vol	long vol
1M	1.0	1.3	0.1	15%
2M	1.4	1.4	1.1	12%
3M	1.6	1.6	1.5	13%
4M	1.2	1.3	0.5	11%
5M	1.1	1.4	0.2	15%
6M	1.1	1.3	0.3	12%
12M	0.9	1.2	-0.3	14%

Exhibit 18: The PMI signal performs reasonably well during the early period of the financial crisis and again during the various stages of the Euro area sovereign crisis, but the 2015 VaR shock did not have a trigger in the form of a macroeconomic growth shock as far as the PMI signal is concerned

Cumulative return from always selling 3Mx10Y volatility and from a signal that turns long volatility when the 3M change in the PMI is more than one standard deviation below its average; shaded areas denote periods where the momentum strategy is long volatility; bp of notional



futures. Intuitively, a less liquid market should be more vulnerable to a rise in volatility, and in principle such vulnerability could arise both for sharp sell-offs and rallies.

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Typically, we have looked at two different indicators of liquidity. The first is market depth, which we measure as the average size of the three largest bids and offers during the day on Bund futures. However, we only have these data available from late 2010, while we are looking to apply indicators for a considerably longer period. Our second market indicator is the so-called Hui-Heubel liquidity ratio, which measures the impact of volumes on market prices, or market breadth.[12]

The ratio essentially shows the price impact normalised by turnover (V/OI), with a large impact suggesting low market breadth, or low liquidity. The evolution of the ratio is shown in **Exhibit 19**, and suggests a relationship between periods of illiquidity and heightened volatility.

We then take this liquidity indicator and apply simple thresholds to denote when the signal should be short or long volatility. We then take two thresholds, a lower threshold where values below that level signal liquid conditions and short volatility positions, and an upper threshold above which it points to long vol. The choice of thresholds is to some degree necessarily arbitrary after having observed a long history of the indicator itself, and we have previously employed thresholds of 0.02 and 0.04 for the lower and higher thresholds respectively in the higher frequency duration signals[13]. **Exhibit 20** shows the information ratios separately for short and long volatility signals to illustrate how the performance varies depending on the chosen threshold, and the proportion of time the signals are short or long volatility. Finally, it shows how the overall liquidity signal performs: *1)* with the 0.02/0.04 thresholds (when it remains neutral for around 19% of the time), *2)* when we restrict the signal to be always short or long vol around the 0.02 threshold, and *3)* when the liquidity signal is either short vol when the HH ratio is below 0.02 and neutral otherwise.

The results suggest that a threshold around 0.02 has historically performed consistently well as a lower threshold to signal short volatility positions. As for the long volatility threshold, the results are more mixed, with a lower threshold typically performing better than a higher threshold. This suggests that the deterioration in liquidity and rise in volatility may be relatively contemporaneous, and that by the time the signal turns long volatility, volatility may already have peaked. We thus prefer the last signal that is short volatility when the HH ratio is below 0.02 and neutral otherwise.

Exhibit 19: Liquidity matters: there appears to be a relationship between periods of illiquidity and heightened volatility
3Mx10Y swaption implied vol and the HH-ratio

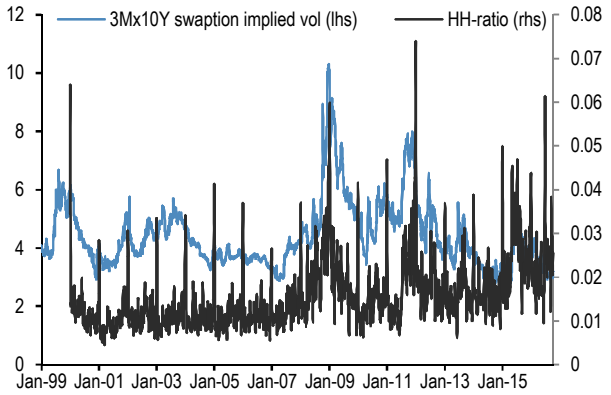

Exhibit 20: A threshold of 0.02 for the HH ratio, around 1 standard deviation above its long term average, has performed well as a lower threshold to signal short volatility, while the performance of long volatility thresholds has been more mixed
Daily return to risk from periods where the liquidity ratio signal is short volatility, long volatility and a combined signal

		Swaption vol	
		IR	Prop of time
Short vol threshold	0.01	1.5	25%
	0.02	1.6	79%
	0.03	1.0	94%
	0.04	1.0	98%
Long vol threshold	0.02	0.2	21%
	0.03	-0.8	6%
	0.04	-1.8	2%
	0.05	-7.2	1%
	0.06	-4.9	0%
Combined	0.02 / 0.04	1.3	
	0.02 / 0.02	1.2	
	0.02 short or neutral only	1.4	

Combining macro signals

In this section, we present a combined strategy for trading Euro area swaption and futures volatility using the signals momentum, carry, PMI and liquidity signals we describe above. Specifically, we use:

1. Momentum: 1M momentum in the cumulative return from selling volatility;

[12] We measure the ratio as:
HH Liquidity ratio = (Pmax – Pmin) / Pmin / (V/OI)
where Pmax is the highest daily price over a 5-day rolling window, Pmin the lowest price over the same period, V is the average daily volume of futures contracts over a 5-day period, and OI is the average open interest over the corresponding period.

[13] That said the 0.02 threshold is broadly consistent with a level of one standard deviation above the average of the HH-ratio for the full sample.

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Exhibit 21: The returns of the four signals are not particularly highly correlated with each other, with the volatility momentum signal providing the greatest diversification relative to the other signals

Correlation in daily returns between signals from 1999 onward

	Vol momentum	Carry	Liquidity	PMI
Vol momentum				
Carry	0.07			
Liquidity	0.01	0.57		
PMI	0.12	0.40	0.50	

2. Carry to risk: long vol when carry-to-risk is below the 30th percentile and rose over the past 1M, short otherwise;
3. PMI: long vol when 3M change more than 1 SD below its cumulative average, otherwise short;
4. Liquidity: turn neutral on vol when the HH liquidity ratio is above 0.02, stay short vol otherwise.

Exhibit 21 shows the correlation of returns on the four different signals since 1999. It shows that returns are not particularly highly correlated with each other, which underlines the diversification benefit from combining the signals together to an overall signal. The highest correlation occurs between the carry and liquidity signals (57%), which is perhaps unsurprising as both signals attempt to identify market conditions conducive for volatility shocks to occur. By contrast, the volatility momentum signal appears to exhibit virtually zero correlation with all other signals, which speaks to the benefits of combining a momentum signal with signals that essentially attempt to identify shocks to macroeconomic and market conditions.

For simplicity, we apply equal weights on each of our four signals. We regard this combined signal as a scalar relative to an overall risk budget. For example, if two of the signals are short vol and two neutral, the combined signal is short 50% of the risk budget applied to the signal. **Exhibit 22** shows the cumulative performance of the combined signal relative to the strategy of always selling volatility, denoting periods where the combined signal is long volatility with grey shading. It shows that the combined signal picks up the spikes in implied volatility during the early stages of the financial crisis in 07/08, the Euro area sovereign crisis in 2011, as well as the VaR shock in 2015. **Exhibit 23** below shows the performance of each of our individual signals as well as the combined equally-weighted signal, and how they perform when they are short and long vol, as well as how the market has performed when the overall signal has been neutral.

Exhibit 22: A simple linear combination of the four signals picks up the spikes in implied volatility during the early stages of the financial crisis in 07/08, the Euro area sovereign crisis in 2011, as well as the 2015 VaR shock

Cumulative return from always selling 3Mx10Y volatility and the combined signal; shaded areas denote periods where the combined strategy is long volatility; bp of notional

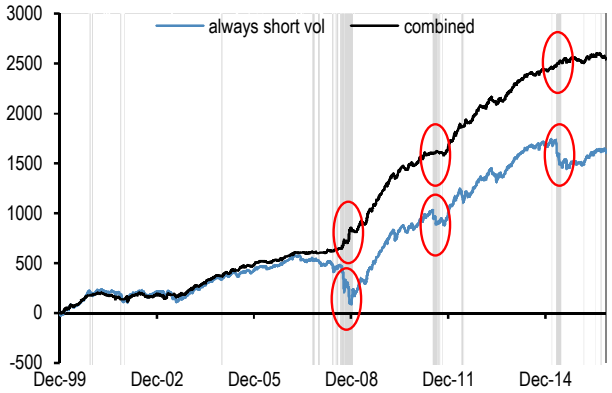

Exhibit 23: Diversification pays off; return to risk from the combined signal is higher than each of the individual signals and more than double that of always selling volatility. When moving to monthly vs. daily rebalancing, the performance is somewhat lower, but still well above always selling volatility

Cumulative returns, annualized daily returns and standard deviations; return to risk and the proportion of time each signal is short or long volatility; bp of notional, IR and %

		Cumulative return	Annualized return	Standard deviation	IR	Proportion of time
Always short volatility		1603	94	96	1.0	
Vol Momentum	Overall	3144	184	95	1.9	
	Short vol	2374	214	75	2.9	65%
	Long vol	771	129	124	1.0	35%
Carry-to-risk	Overall	2739	160	95	1.7	
	Short vol	2171	145	92	1.6	88%
	Long vol	568	268	118	2.3	12%
Liquidity	Overall	1758	103	71	1.4	
	Short vol	1758	131	80	1.6	79%
PMI	Overall	2516	147	95	1.5	
	Short vol	2056	139	88	1.6	87%
	Long vol	460	201	135	1.5	13%
Combined signal (daily rebalancing)	Overall	2539	149	60	2.5	
	Short vol	2274	154	61	2.5	87%
	Long vol	265	317	89	3.6	5%
	Neutral*					8%
		-647	-772	206	-3.7	
Combined signal (monthly rebalancing)	Overall	1967	115	64	1.8	
	Short vol	1819	126	65	1.9	85%
	Long vol	147	158	91	1.7	5%
	Neutral*					10%
		-389	-417	192	-2.2	

* Neutral shows the performance of the "always short volatility" strategy while the combined signal is neutral.

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The principal message from **Exhibit 23** is that we see a similar diversification benefit to what we have seen in applying a combination of value and momentum signals to trading outright duration. The information ratio of the combined signal is higher than each of the individual signals, both from a reduction in volatility and from higher annualized returns. **Moreover, the combined signal has produced higher returns at a lower risk than the outright short gamma strategy**. During the periods when the combined signal is neutral, returns from the "always short vol" strategy has shown a very negative return to risk. The weighted strategy thus helps investors avoid "lazy" short vol positions.

We also look at how the combined signal performs with monthly rather than daily rebalancing. We observe the "current" signal for each of the four signals on the day that the PMI is released, and apply these positions for the subsequent month. It suggests a somewhat lower IR than the daily rebalancing signal when applied to swaptions (1.8 vs. 2.5), but still well in excess of the monthly IR of the "always short vol" benchmark (1.0).

5. ECB Regime

As a macro indicator, we also look at how the central bank regime can impact volatility returns. The undergoing central bank regime tends to bias volatility returns and can also be used as a broad macro indicator to consider gamma positions. We decompose a central bank regime into easing, hiking, and on-hold regimes based on its action on interest rates and announcements of other non-conventional measures such as QE. We divide the easing regime into easing based on ECB's action on policy rates and QE. We consider trades initiated at the beginning of each month and held for a month (non-overlapping samples). **Exhibit 24** shows the results from selling 10Y gamma (swaption and Bund) during these regimes. We get broadly similar results at other parts of the curve as well.

The main conclusions from this analysis are as follows. **First**, selling volatility during on-hold periods is generally profitable with monthly averages and information ratios which are higher compared to that observed otherwise. **Second**, buying gamma during easing rates regimes are generally profitable for Bonds (especially for Bunds) with mixed results for OTC options. Easing rates regimes are generally associated with unexpected central bank actions, declining macro conditions, and general increase in risk aversion. These conditions are ideal for long gamma positions. The results for OTC options are mixed for this regime due to the fact that unlike the Fed, the ECB's pace of rate cut

Exhibit 24: Selling gamma is generally profitable during on-hold and hiking regimes whereas we QE easing regime has yielded mixed results

Statistics of 1M returns from selling 3Mx10Y, 3Mx2Y, front Bund and Schatz straddles; bp of notional

	EASE rates	Ease QE	Hold	Hike	ALL
# of months	45	22	113	40	214
3Mx2Y					
Mean	0.5	0.7	0.9	1.5	1.0
SD	10	4	7	8	8
Ann IR	0.2	0.6	0.5	0.7	0.4
Schatz					
Mean	0.3	0.6	-0.1	0.8	0.2
SD	15	3	8	7	10
Ann IR	0.1	0.6	-0.1	0.4	0.1
3Mx10Y					
Mean	0	-5	13	5	7
SD	41	43	28	23	33
Ann IR	0.0	-0.4	1.6	0.8	0.7
Bund					
Mean	-8	-15	7	4	1
SD	38	55	33	24	36
Ann IR	-0.7	-0.9	0.8	0.5	0.1

was slower in the aftermath of the Lehman crisis (this easing period forms a large part of the sample). While the Fed reached its lows in rates by December 2008, the ECB continued cutting rates in much smaller increments maintaining its easing regime till 2Q09. Volatilities had spiked sharply during end-2008 but had come crashing down during much of 2009 (2009 remains the best year for short gamma returns as we discussed above). As a thought experiment, if we had re-categorized 2009's easing regime as an on-hold period (in line with the Fed), then the results would be in line with our expectation for both OTC and listed options. For instance, information ratio for selling 3Mx10Y and Bunds during "easing" regimes (considering 1H09 as an on-hold period) would change to -0.4 and -1, respectively versus current values of 0 and -0.7, respectively.

Third, on first glance, our results show that QE regime (easing) has been profitable for long volatility positions. This is counter-intuitive – our apriori would have been that due to the general low level of rates, large excess liquidity and broadly stable policy rates, this regime would be supportive of short gamma positions. This discrepancy is mainly due to the Bund VaR shock episode (May – June 2015) during which implied/delivered volatilities had exploded supporting long gamma positions. Short gamma positions in

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3Mx10Y would have *lost* an average of 45bp of notional per month between March and August 2015 whereas they would have made 10bp of notional average per month in the period outside it. Indeed, if we only consider data sample since September 2015, then the information ratio from being short 3Mx10Y gamma would have been +2.1 versus -0.4 without this alteration (this is shown in Exhibit 24). In conclusion, while ECB rate cut regimes are supportive of long vol trades, the rule is less clear during QE periods; there can be periods which is supportive of long vol (expectation of further action, rebound from stretched positions, etc) and vice versa (when QE appears to be in auto-pilot mode). **Finally**, hiking regimes are generally "measured" in nature during which central banks tend to communicate their actions in advance which supports short gamma options. That said, this measured nature of the past hiking regimes can be challenged in the future.

Technical indicators

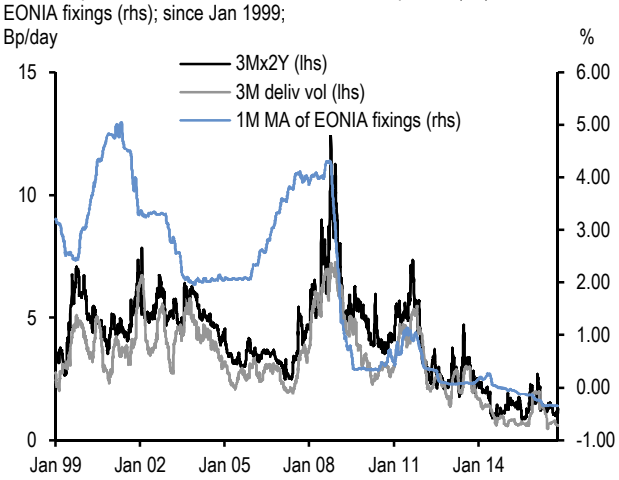
In this section, we look at some technical indicators (such as z-score or percentile of implied volatility, ratio of implied/delivered volatility, etc) and test if they can be reliably used as a signal to trade gamma. Our conclusion is that unlike the macro indicators discussed above, these technical indicators suffer from the regime shift in volatility as yields and volatility levels have moved lower, especially at the front-end, over the last few years as central banks have struggled to boost inflation and have resorted to unconventional monetary policy measures such as negative interest rate policy, quantitative easing, etc. Of course, this behaviour is more conspicuous at the front-end of the curve which has bore the brunt of these super accommodative monetary policies and expectation of "low-for-long" over the past few year. **Exhibit 25** shows the evolution of 3Mx2Y implied and 3M delivered volatility of 2Y swap rate to illustrate our point. This regime shift in volatility makes it rather difficult for technical indicators to work reliably across the entire sample period (since Euro inception in this note). Therefore, in our analysis we also look at the performance of our indicators over the last four years when front-end rates and volatility have remained low compared to prior.

6. Ratio of implied to delivered volatility

In this strategy, we use the ratio of implied volatility to 1M delivered volatility as a trading signal; we go short gamma if the signal is above a pre-defined threshold (say 125%) and go long gamma if the signal is below the pre-defined threshold (say 66%). For a gamma trade, this

Exhibit 25: Super accommodative and unconventional central bank policy rates have pushed front-end yields and implieds to un-precedented lows thereby making it rather difficult for any sort of technical indicators which would work reliably across all regimes

3Mx2Y implied vol and 3M delivered vol on 2Y swap rates (lhs) and 1M MA of EONIA fixings (rhs); since Jan 1999;



ratio is a measure of gamma carry, adjusting for the level of implieds. Thus, we go short gamma if the gamma carry is positive (implied above delivered) and vice versa. We then compare the efficacy of such a strategy versus a simple strategy which sells volatility irrespective of the underlying signal (our benchmark). The hypothesis in this strategy is that this ratio is stationary in nature (locally mean reverting). Indeed a simple statistics test such as the Augmented Dickey-Fuller tests confirms this hypothesis. **Exhibit 26** shows that evolution of this signal for 2Y and 10Y swaps. We highlight the limited number of sample points for the ratio < 100%, indicating the natural bias for short gamma positions.

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Exhibit 27: Indeed, this ratio (which is also an indication of gamma carry in outright gamma positions) is a reliable indicator although the empirical reliability comes mainly from the short gamma side

Statistics from using the (implied to delivered volatility ratio) as a signal to trade gamma (overall, only short, and only long); bp of notional for Average and SD, unitless for information ratios

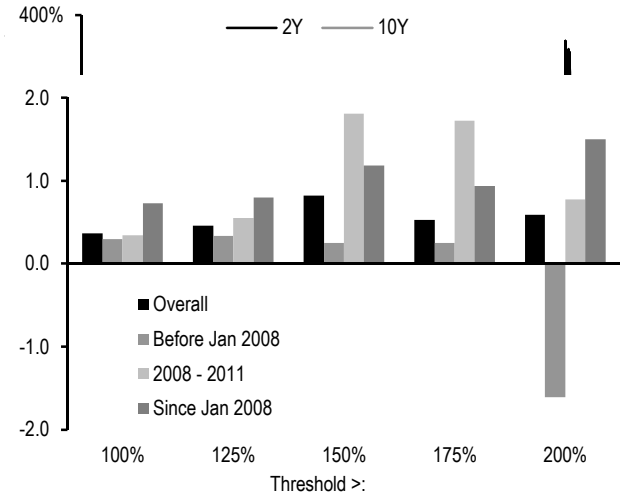
	((Ex-ante imp) % (1M Deliv vol)) > OR ((1M Deliv vol) % (Ex-ante imp)) <					(Ex-ante implied) % (1M Delivered vol) >:					((1M Deliv vol) % (Ex-ante imp)) <					Always sell vol
	100%	125%	150%	175%	200%	100%	125%	150%	175%	200%	100%	125%	150%	175%	200%	
3Mx2Y																
Average	0.8	1.0	1.7	1.4	0.8	1.0	1.1	1.7	0.8	1.8	-0.8	-3.6	-1.7	-1.4	-	0.9
SD	9.0	8.6	7.2	6.2	5.4	9.0	8.6	7.2	5.4	10.6	8.6	4.9	1.1	1.1	-	8.9
Inf ratio	0.29	0.42	0.80	0.79	0.53	0.37	0.46	0.82	0.53	0.59	-0.32	-2.52	-5.21	-4.64	-	0.36
Success ratio	60%	62%	65%	60%	59%	62%	63%	66%	59%	67%	37%	18%	10%	12%	-	62%
3Mx5Y																
Average	2.5	3.0	3.9	5.7	4.7	3.1	3.5	3.9	4.7	4.8	0.4	-5.1	2.3	-	-	2.4
SD	18.8	17.4	17.1	14.7	14.9	18.3	17.5	17.2	14.9	20.4	20.2	13.0	1.5	-	-	18.8
Inf ratio	0.47	0.59	0.79	1.34	1.09	0.59	0.69	0.78	1.09	0.82	0.07	-1.35	5.26	-	-	0.44
Success ratio	59%	61%	61%	67%	67%	63%	63%	61%	67%	65%	41%	32%	92%	-	-	62%
3Mx10Y																
Average	5.7	7.9	5.6	11.1	17.1	7.7	8.2	5.7	17.1	9.5	-2.1	3.1	-3.8	-	-	6.6
SD	36.4	36.6	33.5	28.7	24.1	35.5	36.2	33.7	24.1	41.9	38.9	43.5	5.6	-	-	36.2
Inf ratio	0.55	0.74	0.58	1.34	2.45	0.75	0.78	0.59	2.45	0.79	-0.19	0.25	-2.35	-	-	0.63
Success ratio	61%	61%	58%	65%	73%	66%	63%	58%	73%	64%	41%	34%	40%	-	-	64%

Exhibit 27 shows our results. We compare the information ratio of this strategy where we consider both long and short gamma positions (depending upon the signal) versus the benchmark which is always short vol. Our main observations are as follows. **First**, this strategy appears to work over the entire sample horizon (the first panel of Exhibit 27). The information ratio obtained by trading according to this rule is generally higher compared to the benchmark, especially if the threshold is around 25%. Intuitively, the information ratio generally increases with the threshold. Success ratio in this strategy hovers around 65%.

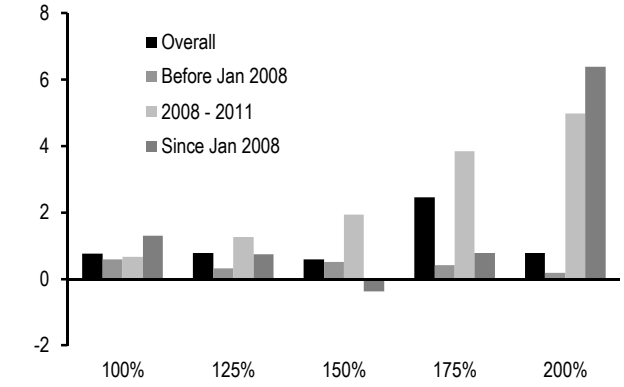
Second, while this signal appears to be reliable, a deeper analysis shows that this reliability comes mainly from trading when the signal indicates to sell gamma. The middle (right) panel of Exhibit 27 shows results of using this signal only to initiate short gamma (long gamma) positions. As seen, selling gamma when the ratio is > 100% is generally a profitable strategy, although the reverse generally does not provide positive returns, on average. While the former is along expected lines, the later part of this observation poses some risk to the usefulness of this signal to initiate long gamma positions given the small number of trades that this generates. For instance, using a threshold of 150% for trading 2Y gamma would have resulted around 1315 trades for short gamma positions since 1999 whereas a mere 20 instances when the signal indicated long gamma positions.

tionary
over the medium term and thus can be thought of providing a
Exhibit 28: Dissecting the results further shows that the
performance of this strategy has improved sharply over the past
few years

Ratio of current implied volatility (3M options) or 1M delivered volatility for 2Y and 10Y swaps; since Jan 1999; %



(B) Selling 10Y gamma



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Additionally, during instances when delivered volatility is indeed above implied volatility, the overall levels of implied volatility is generally high which then tends to reverse quickly leading to almost unpredictable results.

Third, there has been a marked improvement in the overall performance of this strategy in the last four years, a period during which the ECB's policy rates movement has been largely incremental in nature (main refi rate has been cut around 1%, depo rate 65bp, and excess liquidity has remained high keeping front-end volatility low), Euro area inflation has been low and forward guidance has been in place. As a result, long-end yields have declined to all time lows on the back of ECB QE, front-end rates have gradually moved into negative territory, and excess liquidity has kept on increasing all of which contributing towards generally low vol environment. Thus, using a sample set starting from Jan 2012, information ratios are multi-fold higher compared to the overall sample results (**Exhibit 28**). Going forward, we would expect this strategy to work over the medium term as EUR yields are expected to stay low compared to their long term averages as the ECB continues along with its QE program and keeps rates on hold for the next few years. Risks to this hypothesis would come from another Bund VaR shock type episode.

Finally, in the overall sample, trading 10Y gamma based on the signal generated would have yielded higher information ratios compared to 2Y and 5Y gamma, although the reliability at the shorter tail is higher and consistent.

7. Fading the extremes in implieds

Buying low and selling high implieds has not necessarily been a significantly profitable strategy in trading gamma. For example, a simple systematic rule that buys/sells gamma if the 1Y Z-Score of implieds is below/above a certain threshold has yielded mixed results (**Exhibit 29**). While this strategy would have managed close to overall zero P&L for 2Y and 5Y tails, it would have yielded losses in the 10Y sector. This outcome can be explained by the fact that while implieds tend to decline from their local highs, they tend to be sticky when at their lows. Indeed, employing this strategy only from the short side (selling when implieds are above their local highs) would have yielded large information ratio at par or slightly higher than the baseline strategy of selling volatility on a daily basis without applying any filtration.

8. Combining ECB regime and fading extremes in implieds

Exhibit 29: Systematically buying/selling gamma when implieds are below/above a Z-score based threshold does not, on average, outperform the benchmark strategy of selling gamma everyday
Information ratios from a strategy where we buy (sell) gamma if the 1Y Z-score of implieds is below (above) 1.5; since Jan 2000; unitless

	Only short	Only long	Both long and short	Unfiltered
2Y	0.45	-0.60	0.02	0.36
5Y	0.42	-0.81	0.01	0.44
10Y	0.12	-1.31	-0.51	0.63

Exhibit 30: However, combining this strategy with the knowledge of current ECB regime can significantly boost risk reward on an overall basis…
Information ratio from selling various gamma points using a strategy that sells vol if 1Y Zscore is above 1.5 and the ECB is in an hiking or easing regime; buy vol if Zscore is below -1.5 and the ECB is in an easing regime; since Jan 2000; unitless

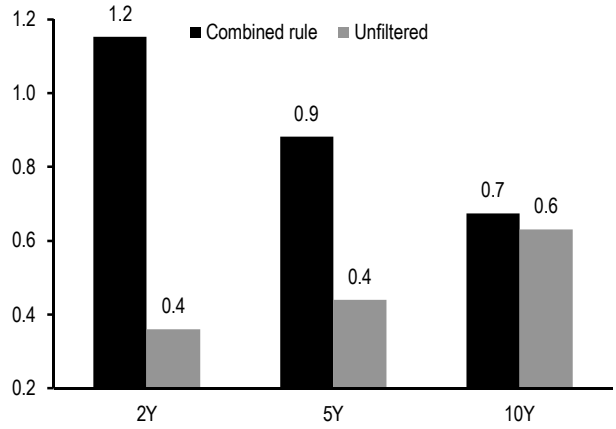

Exhibit 31: …and also from both buying and selling, beating the performance of the benchmark strategy of selling gamma on a daily basis
Information ratio from strategy described in Exhibit 30 for only short gamma trades, only long gamma trades, and overall; unitless

	Only short	Only long	Both long and short	Unfiltered
2Y	1.29	0.77	1.15	0.36
5Y	1.04	0.10	0.88	0.44
10Y	0.64	1.01	0.67	0.63

Exhibit 32: Our analysis shows that we should consider systematically selling gamma only during ECB on-hold and hiking regimes conditional on Z-Score
Schematic of the states of the world stating vol trading rule based on a combination of Z-score of implieds and ECB regime

		Ease (rate cut)	Ease (QE)	Hike	Hold
1Y Z-score	Above threshold	-	Short	Short	Short
	Below threshold	Long	Long?	-	-

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We can improve the performance of such a strategy by combining the valuation argument with the knowledge of existing central bank regime (discussed above). In other words, if we are in an easing (on-hold) regime, then the strategy would not trigger a sell (buy) signal even if implied volatility is above (below) the Z-score threshold (we put the threshold at 1.5). This combined strategy sharply improves the information ratio which is better than the benchmark of selling vol daily (**Exhibit 30**). The improvement in the performance is observed in both buying and selling gamma. **Exhibit 31** shows that the information ratio for both using the strategy to only initiate sells and buys would have been generally higher compared to the benchmark. As discussed above, the drawback of this strategy would be the *ex-ante* knowledge of which ECB regime are we currently in. **Exhibit 32** shows a schematic of this strategy.

Impact of trading costs

Up to this point, our analysis does not explicitly account for trading costs. Implementing a strategy of systematically selling volatility will itself carry some trading costs associated with it, both from rolling options as well as the associated delta hedging. However, we focus here on the trading costs associated with the combined systematic signal compared to the strategy of always selling volatility.

Turning to the combined macro signals first (signals 1-4 above), we focus on the monthly rebalancing combined signal. This is motivated by a the above analysis suggesting that monthly rebalancing captures much of the benefit of using these systematic macro signals to identify when to turn long volatility, and the less frequent trading resulting from that lower frequency. We then apply a cost of 4bp of notional when changing positions, scaling the cost by the size of the position implied by the combined signal (e.g. one signal shifting from short vol to neutral, implies a 0.25 shift in the combined signal). The comparison between returns on the combined signal without trading costs, with trading costs and the benchmark of always selling volatility is shown in **Exhibit 33**. It suggests a moderate reduction in returns for the combined signal, but still higher than the strategy of always selling volatility, mainly through a lower volatility of returns.

Moreover, we note that this comparison may overstate the effect of trading costs on the combined signal relative to always selling vol. This is because the costs associated with always selling volatility include not just the cost of trading options, but also the delta hedging on the underlying. As our combined signal is a linear combination of four individual signals, and can adjust the size of its exposure in steps of a quarter of the risk limit applied to the signal, it does not necessarily incur the same amount of delta hedging costs[14]. Similarly, for the technical signals the strategy remains profitable with good information ratios, especially in the 10Y tails if we include transaction costs.

Exhibit 33: Taking into account trading costs in the combined macro signals shows a modest reduction in performance of the combined signal, though it still outperforms a strategy of always selling vol, now mainly via a reduction in the volatility of returns
Annualized daily return, standard deviation and information ratio; bp of notional and ratio

	Annualized (bp of notional)		IR
	Return	Vol	
No trading costs	117	63	1.8
Trading costs*	102	64	1.6
Always short	96	96	1.0

* Defined as 4bp of notional on options.

Current positioning

The current stance of each signal as well as the combined signals is summarized in Exhibit 2 above. The individual signal positions are binary, with +1 indicating a short volatility position, -1 indicating a long vol position and a 0 indicating a neutral stance. For the combined signal, which is simple equal-weighted linear combination of the four individual signals, can vary between -1 and +1, and we think of it as a scalar such that a value of -0.25 indicates a long vol position of 25% of the risk limit applied to the signal while a value of +1 would indicate a short vol position of 100% of the risk limit. The current signal argues for a modest short volatility position of 25% of the risk weight, with momentum in volatility signaling long vol positions, the liquidity signal having turned neutral, and with the carry and PMI signals suggesting shorts.

On the technical indicator front, the current stance indicates a neutral stance for 10Y gamma – ECB rates regime indicates short gamma, while the rest of the signals suggest we should be neutral on 10Y gamma.

[14] For example, if the combined signal is long vol up to 50% of the risk limit, it does not face the same amount of delta hedging costs as the outright short gamma strategy that is 100% invested.

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Appendix: Performance of macro signals applied to listed instruments

For clients who look to employ signals to trade volatility via listed rather than OTC instruments, Exhibits A1 to A5 show the key performance tables for our momentum, carry, macro shock and liquidity signals, as well as the combined signal, when applying these signals to trade volatility via options on 10Y Bund futures (signals 1 to 5). They suggest that the same signals can be successfully applied via listed instruments.

Exhibit A1: Momentum in volatility performs better for a somewhat longer lookback period (4M) compared to swaption vol
Return to risk from a vol momentum strategy* at different lookback periods since the inception of the Euro in 1999 for the overall strategy, broken down to periods where the signal is short and long volatility, and % of time the signal is long

	Performance of signal			Prop of time
	Overall	Short vol	Long vol	long vol
2W	0.2	0.4	0.0	41%
1M	0.3	0.5	0.1	41%
2M	0.5	0.6	0.3	39%
3M	0.4	0.6	0.2	36%
4M	0.6	0.7	0.4	37%
5M	0.6	0.7	0.4	36%
6M	0.5	0.6	0.3	37%
12M	0.4	0.6	0.3	38%
Combined (2M & 4M)	0.5	0.5	0.6	27%

Exhibit A2: A 30% threshold and 1M lookback period for our carry signal similarly works best
Return to risk from conditional strategy that turns long volatility when RAC is below the relevant percentile thresholds and rising at various lookback periods; overall strategy, and broken down to periods where the signal is short and long volatility, and % of time the signal is long

Percentile threshold	Conditional change	Performance of signal			Proportion of time long vol
		Overall	Short vol	Long vol	
20%	1M	0.5	0.4	1.8	10%
	2M	0.4	0.3	2.2	7%
	3M	0.3	0.3	0.5	7%
	4M	0.3	0.3	1.3	6%
30%	1M	0.6	0.5	1.6	12%
	2M	0.5	0.4	1.7	10%
	3M	0.2	0.3	0.1	9%
	4M	0.4	0.3	0.9	9%
40%	1M	0.6	0.5	1.0	16%
	2M	0.4	0.4	0.7	14%
	3M	0.3	0.3	0.2	13%
	4M	0.4	0.4	0.8	12%

Exhibit A3: 3M lookback periods for PMI changes produce the highest information for trading futures vol
Return to risk from a strategy that turns long volatility when the change in the PMI over the relevant lookback period is more than 1 standard deviation below its average

	Performance of signal			Prop of time
	Overall	Short vol	Long vol	long vol
1M	0.5	0.4	0.8	15%
2M	0.7	0.5	1.5	12%
3M	0.8	0.6	1.6	13%
4M	0.6	0.5	1.3	12%
5M	0.6	0.5	0.9	15%
6M	0.5	0.4	0.8	12%
12M	0.3	0.3	0.2	14%

Exhibit A4: A 0.02 symmetric threshold appears to work well for the HH ratio, but for consistency with our framework for trading vol via OTC instruments outlined above we use the 0.02 threshold for signaling short volatility and a level above that to signal neutral exposure
Return to risk from periods where the liquidity ratio signal is short volatility, long volatility and a combined signal

		IR	Prop of time
Short vol threshold	0.01	0.8	25%
	0.02	0.6	79%
	0.03	0.2	94%
	0.04	0.2	98%
Long vol threshold	0.02	0.7	21%
	0.03	-0.4	6%
	0.04	-2.4	2%
	0.05	-9.0	1%
	0.06	-5.4	0%
Combined	0.02 / 0.04	0.4	
	0.02 / 0.02	0.6	
	0.02 short or neutral only	0.5	

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Exhibit A5: The combined signal shows diversification also works when trading vol via listed instruments

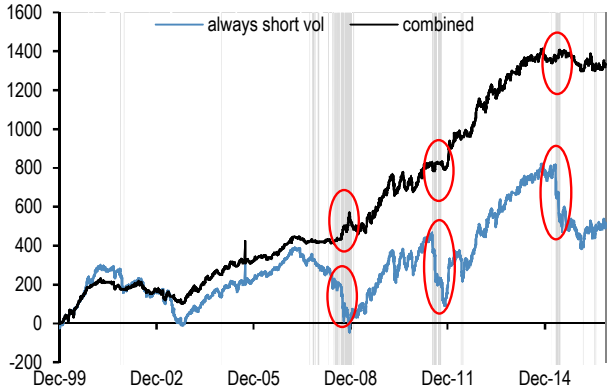
Cumulative returns, annualized returns and standard deviations; return to risk and the proportion of time each signal is short or long volatility; bp of notional, IR and %

		Cumulative return	Annualized return	Standard deviation	IR	Proportion of time
Always short volatility		490	29	131	0.2	
Vol Momentum	Overall	977	57	131	0.4	
	Short vol	734	70	115	0.6	61%
	Long vol	244	37	153	0.2	39%
Carry-to-risk	Overall	1373	80	131	0.6	
	Short vol	932	62	130	0.5	88%
	Long vol	442	208	134	1.6	12%
Liquidity	Overall	938	55	104	0.5	
	Short vol	938	70	117	0.6	79%
PMI	Overall	1681	98	131	0.8	
	Short vol	1084	73	125	0.6	87%
	Long vol	597	261	163	1.6	13%
Combined signal (daily rebalancing)	Overall	1317	77	89	0.9	
	Short vol	1127	76	93	0.8	86%
	Long vol	189	189	78	2.4	6%
	Neutral*	-597	-597	217	-2.8	8%
Combined signal (monthly rebalancing)	Overall	1036	61	95	0.6	
	Short vol	957	66	102	0.7	85%
	Long vol	79	85	77	1.1	5%
	Neutral*	-270	-289	200	-1.4	10%

* Neutral shows the performance of "always short volatility" strategy while the signal is neutral.

Exhibit A6: A simple linear combination of the four signals picks up the spikes in implied volatility during the early stages of the financial crisis in 07/08, the Euro area sovereign crisis in 2011, as well as the 2015 VaR shock

Cumulative performance of the combined signal and an "always short vol" strategy applied to listed options; shaded areas denote periods where the combined strategy is long volatility; bp of notional



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