RV on the EUR swap yield curve: a historical perspective

Improve monetisation of curve dislocation via a beta-stability framework

- **We build a systematic framework to analyse the performance of RV trades on the EUR swap curve and scan for dislocation in level and curve neutral swap butterflies in spot and forward space (looking at standard flies, 1Y/2Y forward gaps and 5Y forward gap flies)**
- **Fading RV in a systematic way has proved profitable across various flies on average since early 2000, with RV on 1Y/2Y forward gaps outperforming the rest**
- **We examine the overall historical performance under different "trigger-criteria" and find that a regression fit of at least 60% R-squared with a distortion in the residual equal to a Z-score of at least 1.5, and a minimum of 4bp of dislocation outperforms other more or less stringent criteria**
- **Further screening of the historical performance across times indicates "critical periods" with either negative or mixed returns which are typically a suggestion of a regime-change that are not fully captured by systematic regression models**
- **With negative performance being typically associated to high volatility in the betas of the regression model, we build an ex-ante "traffic light" system to assess stability of the beta and to provide confidence in the attractiveness of RV trades**
- **A combined Z-score indicator of the betas of the swap butterfly to the level of rates and the slope of the curve proves effective in reducing systematic RV exposure during highly volatile periods reflective of regime change**
- **Our "traffic light" indicator is now flashing red suggesting that recent instability of beta makes RV systematic trading currently unattractive**
- **A potential decline in volatility of swap butterflies betas with ECB upsizing PEPP and containing the sensitivity to USD rates should turn our "traffic light" indicator to green, restoring the attractiveness of a RV systematic approach**

All Exhibits are sourced J.P.Morgan unless otherwise specified.

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See page 16 for analyst certification and important disclosures.

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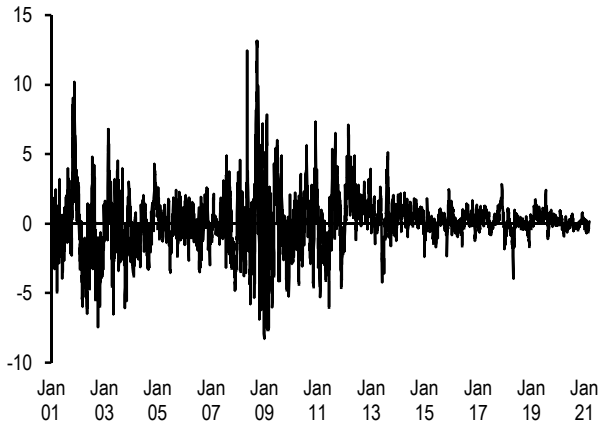
A historical perspective

Relative value opportunities routinely arise on the yield curve driven by various factors such as investor and technical hedging flows, underlying shifts in macro dynamics, amid changing central bank regimes. However, to become RV tradable opportunities these dislocation need to "mean-revert" over a relative short period of time.

In this research note, we look at relative value dynamics within the EUR swap yield curve. While relative value analysis on the yield curve could be implemented by analysing both curve trades weighted for the directionality to yield levels, or butterfly trades adjusted for the level of yields and the slope of the curve, we find the latter more attractive for a systematic approach over long period. Curve directionality is strongly a function of central bank activity or inactivity and apparent dislocation over time could be simply a reflection of broad change in the central bank outlook. Therefore, we narrow our scope further to analysis only level- and curve-neutral flies through different macro periods since the Euro inception (**Exhibit 1**).

Exhibit 1: The dislocations on the yield curve provide plenty of RV opportunities: we develop a systematic framework to monetize these opportunities while watching out for optical dislocations
Rolling 6M residual from regressing 1Yx1Y/2Yx1Y/3Yx1Y 50:50 swap fly versus 30Y swap yield and 2s/30s swap curve; since Jan 2001; bp



The definition of "mean-reversion" for level-and-curve neutral flies gets challenged during periods of shifting underlying macro dynamics or potential changes in central bank regime. This is especially true where these opportunities are systematically identified using historical data analysis and linear regression (or PCA). In our view, we identified two factors which broadly define the success of a relative value trade: *1)* the strength of the regression relationship (measured by regression R-squared) and 2*)* the level of residuals which is primarily used to determine the entry level for the trade. Broadly speaking, the regression has to be strong and *stable*, so that a decent amount of the volatility is explained by the underlying factors, and current data point must be sufficiently dislocated to offer an attractive risk/reward under the critical assumption that the third factor (beyond level of yields and slope of the curve) shows some evidence of mean reversion.

In this research note, we look at the performance of a systematic trading strategy in which we fade any such relative value opportunities (defined on pre-defined thresholds) arising from level- and curve-neutral swap flies over the past two

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decades. **We specifically analyse the performance of these systematic strategies in different periods with the objective of building an enhanced framework to implement these strategies, beyond the statistical dislocation. To summarize our conclusions, negative performances are typically associated to high volatility in the betas of the regression model which are reflective of regime shifts. We build a "traffic light system" which is mainly used to reduce exposure to RV trades during high volatility periods.**

We consider a wide range of level- and curve-neutral butterflies and split our universe pre-determined swap flies into three categories.

1) **Category 1**: **Standard swap flies** (spot, 1Y forward, 2Y forward, and 5Y forward). For example, the 2s/5s/10s, spot, 1Y forward, 2Y forward, and 5Y forward fly. We consider several such pre-determined combination of flies[1];
2) **Category 2**: **5Y tail non-overlapping flies on various 5Y-gap forwards**. For example, 5Yx5Y/10Yx5Y/15Yx5Y level- and curve-neutral swap fly;[2]
3) **Category 3**: **1Y and 2Y gap flies**; For example, 1Yx1Y/2Yx1Y/3Yx1Y, 2Yx2Y/4Yx2Y/6Yx2Y and few such level- and curve-neutral swap flies.[3]

As an initial trading rule, we scan through our entire list of such pre-determined set of level- and curve-neutral swap flies. We then enter into a trading position into *each* fly which offers attractive relative value based on cut off levels for regression R-squared, residual, *and* Z-score of residual. We use 6M regressions for our analysis to capture short term mean reverting behaviour and to reduce the impact of cyclical changes in the macro dynamic. In our analysis, we have considered 12 rule combinations of these three trigger criteria:

a) R-squared: 60% and 80%;
b) Absolute level of residual: 2bp, 3bp, and 4bp; and
c) Absolute Z-score of residual: 1.5 and 2 (**Exhibit 2**).

Exhibit 2: We analyse our strategy across several combinations of trigger criteria to enter into a trade

Entry threshold criteria for regression R-squared, residuals (absolute value), and Z-score (absolute levels)

R-squared	Residuals (bp) (absolute value)	Z-score (absolute value)
60%	2	1.5
80%	3	2
	4	

[1] We use the following standard flies: 1s/2s/3s, 1s/2s/5s, 1s/3s/5s, 2s/3s/5s, 2s/5s/7s, 2s/5s/10s, 2s/7s/12s, 2s/10s/30s, 3s/5s/10s, 3s/7s/15s, 5s/7s/10s, 5s/10s/15s, 5s/10s/30s, 7s/10s/15s, 7s/15s/20s, 10s/12s/15s, 10s/15s/20s, 10s/20s/30s, 12s/15s/20s, 12s/20s/30s, 15s/20s/30s.
[2] 5Y gap flies on following forward starting point: 5s/10s/15s, 10s/15s/20s, 15s/20s/25s, 20s/25s/30s, 25s/30s/35s, 30s/35s/40s, and 35s/40s/45s. So, the first is 5Yx5Y/10Yx5Y/15Yx5Y swap fly.
[3] 1Y and 2Y gap flies on the following forward combinations: 1Yx(1M/1Y/2Y), 1Yx(1Y/2Y/3Y), 1Yx(2Y/3Y/4Y), 1Yx(1M/2Y/4Y), 2Yx(1M/2Y/4Y), 2Yx(2Y/4Y/6Y), 2Yx(4Yx6Yx8Y), and 2Yx(6Y/8Y/10Y).

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Once we enter a trade, we calculate the evolution of the P&L using ex-ante regression betas (out of sample P&L calculations) and hold the trade until *one* of the following three exit conditions is met:

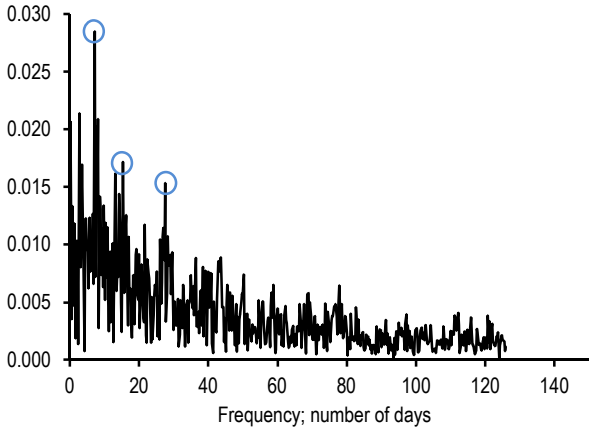
i. The residual has fully reverted to zero. We define complete mean reversion when the out-of-sample residual (calculated using ex-ante regression betas) has crossed zero for the first time based on COB levels. Of course, we miss out on additional P&Ls if the residual continues to move further in a favourable direction, with residual move from rich to cheap or vice versa.

ii. The residual has worsened by another two SD. A further worsening of the residual beyond a threshold would result in stopping out of the trade. Given the criteria above we have stop out at 3.5 or 4 z-score.

iii. 1M (or the trade horizon) has passed. A Fourier analysis of rolling residual shows that the dominant mean reverting frequencies are less than 1M with some peaks around the 2M and 3M horizon as well (**Exhibit 3**). Therefore, as an exit criteria, we close the trade at the end of 1M if neither of the above two criteria are met over this time frame.

Exhibit 3: These residuals have varying degrees of mean reversion. However, for the most part they seem to mean revert within the first month

Fourier transform of residual of the 1Yx1Y/2Yx1Y/3Yx1Y level and curve-neutral fly; peaks shows mean reversion frequency;



Observations: We present some details of our systematic trading strategy. To begin with, we can enter into multiple trades on a given date depending on how many flies satisfy the entry trigger criteria. At best, the total number of trades on a given day is equal to the total number of flies considered, provided all the flies have passed the entry criteria. However, we do not re-enter into the same trade on consecutive days even if it remains attractive versus our metric, in other terms in the rolling set of positions analysed there are never two trades on the same fly. Instead, we may re-enter a trade on a day even if we stopped out of that trade the day before; as our algorithm only filter from the existing trades in the portfolio. This essentially illustrates our confidence in the underlying assumption that residuals eventually mean-revert.

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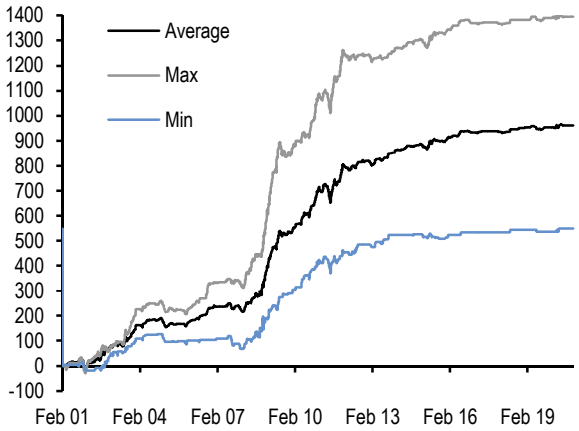
Exhibit 4: A systematic RV trading strategy has been, overall, profitable since Euro inception even though the pace of profitability has declined sharply recently

Cumulative P&L (averaged across all trigger criteria) from a systematic trading strategy of fading RV; since Jan 2001; bp



From an overall perspective, this systematic trading strategy across various flies would have been profitable when implemented since Euro inception. In **Exhibit 4** we plot the cumulative P&L from this strategy. Specifically, we plot the average (averaged across various control triggers) cumulative P&L[4] across the 12 entry trigger criteria discussed above. As seen, the years immediately after the Lehman crisis were particularly profitable for RV trading whereas the pace of profit accumulation has declined considerably over the past few years. This reflects various factors such as more efficient markets, lower macro volatility and subsequent fewer central bank surprises, and potentially more people chasing RV opportunities in a systematic way.

Good vs Critical periods

To better understand the efficacy of RV mean reversion, we look at the evolution of the total P&L split into non-overlapping quarters (**Exhibit 5**). This in our view, gives deeper insight into the performance of this strategy considering the local market conditions. We identify periods around which either the systematic strategy yielded negative results (for example between 3Q04 to 2Q05) or the P&L oscillated around 0 over a couple of quarters (for example in 2015).

1) 3Q04 – 2Q05 (Market pricing ECB hiking)
2) 3Q07 – 4Q07 (Market pricing ECB easing)
3) 2Q11 – 4Q12 (ECB hiking and sovereign debt crisis related volatility)
4) 2015 (ECB QE and Bund VaR shock related volatility)
5) 4Q16 – 1Q18 (Market starting to price ECB QE tapering and eventual rate hikes)
6) 2Q19 (More rate cuts being priced in)

[4] We use the total P&L on any given date obtained from potentially multiple trades and 0 for days without any trade.

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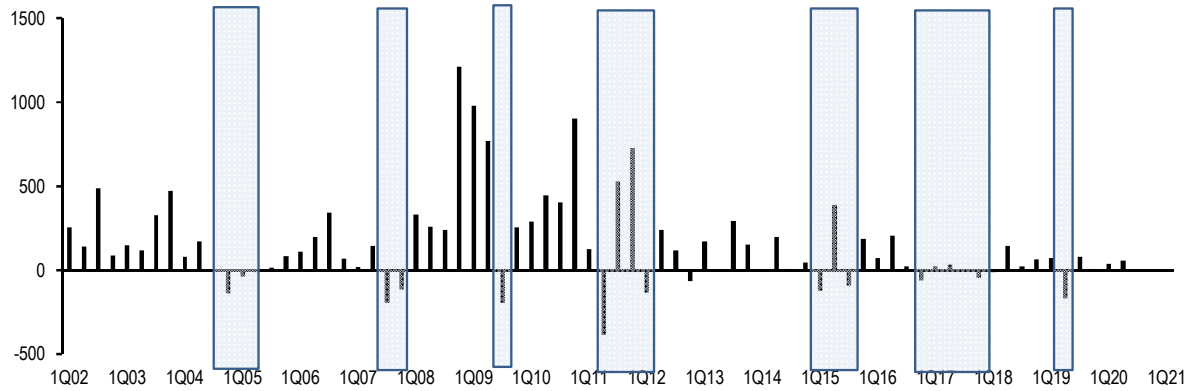
Exhibit 5: We can determine periods of losses or high volatility in P&L by looking at the quarterly P&Ls

Total quarterly P&L (totaled across all 12 trigger criteria); since Jan 2002; bp

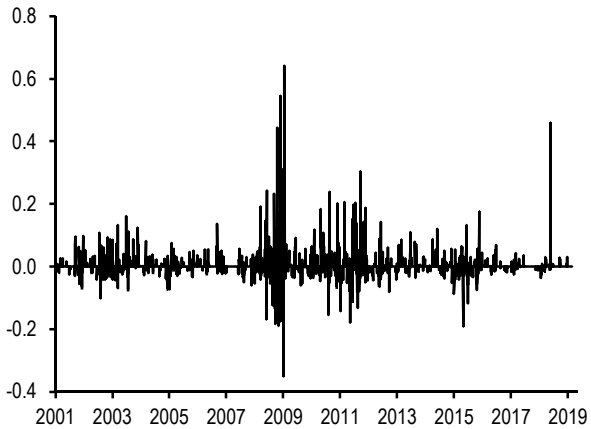


All of these events had largely one thing in common – changing ECB regimes and high market volatility. In the months leading to the 2005-2007 hiking cycle, the RV systematic strategy incurred losses as markets started to price a regime shift leading to ECB hikes. However, during the actual delivery of the hiking cycle (which was well measured and well communicated), the strategy was profitable. Similarly, as an unexpected easing cycle was starting to be priced into the money market curve from 2H07 the RV systematic strategy incurred losses. As it was the case before, some of these losses were recouped when the central bank delivered the easing and eventually money market curve started to price ECB on perma-hold. The sovereign debt crisis period (2011-2012) was also combined with ECB rate hikes in 1H11 and rate cuts in 4Q11 and resulted in large P&L volatility. The Bund VaR shock episode in May 2015, few months after the ECB initiated QE, delivered huge volatility with poor/volatile performance in mean reverting strategies. Similarly, during late 2017/early 2018, when the market started to price ECB hikes within 1-2Y, the strategy incurred losses.

Notable exceptions to the overall success of the RV trading strategy in high volatile episodes were periods post Lehman and around the Fed's taper tantrum (2Q13) where the strategy remained profitable. **Exhibit 6** shows the evolution of the *daily* P&L totaled across all trigger criteria considered above.

Exhibit 6: At a more micro level, the strategy delivered high volatility and extreme P&Ls during the Lehman episode and sovereign debt crisis

Daily total P&L*; since Jan 2001; bp



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* See above for details on strategy.

Looking into the details, we compare the P&Ls of this strategy during "critical periods" (defined as periods where the strategy incurred overall losses) versus "good periods" (the remainder) in **Exhibit 7**. We highlight that the "critical periods" also include quarters where the strategy was temporarily profitable but oscillated into negative in the surrounding quarters. Expectedly, the overall performance (average P&L and success ratio) across all trigger criteria is lower during the "critical periods" compared to the rest. Interestingly though the maximum drawdowns in these strategy does not occur during these "critical" periods suggesting that while the performance is overall poor, other factors may be responsible for large drawdowns occurred during the "good" period. A cursory glance at the evolution of daily P&Ls show that these large drawdowns were generally witnessed in 2008-2009 which, was overall a profitable period, but experienced large volatility in the months around the Lehman crisis on the back of continued deleveraging and thin market conditions.

Exhibit 7: We split the performance of the strategy into "critical" and "good" periods

Statistics (Overall time period and split by "good" and "critical" periods) of the performance of the systematic trading strategy; bp of yield; statistics per trade

R^2	60%	80%	60%	80%	60%	80%	60%	80%	60%	80%	60%	80%
Residual	2	2	3	3	4	4	2	2	3	3	4	4
Zscore	1.5	1.5	1.5	1.5	1.5	1.5	2	2	2	2	2	2
	Overall											
Average	0.7	0.4	1.0	0.6	1.3	0.8	0.7	0.4	1.0	0.7	1.3	0.9
Success Ratio	50%	47%	52%	48%	52%	48%	54%	51%	55%	52%	55%	53%
Max	39	39	39	39	39	39	42	26	42	26	42	26
Min	-19	-16	-19	-16	-19	-16	-14	-13	-14	-13	-14	-13
Total Trades	3587	1964	1929	976	1188	564	2642	1527	1479	785	923	457
	Good period											
Average	0.9	0.7	1.3	1.0	1.6	1.2	0.9	0.7	1.3	1.0	1.5	1.3
Success Ratio	54%	52%	55%	52%	55%	51%	58%	56%	58%	56%	58%	57%
Max	39	39	39	39	39	39	42	26	42	26	42	26
Min	-19	-16	-19	-16	-19	-16	-14	-13	-14	-13	-14	-13
Total Trades	2456	1266	1383	639	905	402	1799	997	1046	518	698	328
	Critical period											
Average	0.1	0.0	0.3	0.0	0.5	-0.1	0.1	-0.1	0.3	0.0	0.4	-0.1
Success Ratio	42%	38%	43%	40%	43%	39%	46%	42%	48%	44%	48%	43%
Max	18	15	18	15	18	15	15	15	15	15	15	15
Min	-8	-7	-8	-7	-8	-7	-11	-9	-11	-9	-11	-9
Total Trades	1131	698	546	337	283	162	843	530	433	267	225	129

We highlight another noteworthy observation from our analysis of "critical" versus "good" periods. **Money market flies** (1Y/2Y gap flies – defined as Category 3 flies above) **tend to perform better relative to other categories of flies on an overall basis and also during "good" periods**. However, the **5Y forward gap flies** (defined as Category 2 flies above) **have outperformed during "critical" periods** versus the other categories (**Exhibit 8**). This is potentially due to the fact that during ECB regime shifts, the front-end exhibits larger volatility and RVs are likely to be optical in nature as opposed to those observed at the long-end of the curve.

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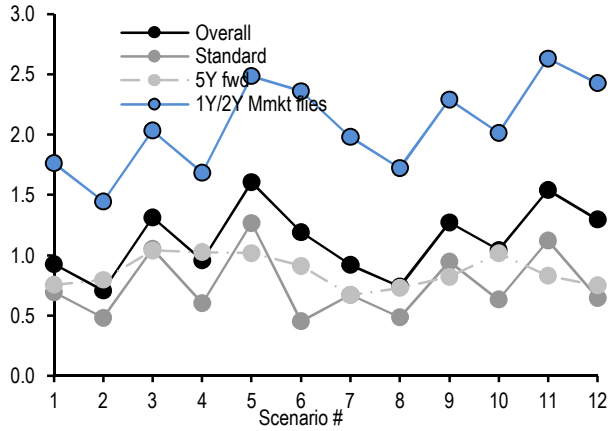
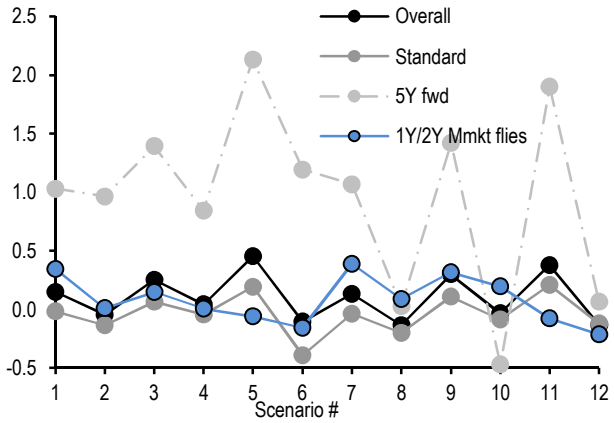
Exhibit 8: While money market flies tend to outperform on an overall basis and during "good" periods, the 5Y forward gap flies have historically performed better during "critical" periods

Average P&L split by categories of flies discussed above across various control triggers; bp

a): Performance during "good period"



b): Performance during "critical period"



Details of the various control triggers:

Control trigger combination:	1	2	3	4	5	6	7	8	9	10	11	12
R^2	60%	80%	60%	80%	60%	80%	60%	80%	60%	80%	60%	80%
Residual	2	2	3	3	4	4	2	2	3	3	4	4
Zscore	1.5	1.5	1.5	1.5	1.5	1.5	2	2	2	2	2	2

In **Exhibit 9**, we further decompose the "critical periods" into the individual sub categories that we have defined earlier. We observe that the success ratio is the worst in 2Q19 when markets started to price rate cuts further into the negative territory as a reflection of the Fed delivering actual rate cuts. Amongst these periods, 2011-2012 (sovereign debt crisis, ECB hikes, and ECB cuts) resulted in overall positive performance.

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Exhibit 9: As expected, the overall strategy has underperformed during these volatile periods with 2Q19 leading the underperformance
Statistics (Overall time period and split by volatile periods) of the performance of the overall systematic trading strategy; bp of yield; statistics per trade

Residual	2	2	3	3	4	4	2	2	3	3	4	4
Zscore	1.5	1.5	1.5	1.5	1.5	1.5	2	2	2	2	2	2
	Overall											
Average	0.7	0.4	1.0	0.6	1.3	0.8	0.7	0.4	1.0	0.7	1.3	0.9
Success Ratio	50%	47%	52%	48%	52%	48%	54%	51%	55%	52%	55%	53%
	3Q04 - 2Q05											
Average	-0.2	-0.2	-0.4	-0.5	-1.1	-1.0	-0.3	-0.4	-0.3	-0.4	-1.5	-1.4
Success Ratio	39%	41%	36%	34%	33%	36%	38%	40%	35%	37%	31%	33%
	2Q07 - 4Q07											
Average	0.0	-0.6	-0.5	-0.9	-1.5	-2.3	0.0	-0.8	-0.5	-1.1	-1.7	-2.9
Success Ratio	48%	32%	40%	30%	19%	8%	48%	36%	43%	33%	18%	10%
	2Q11 - 4Q12											
Average	0.4	0.3	0.7	0.6	1.2	0.6	0.5	0.2	0.9	0.5	1.2	0.8
Success Ratio	47%	44%	50%	50%	51%	47%	53%	49%	57%	53%	59%	54%
	2015											
Average	0.1	-0.1	-0.2	-0.2	-0.6	-0.6	0.0	-0.2	-0.3	-0.2	-0.7	-0.5
Success Ratio	39%	34%	32%	32%	30%	33%	41%	38%	37%	39%	32%	39%
	4Q16 - 1Q18											
Average	-0.2	-0.1	-0.2	0.1	1.1	-0.4	-0.3	-0.1	-0.1	0.1	1.3	0.5
Success Ratio	40%	41%	46%	54%	75%	50%	41%	45%	55%	55%	67%	50%
	2Q19											
Average	-1.2	-1.2	-1.3	-1.3	-1.0	-1.0	-1.0	-1.0	-1.2	-1.2	-1.4	-1.4
Success Ratio	3%	3%	8%	8%	29%	29%	18%	16%	10%	10%	20%	20%

One preliminary and broad observation we make from the above discussion is that this systematic RV strategy has typically worked well during low volatility periods (ECB's measured hiking cycle of 2005-2007, post Lehman period when the Fed was on perma-hold, post QE VaR shock). The peak of this rolling P&L metric broadly coincides with local troughs in implied volatility (**Exhibit 10**), although there is not much of a relationship between these variables otherwise. We present further details on the performance of the various categories of flies.

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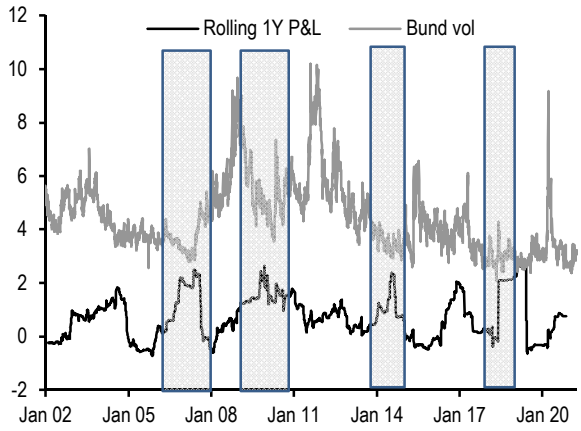
Exhibit 10: The peak of this rolling 1Y metric has broadly coincided with troughs in volatility although there is not much of a relationship otherwise

Rolling 1Y cumulative P&L from a variety of swap RV fly trades (bp) versus 1M MA of Bund implied vol (bp/day); since Jan 2001;

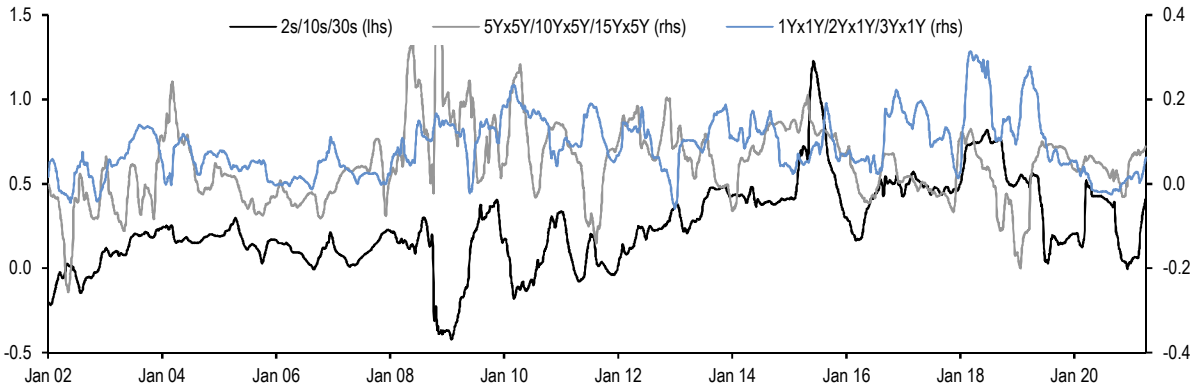


"Traffic light indicator" – development and back testing

The primary reason behind the strategy being ineffective during "critical" periods described above is due to the fact that what appears to be a residual on an ex-ante basis is, in reality, only optical (ex-post) and is the result of a local change in regression betas. In other words, the ex-ante regression betas (weights used to construct RV trades, which are themselves volatile) are different compared to ex-post regression betas. In an ideal scenario, where these ex-ante and ex-post regressions are equal, residuals are highly mean-reverting and a systematic strategy tends to be effective, on average. However, **during periods of volatility** (as is the case during regime shifts for example), **the regression betas are themselves volatile leading to ineffective mean-reversion**. More specifically, the ex-post betas deviate from ex-ante betas during these periods leading to large volatility in P&Ls. In **Exhibit 11**, we look at the evolution of the rolling beta over time for 3 different flies – 1Yx1Y/2Yx1Y/3Yx1Y (capturing the money market sector), 2s/10s/30s (covering the whole yield curve), and 5Yx5Y/10Yx5Y/15Yx5Y forward fly (to capture dynamics in the 10s/30s sector). As seen, the regression betas are themselves volatile and on cursory glance appears to be a function of ECB regimes.

Exhibit 11: Regression betas used for setting up RV trades are not stable over time and are a source of P&L volatility

Rolling 6M regression beta of 2s/10s/30s (lhs), 1Yx1Y/2Yx1Y/3Yx1Y (rhs), and 5Yx5Y/10Yx5Y/15Yx5Y (rhs) 50:50 swap fly versus body yield, after adjusting for the curve; since 1 Jan 2000; %



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We acknowledge that our framework of stress testing a universe of flies for a systematic trading strategy is difficult to import to test the hypothesis of volatile betas leading to volatility in performance: First, it is not necessary for all the flies to generate a trade signal on a given date. Second, for different flies, the betas can be hugely different with different signs (see Exhibit 11) and hence combining them to obtain a holistic single intuitive signal turns out to be quite challenging. Instead, we analyse the betas (versus body and versus wings) of a specific fly, that we believe it is representative of the overall performance. Specifically, the performance of the 1Yx1Y/2Yx1Y/3Yx1Y swap fly exhibits a strong correlation to the performance of the overall strategy (**Exhibit 12**) and hence, in our view, the evolution of the regression betas is a good template for analysing performance of the overall strategy.

Exhibit 12: The performance of the 1Yx1Y/2Yx1Y/3Yx1Y RV fly is a good representation of the performance of the overall strategy

Cumulative P&L of the overall trading strategy (averaged across all 12 control triggers) versus 1Yx1Y/2Yx1Y/3Yx1Y fly; since 1 Jan 2002; bp

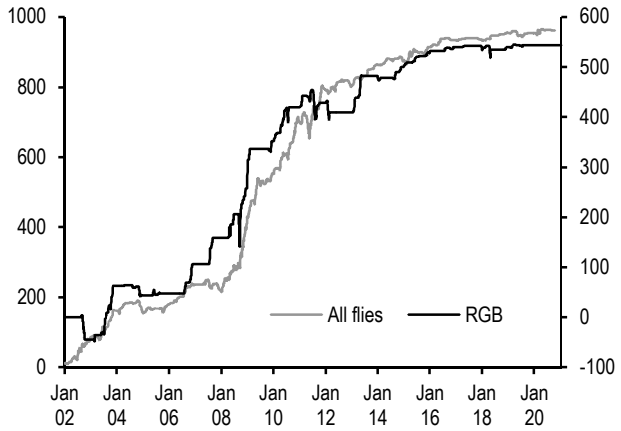

Exhibit 13 shows the evolution of the ex-ante regression betas of the reds/greens/blues 50:50 swap fly (versus greens and versus reds/blues curve). As seen, betas themselves are volatile which typically exacerbates during the "critical periods". We highlight that the evolution of both of these betas (versus the body and versus the wings) are significant contributor of the ex-post P&L of the trading strategy.

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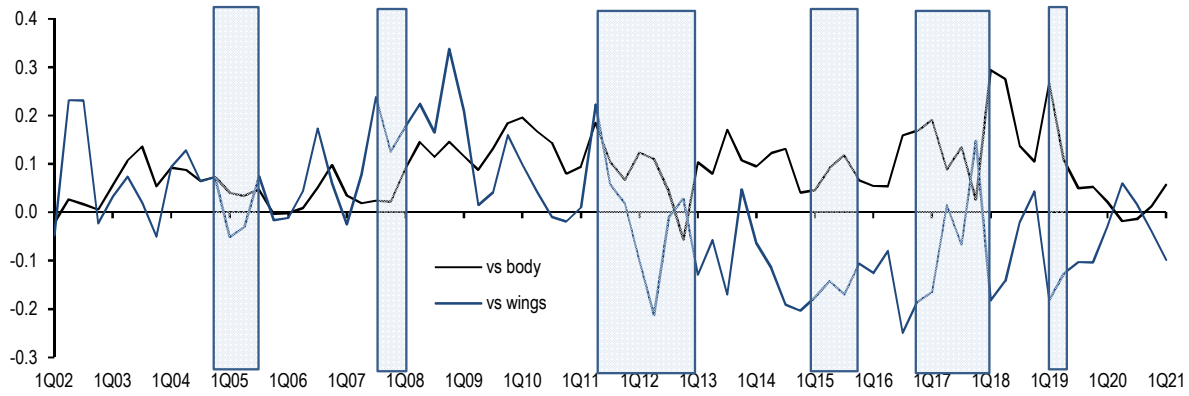
Exhibit 13: The relationship of the swap fly versus its body and wings changes over time and this volatility is a significant contributor to the total P&L

Rolling 6M regression beta of the 1Yx1Y/2Yx1Y/3Yx1Y 50:50 swap fly versus 2Yx1Y swap yield and versus 1Yx1Y/3Yx1Y curve; %



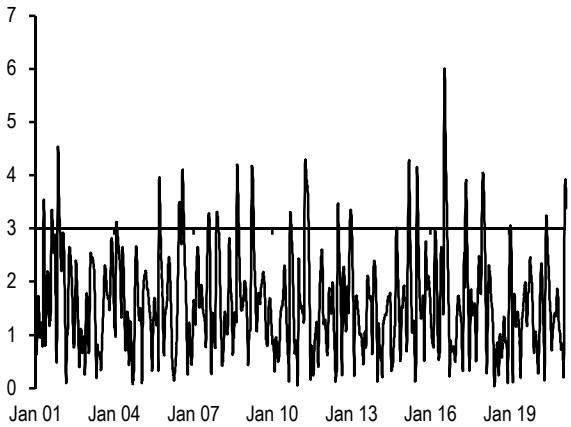
We also develop a unified beta framework to explain the relationship between P&L and regression betas[5]. We build a "*traffic light*" indicator to combine the two betas together via doing the following. **First**, we find the 6M Z-scores of the 3M volatility of each of the regression beta. **Second**, we calculate the quadratic average of the two Z-scores. **Exhibit 14** shows the evolution of this index over the past two decades. If we use 3 as an arbitrary cut off threshold, then we notice this index had increased above this threshold during the "critical periods" discussed above.

"*Traffic light Indicator*" = $\sqrt{(Z_b^2 + Z_w^2)}$

where, Z_b (Z_w) is defined as the 6M Z-score of 3M volatility of the regression beta of the 50:50 fly versus body (wing), after adjusting for the wing (body).

Exhibit 14: We develop a regression beta based "traffic light" indicator which can be used as a signal to avoid RV trades

RV trading signal indicator*; since Jan 2001; unitless



* Index calculated as SQRT($Z_b^2 + Z_w^2$); Z_b (Z_w) is defined as the 6M Z-score of 3M volatility of the regression beta of the 50:50 fly versus body (wing), after adjusting for the wing (body).

[5] Using the regression betas obtained from regressing the reds/greens/blues 50:50 swap fly versus yield and curve – a two factor regression.

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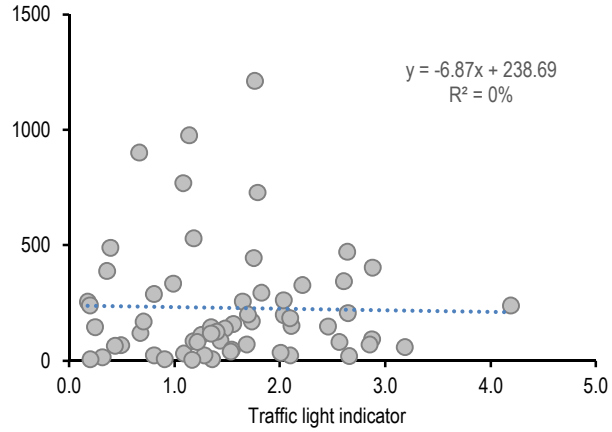
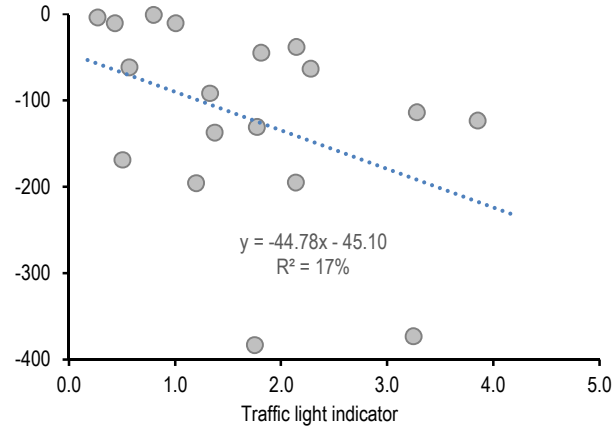
To compare the relationship between P&L and our index discussed above, we run two regressions of the ex-post P&L vs. the ex-ante index (1m before) splitting the sample into positive and negative P&L (**Exhibit 15**). Admittedly, the relationship between these two variables is poor when the strategy is delivering positive P&L indicating that the P&L during these periods is potentially driven by other factors, or that the variability of the beta is small enough not to impact the overall performance. However, we see a decent negative relationship between ex-post P&L and our ex-ante index when the strategy is less effective indicating that high volatility of the index tends to be associated with negative P&L episodes putting a negative drift to the performance of the RV systematic trading strategy.

Exhibit 15: This index exhibits a decent relationship to P&L, especially when the strategy incurs a loss – precisely the linkage we are looking for

Total P&L (only when the P&L is positive) regressed against our RV Trading indicator; quarterly data since1 Jan 2002; bp



Total P&L (only when the P&L is negative) regressed against our RV Trading indicator; quarterly data since 1Jan 2002; bp



We then extend our analysis to incorporate the above mentioned "*traffic light indicator*" as an additional filter to our systematic trading strategy. **Exhibit 16** shows the improvement in the average P&L (per control trigger) and the change in success ratios across these trigger criteria. While the distribution of the increase in average P&L and change in success ratios vary across different thresholds, we find that using a threshold of 3 is optimum in terms of not reducing aggressively the total number of trades while still delivering decent improvement in the profitability. We, finally, also investigate the improvement in the performance of the strategy during the "critical periods" using this additional filter. **Exhibit 17** shows impact of the filter on average P&L (both in terms of magnitude and expressed as a % change from unfiltered data) and change in overall success ratios. As seen, the overall P&L during the "critical period" increases by around 25%, on average, using this filter.

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Exhibit 16: Using the trading signal improves the overall performance, both in terms of average P&L and success ratio

% change in average P&L* when compared against unfiltered data and change in success ratios (numbers shown for various trigger criteria); %

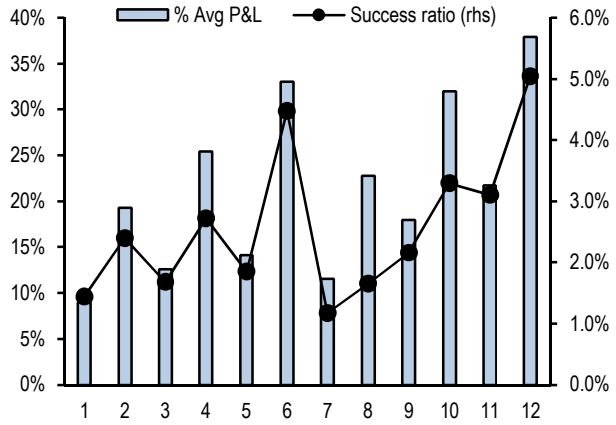


Exhibit 17: Similarly, the overall performance also increases during the "critical periods" using this newly developed RV trading signal

Change in P&L (averaged across 12 control triggers), % increase in average P&L, and change in success ratio (all averaged across 12 control triggers) when using the RV trading signal index during previously defined "critical periods";

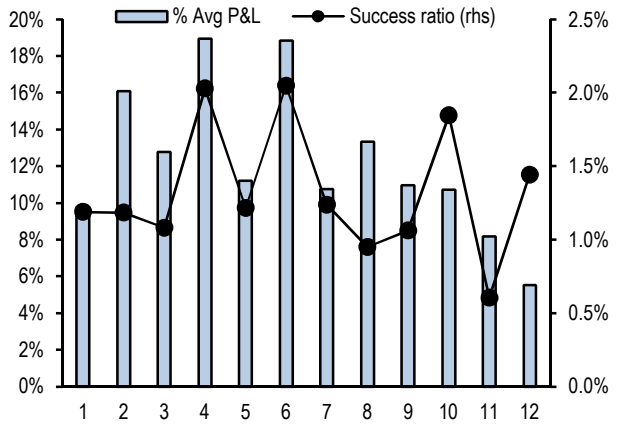
Time period	Change in avg P&L; bp	% increase in avg P&L	Change in success ratio
3Q04 - 2Q05	0.0	0%	0%
3Q07 -4Q07	0.3	63%	7%
2Q11 - 4Q12	0.6	149%	6%
2015	-0.3	-195%	-4%
4Q16 - 1Q18	0.0	82%	1%
2Q19	0.0	0%	0%
Avg	0.2	25%	2%

* RV trading signal based on betas of the 1YxY1/2Yx1Y/3Yx1Y.

We acknowledge that in the P&L improvement analysis above, we have built the RV trade indicator index based on the regression betas of the 1Yx1Y/2Yx1Y/3Yx1Y swap fly. Ideally, users should build this indicator based on the exact fly they wish to trade to improve the reliability of the analysis. Indeed, using index built on the regression betas of the 2s/10s/30s swap fly, we still see decent improvement in the overall performance of the strategy (**Exhibit 18**).

Exhibit 18: Using a "traffic light" indicator built using the betas of the 2s/10s/30s fly also improves the performance. Ideally, users should build this indicator based on the exact fly they wish to trade

% change in average P&L* when compared against unfiltered data and change in success ratios (numbers shown for various trigger criteria); %



* RV trading signal based on betas of the 2s/10s/30s swap fly.

In **conclusion**, while fading relative value opportunities on the yield curve is generally attractive as systematic alpha-generating strategy, one must be cautious around periods of regime shifts where the directionality of the swap curve shifts and any RV could turn out in being eventually only optical in nature. Our " *traffic light*" developed here can help in determining whether mean reversion strategies are attractive or not;[6] currently the signal is flashing "red" indicating that regression betas are currently volatile and now may not be an attractive moment to fade systematically RV dislocation on a level and curve neutral fly. Admittedly, the ECB is still significantly away from lift-off and hence any pricing of regime shift could be premature. However, our "*traffic light*" indicator suggests that, empirically, it is best to avoid entering such RV trades currently as regression betas have not been stable to read current dislocation as opportunity. A potential decline in volatility of swap butterflies betas with ECB upsizing PEPP and containing the sensitivity to USD rates should eventually turn our "*traffic light*" indicator to green, restoring the attractiveness of a RV systematic approach.

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6 * Index calculated as SQRT(Zb2 + Zw2); Zb (Zw) is defined as the 6M Z-score of 3M volatility of the regression beta of the 50:50 fly versus body (wing), after adjusting for the wing (body).

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