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Global Quantitative & Derivatives Strategy
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Trading vol-of-vol risk premium

Harvesting smile convexity across asset classes

Source: Wikipedia

Global Quantitative and Derivatives Strategy

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Executive summary

This publication focuses on the possibility of identifying and monetising a premium from the convexity of volatility smiles, and on the related trading implication, with a particular focus on the strategic implementation of the theme. We will provide extensive coverage across asset classes – FX will receive a particular attention, given the depth of the options market and the typically elevated smile convexity, but Equities and Commodities will be covered, too.

The first part of the paper offers a theoretical overview on the notion of vol convexity premium, and features:

- The definition of the vol convexity premium via a simple expression involving the Volga Greek
- The sensitivity of the premium to term structure dynamics and to non-linear effects
- How plain vanillas and Exotics structures can allow taking an exposure to the vol convexity premium

The second part is entirely dedicated to empirical findings, via cross-asset and cross-instrument backtests. It covers:

- How the vol convexity premium favors using strangles for vol-selling and straddles for vol-buying purposes
- Vol-of-vol strategies for G10 and EM FX plain vanillas via strangle vs. straddle trades
- Smile + Calendar strategies for G10 and EM FX plain vanillas
- Statistical properties enjoyed by FX short vol convexity strategies and diversification benefits for multi-strategy/asset portfolios
- Asymmetric put/call ratio spreads for G10/EM FX vols
- A comprehensive analysis of Var vs. Vol swap FX trades
- Implementation of the vol convexity theme in Equities via Options on the VIX and Var vs. Vol swap trades on the S&P
- Precious Metals Smile and Smile + Calendar strategies via plain vanillas

Appendices I-IV cover some additional pricing/technical aspects that are important but not strictly mandatory for an intuitive understanding of the topic.

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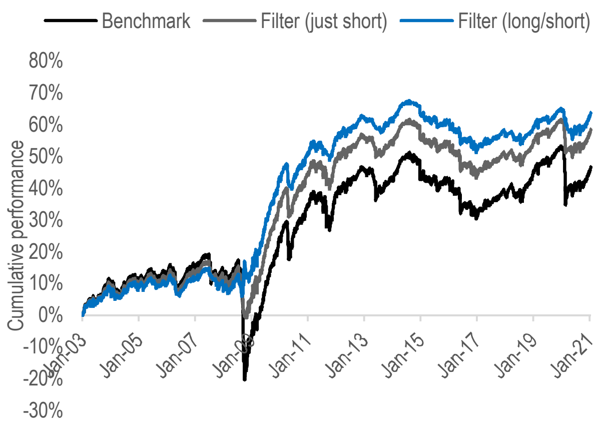
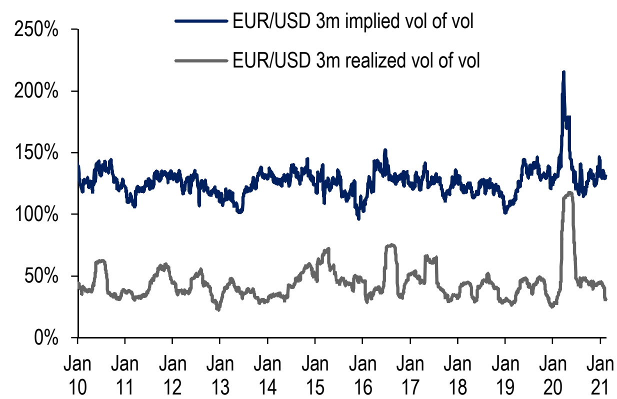
Introduction

Most derivatives traders are aware of the premium associated with implied volatilities, related to the so-called "Gamma" Greek, which controls quadratic fluctuations in spot returns. While a positive Gamma exposure is in principle a very desirable feature, as a delta-hedged portfolio would benefit from large fluctuations regardless of the sign of the spot move, it normally comes at the price of a negative "volatility Carry" or time decay. As such, in the long-run, selling volatility across asset classes is a strategy that delivers solid returns over long investment periods, and one that real-money and leveraged investors are, to a different extent, participating in.

Exhibit 1: Filtering can cut the drawdowns associated with short-Gamma strategies. Time series of EUR/USD implied and realized vol-of-vol





Source: J.P. Morgan Quantitative and Derivatives Strategy

The solid performance from cross-asset short volatility strategies post-GFC was beleaguered by the COVID-19 shock that plagued markets last March, leading to a sharp repricing of volatility levels, which gradually subsided over the following months. Several research pieces discussed practical takeaways for reducing the drawdowns associated with short-volatility strategies. For Equities in particular, high-frequency serial correlation patterns favour optimising the choice of the delta used for hedging the options book (*Optimal option delta-hedging: uncovering the link between mean-reversion and options strategies across markets*, Ravagli et al, November 2018), allowing higher returns with more contained drops. A tactical timing filter delivered satisfactory results in sharply reducing the drawdown experienced by FX short-Gamma strategies over 2020 (Exhibit 1 left-hand side chart, see for instance *Timing FX short-vol strategies - A systematic approach*, Ravagli, Duran-Vara, March 2019), allowing an almost full recovery of the drawdown by February 2021. Finally, playing RV rather than taking an outright long or short view on vols (*Pair trading with FX vols: Should vol mean-reversion be your friend?,* Ravagli, Duran-Vara, 12 February) should naturally reduce the exposure to the direction as undertaken by the vol market.

When building diversified multi-asset or multi-strategy portfolios, de-correlation of the inputs is of the utmost importance for reducing the portfolios' overall volatility and containing drawdowns in adverse environments. In the context of volatility trading, being able to access an alternative source of returns than the well-known volatility-premium would serve the purpose.

Sourcing an alternative source of Carry from vol smiles

In this report, we will investigate an alternative solution for producing positive returns from the vol market by banking on elevated pricing of other smile parameters than just vol, in particular vol smile convexity (or *vol-of-vol* in the trading/pricing jargon). The topic of vol-of-vol trading in FX was recently the subject of several research pieces (see for instance *Softer than shadow and* quicker than flies, All weather vol ratio spreads excel when primed with risk-on/off filter, Oddities in the AUD vol complex), reprising more formal results from academic literature. Here, we'll try to conjugate formal rigour with practical trading takeaways, and provide a rich overview of the topic.

The bulk of the piece will be dedicated to strategies that scoop an extra "vol convexity" premium from volatility smiles. In a perfect analogy with Gamma for spot fluctuations, the so-called Volga Greek letter measures an option's sensitivity to fluctuations in volatility levels, and is similarly associated with a negative time decay, on the back of a mismatch between an implied and a realized quantity, vol-of-vol (Exhibit 1, RHS). The vol-of-vol premium formula simply reads as:

$$PnL_{Volga} = \frac{1}{2}\,\sigma_{ATM}{}^{2}Volga * (\nu^{2}{}_{real} - \nu^{2}{}_{imp})\Delta t$$

where $\upsilon_{imp}, \upsilon_{real}$ are implied and realized "vol-of-vol" parameters. As normally $\nu_{imp} \gg \nu_{real}$, Volga<0 option positions can, therefore, deliver a positive "Smile Volatility Carry" during most market environments, with the exception of those where volatility is itself very volatile.

Amongst the "practical" recipes that can be applied for a wide range of trading and hedging purposes is the observation, on the back of the more theoretical results as presented in this study, that a typically wider premium can be extracted by selling short-dated Out-of-The-Money options, whereas conversely, At-The-Money options offer better value for long optionality trades. For instance, in the context of a systematic framework for hedging FX risk, leveraging on long ATM/short wings structures allows reducing significantly hedging costs vs. forwards.

These results are already useful for optimizing the features of volatility harvesting portfolios. At a deeper level, the extraction of an "alternative" source of vol Carry from the smile compared to the well-known one associated with Gamma can boost the diversification properties of volatility or multi-strategy portfolios, although this will come at the price of a higher exposure to left-tail risk events (see the interplay of Sharpe ratio vs. Skewness for a class of alternative strategies in Bouchaud, Risk Premia: Asymmetric Tail Risks and Excess Returns, 2017).

The access to such an appealing de-correlated (at least to some extent) additional source of income necessarily involves some technicalities and to enter RV trades on each volatility smile, which can be highly sensitive to the impact of trading costs. Throughout the piece, we have aimed to provide conservative assumptions regarding trading costs and rebalancing of vol portfolios, while opening the way for future research where liquidity conditions could directly be associated with wings premia and play the role of an actual input for trading decisions.

Tail-risk hedging strategies (see for instance Nassim Taleb, Black Swan, 2007) have received considerable attention by investors, especially in the context of multi-asset portfolios, where Equities had rallied for more than a decade, before suffering a sharp drop last year due to the COVID-19 health crisis, just to resume their upward trajectory in the second part of the year. A recent research report (*Defensive Risk Premia: Systematic Strategies for the Risk-Off Times*, Tzotchev et al, April 2020) investigated several alternative trading strategies that are aimed at protecting portfolios during risk-aversion episodes.

A more comprehensive analysis of vol convexity RV trades, for trading and/or hedging purposes, will be subject of future research. The results of this piece will generally support implementing long vol convexity strategies via rather long dated instruments, as the front end of the curve is more exposed to the smile-related time decay. That is the case as the vol convexity premium tends to be wider for short maturities, on the back of some peculiar features (most notably, inverted vol curve) of the vol-of-vol market, putting aside "black swan events", where spot and vols move sharply at the same time.

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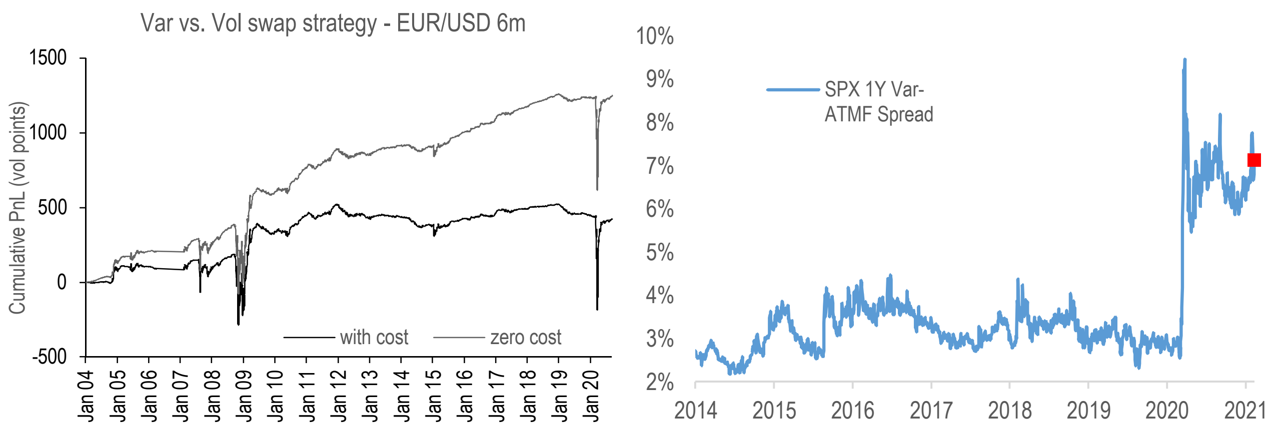
Tactical opportunities in the cross-asset vol convexity space

One of the infrequent vol convexity crash episodes was witnessed precisely last March. The market had been overly complacent in not paying enough attention to the developments on the COVID-19 front, although this is much easier to say with the benefit of hindsight. For instance, a proxy of FX vols, as expressed by the J.P. Morgan VXY Index, had reached its all-time low in mid-February 2020, and started to move markedly higher in early March, whereas the VIX index started rising mode in late-February. In any case, when the repricing occurred, it was brutal, and especially so for assets that were not pricing any premium for the event. Several funds with the wrong positioning ahead of the event went bust as the move unfolded.

While FX vols were low, wings premium had started to build up gradually ahead of the event (Exhibit 1, RHS), which provided some cushion to vol convexity sellers, but was not enough for avoiding sharp drawdowns. The case study of the Vol vs. Var swap short vol convexity strategy in EUR/USD (Exhibit 2, LHS) is telling, and so was its subsequent recovery as fiscal and monetary instruments stepped in to stabilize market conditions. As a consequence, the crisis-related elevated wings premium gradually came off during 2020 (Exhibit 1, RHS) and especially so after the November US election and the late-December EU/UK deal on post-Brexit trade arrangements.

Exhibit 2: Short vol convexity strategies experienced large drawdowns last year. Vol convexity premium remains wide in Equities.



Source: J.P. Morgan Quantitative and Derivatives Strategy

For Equities, the cost of protection via OTM vols also spiked in Mar'20, but remained structurally elevated as the sharp rebound in markets took place, as expressed by the Var – ATMF 1y spread for S&P (Exhibit 2, RHS). This was supported by a decline in volatility risk premia selling flows after last year's wash-out and strong hedging demand, and, to some extent, by the flurry of speculative, retail-based trading activity in a number of stocks that supported OTM calls pricing.

A strong rebound in Equities in the second part of the year was called thanks to the combination of extraordinary rescue packages, higher than expected rebound in growth and light positioning, with risk controlled funds having scaled down Equity exposure as vol remained elevated (see for instance *Market and Volatility Commentary - Market valuations, positioning and potential for a value rally*, Kolanovic, Kaplan, 8-Jul-2020; *Global Asset Allocation: Staying pro-risk, adding back to equity OW*, Kolanovic et al, 10-Jul-2020). As a result, from a tactical perspective, we recommended monetizing the rich convexity risk premium in a few recent publications by trading variance swaps vs. volatility swaps (see *Volatility Review*, 30-Jun-2020, *2021 Equity Derivatives Outlook*, 9-Dec-2020, and *Volatility Review*, 22-Jan-2021). In these trades, we adjusted the vega notional ratio of the two legs to skew the breakeven range lower, by buying a lower vega notional on the vol swap than the vega notional of variance sold.

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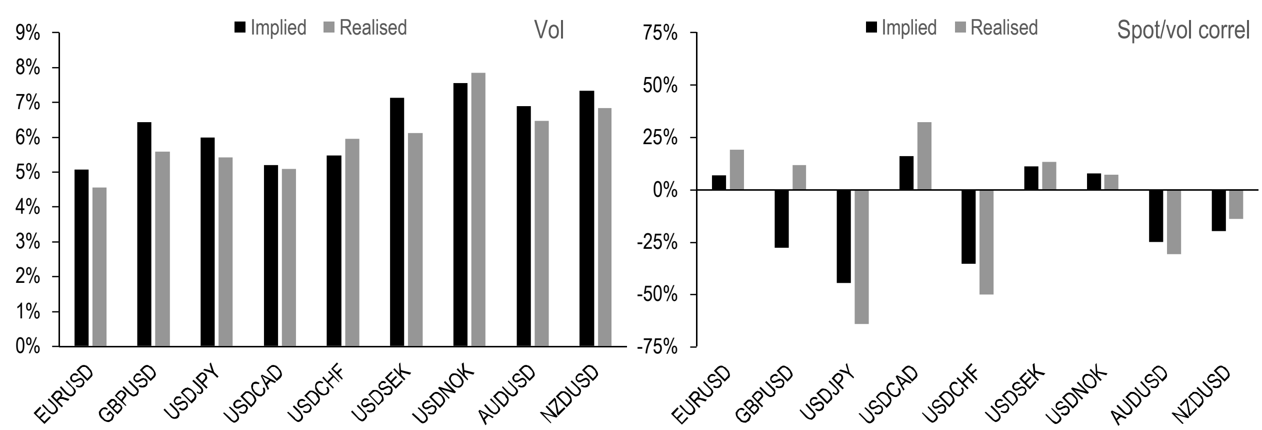
The notion of a vol-of-vol premium

The starting point of this study is an article published a few years ago in academic literature, where the possible overvaluation of short-dated OTM options for the FX market was highlighted (Isolating a risk premium on the volatility of volatility, Ravagli, Risk Magazine, Dec 2015).

Vol-of-vol premium – introducing the concept and some formalism

We try to offer a relatively intuitive description of what the vol-of-vol premium is about, before entering into the realm of hard-core technicalities. We start by showing (Exhibit 3) a current snapshot of implied vs. realized vol (LHS) and skew (RHS) parameters (i.e. spot/volatility correlation, implied parameter obtained via a SABR-calibration) for USD/G10 pairs. Given that stochastic volatility models have a parameter associated with the volatility of volatility, it is natural to present a similar comparison for this parameter, too. On average, implied vol-of-vol tends to be twice as high as realized vol-of-vol (Exhibit 4, LHS), leading to a much wider premium than for vol and skew. Furthermore, this gap or premium appears as a rather persistent feature over time, rather than a coincidence (Exhibit 4 RHS chart, for EUR/USD and USD/JPY). Realized vol-of-vol below is measured as the 3M rolling log-normal realized volatility of fixed maturity 3M ATM volatility. A more precise estimate of this quantity will be introduced in the following sections.

Exhibit 3: USD/G10 3m vol and skew premia (as of July 2020)



Source: J.P. Morgan Quantitative and Derivatives Strategy

While the observation above is interesting per se, there is no *a priori* link between such a feature and any tradeable quantity, in which case the discussion would be merely be of theoretical interest. In fact, under a few limiting assumptions, one can show that such a link can be established (Isolating a risk premium on the volatility of volatility, Ravagli, Risk Magazine, Dec 2015). In the context of stochastic volatility models, such premium can be attributed to the so-called vol-of-vol parameters υ and the corresponding Volga Greek letter:

$$PnL_{Volga} = \frac{1}{2}\,\sigma_{ATM}{}^{2}Volga * (\nu^{2}{}_{real} - \nu^{2}{}_{imp})\Delta t$$

where Δt is the time interval, $\upsilon_{imp}, \upsilon_{real}$ $(\nu^{2}{}_{real} = (\frac{\Delta\sigma_{ATM}}{\sigma_{ATM}})^{2}/\Delta t)$ are implied and realized vol-of-vols, $Volga \equiv \partial Vega/\partial\sigma_{ATM}$. Volga plays a similar role as Gamma does for spot moves, as it expresses the "quadratic" sensitivity to fluctuations in vol levels, which cannot be hedged by simply trading Vega. Short-Volga positions are supported in presence of a vol-vol premium.

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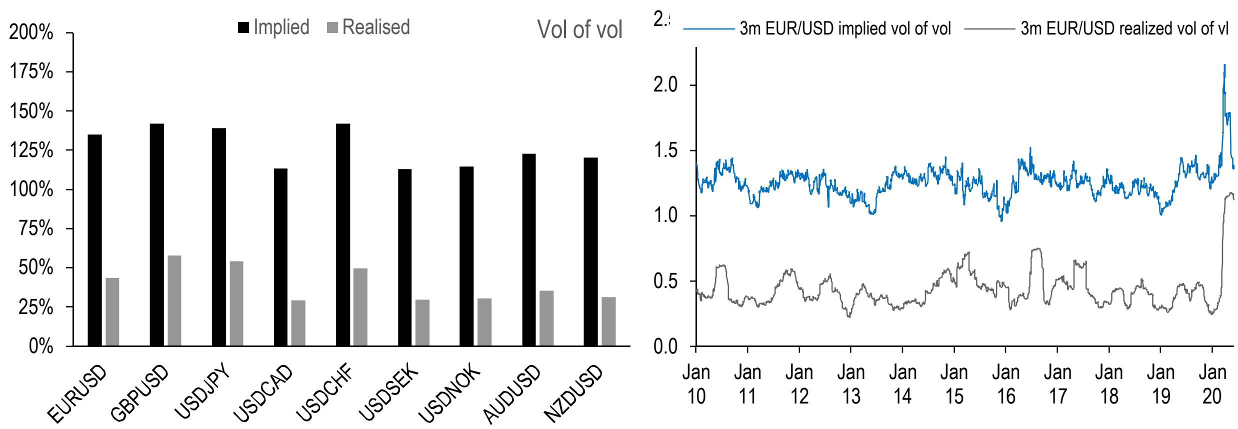
Exhibit 4: Snapshot of 3m imp vs 3m realized G10 vol-of-vol. Time series of implied parameters for EUR/USD & USD/JPY

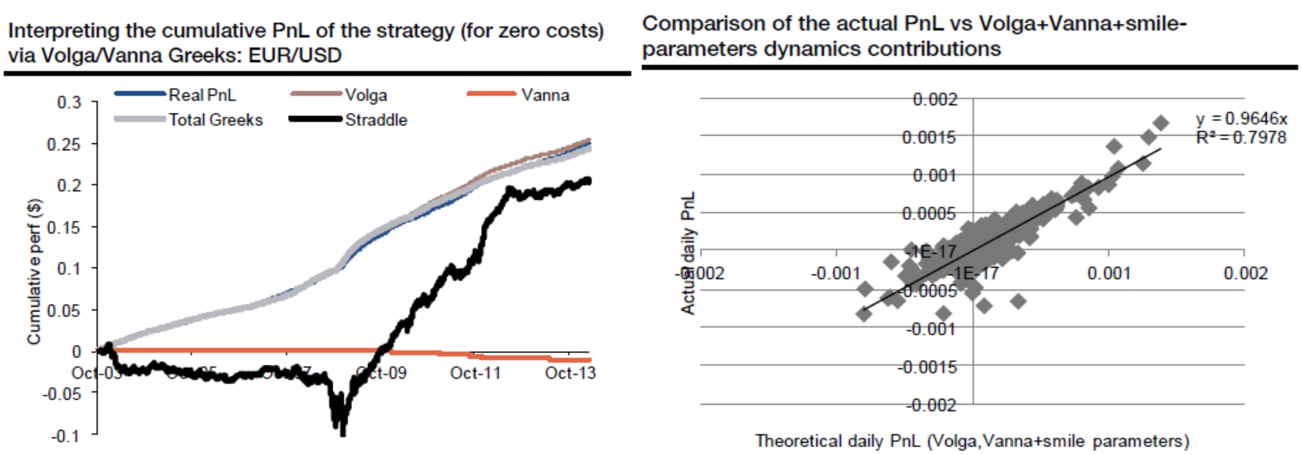


Source: J.P. Morgan Quantitative and Derivatives Strategy

The formula is valid under some limits: short maturity, near-the-money options; zero skew (acceptable for FX, much less so for Equities); flat term structure of vols, which would allow computing realized vol-of-vol via the fixed maturity, rather than fixed expiry, contract. Some of the technical steps for obtaining this result are summarized in Appendix I.

The formula shows the PnL that can be attributed to the Volga Greek over a time interval Δt: if all other Greeks are set to zero, this would also be a proxy of the book's PnL. Based on the formula and previous empirical observations, the mismatch between (daily) implied and realized values would support short Volga or vol-of-vol trades, as backtests in the second part of the piece will actually confirm. Some other theoretical conclusions also emerged, like the model independence of υ_{imp}(different stochastic volatility models converge towards the same estimate of implied vol-of-vol under the limits above, see Appendix II – in the following SABR model will be mostly used for smile calibration) and, consequently, the possibility of interpreting vol-of-vol as a tradeable quantity, via the equation above.

Exhibit 5: PnL of short Volga plain vanilla strategies can be reconciled with expected PnL from Greeks expansion



Source: Risk.net, Dec 2015

Another useful observation is that the expression above mirrors the better-known one for the Gamma axis of risk – compared to the latter, the wider premium contained in vol-of-vol should provide a better cushion to adverse market conditions when harvesting premia from the vol smile.

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Interestingly, given the large mismatch between implied and realized vol-of-vol, as seen earlier, the strategy that perfectly isolates the Volga Greek sensitivity would be associated with elevated risk-adjusted performances, at least in the limit of zero trading costs. This observation leads us to wonder under which circumstances the "theoretical premium" referred to above could benefit market participants and, if so, which type (just market makers, dedicated vol traders, real money investors etc.), depending on their access to liquidity. Exhibit 5 summarizes the results from the aforementioned piece, showing how a suitably constructed options portfolio can match the desired exposure to the vol-of-vol premium, delivering a smooth daily PnL.

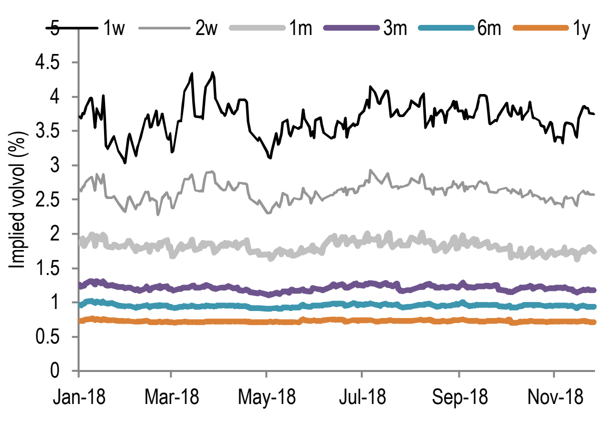
However, interestingly, the results above were derived under the theoretical limit of zero trading costs. For an L/S strategy, assessing the impact of costs is an essential exercise, particularly in this case where the pure "Volga" exposure could be kept only by frequently rebalancing option portfolios. In a practical setting, one would need to find a trade-off between pureness of exposure and impact of trading costs. The main goal of this piece is to put these theoretical results into practice. In this first part, we'll provide an exhaustive overview of the theoretical framework surrounding the topic.

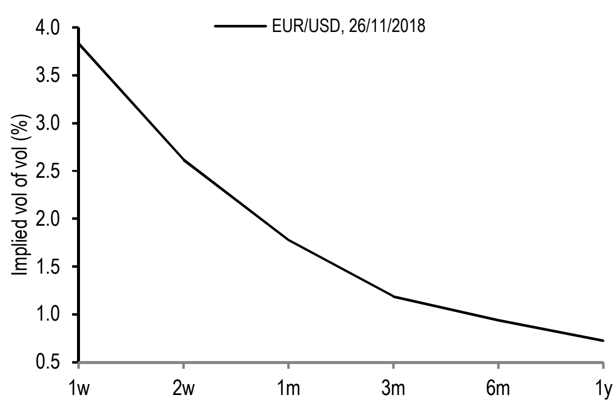
In principle, holding a pure short vol-of-vol position would involve a frequent rebalancing of options portfolios, in order to keep a constant sensitivity to the Volga axis of risk and to hedge sensitivities to other unwanted Greeks. Sharpe ratios of 6 or higher, as corresponding to the setup of Exhibit 6, could only be obtained under these rather unrealistic assumptions. In practice, the marked path-sensitivity of the Volga Greek and the emergence of other spurious sensitivities (such as Gamma and Vega, even if hedged out at inception) will mean that a tradeoff between frequency of rebalancing and impact of trading costs needs to be struck. Before tackling the issue of how to deal with trading costs in realistic backtests, which we do in the second part of the piece, we dig a bit more into the technical aspects that are important for a full understanding of the subject.

Estimating the premium with realistic trading constraints

The results above might make it look like harvesting this premium from wings was an easy exercise, which was not the case in practice. The purpose of this section is to highlight a number of constraints that prevent immediate access to such an apparently wide premium, making the analysis closer to what could be achieved in a realistic trading setting. The significant impact of costs, preventing a high-frequency rebalancing of the portfolios and therefore polluting a pure exposure to the high-premium Volga Greek, will be dealt with in the backtesting-related part of the piece.

Exhibit 6: Vol-of-vol term structure in FX is structurally downward sloping (both for EUR/USD).





Source: J.P. Morgan Quantitative and Derivatives Strategy

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We first address the question how the term structure of volatilities alters the results above, and especially the estimation of the vol-of-vol premium. In the first place, the ATM implied vol curve typically presents a term structure, an effect which is magnified when it comes to pricing wings or vol-of-vol (Exhibit 6, LHS). For the purpose, we calibrate a different SABR stochastic volatility model over smiles of maturities from 1w to 1y – and report the corresponding vol-of-vol parameter for each maturity. In principle, a suitably calibrated Heston model could capture a strip of front-end maturities. More details on stochastic volatility models are reported in Appendix II. A case study for EUR/USD is provided (Exhibit 6, RHS). The LHS chart shows how the lower the time to maturity, the higher and more volatile the corresponding vol-of-vol parameter is. The RHS chart provides a snapshot as of November 2018, and stresses the marked inversion of vol-of-vol term structure. Unlike the shape of the ATM vol curve, which depends on the market regime (upward/downward sloping during normal/risk-off times), the inversion of the vol-of-vol curve is a stable feature that does not change over time. In other words, the long vol-of-vol position is subject to a positive roll-down effect, while the short vol-of-vol trade is negatively impacted.

We now discuss how to take this effect into account as far as the estimation of a premium is concerned, especially when computing realized vol-of-vol. For the calculation, as in Exhibit 5, where the holding period was just 1d, one could simply look at the daily log-return of ATM vol whereas, for longer holding periods, the calculation of realized vol-of-vol of Exhibit 4 was done via the daily log-returns of fixed maturity ATM vol, calculated over 3M periods. The question now is, how to account for the term structure of vols when measuring these quantities. It might be more realistic to measure the realized vol-of-vol by embodying this roll down effect directly, assuming the position is held until expiry (this will be motivated later by the impact of trading costs).

We start by showing the general mechanism how the curve roll-down impacts the standard Gamma/Vega sensitivity related to ATM vol positions, before fine tuning for the wings exposure. Let us consider the case where the ATM vol curve can be simply modelled as an upward sloping curve ($\alpha > 0$) as:

$$\sigma = \sigma_0 + \alpha\, T$$

More generally $\alpha = -\frac{\partial \sigma}{\partial t}$ from the local shape of the vol TS curve. By neglecting other Greeks, the PnL over Δt reads as:

$$\Delta PnL = \frac{1}{2} S^2 \Gamma \left(\sigma_{real}^2 - \sigma_{imp}^2\right) \Delta t + roll\ down\ term + \cdots$$

Assuming no change in the shape of the vol curve, $Roll\ down\ term$ can be expressed as:

$$Roll\ down\ term = -\text{Vega} * \alpha\, \Delta t = -\Gamma S^2 \sigma \tau \alpha \Delta t$$

$$\Delta PnL = \frac{1}{2} S^2 \Gamma \left(\sigma_{real}^2 - \sigma_{imp}^2 - 2\sigma\tau\alpha\right) \Delta t + \cdots$$

In other words, assuming no changes in vol curve (i.e., explicit Vega terms contribution), PnL can be calculated by simply accounting for the following curve-based adjustment to the realized vol:

$$\sigma^2{}_{real} = \sigma^2{}_{real} - 2\alpha\sigma\Delta t$$

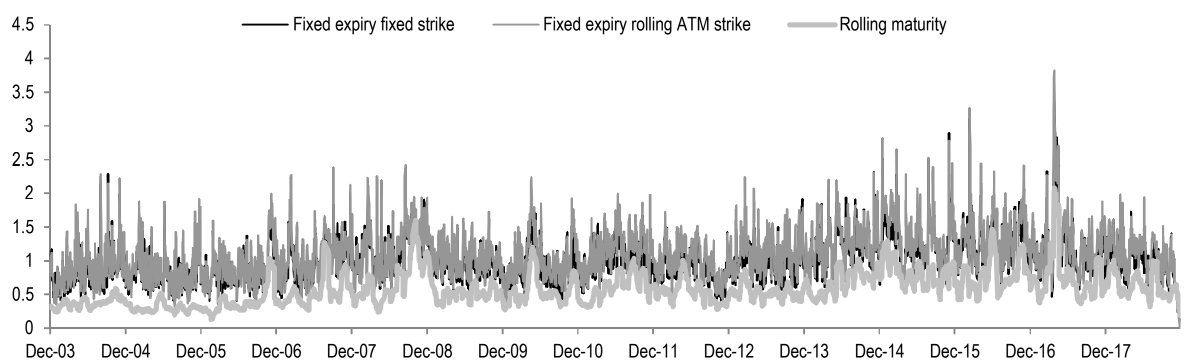
Vol-sellers will lock in an instantaneously wider PnL given the vol-curve adjustment. However, from that point on, they will also have to mark-to-market lower the level of implied vol they are selling at:

$$\sigma = \sigma_0 + \alpha\, T \rightarrow \Delta\sigma = -\alpha \Delta t$$

which implies, going forward, a lower PnL on the back of tighter vol premia as implied vols gradually drop following curve dynamics. In other words, by unwinding quickly, one can lock in a higher PnL given the favourable roll-down effect on the curve one immediately accounts for via the MtM pricing of the vol. In practice, while the effect above is clear for short holdings over time to maturity, it becomes more contained if the position is kept in the book until expiry, given the compensation between the two factors highlighted. In this respect, academic research has investigated how the expected value and volatility of the option's PnL at expiry varies with the choice of the volatility parameter used for delta-hedging[1]. One could repeat the calculation for the wings and highlight the sensitivity of an option position to vol-of-vol term structure, although calculations would be more involved and will not be shown here. Still, the conclusion would remain that adverse roll-down features of implied parameters would mostly impact PnL for short-dated holdings rather than when kept until expiry.

However, the main difference between the Gamma and Volga Greeks relates to the underlying "realized" fluctuation of market variable they are exposed to: spot and volatility, respectively. In the former case, there is no term structure of spot, which means that high frequency (let's say, daily) realized vol will not depend on the tenor. That is not the case for vols, as the inverted term structure of vol-of-vols means that short-dated contracts tend to be much more volatile than longer-dated ones: the realized vol-of-vol depends on the tenor of the contract and impacts adversely the short-Volga trades, especially as expiry approaches. In order to get a sense of vol-of-vol premium, and take this roll-down effect into account, it's important to measure the realized volatility of the actual contract a position is exposed to rather than of the rolling fixed maturity vol.

Exhibit 7: vol of fixed expiry vol higher than for fixed maturity vol. 1m EUR/USD case



Source: J.P. Morgan Quantitative and Derivatives Strategy

In Exhibit 7, we show the time series of 1m realized vol-of-vol, for 1m EUR/USD. The calculation is backward looking, i.e. for each date, it refers to the past month. We provide three different estimates based on: a) running 1m ATM vol (same as Exhibit 5); b) fixed expiry ATM vol; c) fixed expiry, fixed strike vol. a) is the case offering the most convenient calculation, c) is the one which relates directly to an actual contract within the book (assuming one trades daily) and which properly takes into account smile convexity and spot fluctuations, not considered in b)[2]. Anyway, from the chart, we can see how the realistic estimate c) is structurally higher than the naïve one a), which correspondingly implies a reduction of the wings premium compared to the optically

[1] See Derman, Miler 2016; Ahmad, Wilmott, 2005 for more details

[2] A proper analysis of the joint spot, vols dynamics would require assessing the sticky-delta vs. sticky-strike interplay for different asset classes, as per Derman 1999

appealing one of Exhibit 4, for instance. Still, we stress how the screening as proposed here remains a qualitative one, as it does not directly account for the path sensitivity of the Greeks, and especially the Volga one, in this case. Rather than faithfully describing a daily PnL, it can be useful for expressing the long-term potential of strategies that take a position on the smile wings.

Given the more realistic assumptions, we will rely on the fixed Expiry/Fixed strike calculation for the realized vol-of-vol. A more granular analysis across USD/G10 pairs and maturities is detailed in Exhibit 8 – we omit showing results for EM currencies given the drier liquidity (backtests including trading costs will be shown in any case in the second part of the piece). Having carried out daily analyses for implied and realized vol-of-vols (as described above), the chart summarized long-term averages of both quantities, with data since Jan 2004, and the premium stands for their difference. The main observation is that a vol-of-vol premium appears apparent across all currencies and maturities, despite being reduced in magnitude given the more realistic assessment of realized quantity, taking into account the term-structure effect, vs. the naïve one of Exhibit 4.

Exhibit 8: A realistic estimate of USD/G10 vol-of-vol parameters for different maturities

		EUR/USD	GBP/USD	USD/JPY	USD/CHF	USD/CAD	USD/NOK	USD/SEK	AUD/USD	NZD/USD
1m	imp	1.89	1.93	2.11	1.94	1.81	1.72	1.73	1.87	1.83
	real	1.06	1.07	1.16	1.11	1.00	0.98	1.00	1.10	1.09
	premium	0.83	0.86	0.95	0.83	0.80	0.74	0.73	0.77	0.74
3m	imp	1.22	1.24	1.38	1.25	1.17	1.08	1.09	1.27	1.23
	real	0.76	0.78	0.84	0.81	0.73	0.70	0.70	0.80	0.79
	premium	0.46	0.47	0.53	0.44	0.43	0.39	0.39	0.47	0.45
6m	imp	0.92	0.94	1.06	0.94	0.88	0.80	0.81	0.98	0.95
	real	0.58	0.59	0.67	0.62	0.55	0.53	0.53	0.61	0.59
	premium	0.34	0.35	0.39	0.32	0.33	0.27	0.28	0.37	0.36

Source: J.P. Morgan Quantitative and Derivatives Strategy

The second feature from the table is that the premium tends to be much wider for short-dated options: for a given (negative) unit of Volga-risk available, trading shorter-dated options would be associated with a higher expected PnL. Maturity sensitivity of Volga relative to Gamma and Vega Greeks needs to be accounted for when gauging expected PnLs for an actual portfolio. Some details on the calculation of Volga and other Greeks, especially as far as smile adjustments are concerned, will be reported into Appendix I. We anticipate that, unlike for Gamma, the typical Volga sensitivity for a fixed-delta plain vanilla option combination (like straddle vs strangle) that trades wings vs. ATM vol typically rises with maturity, although Vega-like sensitivities to change in smile parameters will rise, too. The tighter vol-vol premium is therefore balanced by a rising Volga exposure for rising maturities or, in other words, longer-dated options could allow budgeting the same unit of Volga risk by reducing the notionals associated with short OTM vol positions. In general, while short-maturities are preferred from a vol-of-vol premium perspective, maturity and strike sensitivities of Greek letters will require a careful examination of a portfolio's risk exposure in order to optimize the set of parameters involved (maturities, relative notionals, and, when trading plain vanillas, also strikes/deltas).

Average behaviour tends to be quite consistent across different USD/G10 pairs, implying that the effect we are highlighting is well established and not resulting from specific idiosyncrasies taking place in a few sparse cases. We recall for readers that the analysis above assumes the possibility of trading at mid, and that impact of costs might be very much penalizing at the very front-end of the curves. The direct assessment on impact of costs in the second part of this piece will clarify which maturities offer the best ex-post performance measures.

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Convexity adjustment (or vol-of-vol of vol…) adversely impacting short-Volga trades

We have seen that, even after accounting for term-structure adjustments (and before costs), implied vol-of-vol structurally trades above realized vol-of-vol, which, thanks to the earlier formula, leads to the notion of a risk premium on that parameter. In the table above, the premium was simply estimated as the difference between long-term averages of implied and realized vol-of-vols. The question we ask ourselves now is how to properly estimate that premium by accounting for the fact that the payoff for the short-Volga trade is quadratic in the parameters. When taking expectations (for simplicity, PnL_{Volga} below stands for the *short-Volga* position):

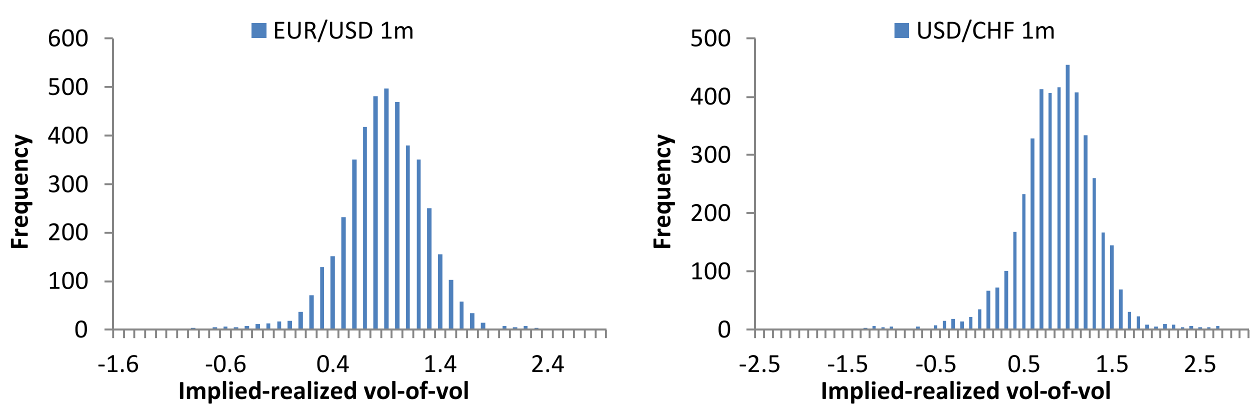
$$E(PnL_{Volga}) \approx E({\nu^2}_{imp} - {\nu^2}_{real})$$

the latter terms could be estimated via the squares of the expected values only in the limit were the parameters are constant, i.e. with zero volatility. Jensen's inequality allows accounting for the impact of the fluctuations, which will grant a more reliable estimate of the premium when trading such quadratic payoffs. The convexity adjustment can be analytically estimated by assuming that ν_{imp}, ν_{real} are Gaussian variables $\nu_{imp} = N\left(\overline{\nu_{imp}}, \sigma_{imp}\right),\ \nu_{real} = N(\overline{\nu_{real}}, \sigma_{real})$, leading to

$$E\left(PnL_{Volga}\right) \approx \overline{\nu_{imp}}^2 - \overline{\nu_{real}}^2 + {\sigma_{imp}}^2 - {\sigma_{real}}^2$$

Having assessed that on average the premium is positive ($\overline{\nu_{imp}}^2 - \overline{\nu_{real}}^2 > 0$), the formula shows that the impact of the convexity adjustment simply depends on the relative magnitude of fluctuations for vol-of-vol quantities.

Exhibit 9: Distribution of implied-realized vol-of-vol for EUR/USD and USD/CHF shows a clear fatter left-tail



Source: J.P. Morgan Quantitative and Derivatives Strategy

We start by considering a couple of case studies (Exhibit 9), showing the historical distribution of $\nu_{imp} - \nu_{real}$ for 1m EUR/USD, USD/CHF. For any starting date, we compare the initial value of the implied parameter with the corresponding parameter realizing over the future 1m period. In both cases, the distribution of the difference is centred around a positive value. However, the distribution of the fluctuations is clearly skewed to the left, suggesting a higher volatility for the realized parameter over the implied one, and a positive skew in the distribution of the vols: when "surprise" moves happen, that is on the upside. While the effect is barely visible for EUR/USD (LHS chart), the left tail is considerably fatter for USD/CHF (RHS chart), especially as a result of the SNB removing the CHF peg on EUR in January 2015.

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Exhibit 10: Adjusted estimate of vol-of-vol premium in presence of statistical fluctuations

Fluctuations are computed as long-term standard deviations of corresponding parameters. Volvol quadratic premium (%) is measured based on the formula above.

		EUR/USD	GBP/USD	USD/JPY	USD/CHF	USD/CAD	USD/NOK	USD/SEK	AUD/USD	NZD/USD
1m	imp-fluctuations	0.26	0.27	0.31	0.33	0.22	0.21	0.22	0.24	0.25
	real-fluctuations	0.36	0.38	0.43	0.41	0.31	0.38	0.37	0.38	0.37
	Volvol quadratic premium (%)	66.7%	67.4%	67.7%	65.8%	67.6%	64.0%	63.7%	63.2%	62.1%
3m	imp-fluctuations	0.16	0.16	0.19	0.21	0.15	0.12	0.12	0.18	0.17
	real-fluctuations	0.22	0.24	0.27	0.27	0.20	0.25	0.23	0.25	0.24
	Volvol quadratic premium (%)	59.2%	59.0%	60.4%	56.3%	59.0%	54.5%	55.0%	58.4%	57.3%
6m	imp-fluctuations	0.13	0.13	0.14	0.16	0.11	0.09	0.09	0.15	0.14
	real-fluctuations	0.17	0.17	0.19	0.21	0.15	0.19	0.16	0.18	0.18
	Volvol quadratic premium (%)	58.7%	58.6%	59.1%	54.7%	59.8%	52.6%	54.0%	60.2%	59.6%

Source: J.P. Morgan Quantitative and Derivatives Strategy

Exhibit 10 considers the same case study as Exhibit 8, but by focusing on the estimation of sample volatilities for the parameters. We see that consistently across pairs and maturities the sample volatility of realized vol-of-vol is higher than for the corresponding implied parameter. Based on the formula above, this leads to a narrower estimate of the vol-of-vol premium when taking into account fluctuations. Still, the latter remains positive for all cases considered – in the table, the quadratic "Volga" premium is calculated in % terms as per

$$Quadratic\ Volga\ premium\ (\%) = (\overline{\nu_{imp}}^2 - \overline{\nu_{real}}^2 + \sigma_{imp}{}^2 - \sigma_{real}{}^2)/\overline{\nu_{imp}}^2$$

Quantitatively, we see how a proportion ranging from 50% to roughly 70% of the pricing of vol (actually, variance) convexity could be interpreted as a genuine premium. This more accurate estimate allows us to assess that, as introduced earlier, the volvol premium tends to be wider for short-dated options. We recall that calculations for estimating fluctuations are performed by using daily data.

Even when taking into account the term structure and fluctuations adjustments as reviewed above, it appears clear that there should be room for testing these short vol-convexity strategies in practice. We have already discussed how, beyond market-making desks, which are capable of accessing liquidity at favourable conditions, the idea of taking into account the impact of costs will be mandatory for the strategy to be relevant for final investors. Rather than trying to encompass the impact of costs via an additional formula, we'll leave it to the brute force calculation overviewing long-term backtests to assess what portion of the zero-cost premium would be left there to harvest. Before addressing the topic in the second part of this note, in the following we will review a few possible implementations of the short vol-of-vol theme via plain vanilla and exotics payoffs.

Linking vol-of-vol parameters to plain vanilla and exotics pricing

Results shown so far in the piece generally support the implementation of trading strategies that systematically sell the vol-of-vol parameter, especially on short maturities. No-arbitrage conditions within pricing models require a common sensitivity of plain vanilla and exotic products to first principle vol dynamics/smile parameters. Before reviewing actual backtests, in the following section we will review which option structures can offer the desired short vol-of-vol exposure.

Plain vanillas' sensitivity to vol-of-vol parameter

Vol-of-vol parameter has a direct impact on volatility smiles, pushing volatility convexity higher, leading to higher OTM vols vs. ATM vol, as discussed in Appendix II. In Appendix I, it is shown how, for the smile expansion ($x = \log(K/S)$ is the log-moneyness):

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$$\sigma(x, \sigma_0) = \sigma_0(1 + a(\sigma_0)x + \frac{b(\sigma_0)}{2}x^2)$$

Under the limit of zero skew (i.e., $a = 0$) one has:

$$\nu^2 = 3\sigma_0 \frac{\partial^2 \sigma}{\partial x^2}|_{x=0}$$

therefore proving the link between implied vol-of-vol and smile convexity (and the fact that the latter needs to be positive) and therefore the fact that higher vol-of-vols lead to higher values of OTM options vs. ATM ones. The interpretation can be made more intuitive when considering Monte Carlo simulations that relate a volatility of volatility parameter with the fatness of the distribution in the tails. Furthermore, one can formally prove that the kurtosis of a Gaussian variable η (with zero expected value) subject to a stochastic volatility σ is strictly positive:

$$\bar{\kappa} = \frac{\overline{< \eta^4 >}}{\overline{(< \eta^2 >)^2}} - 3 = 3(\frac{\overline{\sigma^4}}{\overline{\overline{(\sigma^2)^2}}} - 1)$$

A stochastic volatility, with $\overline{\sigma^4} > (\overline{\sigma^2})^2$, naturally induces a positive kurtosis $\bar{\kappa}$. In the formula, we have referred to $< \cdots >, \overline{(\ldots)}$ as averages over return, volatility random processes, respectively.

Based on these results, we list a set of practical takeaways that should allow investors to benefit from elevated vol-of-vols when trading plain vanilla options. Comments above, and the fact that the Volga exposure of risk rises for OTM options (see Appendix I), are more supportive of selling volatility on OTM options than ATM ones – we have seen in Exhibit 3, 4 how the volvol premium should be wider than the one for vols, therefore supporting Volga over Gamma exposures (at least under the limit of zero costs). For the purpose of Theta-collection via short delta-hedged options, a yield-enhancing solution widely applied in the real-money space, the latter argument should support the implementation via strangles over straddles. We will share more details on the advantages of strangles over straddles later in the piece.

A second class of "pure vol-of-vol" solutions via plain vanillas, more suited for dedicated derivatives traders, would involve isolating the Volga axis of risk and neutralizing Gamma or Vega sensitivities whose corresponding PnL turns out to be more volatile. This will typically involve trading symmetric (straddle vs strangle) or non-symmetric (ratio spread) structures, where the relative scaling of the long/short legs will play a prominent role.

Exotics (I) – Var and Vol swaps

Here we review how "pure vol", liquid exotic products variance and volatility swaps can allow investors to benefit from elevated implied vol-of-vol parameters. In order to reduce the amount of technical content, we refer to Appendix II where a class of stochastic volatility models is introduced and pick the SABR one for illustrative purposes in the following. More details on the payoffs and the pricing of var and vol swaps are summarized in Appendix III.

Variance swaps are an instrument for betting on the future level of realized variance as experienced by the underlying spot variable over a future interval of time. By virtue of the quadratic expression of the payoff, Variance swaps can be statically replicated with a strip of plain vanilla options, which, in practice, means that the Variance swap strike can be expressed as a well-defined function of the market volatility smile, and that therefore this replication is model-independent. Within the SABR model (with $\beta = 1$), one can find the following analytical formula for the Var swap strike:

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$$K_{var} = \frac{1}{T}\frac{{\sigma_0}^2}{\upsilon^2}\left(exp\left({\nu^2}_{imp}T\right) - 1\right)$$

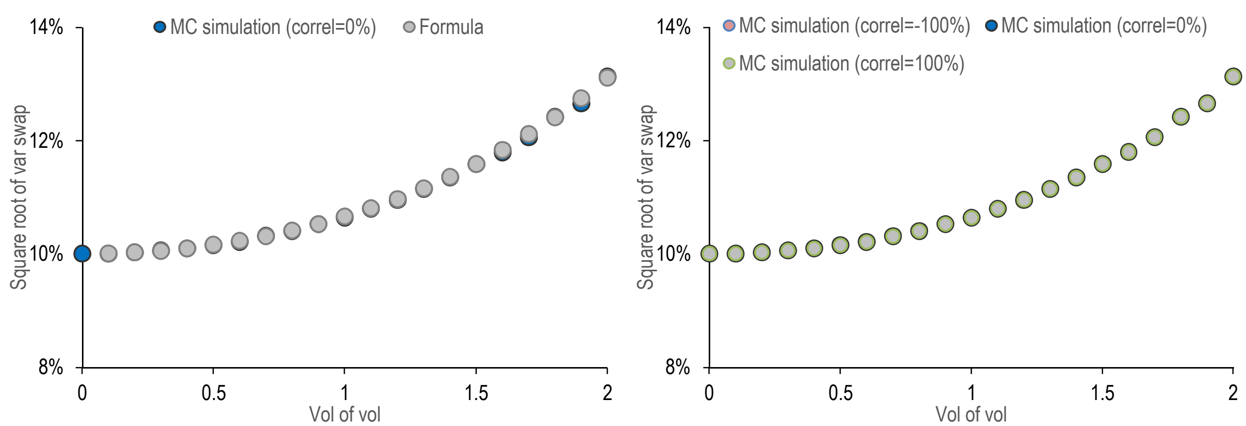
In absence of marked term structure effects, the instantaneous vol σ_0 of the SABR model can represent a good first-approximation of the implied vol σ_{imp} for the maturity at which calibration is performed, with ν_{imp}being the corresponding implied vol-of-vol. For ${\nu^2}_{imp}T \ll 1$, the above leads to:

$$K_{var} = {\sigma_{imp}}^2\left(1 + \frac{{\nu^2}_{imp}T}{2}\right)\ ;\ \sqrt{K_{var}} = \sigma_{imp}(1 + \frac{{\nu^2}_{imp}T}{4})$$

Results above show how the vol-of-vol term introduces a correction for the (square root of) var swap strike from the ATM vol value; this positive correction is expected to be quadratic in vol-of-vol and linear in maturities. However, we have seen how volvol tends to decrease with larger maturities (its vol curve is inverted, see Exhibit 6 and 8), which makes ν^2T grow "slowly". The formula does not exhibit any dependence on skew (or spot/vol correlation) parameter.

This result is consistent with the MC simulations below (Exhibit 11), which confirm a roughly quadratic rise with volvol parameter (LHS) and that there is no sensitivity on the correlation/skew parameter (RHS). Agreement between formula and simulation is also tested across different maturities, but not displayed below. Simulations (sample of 50000) refer to a case study with 3m maturity and where σ_0 is 10%.

Exhibit 11: Monte Carlo simulations confirm the agreement with the analytical formula for variance swap pricing



Source: J.P. Morgan Quantitative and Derivatives Strategy

One can easily show that, assuming that the spot and vol variables follow a SABR process in the statistical measure with vol and vol-of-vol parameters $\sigma_{stat}, \nu_{stat}$, for $\sigma_{imp} \cong \sigma_{stat}$ the statistical expected value of a short variance swap payoff can be approximated as:

$$E_{sta}(VarSwap) = N_{var}(\left({\sigma_{imp}}^2 - {\sigma_{stat}}^2\right) + {\sigma_{imp}}^2\frac{T}{2}\left({\nu^2}_{imp} - {\nu^2}_{stat}\right))$$

The compact formula above shows that a variance swap is in principle exposed to both vol $(\sigma_{imp} - \sigma_{stat})$ and vol-of-vol $(\nu_{imp} - \nu_{stat})$ premia, and that the sensitivity on the latter rises in case of large maturity and elevated smile convexity.

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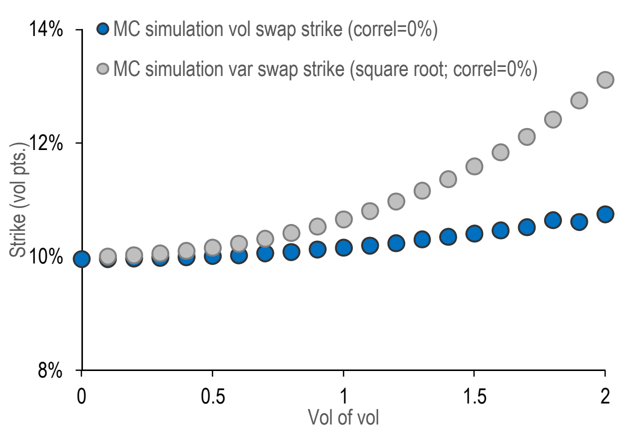
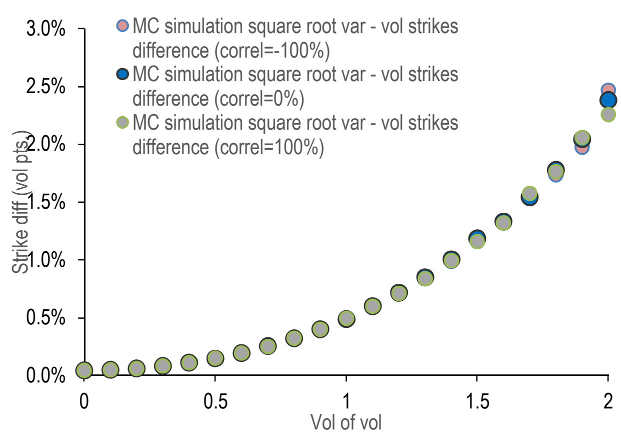
Vol swaps offer an exposure to the realized volatility (i.e., square root of variance) of the underlying asset over a future horizon. Because of the non-linear, square root feature in the payoff, vol swaps *cannot* be statistically replicated, which introduces a dependence of vol *dynamics* beyond market pricing of smiles. In other words, different models would lead in principle to different prices of vol swaps after agreeing with market values of vol smiles. We refer readers to Volatility Swaps, (D.Silvestrini & B.Kaplan, June 2010, JPM Research) for background.

That said, a common result across different pricing models is that, for Vol swaps, vol smile convexity adjustment is less important than for Variance swaps. So, in principle a RV between Var and Vol swap should allow taking a position on the vol-of-vol parameter. This intuition is again confirmed by the MC simulation within SABR (Exhibit 12, LHS) which, again, shows no sensitivity to the skew parameter (RHS chart) for the $\delta_K = \sqrt{K_{Var}} - K_{vol}$ Var/Vol spread.

Convexity adjustment arguments (Jensens's inequality) again can be invoked for showing that stochastic volatility $E(\sigma_R^2) > E(\sigma_R)^2$ leads to $\delta_K > 0$, where σ_R stands for realized volatility at expiry. With the relative scaling above, the short Variance/long Vol swap structure is profitable if $\sigma_R < \sigma_{BE} = \sqrt{K_{Var}} + \delta_K$, where σ_{BE} is the breakeven point in terms of realized volatility. The breakeven point of the RV structure is improved vs. that of the short variance swap trade alone $({\sigma_{BE}}^{Var\ Swap} = \sqrt{K_{Var}})$ thanks to the long Vol swap hedge and to the favorable relative location of the two strikes. Obviously, for comparable units of Vega notionals involved, the PnL of the RV trade will be exposed to lower volatility than that of the outright short vol position.

Exhibit 12: Monte Carlo simulation within SABR shows a weaker vol-of-vol sensitivity for Vol than Var swaps.





Source: J.P. Morgan Quantitative and Derivatives Strategy

The question is then how to scale a short Var/long Vol swap trade in order to isolate vol convexity sensitivity. Academic research (Carr, Lee, 2007) suggests that vol swap sensitivity on vol-of-vol is typically weak, allowing to approximate the vol swap with the ATM vol $K_{vol} \cong \sigma_{imp}$ (i.e., by neglecting the weak vol-of-vol sensitivity as displayed in Exhibit 12 LHS). This would lead to the following functional expression within SABR as:

$$\delta_K = \sigma_{imp} {\upsilon_{imp}}^2 \tau / 4$$

By introducing the RV payoff long vol swap/short variance swap with equal vol notional N_{Vol} on both legs (i.e., by choosing $N_{Var} = N_{Vol}/2\sqrt{K_{Var}}$) one gets:

$$Var_{PO} = N_{Var}(\sigma_R^2 - K_{Var});\ Vol_{PO} = N_{Vol}(\sigma_R - K_{Vol});\ RV_{PO} = Vol_{PO} - Var_{PO}$$

It's straightforward to show that (more details in Appendix IV), at least within SABR and with the approximation above on the vol swap strike, the expected value of the RV payoff in the statistical measure is then just:

$$E_{sta}(RV_{PO}) = N_{Vol}\sigma_{imp}\tau/4({\upsilon^2}_{imp} - {\upsilon^2}_{sta})$$

which precisely offers a pure vol-of-vol premium exposure. We refer to Appendix IV for more details on the RV payoff when one considers a premium between implied and realized vols $\Delta\sigma = \sigma_{imp} - \sigma_{stat}$ and a more general scaling of strikes (via additional parameters α, β) as consistent with SABR/Stochastic Volatility models (Skalli, Youssfi, 2013):

$$K_{vol} = \sigma_{imp}(1 + \alpha\, \sigma_{imp}\ {\upsilon^2}_{imp}\, \tau)\ ;\ \sqrt{K_{var}} = \sigma_{imp}\left(1 + \beta\, \sigma_{imp}\ {\upsilon^2}_{imp}\, \tau\right)$$

One finds that, in the case of large mismatches $\Delta\sigma$ between implied and sample realized vols, the RV trade will be exposed to such "spurious" factor and end up not being a pure vol-of-vol play. The payoff is negatively impacted in the case of large mismatches between implied and sample realized volatility (i.e., large and negative $\Delta\sigma$). Under some approximations, a proxy expression for the RV payoff would become:

$$E_{sta}(RV_{PO}) \cong N_{Vol}\tau(\beta - \alpha)(\sigma_{imp}\left({\upsilon^2}_{imp} - {\upsilon^2}_{sta}\right) + \Delta\sigma\, {\upsilon^2}_{sta})$$

We recall in any case that these results were obtained under the limit where the market follows a SABR dynamic with constant parameters over time – we have seen in an earlier section how the inclusion of fluctuations of implied/realized parameters would likely impose a reduction of the premium estimated under the zero-fluctuation limit, given the higher exposure of Var swap to episodes of large realized volatility. We will consider such RV backtests in the second part of the piece, where the impact of trading costs will be also discussed.

Exotics (II) – Options on options

The implied vol-of-vol parameter has been so far invoked, in the context of plain vanilla and var/vol swap exotic pricing, as a factor leading to fatter-tailed vol smiles, but not as one that could be traded directly. Options on options would grant, via the well-known delta-hedging exercise, the possibility of trading the mismatch between the implied and the realized parameters more or less directly. In the following, we add a few comments on the topic. We refer readers to the piece Options on Implied Volatility (Silvestrini, Kaplan, March 2010, JPM Research) for a more comprehensive overview.

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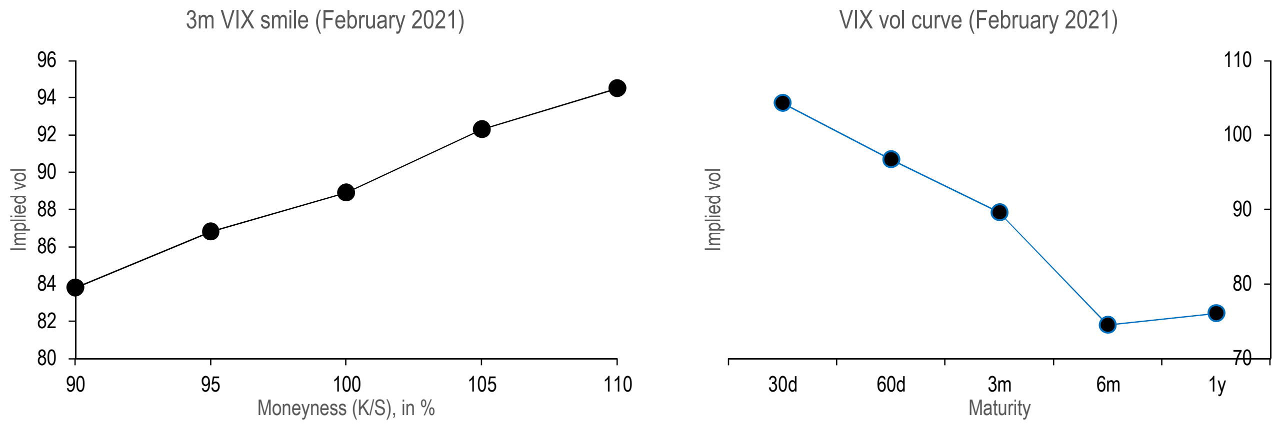
Exhibit 13: Options on the VIX: snapshot of smile and term structure as of February 2021



Source: J.P. Morgan Quantitative and Derivatives Strategy

On the pricing/theoretical side, the main question concerns the link between the implied parameter introduced to drive smile convexity higher and the input required to price options on volatility. While one would intuitively expect a relationship between the two, a sound pricing framework is needed to assess this possible interplay. For instance, a whole smile of implied volatilities is required for pricing options on vols with different strikes, whereas the stochastic volatility model allows pricing OTM options thanks to a single vol-of-vol. Recent academic literature applied to the interplay between S&P and VIX options pricing (see ref. Guyon, Risk, 2020) can shed some light on the link between the two markets, by introducing a self-consistent model allowing the joint calibration of SPX and VIX smiles. One would find that, for VIX options, smile tends to be skewed to the right and vol convexity is not necessarily positive; VIX vol curve is typically inverted, in line with the earlier analysis on FX implied vol-of-vol. A snapshot of VIX options smile and vol curve as of February 2021 is displayed in Exhibit 13.

A few comments are required more on the practical side. Hedging the underlying “delta-one” positions to which an option on vol is exposed would require an underlying liquid futures market on the vols themselves. Futures markets on the underlying implied vols are, so far, available only for the VIX, not for FX and other asset classes, therefore preventing clients from carrying out the delta hedging exercise referred to above: short options on vols would be implemented in “naked” format, which would introduce some additional fluctuations compared to "pure vol-of-vol" trading strategies reviewed in this piece. Also, volumes and liquidity on these options on vol products tend to be much drier than plain vanillas or first generation exotics across asset classes. In FX, there is some liquidity for the market of options on vol swaps. For these reasons, we will just investigate Equity option on option backtests in the second part of the piece.

We recall for readers that many other exotic products could offer a more or less direct exposure to vol-of-vol (we can list at expiry ranges, DNTs, vol swaps with caps), while exhibiting at the same time a different sensitivity to other market parameters (e.g., outright long vs. short vol etc.). That said, for an introductory overview, backtesting analysis will be limited to var/vol swaps reviewed above and VIX options.

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Vol-of-vol strategies after trading costs

Having introduced the required technical background and shed some light on the most theoretical aspects, we now come to the core discussion of how the earlier results can be translated in actual trading or investment solutions. Most of the results will be presented for the FX asset class, where the deep option liquidity on most traded currencies and notoriously elevated smile convexity favour the aforementioned short-Volga theme. Still, we will add some flavour on Equity and Precious metals backtests in a dedicated section. The bulk of the results will be dedicated to plain vanillas but, as introduced in the first part, we will cover RV between Variance and Vol swaps and options on VIX as well. In the following, we will aim to cover the issue of impact of trading costs as accurately as possible, by providing a rather detailed analysis on the relative scaling between short and long vol legs in order to keep impact of costs under control.

Plain vanilla backtests will be covered into four distinct sections. The first one regards the general implications on the vol-of-vol premia for optimizing the strikes of long and short vol trades. A second one details more specifically vol-of-vol strategies and the sensitivity to the relative scalings of the long and short vol legs involved. We then consider calendar strategies and apply a smile-adjustment to the standard “straddle vs. straddle” calendar trade. In a fourth section, we review ratio spread structures whose PnL is due both to vol-of-vol and skew sensitivities. A general discussion of the statistical properties enjoyed by vol convexity strategies is then provided. We finally move to Exotics, with a section dedicated to FX Var vs. Vol swap strategies, and one introducing results for Equities and Precious Metals.

Plain vanillas backtesting settings

We now share more details on how plain vanillas backtests are performed. The vol convexity theme will be exploited via different implementations (possibly involving different maturities and relative scalings) of the long straddle vs. short strangle RV trade. Strangle always refer to the 25delta moneyness that ensures elevated liquidity and avoids some “model-dependence” that can be associated with deep OTM strikes. Throughout the plain vanillas section, all G10 backtests refer to the January 2004 to November 2020 period. The same applies to EM currencies with a few exceptions regarding the starting date: PLN, ZAR, CNH, TWD and RUB (Jan 2016). For the costs, we will assume constant over time 0.3 (0.5) vols wide bid/ask spread (as applied to the higher-Vega leg) and 1 (3) bps wide for delta-hedging for G10 (EM) options. These appear reasonable assumptions, considering that costs could be tighter in high-liquidity/low vol markets and higher during periods of stress. The lower trading costs naturally favour an implementation of smile strategies for more liquid G10 vols.

We cumulate positions by trading daily, and letting each trade each its natural expiry (in order to avoid re-balancing costs). We set a common constraint on the cumulative Vega of the portfolios, especially when different maturities are involved: the sum of all the Vegas of the short legs at inception needs to add up to the unit reference amount. We will express yearly returns for our strategies after imposing such constraints on the Vegas. For the calendars, we assume that we can unwind at market value the longer-dated leg when the shorter-dated one reaches expiry. In practice, the latter assumption could be realistic at times and optimistic during high-vol markets.

Vol convexity premium – general implications for volatility trades

In this section, we show how the notion of a vol convexity premium, as introduced earlier in the piece, can be generally related to the performance of outright long or short volatility trades, as strikes are varied across each volatility surface. Later sections will discuss how more advanced long/short strategies can be constructed in order to isolate a cleaner exposure to such a premium.

Exhibit 14: G10 short-vol strategies, 1m and 3m straddle and 25delta strangles

1m	Straddle			Strangle			3m	Straddle			Strangle		
FX-pair	Return	Vol	Sharpe	Return	Vol	Sharpe	FX-pair	Return	Vol	Sharpe	Return	Vol	Sharpe
EUR-USD	3.0%	7.8%	0.38	5.4%	7.9%	0.69	EUR-USD	1.9%	4.2%	0.44	2.5%	4.2%	0.60
GBP-USD	-4.6%	11.2%	-0.41	-1.0%	10.3%	-0.09	GBP-USD	-0.6%	6.0%	-0.11	0.5%	5.7%	0.08
USD-JPY	2.7%	10.9%	0.24	4.5%	11.0%	0.41	USD-JPY	1.0%	5.5%	0.17	1.7%	5.9%	0.28
USD-CHF	-5.4%	17.3%	-0.31	-2.5%	19.7%	-0.13	USD-CHF	-1.5%	8.6%	-0.18	-0.9%	9.9%	-0.09
USD-CAD	-2.4%	7.4%	-0.33	0.5%	7.4%	0.07	USD-CAD	0.6%	3.5%	0.16	1.0%	3.5%	0.30
USD-NOK	-3.7%	11.3%	-0.33	-2.4%	11.4%	-0.21	USD-NOK	-0.6%	4.9%	-0.11	0.2%	4.9%	0.03
USD-SEK	-1.9%	9.7%	-0.19	0.2%	9.7%	0.02	USD-SEK	0.2%	4.4%	0.05	0.9%	4.4%	0.21
AUD-USD	-3.3%	12.9%	-0.26	-2.2%	13.1%	-0.17	AUD-USD	0.0%	7.4%	0.00	0.4%	7.4%	0.06
NZD-USD	-4.7%	12.7%	-0.37	-3.4%	12.8%	-0.26	NZD-USD	-0.9%	6.9%	-0.12	-0.4%	6.9%	-0.06

Source: J.P. Morgan Quantitative and Derivatives Strategy

The statistical richness of implied vol-of-vol (see for instance Exhibit 8), implies an excessive curvature of vol smiles (this can be seen more explicitly by relying on a class of stochastic vol models, see Appendix II) and should lead to the notion that OTM options offer better value for short-vol trades, with ATM vols better suited for vol-buying purposes. We start by considering the performance of 1m/3m straddles and strangles (25delta) short volatility strategies across USD/G10 pairs (Exhibit 14). As discussed above, notionals are chosen to guarantee the same unit of Vega across different trades. The comparison of return and Sharpe ratio profiles systematically confirms the outperformance of strangles over straddles as instruments for implementing short-vol trades: while the latter trade benefits from just the volatility premium, the former receives a further boost via the extra wings risk premium. Strangles are better suited than straddles for premium harvesting purposes also given their more stable Delta, Gamma profiles, implying a lower path sensitivity for the PnL generation and a reduced impact of delta-related trading costs. For G10 high-beta currencies, the added value of selling vol via the wings appears more muted than for the G4 pairs. 1m options seem to outperform 3m ones from a performance measures standpoint. While we apply similar constraints on the Vegas at inception, the higher returns/vols as corresponding to the shorter maturity instruments are understood via the relatively higher Gamma, the factor mostly responsible for the PnL of the strategies given its exposure to the volatility premium.

Exhibit 15: EM short-vol strategies, 1m and 3m straddle and 25delta strangles

1m	Straddle			Strangle			3m	Straddle			Strangle		
FX-pair	Return	Vol	Sharpe	Return	Vol	Sharpe	FX-pair	Return	Vol	Sharpe	Return	Vol	Sharpe
USD-BRL	12.8%	15.5%	0.82	13.6%	15.7%	0.86	USD-BRL	4.5%	7.2%	0.62	4.7%	7.3%	0.65
USD-MXN	11.4%	14.3%	0.79	12.9%	14.8%	0.87	USD-MXN	4.5%	7.7%	0.59	4.9%	9.1%	0.54
USD-TRY	15.4%	14.5%	1.06	16.1%	16.9%	0.95	USD-TRY	6.4%	7.5%	0.85	6.7%	8.2%	0.81
USD-ZAR	4.8%	13.6%	0.35	7.9%	14.3%	0.55	USD-ZAR	2.8%	6.4%	0.44	3.8%	6.9%	0.56
USD-PLN	2.5%	11.0%	0.23	4.5%	11.5%	0.39	USD-PLN	2.2%	4.9%	0.46	2.5%	5.3%	0.47
USD-HUF	-3.0%	10.6%	-0.28	1.4%	10.9%	0.13	USD-HUF	0.5%	5.0%	0.10	2.1%	5.2%	0.41
USD-KRW	11.7%	11.3%	1.03	12.9%	12.4%	1.04	USD-KRW	4.5%	6.2%	0.73	4.0%	6.9%	0.57
USD-SGD	2.8%	4.9%	0.58	4.2%	4.9%	0.87	USD-SGD	1.9%	2.5%	0.75	2.2%	2.7%	0.84
USD-CNH	3.5%	6.2%	0.57	3.7%	6.4%	0.57	USD-CNH	1.6%	4.1%	0.38	1.5%	4.7%	0.32
USD-INR	14.9%	6.6%	2.24	14.0%	6.9%	2.03	USD-INR	5.4%	3.7%	1.45	5.0%	4.1%	1.21
USD-TWD	10.4%	4.5%	2.33	9.7%	4.8%	2.00	USD-TWD	3.1%	2.4%	1.28	3.0%	2.7%	1.12
USD-IDR	26.4%	10.6%	2.50	23.7%	12.1%	1.95	USD-IDR	8.7%	6.2%	1.41	7.9%	7.3%	1.09
USD-RUB	12.0%	11.7%	1.03	13.3%	13.2%	1.01	USD-RUB	5.7%	5.5%	1.03	5.7%	6.5%	0.88

Source: J.P. Morgan Quantitative and Derivatives Strategy

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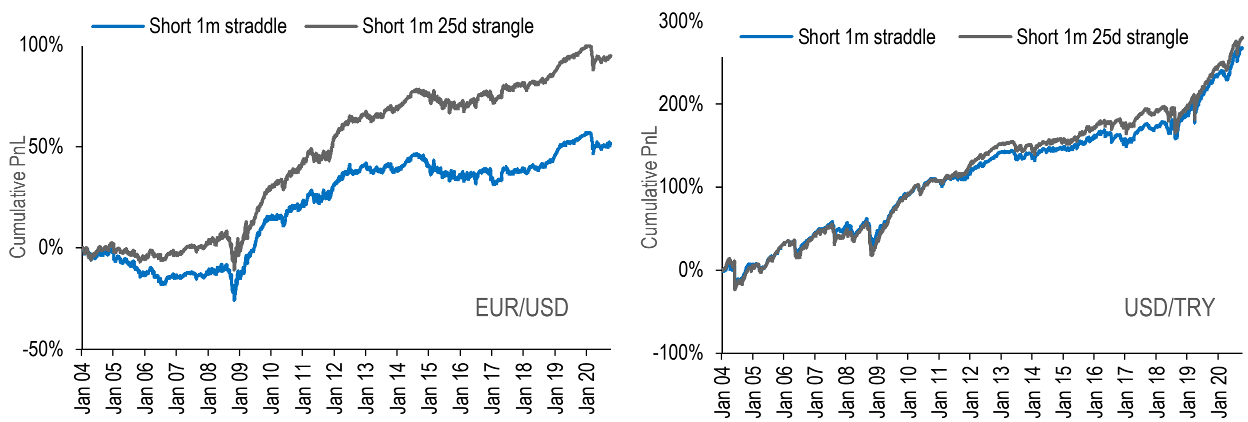
Similar to what we saw for high-beta G10, the added value for EM vols of selling strangles over straddles is much more muted (Exhibit 15). We can interpret that via the multi-sigma moves that EM currencies can occasionally undergo, leading to spikes in vol-of-vol which, due the non-linear payoff sensitivity, can prove impactful to the PnL. The two case studies considered (Exhibit 16), for GBP/USD and USD/TRY, are indicative of this different behaviour between the different groups of currencies.

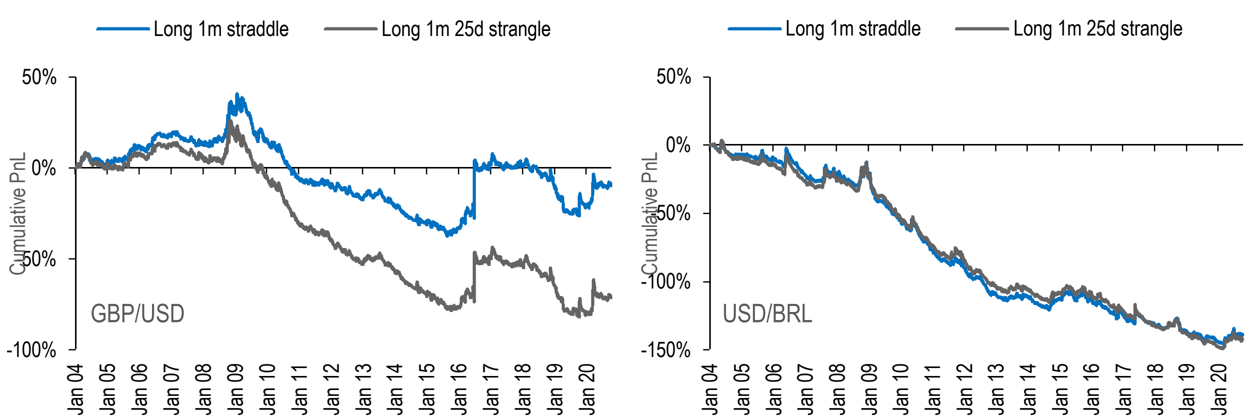
Exhibit 16: Taking an exposure on smile convexity generally brings better value for G10 than EM currencies



Source: J.P. Morgan Quantitative and Derivatives Strategy

Opposite conclusions can be drawn when it comes to considering long vol trades (Exhibit 17). For the same unit of Vega notional, ATM vol ownership is largely preferred across G10 vols, benefiting from occasional outbursts of volatility as we can see from the chart for GBP/USD in 2016 (and similarly for USD/CHF in January 2015), whereas the case study on USD/BRL, as displayed in the chart, suggests that this added value is milder on EM vols in general.

Exhibit 17: When buying vol systematically, straddles offer better value than strangles, especially for G10 vols, given no volvol exposure



Source: J.P. Morgan Quantitative and Derivatives Strategy

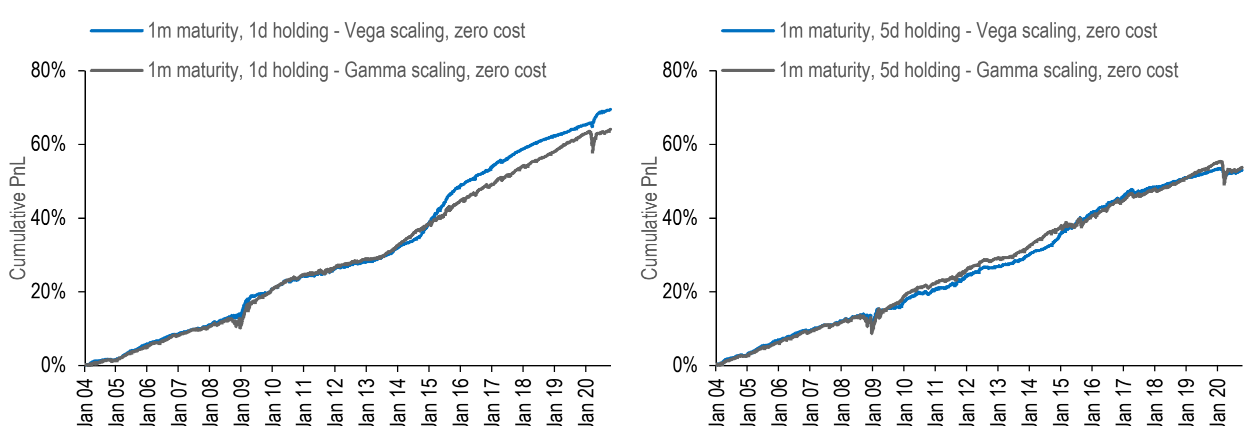
Regarding the sensitivity to the maturity parameter, as displayed in Exhibits 14 and 15, better performance measures are associated with short-volatility strategies of 1m maturity. Results, as presented in the following sections, will support the notion that wider vol/smile premia can be harvested at the front-end of vol curves, although the higher trading costs for very short maturities will target the optimal maturity in the 1m-3m range.

Short-Volga trades – Adjusting the relative scaling of long/short legs

This section sheds more light on how to construct option portfolios for taking a purer exposure to the volvol premium. We expand here on the results first introduced in an earlier short note (*Softer than shadow and quicker than flies*– Ravagli et al, June 2020). We'll start by considering the zero cost case, for reasons that will become clearer as we advance in the discussion. For zero costs, one could constantly re-strike portfolios in a way that the desired short-Volga exposure is maintained intact while hedging other Greeks. The simplest way to achieve that consists of entering short-Volga (at inception) portfolios with a Gamma or Vega neutrality constraint, and unwinding the trades after a short holding period. The formulas, as introduced earlier and more extensively in Appendix I, confirm that a Gamma- or Vega-neutral long straddle/short strangle construct is structurally short-Volga. After imposing Gamma or Vega neutrality, the resulting portfolio has just a modest sensitivity to the other un-hedged Greek, so that the trade is very close to being a pure vol-of-vol one. Holding periods of 1 or 5 (working) days were considered as an illustrative example, ensuring that the pure sensitivity on the desired Greek letter is not polluted by passing of time and path sensitivity.

We can see (Exhibit 18) that, in the limit of zero cost, the short-Volga strategy could deliver impressively smooth returns, confirming the possibility of locking-in the wide volvol premium. The difference between Gamma- and Vega-neutral constraints appears rather modest, with the former case suffering milder drawdowns. It is, on the other hand, much clearer how the 1d holding period (LHS chart) largely outperforms the 5d holding period (RHS chart), as a result of the larger volatility of the latter case, on the back of spurious sensitivities kicking-in, polluting the "purity" of the trade. In order to compare returns, given that we cumulate positions by trading daily, we scale daily positions so that, regardless of the holding period, the portfolio short leg's cumulative Vega is the same (equal to the reference one unit amount). Longer holding periods imply a reduction of returns, too.

Exhibit 18: Short-Volga portfolios with 1d/5d holding periods and Vega and Gamma scalings at inception – 1m maturity



Source: J.P. Morgan Quantitative and Derivatives Strategy

In the limit of zero costs, these short-Volga portfolios would be associated with elevated Sharpe ratios; even higher performance measures could be obtained by imposing the simultaneous constraint of Gamma- and Vega-neutrality, which can be achieved by adding a third option (for instance with a longer maturity) to the constructs.

The possibility of holding RV options portfolios with holding periods of 1 or 5 days would be totally unfeasible from a trading costs perspective, as most market players cannot trade at mid. Therefore, the stringent constraints as described in the case study above, while illustrative for understanding PnL generation dynamics, need to be relaxed for a more realistic trading setting. There are at least two ways for overcoming the limitation above without "re-striking" at a high frequency basis:

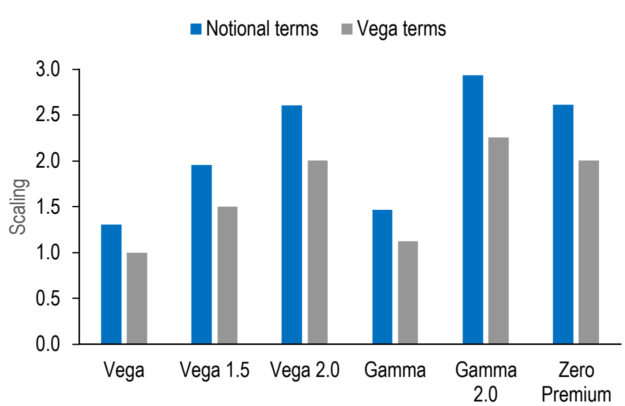
1. When adding new trades (e.g. on a daily basis) one imposes constraints to the Greeks of the overall portfolio. Each new trade is then kept in the portfolio until its natural expiry. One needs to define the rule that allows new trades to be added to the portfolio.
2. Re-striking is naturally done at a lower frequency than weekly, including holding each trade until its natural expiry.

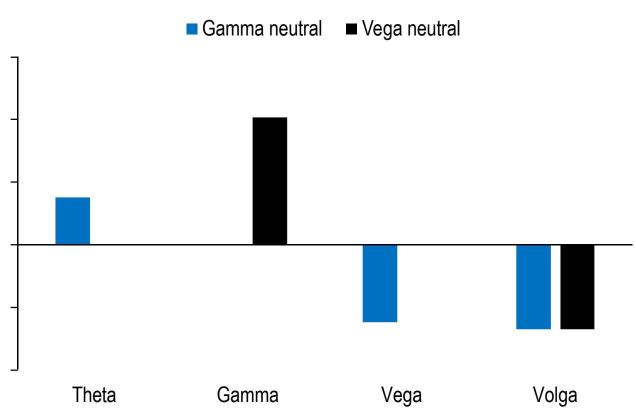
The difficulty of approach 1) consists in a heavy reliance on the rebalancing algo over the "alpha" generation process in itself. For this reason, we prefer relying on approach 2) for illustrative purposes – the quest of a realistic high-frequency rebalancing strategy will be the subject of future research. The main shortcoming of approach 2) is that of a strong path sensitivity, for each trade, regarding the Greeks exposure. A trade that is constructed to be pure short-Volga at inception will necessarily pick spurious sensitivities (most notably, Gamma, Vega and Vanna) over the time before expiry, polluting the "purity" of the desired short-Volga trade. The issue will become more and more severe as the holding period relative to the initial maturity of each trade is increased.

Necessarily, a trade-off is required for balancing the impact of costs vs. the purity of the trades. A way for overcoming the latter issue consists of adjusting the required Gamma or Volga sensitivities of the trades at inception, introducing a natural mechanism to reduce the path-sensitivity issue. While the premium on the Gamma Greek is on paper lower than for the Volga Greek, adding a short-Gamma constraint would make the issue of costs easier to manage.

In the following, we will consider different relative scalings between long and short vol legs, corresponding to different Vega and Gamma constraints on each trade at inception. Each relative scaling will be expressed both in Vega and notional terms, in the tables summarizing the results. By anticipating the case study on EUR/USD, as presented in the next section, Exhibit 19 (LHS chart) shows the Vega and notional ratios (as expressed, short leg vs. long leg) different scaling that correspond to the 1m EUR/USD case, as averaged over 15+ yrs.

Exhibit 19: Different scalings in Notional and Vega terms (EUR/USD 1m case). Portfolio Greeks profiles for different constraints.





Source: J.P. Morgan Quantitative and Derivatives Strategy

The different scalings impact the risk profile of the corresponding portfolios. As an example, for the straddle vs. strangle RV, Vega-neutral is long Gamma, whereas Gamma-neutral is short Vega, while, in both cases, guaranteeing the desired short-Volga exposure (Exhibit 19, RHS – suitable units are used for each Greek). As such, the optimal choice of this parameter could be the result of an optimization process, or based on specific portfolio needs.

The procedure for calculating the Greeks calls for a few extra remarks. The results of the academic piece (Ravagli, 2015) impose a well-specified adjustment to Vega and Gamma in order to isolate the desired Volga sensitivity from other axes of risk (Appendix I). In practice, pricing models might introduce different constraints for adjusting traders' needs. The following results will rely on the internal J.P. Morgan pricing tools, which, by taking into account other requirements (like, constraint on the fat tails of implied distributions), could differ from the formulas and introduce some residual biases in the calculations, especially when adding constraints on Vega or Gamma.

Smile strategies – case study on EUR/USD

We review straddle vs. strangle strategies for isolating a more direct exposure to vol convexity premium. We start with a granular analysis for EUR/USD that, given its elevated liquidity, proves the most natural candidate for testing cost-sensitive smile strategies. We will impose different constraints when scaling the two legs. Vega- or Gamma-neutrality constraints would offer the cleanest exposure to the vol-of-vol premium, as we have seen in the previous sections for the zero cost case, but could be excessively penalised by the impact of trading costs. We then consider a wider range of relative scalings (1:1, 1:1.5 and 1:2 in Vega notionals for long vs. short leg, 1:1 and 1:1.5 in Gamma notionals and equal % premium), where an increased allocation to the short leg will allow better navigation of the impact of costs. The portfolio's resulting exposure to other Greeks than Volga will crucially depend on such scaling, and the higher the allocation to the short leg vs. the long one, the higher the exposure to vol over vol convexity premium.

Exhibit 20: Summary of statistics for smile strategies on EUR/USD

				Straddle		*Smile long/short*		*Smile long/short (zero cost)*	
Maturity	Scaling	Not ratio	Vega ratio	Mean Ret	Sharpe	Smile Mean Ret	Smile Sharpe	Smile Mean Ret	Smile Sharpe
1w	Vega	1.30	1.00	4.5%	0.34	3.5%	0.82	8.4%	1.98
1w	Vega_1.5	1.95	1.50	4.5%	0.34	6.9%	1.34	11.7%	2.29
1w	Vega_2.0	2.60	2.00	4.5%	0.34	8.5%	1.26	13.4%	2.00
1w	Gamma	1.48	1.14	4.5%	0.34	4.6%	1.09	9.4%	2.25
1w	Gamma_2.0	2.96	2.27	4.5%	0.34	8.9%	1.23	13.9%	1.92
1w	Zero Premium	2.61	2.01	4.5%	0.34	8.5%	1.26	13.4%	2.00
1m	Vega	1.30	1.00	3.0%	0.39	0.2%	0.10	2.4%	0.99
1m	Vega_1.5	1.95	1.50	3.0%	0.39	2.1%	0.63	4.3%	1.28
1m	Vega_2.0	2.60	2.00	3.0%	0.38	3.0%	0.69	5.2%	1.21
1m	Gamma	1.47	1.13	3.0%	0.38	0.7%	0.26	2.9%	1.09
1m	Gamma_2.0	2.93	2.25	3.0%	0.38	3.2%	0.68	5.4%	1.16
1m	Zero Premium	2.61	2.00	3.0%	0.38	3.0%	0.68	5.2%	1.21
3m	Vega	1.32	1.00	1.9%	0.45	-0.1%	-0.09	0.6%	0.59
3m	Vega_1.5	1.97	1.50	1.9%	0.45	0.8%	0.49	1.5%	0.93
3m	Vega_2.0	2.63	2.00	1.9%	0.45	1.3%	0.56	2.0%	0.89
3m	Gamma	1.48	1.12	1.9%	0.45	0.1%	0.12	0.9%	0.73
3m	Gamma_2.0	2.95	2.24	1.9%	0.45	1.4%	0.56	2.1%	0.87
3m	Zero Premium	2.58	1.97	1.9%	0.45	1.2%	0.56	2.0%	0.90
6m	Vega	1.32	1.00	1.2%	0.41	0.1%	0.16	0.5%	0.64
6m	Vega_1.5	1.99	1.50	1.2%	0.41	0.7%	0.59	1.0%	0.90
6m	Vega_2.0	2.65	2.00	1.2%	0.41	0.9%	0.60	1.3%	0.83
6m	Gamma	1.48	1.11	1.2%	0.41	0.2%	0.30	0.6%	0.73
6m	Gamma_2.0	2.95	2.23	1.2%	0.41	1.0%	0.58	1.3%	0.80
6m	Zero Premium	2.56	1.94	1.2%	0.41	0.9%	0.60	1.2%	0.85

Source: J.P. Morgan Quantitative and Derivatives Strategy

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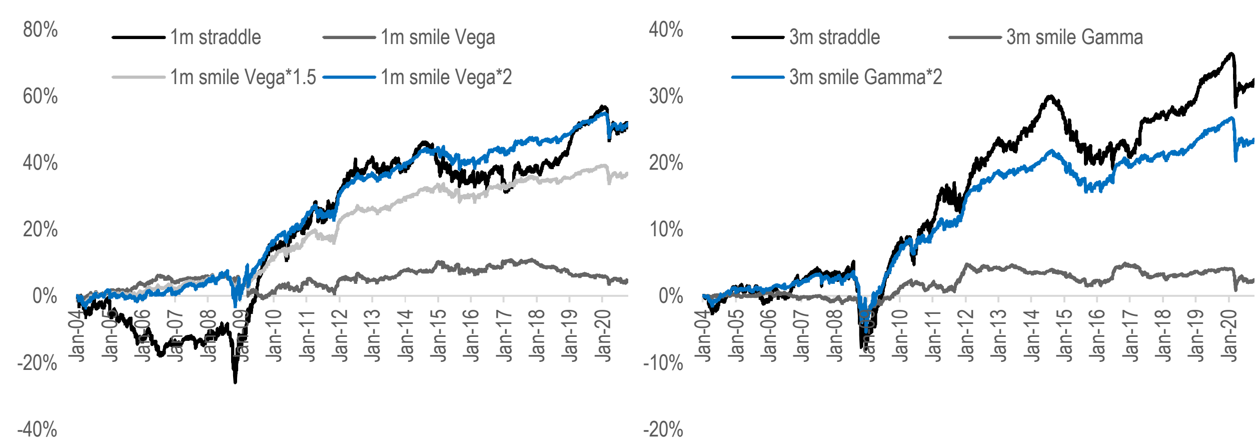
Exhibit 20 summarizes results for such EUR/USD smile strategies. The same maturity parameter for both long and short vol legs is varied from 1w to 6m. We will discuss later the combination of calendar and smile strategies. For each maturity and relative scaling combination, we display ratios of asset currency notionals and of Vega notionals. We then compare performance statistics for the short straddle (with cost) and for the smile long/short strategy (w/wo costs). Regardless of the scaling considered, returns are to be interpreted in relation to the portfolios where the cumulative Vega (at inception) for the short legs adds to the reference unit amount.

In the limit of zero costs, the smile strategies are associated with much higher risk-adjusted measures than for short-straddle strategies, even when the holding period of each trade is set to its natural Expiry. We have seen earlier that the highest performance metrics for zero costs would be achieved by reducing holding periods to 1 day or 1 week in order to mitigate the impact from "spurious" Greeks altering the vol-vol-related PnL. Different scaling mechanisms are associated with similar risk-adjusted metrics under the zero cost limit. As we have seen earlier, Gamma and Vega neutrality constraints are associated with structurally different Theta exposures, whose difference could have an impact on performance measures especially for short holding periods.

Even when accounting for trading costs, smile-adjusted strategies tend to outperform the basic short-straddle position, benchmark of any vol premium-harvesting strategy. With our assumptions on costs, the best backtests correspond to short Expiries (1w and 1m). The comparison with the zero-cost limit shows how, on average, trading costs eat up roughly 50% of the strategy's return. This aspect explains how vol-of-vol strategies require a dedicated attention to trading costs and a privileged access to liquidity for a successful implementation, offering a theoretical edge to market-making desks and clients being able to access tightest spreads. Also, the necessity of managing the impact of costs tilts the optimal scalings towards those that are net short Vega, like -1.5/+1 ones, making the strategies "hybrid" as far as a joint vol and vol-of-vol exposures.

Exhibit 21: Time series of EUR/USD smile-strategies: 1m, 3m maturities



Source: J.P. Morgan Quantitative and Derivatives Strategy

Two time-series case studies might shed some light on the PnL generation process for the different strategies/relative scalings (Exhibit 21). For the 1m (LHS chart) case, we compare short-straddle with three different smile strategies, where different constraints on the relative Vegas are imposed. The Vega-neutral strategy suffers excessively from the impact of costs, but the -1.5/+1 and -2/+1 Vega scalings deliver long-term returns that are comparable with those for the short-straddle strategy, but much less volatile and with less severe drawdowns. For the 3m case (RHS chart), a similar pattern is at play; the smile strategy where a constraint is applied on the Gamma of the portfolio is associated with more volatile returns than for the strategy where a Vega constraint is applied.

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Smile strategies for G10 & EM options

We now move to considering smile strategies for other G10 and EM options, by overviewing the more limited subset of 1m, 3m maturities and -1.5/+1.0 Vega notionals scaling only, for the sake of brevity. The choice is rather arbitrary but covers a setting that displayed interesting properties when applied to EUR/USD, as seen above, allowing us to sustain the impact of costs better than the Vega-neutral or Gamma-neutral scalings. We have categorized these as "hybrid" short vol and vol-of-vol strategies as they carry a net short Vega/Gamma exposure on top of the short Volga exposure.

Exhibit 22: Summary of statistics for smile strategies on G10 vols

1m	*Straddle*			*1/1.5 Vegas smile strat*			3m	*Straddle*			*1/1.5 Vegas smile strat*		
FX-pair	**Return**	**Vol**	**Sharpe**	**Return**	**Vol**	**Sharpe**	FX-pair	**Return**	**Vol**	**Sharpe**	**Return**	**Vol**	**Sharpe**
EUR-USD	3.0%	7.8%	0.38	2.1%	3.4%	0.63	EUR-USD	1.9%	4.2%	0.45	0.8%	1.7%	0.49
GBP-USD	-4.6%	11.2%	-0.41	0.7%	3.4%	0.20	GBP-USD	-0.6%	6.0%	-0.10	0.5%	1.9%	0.23
USD-JPY	2.2%	11.1%	0.20	1.1%	4.4%	0.25	USD-JPY	0.9%	5.5%	0.16	0.5%	2.5%	0.21
USD-CHF	-5.5%	17.3%	-0.32	-0.4%	8.5%	-0.05	USD-CHF	-1.6%	8.6%	-0.18	-0.4%	4.3%	-0.08
USD-CAD	-2.6%	7.5%	-0.35	0.7%	3.0%	0.24	USD-CAD	0.5%	3.5%	0.16	0.2%	1.4%	0.16
USD-NOK	-3.7%	11.3%	-0.33	-2.1%	4.6%	-0.46	USD-NOK	-0.6%	4.9%	-0.12	-0.2%	2.0%	-0.08
USD-SEK	-2.0%	9.7%	-0.20	0.0%	3.9%	-0.01	USD-SEK	0.2%	4.4%	0.05	0.3%	1.8%	0.16
AUD-USD	-3.4%	12.8%	-0.26	-1.4%	5.2%	-0.26	AUD-USD	0.0%	7.4%	0.00	0.0%	2.8%	0.00
NZD-USD	-4.8%	12.7%	-0.38	-1.6%	5.2%	-0.32	NZD-USD	-0.9%	6.9%	-0.13	-0.3%	2.6%	-0.10

Source: J.P. Morgan Quantitative and Derivatives Strategy

We can see Exhibit 22 how, in the vast majority of cases, and especially so for the high-liquidity/low-beta currencies, the smile strategy outperforms the basic short-straddle trade in terms of higher risk-adjusted returns. The added value of the wings-selling trades appears less marked for some of the high-beta currencies (NOK, AUD, NZD) where the occasional jumpy moves in the cash market correspond to multi-sigma moves, therefore questioning the nature of a wings premium. The intuition of a possible link between market liquidity and wings premia is appealing but would require further investigation to be properly addressed.

Exhibit 23: Summary of statistics for smile strategies on EM vols

1m	*Straddle*			*1/1.5 Vegas smile strat*			3m	*Straddle*			*1/1.5 Vegas smile strat*		
FX-pair	**Return**	**Vol**	**Sharpe**	**Return**	**Vol**	**Sharpe**	FX-pair	**Return**	**Vol**	**Sharpe**	**Return**	**Vol**	**Sharpe**
USD-BRL	13.1%	15.5%	0.84	2.5%	6.2%	0.40	USD-BRL	4.7%	7.2%	0.64	0.9%	2.9%	0.32
USD-MXN	11.5%	14.3%	0.81	2.8%	6.1%	0.47	USD-MXN	4.6%	7.7%	0.60	1.0%	4.2%	0.24
USD-TRY	15.5%	14.6%	1.06	3.4%	8.3%	0.41	USD-TRY	6.4%	7.5%	0.85	1.7%	3.8%	0.43
USD-ZAR	4.8%	13.6%	0.35	2.2%	6.1%	0.36	USD-ZAR	2.8%	6.4%	0.44	1.1%	3.1%	0.35
USD-PLN	2.5%	11.0%	0.23	0.3%	5.1%	0.06	USD-PLN	2.2%	4.9%	0.46	0.2%	2.5%	0.07
USD-HUF	-3.1%	10.6%	-0.29	0.8%	4.7%	0.16	USD-HUF	0.5%	5.0%	0.09	0.9%	2.3%	0.38
USD-KRW	11.7%	11.3%	1.03	2.4%	5.4%	0.45	USD-KRW	4.5%	6.2%	0.73	0.0%	3.1%	0.00
USD-SGD	2.8%	4.9%	0.58	-0.2%	2.0%	-0.12	USD-SGD	1.9%	2.5%	0.75	0.2%	1.2%	0.14
USD-CNH	3.5%	6.2%	0.57	-1.7%	2.4%	-0.68	USD-CNH	1.6%	4.1%	0.38	-0.5%	2.0%	-0.23
USD-INR	14.8%	6.7%	2.22	1.4%	3.0%	0.46	USD-INR	5.3%	3.7%	1.44	0.5%	1.8%	0.28
USD-TWD	10.4%	4.5%	2.33	0.0%	2.2%	-0.02	USD-TWD	3.1%	2.4%	1.28	0.0%	1.3%	0.00
USD-IDR	26.5%	10.5%	2.51	3.5%	5.8%	0.60	USD-IDR	8.8%	6.2%	1.42	1.2%	3.4%	0.35
USD-RUB	12.0%	11.7%	1.03	2.7%	6.5%	0.42	USD-RUB	5.7%	5.5%	1.03	1.1%	3.2%	0.35

Source: J.P. Morgan Quantitative and Derivatives Strategy

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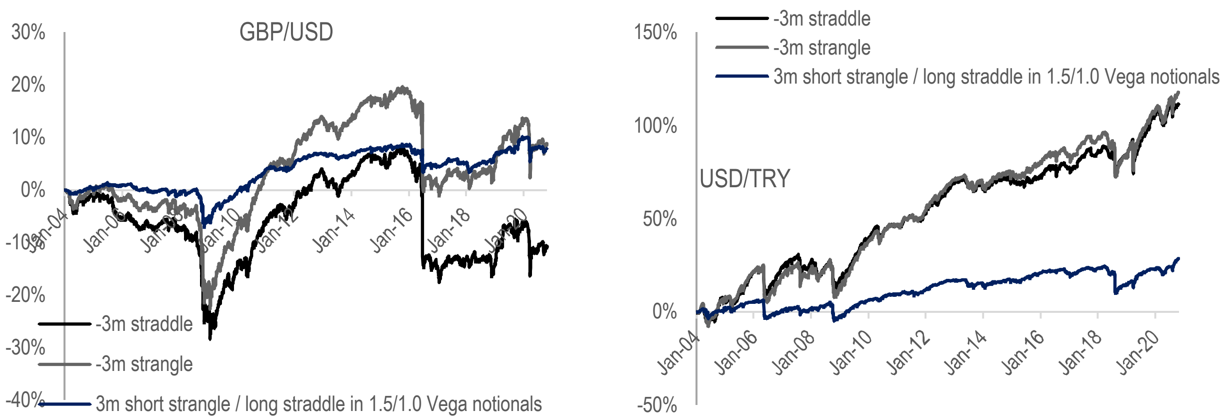
For EM currencies (Exhibit 23) the higher impact of vol trading costs and the more frequent occurrences of liquidity-squeeze episodes reduce considerably the appeal of the short-wings strategies. 0.5 vol wide costs on CNH might prove too conservative an assumption given the low vol nature of the pair (vs. USD). In some cases (like USD/TWD), the outright underperformance of short-strangle vs. short-straddle strategy prevents the possibility of scooping any extra premium via the wings. For most EM currencies herein presented, results are heavily impacted by the convexity crash as witnessed in spring 2020.

Exhibit 24: Two time series examples show the different performance of smile strategies for G10 and EM currencies



Source: J.P. Morgan Quantitative and Derivatives Strategy

Two time series examples (Exhibit 24) can help show the different behaviour of the smile strategies depending on the nature of the currency. The short wings strategy largely outperformed the short vol ones (both straddle and strangle) across the 2016 Brexit referendum episode, matching the short-strangle long-term return but with much lower volatility and drawdowns. The added value of selling strangles over straddles, in case of USD/TRY, is rather modest, consequently limiting the potential of -1.5/+1 short wings strategy.

Smile-adjusted calendars

Calendar strategies positioning for steeper volatility curves can mitigate directional risk as associated with outright short-Gamma trades. Such calendar strategies are known to be particularly effective when the Gamma segment of vol curves is artificially guided by central banks, aiming to monitor/control the level of spot realized volatilities, as it often occurs for EM currencies (see for instance *Front-end USD/CNH vol a high-conviction short*, Sandilya, Feb 2020). Academic literature (Della Corte, Sarno, Tsiakas Journal of Financial Economics, 2011) confirms the existence of a structural bias, at least for the FX market, related to the overvaluation of implied forward volatilities relative to the future level of spot implied volatilities.

While the bulk of this piece is dedicated to smile rather than vol curve dynamics, it is natural to investigate how the interplay of the two effects could be exploited for boosting returns from a systematic implementation standpoint. We therefore reprise the analysis of an earlier piece (*Smiling at vol curves*, July 2020), where the idea of applying a smile adjustment to short-front/long-farther end calendar trades was first introduced.

As we have seen earlier, the relative scaling of the long and short legs, in terms of Vega notionals, is a crucial parameter for defining the overall risk-exposure of the resulting portfolio and its capacity of weathering the adverse impact of trading costs. The matter is further complicated by the marked maturity dependency of the typical Greeks involved in the risk-management process of such trades, a topic that would deserve a discussion on its own.

We start by showing a rather detailed matrix of statistics applying a smile twist to the calendar strategies, by focusing on EUR/USD only. Calendar considered are -1w/+1m, -1m/+3m, -3m/+1y and -6m/+2y. The benchmark implementation of the calendars is in straddle vs. straddle format, whereas the smile-adjusted one relies on strangles as the vol-selling leg. For this rather exhaustive case study, we consider the 6 different relative scalings of the two legs as introduced earlier. We add new trades on a daily basis keeping them in the book until the expiry of the short-leg. Conventions adopted is that PnLs are expressed in % terms, assuming a constant Vega for the short leg on each of the new trades (we assume that the sum of all the Vegas at inception adds to a reference unit Vega).

By looking at the full set of results (Exhibit 25), we see that the added value of using strangles rather than straddles for the funding leg appears structural. The added value is more marked for the front end segment of the vol curves, although here the sensitivity on trading costs might be higher than for the body of the curve.

Exhibit 25: EUR/USD calendar strategies – smile-twist systematically adds value

			Short straddle vs. long straddle				Short strangle vs. long straddle			
Ten_s	Ten_l	Scaling	Not ratio	Vega ratio	Mean ret	Sharpe	Not ratio	Vega ratio	Mean ret	Sharpe
1w	1m	Vega	2.10	1.00	3.0%	0.31	2.73	1.00	11.4%	1.27
1w	1m	Vega_1.5	3.15	1.50	3.5%	0.32	4.10	1.50	11.9%	1.18
1w	1m	Vega_2.0	4.20	2.00	3.7%	0.33	5.47	2.00	12.2%	1.14
1w	1m	Gamma	0.48	0.23	-2.8%	-0.24	0.71	0.26	6.1%	0.63
1w	1m	Gamma_2.0	0.96	0.46	0.9%	0.13	1.41	0.52	9.6%	1.40
1w	1m	Zero Premium	2.12	1.01	3.1%	0.32	5.53	2.02	12.2%	1.15
1m	3m	Vega	1.72	1.00	0.3%	0.06	2.24	1.00	2.8%	0.67
1m	3m	Vega_1.5	2.58	1.50	1.2%	0.23	3.36	1.50	3.7%	0.73
1m	3m	Vega_2.0	3.45	2.00	1.6%	0.28	4.49	2.00	4.1%	0.73
1m	3m	Gamma	0.58	0.34	-5.5%	-0.59	0.85	0.38	-2.4%	-0.29
1m	3m	Gamma_2.0	1.15	0.67	-1.2%	-0.31	1.69	0.75	1.6%	0.40
1m	3m	Zero Premium	1.77	1.03	0.5%	0.11	4.61	2.06	4.2%	0.75
3m	1y	Vega	1.99	1.00	0.9%	0.41	2.62	1.00	1.6%	0.68
3m	1y	Vega_1.5	2.99	1.50	1.2%	0.48	3.93	1.50	1.9%	0.72
3m	1y	Vega_2.0	3.98	2.00	1.4%	0.48	5.24	2.00	2.0%	0.70
3m	1y	Gamma	0.49	0.24	-2.4%	-0.23	0.72	0.27	-1.4%	-0.16
3m	1y	Gamma_2.0	0.97	0.49	-0.2%	-0.06	1.44	0.55	0.6%	0.15
3m	1y	Zero Premium	2.09	1.05	1.0%	0.46	5.39	2.06	2.1%	0.71
6m	2y	Vega	1.97	1.00	0.7%	0.56	2.62	1.00	1.2%	0.84
6m	2y	Vega_1.5	2.96	1.50	0.9%	0.60	3.92	1.50	1.4%	0.89
6m	2y	Vega_2.0	3.95	2.00	1.0%	0.55	5.23	2.00	1.4%	0.81
6m	2y	Gamma	0.48	0.24	-0.9%	-0.09	0.70	0.27	-0.3%	-0.04
6m	2y	Gamma_2.0	0.95	0.48	0.2%	0.05	1.40	0.54	0.7%	0.22
6m	2y	Zero Premium	2.06	1.04	0.8%	0.58	5.27	2.02	1.4%	0.82

Source: J.P. Morgan Quantitative and Derivatives Strategy

As mentioned earlier, the sensitivity of the risk-adjusted returns on the scaling rule (i.e., the negative results associated with the Gamma-neutral constructs) can be understood via the maturity sensitivity of the Greek letters (i.e., a Gamma-neutral calendar is long Vega). With these caveats in mind, the results presented suggest the value of such smile-adjusted calendars for systematic implementation purposes.

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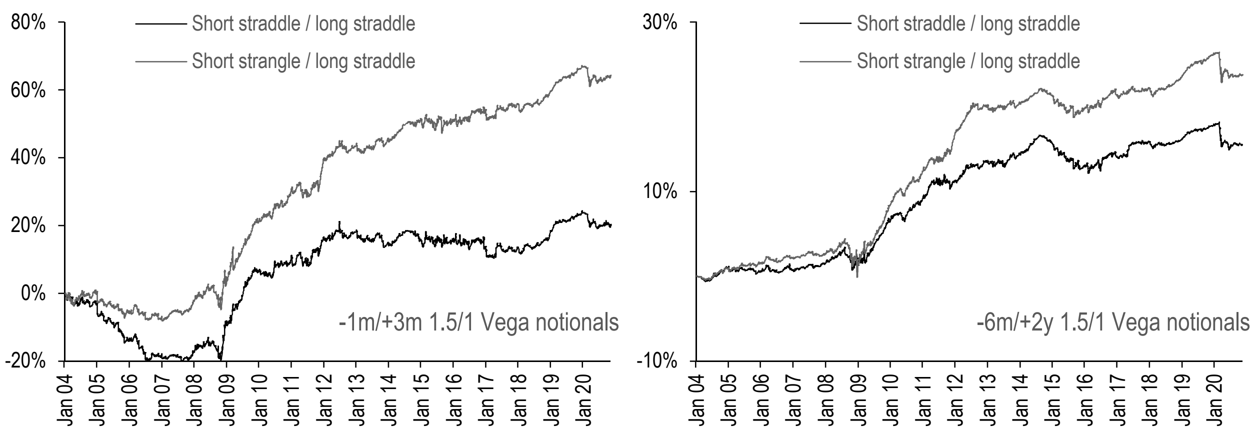
Two case studies we consider (Exhibit 26) confirm the smooth PnL can be generated by these strategies. One possible issue associated with vol steepening calendars is that, during the risk-aversion period, vol curves invert and the hedge as provided by the long-dated might prove only partially effective. Harvesting a premium on the smile jointly with one on the curve could in principle lead to an accumulation of risk difficult to manage during crisis episodes. Such accumulation of risk appears manageable at least for the EUR/USD case, as per the two time series charts.

Exhibit 26: Time series EUR/USD – 1m/3m and 6m/2y in 1/1.5 Vega notionals



Source: J.P. Morgan Quantitative and Derivatives Strategy

Results for a subset of the calendar strategies (-1.5/+1 Vega ratios for -1m/+3m and -6m/+2y maturities) as applied to the wider USD/G10 space (Exhibit 27) confirm the conclusion of the EUR/USD case, with an added value of the smile adjustment when applied to calendar strategies.

Exhibit 27: Stats – G10 1m/3m, 3m/1y 1/1.5 Vegas

1m/3m, 1.5/1 Vegas	Straddle vs. straddle			Strangle vs. straddle			6m/2y, 1.5/1 Vegas	Straddle vs. straddle			Strangle vs. straddle		
FX-pair	Return	Vol	Sharpe	Return	Vol	Sharpe	FX-pair	Return	Vol	Sharpe	Return	Vol	Sharpe
EUR-USD	1.2%	2.5%	0.48	1.9%	2.6%	0.72	EUR-USD	0.9%	1.5%	0.60	1.4%	1.5%	0.89
GBP-USD	-0.5%	4.0%	-0.13	0.6%	3.7%	0.16	GBP-USD	0.1%	2.4%	0.05	0.4%	2.2%	0.17
USD-JPY	0.7%	3.6%	0.19	1.5%	3.9%	0.39	USD-JPY	0.6%	2.5%	0.23	0.9%	2.6%	0.34
USD-CHF	-1.5%	6.4%	-0.24	-0.8%	7.7%	-0.11	USD-CHF	-0.1%	3.2%	-0.04	0.2%	3.9%	0.05
USD-CAD	0.2%	2.3%	0.07	0.7%	2.2%	0.32	USD-CAD	0.3%	1.3%	0.24	0.6%	1.2%	0.49
USD-NOK	-0.8%	3.5%	-0.23	0.0%	3.4%	0.00	USD-NOK	0.0%	1.8%	-0.02	0.4%	1.9%	0.22
USD-SEK	-0.2%	3.0%	-0.05	0.6%	3.0%	0.20	USD-SEK	0.3%	1.6%	0.17	0.7%	1.6%	0.45
AUD-USD	-0.1%	4.3%	-0.03	0.3%	4.5%	0.07	AUD-USD	0.4%	2.7%	0.14	0.6%	2.7%	0.21
NZD-USD	-0.7%	4.1%	-0.16	-0.2%	4.2%	-0.04	NZD-USD	0.0%	2.6%	-0.01	0.2%	2.4%	0.07

Source: J.P. Morgan Quantitative and Derivatives Strategy

When broadening further the scope of the analysis, again, the time series analysis for two USD vols (USD/SEK and USD/TRY, Exhibit 28) confirms how, in general, the combination of smile with term structure drivers can lead to PnL profiles that appear absolutely manageable, reducing

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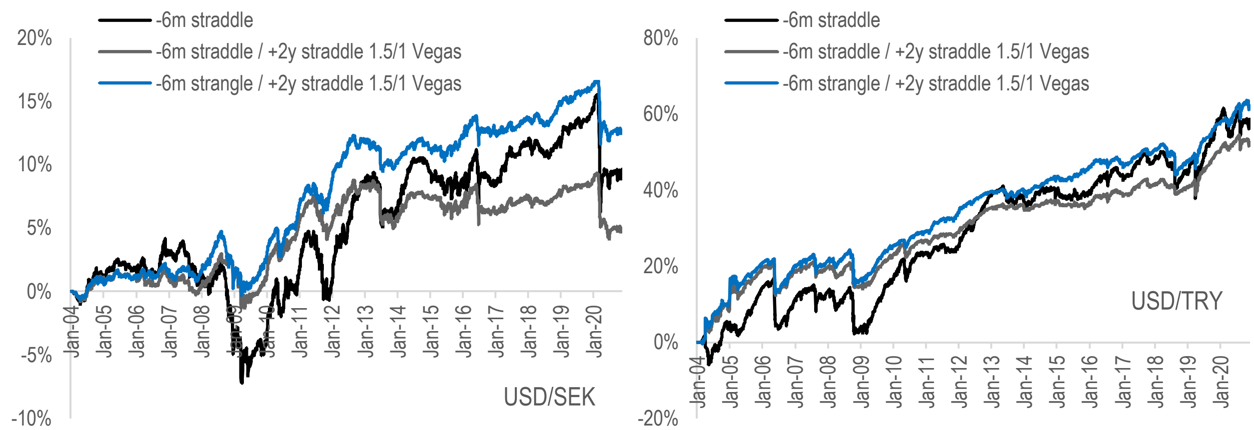
drawdowns if compared to outright short Gamma trades, and especially so via the calendar mechanism.

Exhibit 28: Two case studies of smile adjusted calendar strategies for G10 and EM vols confirm the value of the smile+curve combination



Source: J.P. Morgan Quantitative and Derivatives Strategy

As we discussed earlier, and more specifically for EM (Exhibit 29), the added value of the smile adjustment is less clear-cut, especially at the front-end of the curve, given the jumpy nature of some currencies in this space. Instead, genuine added value could be found in the diversification benefit as introduced within a portfolio of strategies involving EM currencies.

Exhibit 29: Stats – EM 1m/3m, 3m/1y 1/1.5 Vegas

1m/3m, 1.5/1 Vegas	Straddle vs. straddle			Strangle vs. straddle			6m/2y, 1.5/1 Vegas	Straddle vs. straddle			Strangle vs. straddle		
FX-pair	Return	Vol	Sharpe	Return	Vol	Sharpe	FX-pair	Return	Vol	Sharpe	Return	Vol	Sharpe
USD-BRL	3.4%	5.2%	0.66	3.7%	5.2%	0.71	USD-BRL	1.8%	2.9%	0.63	1.8%	3.0%	0.61
USD-MXN	3.4%	4.5%	0.75	3.8%	5.6%	0.67	USD-MXN	2.0%	3.0%	0.67	2.0%	4.0%	0.51
USD-TRY	5.2%	5.3%	0.98	5.4%	5.7%	0.94	USD-TRY	3.0%	4.0%	0.76	3.5%	3.9%	0.90
USD-ZAR	2.1%	4.5%	0.48	3.1%	4.6%	0.68	USD-ZAR	1.1%	2.2%	0.51	1.6%	2.6%	0.64
USD-PLN	1.3%	3.3%	0.40	1.6%	3.7%	0.44	USD-PLN	1.0%	2.0%	0.48	1.2%	2.0%	0.61
USD-HUF	-0.1%	3.4%	-0.04	1.5%	3.6%	0.41	USD-HUF	0.5%	2.0%	0.27	1.2%	2.1%	0.58
USD-KRW	3.4%	3.8%	0.90	2.8%	4.3%	0.65	USD-KRW	1.4%	2.1%	0.69	1.7%	2.5%	0.69
USD-SGD	1.2%	1.6%	0.79	1.6%	1.7%	0.97	USD-SGD	0.7%	1.0%	0.68	1.0%	1.0%	0.91
USD-CNH	0.3%	3.1%	0.09	0.3%	3.7%	0.07	USD-CNH	0.4%	1.9%	0.23	0.4%	2.1%	0.18
USD-INR	4.1%	2.2%	1.91	3.7%	2.4%	1.57	USD-INR	2.1%	1.5%	1.41	2.1%	1.6%	1.36
USD-TWD	2.5%	1.6%	1.59	2.4%	1.8%	1.34	USD-TWD	1.2%	1.0%	1.21	1.3%	1.1%	1.20
USD-IDR	6.8%	3.4%	1.98	6.1%	4.4%	1.40	USD-IDR	3.2%	2.5%	1.28	3.1%	3.0%	1.03
USD-RUB	3.9%	3.3%	1.19	4.0%	4.1%	0.97	USD-RUB	2.1%	2.0%	1.07	2.1%	2.6%	0.82

Source: J.P. Morgan Quantitative and Derivatives Strategy

Three-legged constructs involving a strangle vs. straddle RV of the same maturity and, let's say, a straddle of a longer maturity can be constructed for building short-Volga option portfolios while satisfying the constraint of having zero Gamma and Vega at inception. At least under the zero cost limit, such portfolios are associated with higher risk-adjusted returns than those where residual Gamma or Vega sensitivities are left unhedged. We will investigate the topic in more in depth in future research pieces.

Statistical properties of short vol-of-vol strategies

We now investigate some statistical properties of smile strategies that are relevant for portfolio construction purposes. We start with a closer focus on EUR/USD, given its deep liquidity/suitability for wings selling purposes, and begin illustrating the zero-cost case, as some features are general and can be best expressed under this limit.

We review the correlation properties of short straddle, short strangle and long straddle vs. short strangle in 1:-1, 1:-1.5, 1:-2 Vega weights, for 1m and 3m maturities, with trades held until Expiry (Exhibit 30). A great feature regards the negative correl between pure vol and pure vol-of-vol strats (1:-1 Vega weights) that could lead to huge diversification benefits within a portfolio of vol strategies. When looking at the correlation between straddle and hybrid vol/vol-vol smile strategies (i.e., with vega weights of 1:-1.5 and 1:-2), we find it is positive but lower than between the short-straddle vs. short-strangle strategies, therefore bringing a significant diversification benefit even for these more realistic constructs. We are considering here zero costs, and we have seen that, in the presence of costs, the hybrid vol/vol-of-vol trade might be more realistic from the perspective of handling the impact of costs. When applying portfolio construction/optimization tools to a realistic portfolio of vol strategies, the features above are greatly welcome in reducing the vol of the portfolio for a similar amount of target return. Such properties would also come in handy when assessing the suitability of a vol premia strategy within a broader portfolio of systematic factor-based strategies, especially those with a risk-on tilt, such as carry trades.

Exhibit 30: Correlation matrix for EUR/USD vol and vol-of-vol strategies (long-term correlations computed for zero cost)

Long-term corr	1m straddle	1m strangle	1m Vega	1m Vega 1.5	1m Vega 2	3m straddle	3m strangle	3m Vega	3m Vega 1.5	3m Vega 2
1m straddle	100%	95%	-12%	68%	82%	88%	87%	-4%	71%	80%
1m strangle	95%	100%	19%	87%	96%	90%	92%	9%	81%	88%
1m Vega	-12%	19%	100%	65%	46%	8%	19%	40%	33%	27%
1m Vega 1.5	68%	87%	65%	100%	98%	74%	81%	27%	79%	82%
1m Vega 2	82%	96%	46%	98%	100%	83%	88%	19%	83%	87%
3m straddle	88%	90%	8%	74%	83%	100%	97%	-12%	76%	88%
3m strangle	87%	92%	19%	81%	88%	97%	100%	14%	90%	97%
3m Vega	-4%	9%	40%	27%	19%	-12%	14%	100%	56%	38%
3m Vega 1.5	71%	81%	33%	79%	83%	76%	90%	56%	100%	98%
3m Vega 2	80%	88%	27%	82%	87%	88%	97%	38%	98%	100%

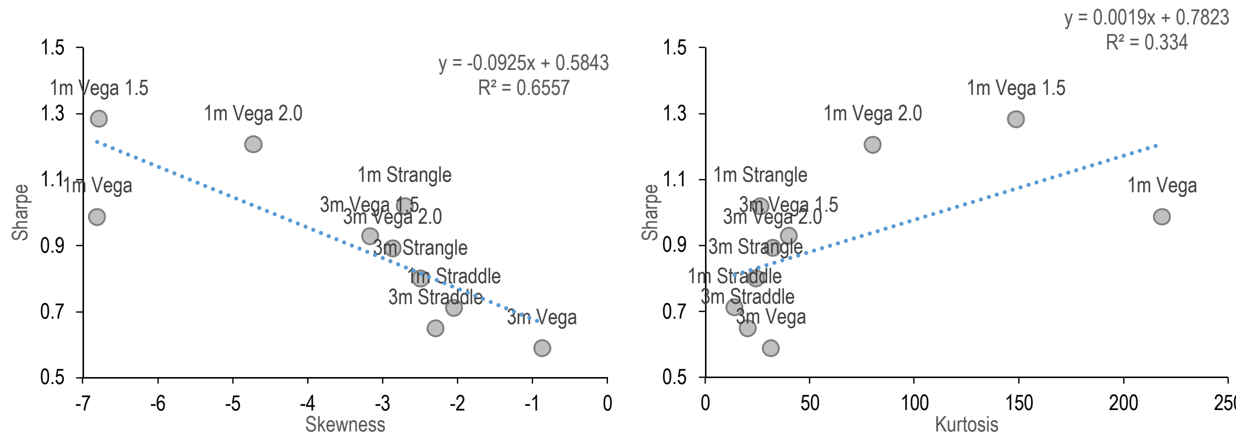
Source: J.P. Morgan Quantitative and Derivatives Strategy

However, the investment space rarely offers free lunches, and that applies even to sophisticated traders. Exhibit 31 explains what the price is one has to pay for taking an exposure to the "de-correlated" vol convexity premium: the higher Sharpe ratios for the strategies exposed to the vol convexity premium come at the price of more unfavourable distribution properties for the corresponding PnL function, with more negative skewness (LHS chart) and higher kurtosis (RHS chart). Both measures are reasonably well correlated with the Sharpe ratio itself, as expressed by decent levels of R2 in a linear regression framework. This result is consistent with previous academic research on the subject (see Bouchaud et al, Risk Premia: Asymmetric Tail Risks and Excess Returns Quantitative Finance, 2017).

Vol buyers are happy to exchange a negative time-decay during benign markets for the prospect of large gains during episodic vol spikes, and the resulting positive skewness is a welcome feature for hedging or portfolio construction purposes. Momentum strategies (*Designing robust trend-*

[following system – Behind the scenes of trend-following](), Tzotchev et al, Feb 2018) are also aimed at providing a similarly favourable exposure to market downturns, with positive skewness.

Exhibit 31: Elevated Sharpe ratios of vol-of-vol strategies come at the price of higher fat-tail risk (more negative skew and higher kurtosis)



Source: J.P. Morgan Quantitative and Derivatives Strategy

When looking at the broader G10 space (Exhibit 32), for a subset of 1m strategies (short straddle and 1/-1 straddle/strangle, both zero costs), correls are generally quite low and typically lower for the strategies having an exposure to the smile than for the straddles. If we take as an example EUR/USD vs. GBP/USD, correl of vol strategies is 46% and of smile strategies 6%, and this is similar across many other pairs.

Exhibit 32: Smile premium allows reducing correlation across different pairs (long-term correlations computed for zero cost)

LT corr	EUR vol	EUR sml	GBP vol	GBP sml	JPY vol	JPY sml	CHF vol	CHF sml	CAD vol	CAD sml	NOK vol	NOK sml	SEK vol	SEK sml	AUD vol	AUD sml	NZD vol	NZD sml
EUR vol	100%	-12%	46%	-3%	2%	-3%	3%	-1%	2%	0%	-1%	1%	0%	1%	0%	0%	46%	2%
EUR sml	-12%	100%	5%	6%	1%	-2%	1%	1%	-1%	-1%	-2%	0%	-2%	3%	-4%	1%	3%	31%
GBP vol	46%	5%	100%	-45%	0%	-2%	1%	-1%	0%	-1%	2%	-2%	2%	2%	2%	-2%	34%	5%
GBP sml	-3%	6%	-45%	100%	4%	1%	2%	2%	5%	3%	2%	1%	1%	0%	0%	2%	1%	6%
JPY vol	2%	1%	0%	4%	100%	-7%	20%	7%	30%	10%	33%	15%	31%	11%	46%	16%	6%	-2%
JPY sml	-3%	-2%	-2%	1%	-7%	100%	3%	8%	2%	6%	7%	3%	7%	1%	10%	0%	0%	-1%
CHF vol	3%	1%	1%	2%	20%	3%	100%	63%	17%	2%	29%	6%	31%	8%	19%	5%	0%	1%
CHF sml	-1%	1%	-1%	2%	7%	8%	63%	100%	5%	7%	11%	8%	11%	13%	7%	5%	0%	-1%
CAD vol	2%	-1%	0%	5%	30%	2%	17%	5%	100%	-13%	45%	7%	39%	12%	49%	7%	1%	-2%
CAD sml	0%	-1%	-1%	3%	10%	6%	2%	7%	-13%	100%	2%	4%	3%	7%	10%	12%	2%	1%
NOK vol	-1%	-2%	2%	2%	33%	7%	29%	11%	45%	2%	100%	-11%	73%	6%	48%	10%	1%	-1%
NOK sml	1%	0%	-2%	1%	15%	3%	6%	8%	7%	4%	-11%	100%	0%	41%	13%	25%	0%	-1%
SEK vol	0%	-2%	2%	1%	31%	7%	31%	11%	39%	3%	73%	0%	100%	-14%	43%	3%	2%	-1%
SEK sml	1%	3%	2%	0%	11%	1%	8%	13%	12%	7%	6%	41%	-14%	100%	13%	21%	2%	-1%
AUD vol	0%	-4%	2%	0%	46%	10%	19%	7%	49%	10%	48%	13%	43%	13%	100%	-6%	5%	-5%
AUD sml	0%	1%	-2%	2%	16%	0%	5%	5%	7%	12%	10%	25%	3%	21%	-6%	100%	-2%	2%
NZD vol	46%	3%	34%	1%	6%	0%	0%	0%	1%	2%	1%	0%	2%	2%	5%	-2%	100%	-10%
NZD sml	2%	31%	5%	6%	-2%	-1%	1%	-1%	-2%	1%	-1%	-1%	-1%	-1%	-5%	2%	-10%	100%

Source: J.P. Morgan Quantitative and Derivatives Strategy

Once again, these results refer to the zero-cost case, and the inclusion of costs would naturally lead to higher correlations and favour the adoption of the more realistic -1.5/+1 scaling for the smile constructs. Yet, conclusions as far as the de-correlated source of positive returns via the smile remain broadly unchanged. Our future research will investigate more in detail the risk-management properties of vol strategies for portfolio construction purposes.

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Ratio spread vol structures

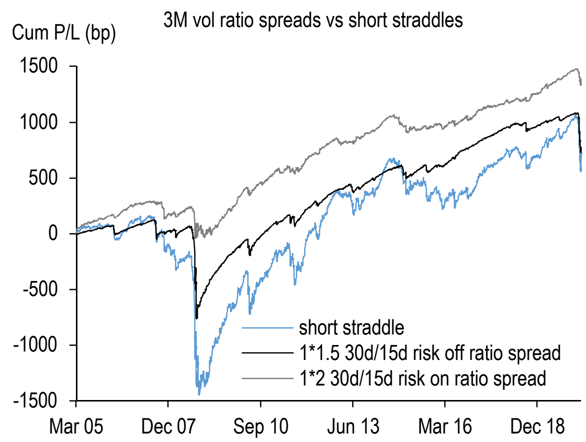
Theta-harvesting strategies via ratio spreads structures were the subject of recent research reports (*All weather vol ratio spreads excel when primed with risk on/off filter*, Jankovic, 1 April 2020; *Oddities in the AUD vol complex*, Sandilya, 30 April 2020). We analyze two types of structures: a) tactical theta collecting via delta-hedged risk off ratio spreads, which is geared toward a risk-supportive environment (e.g., USD/CAD ATM/25D vol ratio call spreads), and b) earning theta without taking left tail risk, which brings income during more vulnerable times (e.g., USD/MXN ATM/25D vol put ratio spread). We look at the performance of such structures across 51 currency pairs (USD, JPY and EUR G10 and EM pairs), two strikes combinations (30d/20d, 25d/10d) and notionals (1*1, 1*1.5 and 1*2 of Vega weights) and add trade timing component based on our custom risk-aversion gamma trading filter. Even a naïve strategy of equal-weighted baskets of vol ratio spreads without filtering or currency selection outperforms the equivalent basket of short straddles over a period of 15 years (Exhibit 33) and shows more favorable long-term risk-adjusted returns and lower drawdowns.

Exhibit 33: Naïve equal-weighted baskets of vol ratio spreads without filtering or currency selection outperformed the equivalent basket of short straddles over a period of 15 years.

Holding period 1-mo. Delta hedged daily with at expiry matched smile forwards. 51 currency pairs (24 USD, JPY and EUR G10, and 13 USD/EM, 5 JPY/EM and 9 EUR/EM pairs). No transaction costs.

performance stats

	short straddle	risk off 1*1.5	risk on 1*2
mean ret	46	50	89
stDev	230	118	90
risk adj ret	0.20	0.42	0.99
Max DD	-1613	-887	-341
Max DD/vol	-7.0	-7.5	-3.8



Source: J.P. Morgan

We find 1xN vol ratio spread structures to be robust vol-vol premium-harvesting strategies that complement long vol portfolios and whose Greeks/risk sensitivities can be tuned with N. We distinguish between two major categories of vol ratio spread constructs: the structures on a) risk-off side of skew and b) risk-on, i.e. weak side of risk reversal. While the resulting skew sensitivities will be opposites (one positive and one negative), both types of ratio spread structure are long ATM/short OTM vol, and therefore offer a natural implementation of the vol convexity harvesting theme.

Earning theta without taking left tail risk

A distinct type of vol ratio spreads is where the short notional is placed on the weak side of the risk reversals. Here, we designate such structures as "risk on" ratio spreads. They are particularly interesting because: a) such structures net earn theta without taking on short high beta tail risk, b) are covered to a fair extent against spikes of high beta volatility given the long risk-reversal sensitivity embedded in the structure (selling OTM "safe" currency, e.g., USD, EUR or JPY puts imparts positive risk reversal sensitivity), and c) are short OTM vs. ATM vol, and therefore can reap the extra premium embedded in the former without taking excessive Gamma/Vega risk.

Exhibit 34 shows a long-term performance analysis across various equal-weighted static currency baskets, notionals sizing (market neutral, vega neutral and 1*2 vega) and FX vol regimes. The exhibit shows detail breakdown for 6M tenor only, but similar behavior is observed for 3M and 12M tenor. A few observations:

- 6M G10 basket performance is solid, returning ~3.5-5 vol/year after transaction cost (TC), interrupted on two occasions only – GFC and the 2014 USD rally. EUR/G10 and JPY/G10 baskets felt quite some pain during the 2014/2015 high vol period, which covers the CHF de-peg. 2017 & 2019 came in line with the long-term low-vol average returns.
- Notably, EM basket performance is weighed down by costs and big underperformers such as SGD and KRW, but as a whole does reasonably well during the major vol shocks.
- The comparison of vega neutral structures (modestly long gamma, neutral vega) with the 1*2s (short gamma, short vega) clearly illustrates the effectiveness in containing negative impact from vol events by tweaking lower the short strike notional.

Exhibit 34: Performance of delta-hedged ratio risk on spreads across static baskets shows EM performance weighed down by transaction costs and big underperformers such as SGD, and KRW.

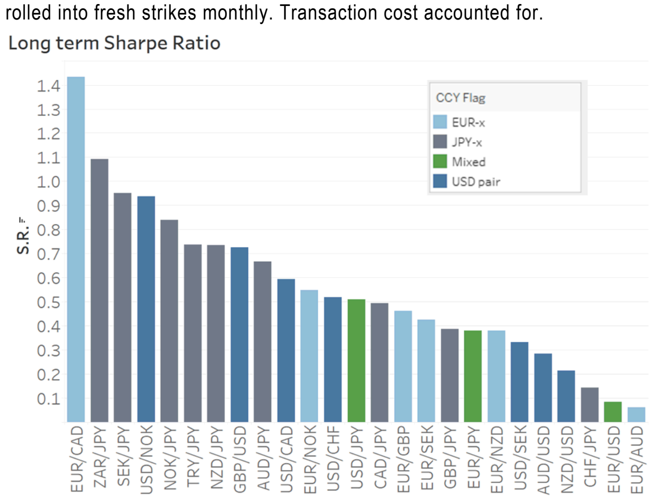
Time period of 15 years: Nov 2004 - present. High vol episodes designate major vol events. All options delta-hedged daily using smile forward deltas and option expiry matched forwards. Positions held for a month. Transaction costs accounted for.

Cumulative P/L (vol pts)		Low Vol	High vol episodes						2017	2019
			GFC	Greece-1	EMU	Greece-2	Taper	USD-rally		
Basket	1:N	14-yrs	9/08-12/08	5/10-7/10	7/11-12/11	5/12-8/12	5/13-8/13	8/14-2/15		
6M Options										
USD/G10	M/N	(13.6)	6.3	(0.1)	2.1	(1.3)	0.8	1.8	(2.3)	(2.0)
	V/N	13.7	1.1	0.5	1.2	0.2	0.5	0.1	(0.1)	(0.0)
	1*2 vega	**56.5**	**(9.5)**	**1.7**	**(1.0)**	**2.8**	**(0.3)**	**(3.7)**	**3.7**	**3.3**
EUR/G10	M/N	(19.2)	6.0	0.2	0.2	(1.0)	0.2	3.6	(2.5)	(2.1)
	V/N	15.4	0.9	0.6	0.0	0.3	0.6	(4.7)	0.4	0.1
	1*2 vega	**67.5**	**(9.6)**	**1.2**	**(1.0)**	**2.7**	**1.1**	**(21.9)**	**5.0**	**3.4**
JPY/G10	M/N	(7.5)	7.9	(0.0)	1.8	(0.7)	(0.6)	0.9	(3.5)	(2.7)
	V/N	15.2	2.6	0.4	0.7	0.5	0.7	(2.8)	(0.4)	(0.4)
	1*2 vega	**41.8**	**(8.3)**	**1.2**	**(2.0)**	**2.6**	**3.0**	**(10.9)**	**4.5**	**3.1**
High Beta G10	M/N	(13.4)	8.3	0.6	1.7	(1.1)	0.7	1.0	(2.8)	(2.1)
	V/N	13.9	2.5	0.9	1.0	0.2	0.7	(1.0)	(0.2)	(0.1)
	1*2 vega	**51.4**	**(9.5)**	**1.3**	**(0.8)**	**2.5**	**0.4**	**(5.7)**	**3.7**	**2.9**
USD/EM	M/N	(55.4)	5.2	(0.4)	1.5	(1.2)	0.1	(0.1)	(4.8)	(4.3)
	V/N	(18.9)	1.1	(0.1)	0.5	(0.3)	(0.0)	(1.1)	(1.9)	(1.3)
	1*2 vega	**15.5**	**(7.8)**	**0.1**	**(2.8)**	**0.8**	**(0.9)**	**(4.8)**	**1.3**	**2.3**
EUR/EM	M/N	(42.6)	8.3	(0.3)	1.6	(1.3)	0.1	0.3	(3.7)	(3.9)
	V/N	(4.6)	1.1	0.4	0.9	(0.4)	0.3	(3.4)	(0.8)	(1.1)
	1*2 vega	**32.3**	**(14.2)**	**1.3**	**(1.7)**	**0.7**	**0.3**	**(12.4)**	**2.3**	**2.0**
JPY/EM	M/N	(39.9)	8.7	0.3	1.6	(1.2)	(0.8)	0.1	(5.5)	(5.2)
	V/N	21.5	(5.4)	0.9	0.1	0.5	(0.3)	(0.4)	(0.2)	(0.2)
	1*2 vega	**106.2**	**(34.3)**	**1.8**	**(4.0)**	**3.4**	**(0.0)**	**(3.1)**	**7.6**	**7.5**
Avg 6M	M/N	(29.7)	7.1	(0.1)	1.5	(1.1)	(0.0)	1.1	(3.7)	(3.4)
	V/N	7.1	0.2	0.5	0.6	0.1	0.3	(2.0)	(0.5)	(0.5)
	1*2 vega	**53.3**	**(13.9)**	**1.2**	**(2.1)**	**2.2**	**0.5**	**(9.5)**	**4.1**	**3.6**
Avg 3M	M/N	(34.0)	7.1	(0.1)	1.7	(1.1)	0.0	1.1	(4.6)	(4.1)
	V/N	16.9	(0.4)	0.7	0.4	0.4	0.4	(3.5)	(0.4)	(0.1)
	1*2 vega	**91.4**	**(16.0)**	**2.0**	**(2.9)**	**3.0**	**0.7**	**(13.9)**	**6.2**	**6.5**

Source: J.P.Morgan

Exhibit 35: High beta (notably Scandies, CAD & AUD) dominates the long-term ranking of vega neutral vol ratio put spreads.

6M expiry options, equal vega notionals. Only currency pairs with 15-yrs Sharpe >0 shown. Structures hedged daily using smile forward deltas and rolled into fresh strikes monthly. Transaction cost accounted for.



Source: J.P.Morgan

Around risk-off episodes, less aggressive call spreads and 1*1.5 ratios are more suitable, and so is avoiding front-end options where spot gyrations c upset skew theta P/L; we then focus on 6M tenor, ~40% slower in harvesting skew decay than 3M. Note that 1*N with N ≤ 1.5 is less inclined to show a blanket positive long-term (15-yr) performance irrespective of currency selection. Exhibit 35 finds high beta (notably Scandies, CAD & AUD) to dominate 15-yr performance.

Exhibit 36: USDTRY 1*2 ratio spreads 10-yr performance during USDTRY spot rallies & selloffs

Annualized P/L (bps) per trade reported. 3-mo holding period. Delta hedged daily at forward delta with expiry matched forwards. No TC.

		Put			Call				
		10	25	atm	atm	25	10	1*2 Put	1*2 Call
Dn	3M	-146	-312	-399	-403	-295	-148	225	186
	6M	-181	-352	-496	-499	-418	-216	208	336
	9M	-194	-368	-519	-523	-456	-250	218	388
	12M	-198	-373	-524	-528	-468	-267	223	408
Up	3M	-17	-25	-33	-30	-43	-13	17	55
	6M	-21	-1	43	47	30	25	45	-13
	9M	-20	17	78	82	70	43	44	-59
	12M	-13	36	108	113	108	65	36	-103

Source: J.P. Morgan

Recently we advocated such a trade in USD/TRY (see *here*). Exhibit 36 runs a long horizon (10-yr) backtest for delta-hedged returns of vanilla USD/TRY options across various tenors and strikes on the surface, and sub-divides them into two categories, according to USD/TRY rallies (designated as Up) and declines (Dn). The intent is to find a structure that fares well as TRY rallies but does not get disproportionately hurt if spot goes the other way. An analysis of long/short combinations of various strike/tenor combinations suggests that simple delta-hedged 1*2 ratio USD put/TRY call spreads show favorably skewed return profiles in spot up vs. down regimes by virtue of being long skew, which mitigates negative impact during the adverse episodes, and due to becoming net short vol (vs being near vega natural at initiation) as USD/TRY moves in risk-on direction, which tends to help the P/L during risk-on episodes.

Exhibit 37: Delta-hedged risk off ratio call spreads have been historically strong income generator outside the GFC episode

Time period of 15 years: March 2005 - present. High vol episodes designate major vol events. All options delta-hedged daily using smile forward deltas and option expiry matched forwards. Strikes 30D/10D. Positions held for a month. Transaction costs accounted for.

Cumulative P/L (vol pts)		Low Vol	High vol episodes						2017	2019
			GFC	Greece-1	EMU	Greece-2	Taper	USD-rally		
Basket	1:N	14-yrs	9/08-12/08	5/10-7/10	7/11-12/11	5/12-8/12	5/13-8/13	8/14-2/15		
6M Options										
USD/G10	M/N	(24.2)	5.8	(0.2)	1.7	(1.7)	0.9	1.5	(3.3)	(2.6)
	V/N	30.0	(8.9)	0.6	0.5	0.8	0.3	(2.7)	1.9	0.3
	1*2 vega	**126.8**	**(38.7)**	**2.1**	**(2.2)**	**5.6**	**(0.9)**	**(11.4)**	**11.4**	**5.3**
EUR/G10	M/N	(28.3)	5.3	0.0	(0.2)	(1.1)	0.2	0.9	(2.9)	(2.6)
	V/N	8.3	(6.9)	0.1	0.4	0.2	(0.2)	(1.0)	0.5	(0.6)
	1*2 vega	**64.5**	**(31.5)**	**(0.0)**	**1.1**	**2.6**	**(1.3)**	**(5.8)**	**6.0**	**2.2**
JPY/G10	M/N	(19.6)	9.8	0.4	0.8	(1.2)	(0.6)	0.9	(5.2)	(3.3)
	V/N	57.4	(19.3)	1.0	1.4	2.2	(0.6)	0.0	3.3	0.4
	1*2 vega	**193.0**	**(77.8)**	**2.0**	**1.9**	**8.7**	**(0.8)**	**(2.6)**	**18.9**	**6.7**
High Beta G10	M/N	(26.1)	8.0	0.7	1.2	(1.5)	0.9	0.7	(3.8)	(2.5)
	V/N	32.4	(15.5)	0.5	1.1	1.1	(0.2)	(1.2)	1.9	0.1
	1*2 vega	**132.0**	**(62.7)**	**(0.1)**	**0.5**	**6.1**	**(2.6)**	**(5.7)**	**12.0**	**4.3**
USD/EM	M/N	(74.7)	1.6	(0.7)	1.8	(2.1)	0.3	(0.3)	(6.6)	(5.2)
	V/N	3.3	(21.5)	(0.4)	(1.9)	0.6	(0.8)	(2.7)	(0.4)	(1.0)
	1*2 vega	**120.9**	**(68.5)**	**(0.1)**	**(10.3)**	**5.2**	**(3.7)**	**(9.3)**	**9.3**	**5.2**
EUR/EM	M/N	(69.0)	5.1	(0.9)	1.0	(2.3)	0.2	0.0	(5.6)	(4.8)
	V/N	(14.4)	(14.7)	(0.6)	(0.8)	(0.5)	(1.3)	(3.4)	(0.8)	(1.9)
	1*2 vega	**55.6**	**(55.1)**	**(0.3)**	**(5.5)**	**2.3**	**(4.9)**	**(12.1)**	**6.0**	**1.5**
JPY/EM	M/N	(61.2)	3.6	(0.2)	1.0	(1.8)	(0.9)	(0.2)	(7.0)	(5.7)
	V/N	37.5	(33.1)	0.3	(0.7)	1.8	(2.0)	1.3	2.5	0.3
	1*2 vega	**196.5**	**(107.3)**	**1.0**	**(5.2)**	**8.4**	**(4.7)**	**2.7**	**18.7**	**10.1**
Avg 6M	M/N	(46.2)	5.2	(0.3)	1.0	(1.7)	0.0	0.5	(5.1)	(4.0)
	V/N	20.4	(17.4)	0.2	(0.2)	0.9	(0.7)	(1.4)	1.1	(0.4)
	1*2 vega	**126.2**	**(63.1)**	**0.8**	**(3.4)**	**5.5**	**(2.7)**	**(6.4)**	**11.7**	**5.2**
Avg 3M	M/N	(72.5)	2.6	(0.4)	1.5	(1.4)	0.8	1.4	(6.5)	(4.9)
	V/N	37.4	(26.2)	0.2	1.3	0.7	(1.1)	(0.3)	2.3	0.2
	1*2 vega	**230.3**	**(84.4)**	**1.1**	**0.3**	**4.5**	**(5.2)**	**(4.8)**	**18.1**	**8.7**

Source: J.P. Morgan

Tactical theta collecting via delta-hedged risk off ratio spreads

Risk premium harvesting via traditional straddle selling can be a challenging proposition when spot gyrations pose risk in front-end tenors and inverted curves challenge executing it in the back tenors. A close, but safer, alternative is 1*N ratio call or put spreads (delta-hedged) on the rich side of the skew as a class of structures that can monetize risk premia in vol smiles. Placing the short notional overweight on the "risk-off" side, these structures sell risk-reversals, resulting in quick collection of premium, but are exposed to left tail and are, thus, suitable only when there is no imminent risk from sell-offs.

We run the long-term performance backtest across various currency baskets, various notional sizing schemes (market neutral, vega neutral and 1*2 vega ratio) and FX vol regimes (Exhibit 37). Key observations are as follows: 6M options historically returned ~9vol/year after transaction costs during favorable times (16vols in 3M tenor), and were severely interrupted on only three occasions – GFC'08, the taper and the USD rally of '14/'15. Unsurprisingly, the returns are about 2-2.5X the P/L from the equivalent "risk-on" vol ratio spreads. Vega neutral structures (modestly long gamma, neutral vega) mitigate the losses during high-vol episodes but not as effectively as in case of "risk-on" vol ratio structures.

One intuitive way for screening for the currencies with the most favorable backdrop for 1*2 risk-off vol spread structures is to look at the following two measures: a) medium-term performance measured via, for example, 3-year Sharpe, and b) current pricing of the 1*2 structures expressed as 1-y Z-score of skew/ATM vol ratio. The best candidates should ideally show simultaneously favorable current pricing and high historical Sharpe ratio.

Exhibit 38: Strong performance of skew harvesting structures in aftermath of global growth reaching cycle low

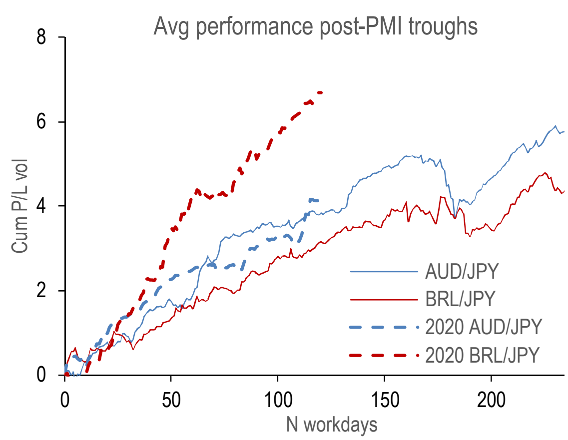
3M structures, delta hedged daily at forward delta with expiry matched forwards. Full width b/o on EM 0.5vols, 0.3vols for illiquid G10 crosses and 0.15vols for such as USD/JPY and EUR/JPY. Sharpe reported for 10yr, 5yr, 2020 since Jan, 2020 since April and performance in post PMI low in 2009, 2012 and 2016.

S.R.	1*1.5 (atm/25d) JPY call ratio spreads					
Pair	10y	5y	2020	Apr	PMI	Avg
EUR/JPY	2.1	1.4	1.4	7.7	3.1	3.1
JPY/KRW	0.4	1.1	-0.1	7.4	3.1	2.4
AUD/JPY	1.1	0.8	-0.1	8.1	4.7	2.9
GBP/JPY	1.3	1.1	0.6	7.1	2.2	2.5
CHF/JPY	0.9	1.3	1.0	7.8	3.2	2.8
CAD/JPY	1.3	1.0	0.2	8.8	3.8	3.0
BRL/JPY	1.7	1.5	0.5	5.2	3.2	2.4
NOK/JPY	0.4	0.5	-0.7	5.8	2.7	1.7
TRY/JPY	1.3	0.3	1.0	3.1	1.3	1.4
USD/JPY	1.0	0.9	0.4	6.1	2.1	2.1
MXN/JPY	0.5	0.2	-0.8	8.6	2.8	2.3
NZD/JPY	0.4	0.8	0.4	9.6	5.4	3.3
SEK/JPY	0.0	1.2	0.3	6.7	2.6	2.2
ZAR/JPY	0.1	1.3	0.3	5.3	0.1	1.4
Avg	0.9	1.0	0.3	7.0	2.9	

Source: J.P.Morgan

Exhibit 39: Strong AUD 1*1.5 performance post-PMI troughs.

3M structures, delta hedged daily at forward delta with expiry matched forwards. PMI low in 2009, 2012 and 2016.



Source: J.P. Morgan

Riding short Yen/cross Yen skews in the current environment is one example of "risk-off" vol ratio spreads. USD/JPY risk-reversal/ATM ratios have recovered from their 1Q20 COVID extreme, but have more room to normalize, if the post GFC recovery is any reference. Even if such vol surface normalization does not imminently materialize, there is value in fading the skew set-up by systematically selling delta-hedged riskies (i.e. selling JPY calls vs. buying JPY puts) in sub-3M expiries. That should ensure a faster pace of theta accretion amid slow-burn Yen strength, which leads to to underperformance in JPY and x-JPY skews.

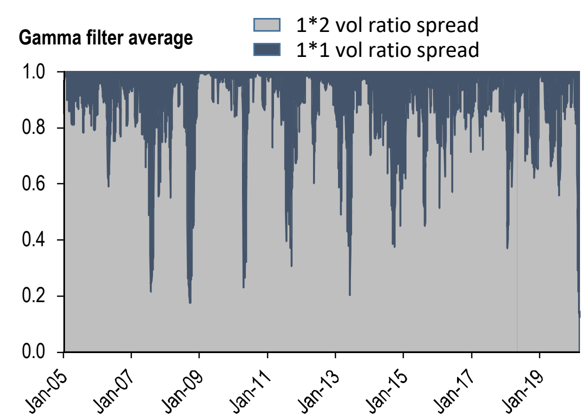
We analyze long-term historical performance (10-yr, 5-yr) for JPY ratio call spreads and compare it to 2020 performance as well as to the average performance during the 2009, 2012 and 2016 PMI recovery periods (Exhibit 38). The table shows that JPY skew harvesting is broadly best supported during economic recoveries (i.e. the performance reported in the PMI column is generally > than the 10-yr performance). That is particularly the case in high beta yen crosses such as KRW, AUD, NZD and BRL. We find 1:1.5 to outperform the more aggressive skew selling constructs such as 1:2 in x-JPY. Exhibit 39 displays cumulative returns (in vols) of AUD/JPY ratio spreads around PMI troughs to 1-yr out. Net of TC, AUD/JPY structure collected more than 6vol of P/L in a steady fashion during previous PMI cycles and is on track to do so again in the 2020 cycle.

Switching between 1*2s and market neutral ratio spreads during market duress incorporated via Gamma trade timing filter

Instead of ad-hoc deciding the notionals, one can utilize a gamma trading filter. Originally successfully introduced for short vol trades timing (*Timing FX short vol strategies*, Ravagli & Duran-Vara, March 2019), cutting the drawdown by 43%, the framework was later expanded to long/short gamma trading, driving down the drawdowns by 70%. The model relies on a set of common global indicators and along with currency specific variables (Ted spreads, VIX, Gold/Silver and VXY, etc). In this analysis, we simplistically utilize the gamma timing filter to determine the notionals split between 1*2 vega ratio spreads and M/N ratio spread.

Exhibit 40: Gamma filter tactical indicator still near an historical extreme in terms of defensive exposure.

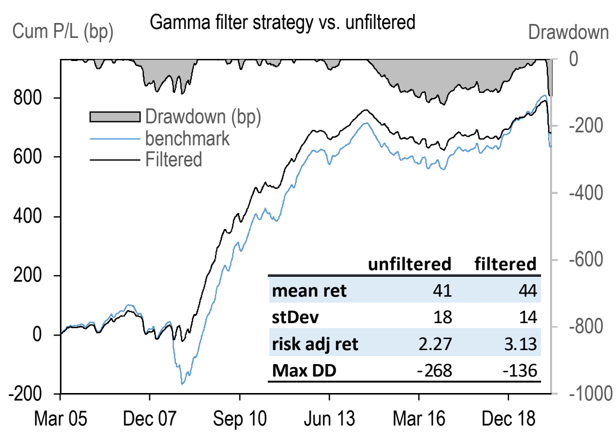
The gamma filter level indicates the ratio between the riskier 1*2 ratio spread and a more defensive 1*1 vol ratio spread.



Source: J.P.Morgan

Exhibit 41: Switching between 1*2 and M/N ratio spread structure based on the Gamma filter narrows max drawdowns by almost 50%.

Basket of 9 USD/G10 & 9 USD/EM pairs on which the Gamma filter is applied. 3M tenor, 1-mo holding period. Trades entered daily. Structures delta hedged daily via at expiry matched smile forwards. Transaction costs accounted for.



	unfiltered	filtered
mean ret	41	44
stDev	18	14
risk adj ret	2.27	3.13
Max DD	-268	-136

Source: J.P.Morgan

The filter signal as given in Exhibit 40 is always within [0,1] range, and is the result of an average across a basket of 9 USD/G10 & 9 USD/EM pairs. While there is a high degree of correlation among the individual currency filters due to the shared global variables the actual filter is different for each currency pair and is applied on each pair separately. We test a simple switching strategy, under which the value 0.75, for example, means 75% of notional goes into 1*2 and 25% into M/N risk ratio structure. The long-term backtest in Exhibit 41 shows a clear benefit from utilizing the filtering methodology. As in the previous study in timing short vol strategies, the volatility of returns is materially improved as the max drawdown is cut by almost 50%. Namely, dynamic switching between riskier 1*2 ratio spreads and more defensive market neutral notional vol spreads, based on our custom risk-aversion gamma trading filter, reduces volatility of returns, materially improving risk-adjusted returns, while nearly halving max drawdowns.

To conclude, both types of "risk-off" and "risk-on" ratio spreads can deliver long-term attractive returns (see Exhibit 33, for zero cost), although the PnL's distribution properties would be sensitive to the market environment on the back of an opposite sensitivity to the skew. As such, given that a skew premium cannot justify a positive performance for both classes of trades, we ultimately attribute the long-term positive returns of ratio spreads to an exposure to vol-of-vol premium. Sensitivity to the vol premium would arise in case of non-market-neutral constructs (i.e., N above 1). However, we stress that, unlike the rest of skew-neutral symmetric constructs investigated throughout this piece, each ratio spread trade will be exposed to the skew as well, given the implementation via calls or puts rather than straddles and strangles. The application of timing indicators can prove useful for optimizing such "directional" risk exposure for each trade.

Var vs. Vol swap RV constructs

Capturing the volatility of volatility premium via RV of Variance vs. Volatility Swaps is rather straightforward. The strike at inception of a Var swap is higher than that of a Vol Swap. Intuitively, the difference in strikes is related to the volatility of volatility: the higher the vol-of-vol, the more expensive the convexity effect of variance – in other words, we need to compensate for the fact that variance is convex in volatility, whereas Vol Swap payoff is linear, as per Jensen's inequality, by commanding an initial premium. We have seen in an earlier section that, in first approximation, the RV of a short Variance swap/long Vol swap with equal Vega notionals is:

$$E_{sta}(RV_{PO}) = N_{Vol}\sigma_{imp}\tau/4({\upsilon^2}_{imp} - {\upsilon^2}_{sta})$$

which directly allows taking a view on the vol-of-vol premium. More details on the pricing of var/vol swaps and on the sensitivities of the RV payoff are reported in Appendices III and IV.

We backtest the RV strategy long Vol/short Var swap with equal Vega notionals. Effectively, this means that if the difference in final payoff between Var and Vol Swap is large enough to offset the initial premium earned, you will have a negative PnL at the expiry, and, if the difference in payoff is smaller than the premium earned at inception, you will obtain a positive PnL. The final PnL of the trade is maximum if the realized Vol is equal to the fair strike at inception of the Vol swap (you will capture the entire initial premium) and it becomes more negative the higher the difference between the two. This is done on a daily basis, with a matching tenor and currency pair for the Vol and Var Swap. Please note that in trading conventions the mean return, which appears in the habitual statistics formula for variance, is ditched. This has the benefit of making the payoff perfectly additive (i.e. 1-year variance can be split into two 6-month segments). For simplicity, the following charts will not include a mark-to-market term but will simply describe cumulative PnLs as accounted after each trades reaches expiry.

The long/short strategy leads to promising results on liquid pairs like 1m EUR/USD and USD/JPY (Exhibit 42); in both cases, in the limit of zero costs, the strategy would steadily monetize the vol convexity premium and provide a smooth PnL, with low volatility. Spring 2020 was associated with the largest drawdown on record. The impact of trading costs is severe for the strategies, challenging the possibility of a systematic implementation of the theme via exotics, while leaving the door open to enter the trade when liquidity conditions are benign (i.e., tight bid/ask spreads) or when one-off opportunities arise (market making desks risk-recycling, or axes).

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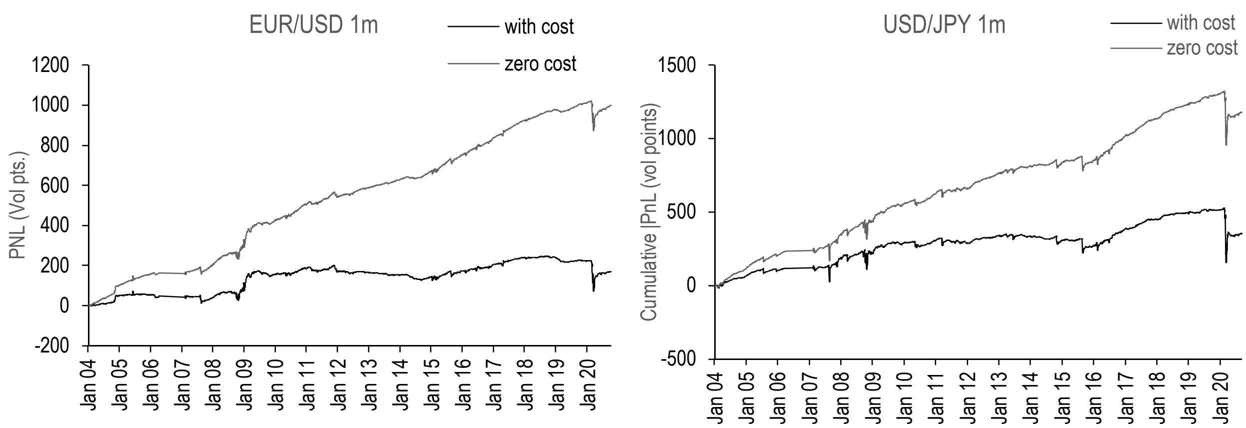
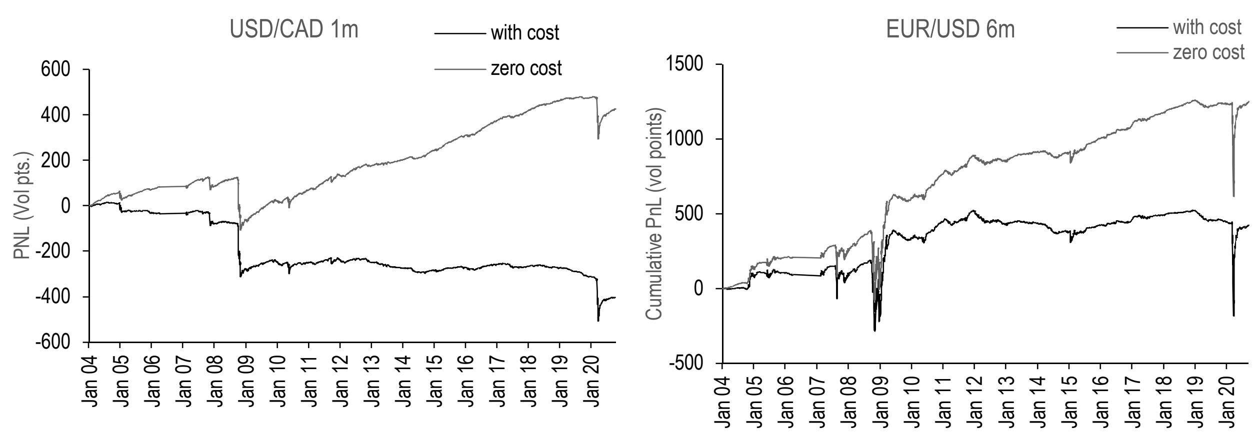
Exhibit 42: 1m Var/vol swap strategy on EUR/USD and USD/JPY



Source: J.P. Morgan Quantitative and Derivatives Strategy

As we have seen in the case of plain vanillas, short vol convexity trades are less appealing when we consider EM or high-beta G10 vs. hard currencies, given the jumpier nature of the currencies involved. This is confirmed when comparing USD/CAD (Exhibit 43, LHS) to EUR/USD and USD/JPY as seen in the previous chart.

Exhibit 43: Two more examples of Var/vol swap strategy: USD/CAD (1m) and EUR/USD (6m)



Source: J.P. Morgan Quantitative and Derivatives Strategy

When it comes to volatility premium – i.e. the difference between implied volatility and realized volatility, it is known that it displays some sensitivity to the option's maturity. Typically, front-dated, Gamma options offer a cleaner exposure to the volatility premium theme. For the vol-of-vol, as we have seen earlier (Exhibit 8 for instance), the premium is wider the shorter the maturity, which generally favors short-maturity Var/Vol swap plays. For EUR/USD (Exhibit 43, RHS), the 6m backtest is associated with a more volatile PnL profile than for the short maturity 1m case.

More broadly, within G10 (Exhibit 44), the strategy produces, on average, a very slightly positive PnL before costs if we average across currencies and tenors, namely 0.04 vol pts per trade. This is even higher if we choose the shorter 1-month tenor – which would mean an average PnL of 0.09 vol pts before costs. Likewise, the average risk-adj. returns of the strategy are 0.21 before costs across currencies and tenors but 0.45 if we look at the shorter 1-month tenor. However, if we take into account costs, we see that that for a bid/ask spread of 0.4 vol pts, the strategy would produce a -0.16 vol pts across currencies and tenors, and a -0.14 risk adj. return. Further, if we look at the higher moments of the strategy, we can see that it holds two very undesirable features – negative skewness and high kurtosis – thus rendering the strategy less appealing to investors.

Exhibit 44: Statistics for the Vol-of-vol strategy PnLs for different currencies and different tenors. Time period considered is 2007-2020.

		Cost		No Cost			
Currency	Ten	PNLper trade/ Vol pts	Risk Adj. Returns	PNLper trade/ Vol pts	Risk Adj. Returns	Skewness*	Kurtosis*
AUD-USD	1M	-0.26	-0.39	-0.06	-0.10	-16.8	374
EUR-USD	1M	0.03	0.22	0.23	1.52	-3.3	100
GBP-USD	1M	-0.07	-0.25	0.13	0.52	-10.5	273
NZD-USD	1M	0.04	0.09	0.24	0.49	-14.6	426
USD-CAD	1M	-0.10	-0.53	0.10	0.49	-13.4	311
USD-CHF	1M	-0.39	-0.27	-0.19	-0.13	-45.4	2285
USD-JPY	1M	-0.01	-0.02	0.19	0.45	-22.1	865
USD-NOK	1M	-0.25	-0.31	-0.05	-0.06	-21.3	744
USD-SEK	1M	0.01	0.03	0.21	0.90	-12.7	340
AUD-USD	3M	-0.72	-0.42	-0.52	-0.30	-11.6	262
EUR-USD	3M	0.05	0.13	0.25	0.58	-2.9	192
GBP-USD	3M	-0.06	-0.09	0.14	0.23	-10.4	323
NZD-USD	3M	-0.10	-0.09	0.10	0.09	-7.9	288
USD-CAD	3M	-0.24	-0.50	-0.04	-0.08	-7.7	172
USD-CHF	3M	-0.25	-0.17	-0.05	-0.04	-39.1	1862
USD-JPY	3M	0.01	0.01	0.21	0.22	-12.9	414
USD-NOK	3M	-0.39	-0.24	-0.19	-0.11	-20.5	856
USD-SEK	3M	-0.04	-0.07	0.16	0.31	-7.0	181
AUD-USD	6M	-0.73	-0.30	-0.53	-0.22	-8.2	211
EUR-USD	6M	0.07	0.10	0.27	0.37	-2.1	133
GBP-USD	6M	-0.04	-0.04	0.16	0.18	-6.4	170
NZD-USD	6M	-0.06	-0.04	0.14	0.09	-5.3	275
USD-CAD	6M	-0.27	-0.39	-0.07	-0.10	-6.1	184
USD-CHF	6M	-0.18	-0.10	0.02	0.01	-33.2	1504
USD-JPY	6M	0.12	0.10	0.32	0.27	-9.8	283
USD-NOK	6M	-0.37	-0.20	-0.17	-0.09	-20.3	856
USD-SEK	6M	-0.09	-0.10	0.11	0.13	-5.4	131

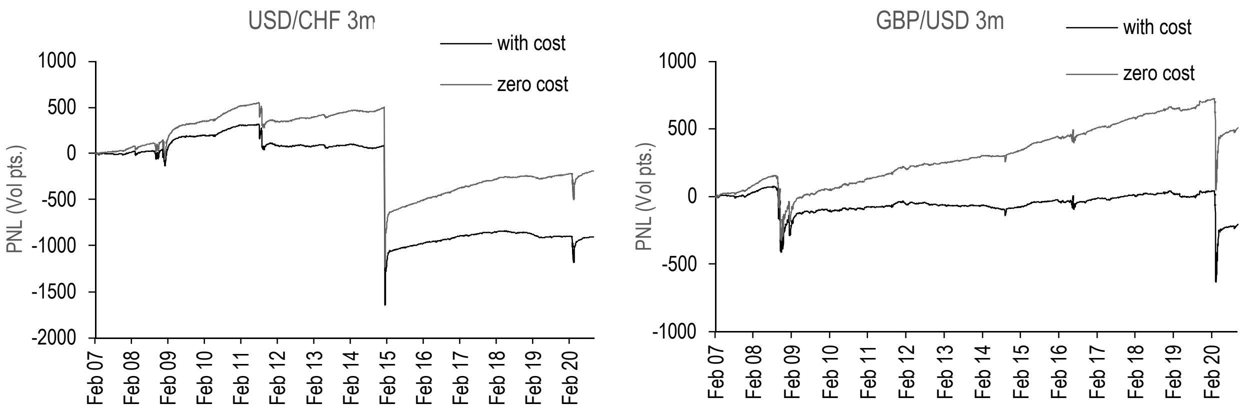
*Skewness and Kurtosis are not affected by constant costs

Source: J.P. Morgan Quantitative and Derivatives Strategy

As mentioned earlier, trading costs have a great impact on this strategy, and determine whether it is profitable or not. In fact, by looking at Exhibit 44, we can clearly see that across currency pairs and tenors, with the current cost estimation, 37% of the strategies switch signs (i.e. go from profitable to unprofitable after costs).

GBP and CHF are two case studies that call for additional investigation in the light of, respectively, large spot moves as occurred during the SNB de-pegging event in January 2015 and Brexit referendum in June 2016 (Exhibit 45).

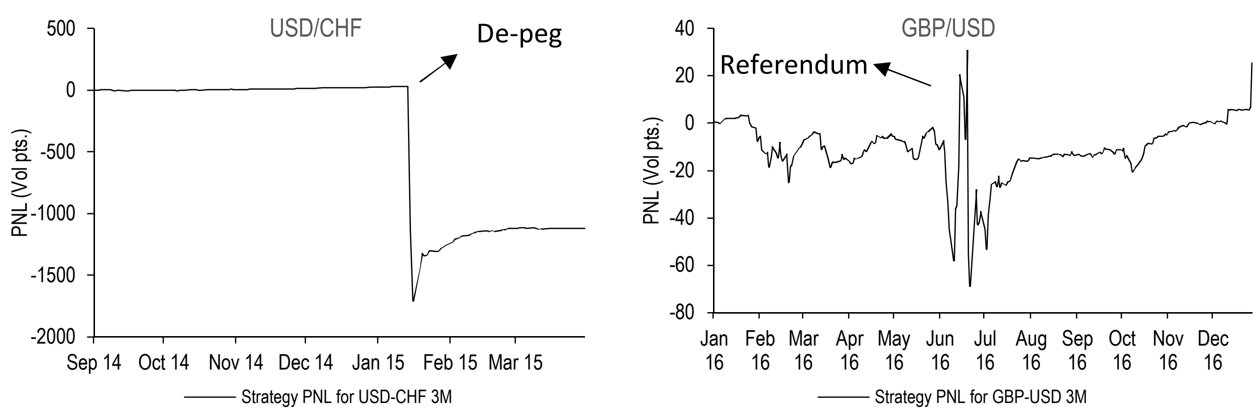
Exhibit 45: PnLs time series in vol pts. for the 3M Var/ Vol swap strategy in USD-CHF and GBP-USD



Source: J.P. Morgan Quantitative and Derivatives Strategy

The fact that a probability of de-pegging by the SNB in 2015 was not priced-in in markets prior to the event itself, meant that the Var/Vol swap strategy in USD/CHF suffered one of the greatest drawdowns across all currencies considered (Exhibit 46, LHS). On the other hand, despite the fact that the delta one move was comparable in size in GBP/USD after the 2016 Brexit referendum, the strategy did not suffer a comparible drawdown (Exhibit 46, RHS). This is due to the fact that, before the referendum, a possible extreme drop was partly priced-in, and most likely it meant that the selling of vol-of-vol premium (at attractive levels) pre-referendum was insuring the sellers against such drop, something that most likely did not happen in USD/CHF in 2015.

Exhibit 46: Zoom in of the PnLs time series in vol pts. for the 3M Var/ Vol swap strategy (with costs) in USD-CHF and GBP-USD around the de-pegging in 2015 and the Brexit referendum in 2016 respectively



Source: J.P. Morgan Quantitative and Derivatives Strategy

As for plain vanillas, the empirical PnL of such RV strategies can be compared with the formulas as introduced earlier in the piece. For the purpose, we consider the one where the expected PnL accounts for a large mismatch in implied/realized vol parameters beyond vol convexity ones:

$$E_{sta}(RV_{PO}) \cong N_{Vol}\tau(\beta - \alpha)(\sigma_{imp}(\upsilon^2{}_{imp} - \upsilon^2{}_{sta}) + \Delta\sigma\, \upsilon^2{}_{sta})$$

valid at order one in ex-post vol premium parameter, and neglecting the cross vol/vol-of-vol term.

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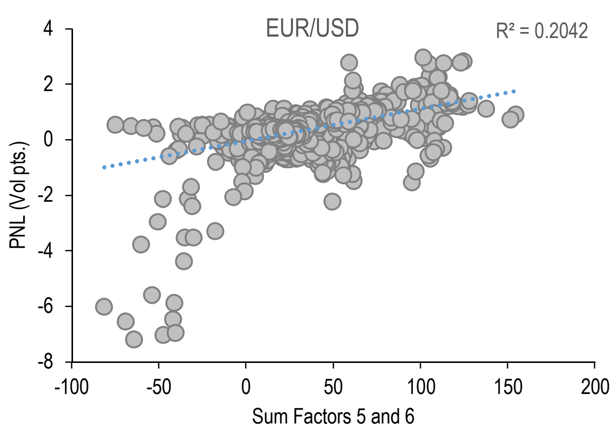
Exhibit 47: R-Squares obtained when regressing the PNL of the EUR/USD 1m Vol-of-vol strategy vs a number of factors

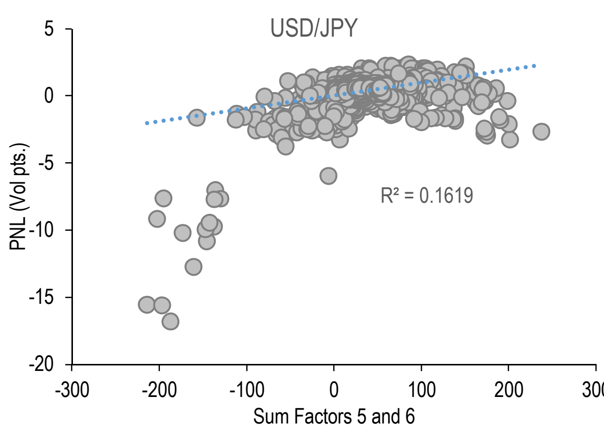
Term	Factor	R-Squared
1	Difference squared of realized and implied Vol of Vol	9%
2	Imp Vol	8%
3	Realized Vol	7%
4	Imp Vol - Realized Vol	0%
5	Difference squared of realized and implied Vol of Vol * Imp Vol	14%
6	(Imp Vol - Realized Vol) *(Squared of Realized Vol of Vol)	15%
7	Multi linear regression of (5 and 6)	27%
8	Simple linear regression of (5+6)	20%

Source: J.P. Morgan Quantitative and Derivatives Strategy

We have empirically tested, on EUR/USD 1m, the validity of the formula above by considering different factors in a regression framework and the corresponding R^2 metrics (Exhibit 47). The strategy is sensitive to the both realized vol (7% R-squared) and implied vol (8% R-squared), as well as to the vol-of-vol premium (9% R-squared), but uncorrelated to the Implied-Realized Vol premium. The combination where factors 5 and 6 of the table are summed with equal weight, i.e. a test of the formula above, leads to a 20% R^2, outperforming all other factors except for the multi-linear regression 8 (27% R^2, which adds one extra degree of freedom by optimising the relative coefficient entering the sum).

Exhibit 48: Scatter plot and R-Squared obtained after regressing the PNL of the EUR/USD 1m Vol-of-vol strategy vs factor 8 of Exhibit 47





Source: J.P. Morgan Quantitative and Derivatives Strategy

If we do a scatter plot of the Var/Vol swap strategy PnL for the 1m in EUR/USD and USD/JPY vs the sum of the factors 5 and 6 (Exhibit 48), i.e. factor 8 in Exhibit 47, we can see that the linear regression fits well in both currencies (except when the PnL of the strategy is very negative). We conclude that the approximate (see the earlier section on the main assumptions) formula for the RV PnL provides with a decent, although far from perfect, starting point for PnL generation. Additional work (like considering extra terms in the expansion or a more accurate model for pricing purposes than SABR) would be needed to obtain higher R^2 and closer match between theoretical vs. empirical PnLs.

Other asset classes

While the notion of vol convexity risk premium can, in principle, be applied to all asset classes, the backtest and PnL analyses presented so far have mostly focused on the FX market. In this section, we will consider applications for Equity and Commodity asset classes.

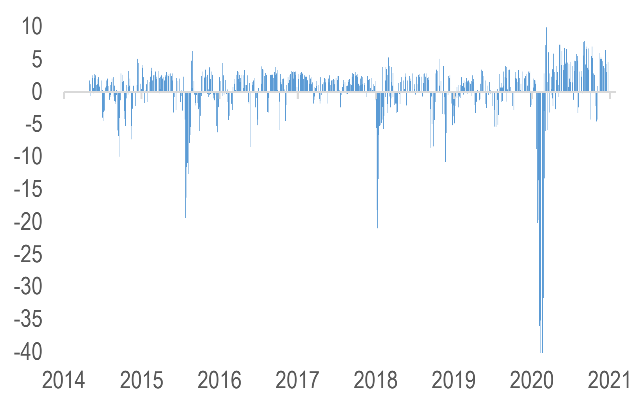
Equities

In equities, we find the existence of a structural implied vol-of-vol risk premium, due to a supply/demand mismatch. Vol-of-vol is generally positively correlated to volatility, and negatively correlated to equity returns. Thus, similar to volatility itself, vol-of-vol represents a form of insurance for risky asset portfolios, leading to excess investor demand for vol-of-vol as it is bought for hedging purposes. In particular, demand for tail hedges (such as deep OTM puts) exceeds supply, as they are used to insure portfolios against large downside moves and to lower capital reserve requirements. For example, financial company regulations – such as Basel III, Dodd-Frank and Solvency II – explicitly link portfolio performance during stress scenarios to capital requirements, incentivizing dealers and insurers to buy (or not sell) tail hedges in order to mitigate their capital costs. The demand/supply imbalance for these tail hedges drives up their cost, which boosts skew convexity and implied vol-of-vol.

VIX Options

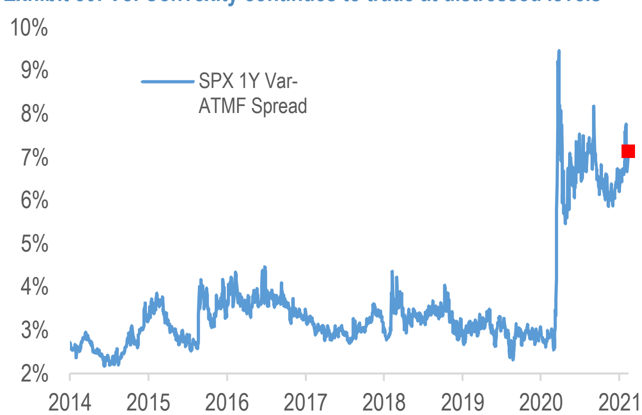
Perhaps the most straightforward way to trade implied vol-of-vol in equities is via VIX options, as the VIX itself is a measure of 1M implied volatility on the S&P 500, so options on the VIX are priced based on vol-of-vol. In our 2014 VIX report, we examined the risk premia embedded in VIX derivatives – specifically the futures term structure, option implied to realized volatility premium, and volatility skew. The second of these is a direct measure of the vol-of-vol risk premium. In that report, we found there is indeed a structural VIX implied volatility premium due to a demand/supply imbalance (i.e. excess demand for VIX calls as portfolio hedges) and the fact that VIX option sellers are exposed to spike/tail risks that they need to be compensated for. For example, we found that a short 1M straddle position was profitable 80% of the time over the prior 4 years, delivering an average ~1.4 vega return.

Exhibit 49: Premium of 1M VIX straddle to the subsequent VIX move



Source: J.P. Morgan Quantitative and Derivatives Strategy

Exhibit 50: Vol Convexity continues to trade at distressed levels



Source: J.P. Morgan Equity Derivatives Strategy.

In the nearly 7 years that passed since we published the above-linked note, we continued to see a structural VIX implied volatility risk premium, albeit one that was materially smaller than the one we found in 2014 (Exhibit 49). The smaller premium is likely due to increased activity in volatility/vol-of-vol risk premium harvesting strategies (prior to the COVID-19 pandemic), and numerous sharp market sell-offs driven by market fragility (i.e. a negative feedback loop between liquidity, volatility and flows), such as in Aug'15, Feb'18, Dec'18 and Mar'20, which drove spikes in volatility and vol-of-vol. We estimate that a short 1M straddle delivered an average monthly profit of 0.2 vega (median of 1.3 vega) between May'14 and Dec'20, and yielded a positive return 70% of the time. Excluding the pandemic, which featured the largest and fastest ever VIX spike (discussed here), short 1M VIX straddles delivered an average monthly profit of 0.4 vega (median of 1.15 vega) from May'14 to Dec'19.

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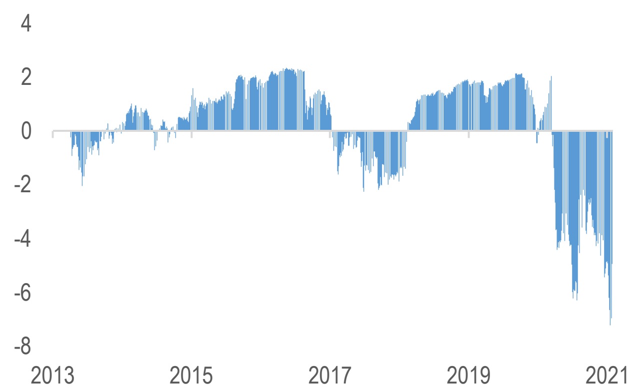
Variance Swap Convexity

Another way to trade vol-of-vol in equities is through variance vs. volatility swap spreads. As we discussed in *Volatility Swaps*, D.Silvestrini & B.Kaplan, 2-Jun-2010, since a variance swap's payout is convex (quadratic) in realized volatility, while the vol swap's is linear in volatility, the difference between their payoffs is driven primarily by vol-of-vol. If vol-of-vol is low then the spread is likely to have a relatively small payoff at expiry, as the volatility level will likely be close to the strike and the gain from the convexity of the variance swap compared to the linear volatility swap will be modest. As these instruments price in an expectation of the benefit of this convexity at inception, a fair variance swap strike will be higher than a volatility swap strike for the same underlying/tenor, and the spread between their strikes is a measure of implied vol-of-vol. The larger the expected (implied) vol-of-vol, the larger the variance-volatility swap spread should be, as it becomes more likely that the spread will deliver a large payoff at expiry. If held to maturity, the terminal payout of a variance vs. vol swap spread is linked solely to the difference between the actual realized volatility over the life of the trade and expected volatility (i.e. swap strikes), a measure of realized vol-of-vol. Thus, we can also examine the vol-of-vol risk premium by analyzing the P/L of var-vol swap spread trades.

In Exhibit 51, we show the terminal P/L for trading 1Y S&P 500 short variance vs. long volatility swaps (with equal vega notional on both legs) historically and, in Exhibit 52, we show historical performance stats for this structure using different tenors. Due to the higher vol-of-vol over short time horizons, higher structural hedging demand at longer tenors (e.g. 6M-2Y), and extreme but relatively short-lived volatility spike during the pandemic last year, average performance was stronger and maximum losses much smaller for longer tenors. However, excluding the pandemic period, we find a moderate structural vol-of-vol premium at all but the shortest tenor, as the var-vol swap spread delivered positive average returns.

Exhibit 51: S&P 500 1Y short var vs. long vol swap terminal P/L (vega)



Source: J.P. Morgan Quantitative and Derivatives Strategy

Exhibit 52: Backtest performance stats for S&P 500 short variance vs. long vol swap at various tenors

Tenor:	1M	3M	6M	1Y
Past ~9Y				
Avg P/L (vega)	-0.91	-1.01	-0.43	0.20
Median P/L (vega)	0.09	0.48	0.64	0.75
% positive	54%	64%	68%	65%
Max loss (vega)	-193.6	-73.3	-28.5	-7.2
Excluding pandemic				
Avg P/L (vega)	-0.15	0.39	0.64	0.72
Median P/L (vega)	0.05	0.50	0.78	1.03
% positive	52%	65%	73%	73%
Max loss (vega)	-16.9	-2.4	-2.0	-2.3

Source: J.P. Morgan Quantitative and Derivatives Strategy. No transaction costs are assumed

While the across-the-cycle premium in vol convexity appears moderate, likely the best opportunities for monetizing it arise in the aftermath of a market crisis, when risk premia widen. Implied convexity in equity markets surged during start of the the COVID-19 crisis, alongside other risk metrics (e.g. short-dated volatility spiked to its highest levels in over 30 years). Yet, even while most other equity derivatives risk metrics declined significantly as markets recovered over the course of 2020, convexity continues to trade at distressed levels and lags the recovery in other risk premia (Exhibit 50). As a result, we recommended monetizing the rich convexity risk premium in a few recent publications by trading variance swaps vs. volatility swaps (see *Volatility Review*, 30-Jun-2020, *2021 Equity Derivatives Outlook*, 9-Dec-2020, and *Volatility Review*, 22-Jan-2021). In these trades, we adjusted the vega notional ratio of the two legs to skew the

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breakeven range lower, by buying a lower vega notional on the vol swap than the vega notional of variance sold.

Indeed, we find that higher average and risk-adjusted returns would have been earned historically by scaling down the vega notional on the long volatility swap (illustrated in Exhibit 53), due to the existence of a persistent index implied volatility premium. In other words, the fair variance strike was structurally above the subsequent realized volatility, so the average performance of the trade was improved by reducing leverage on the long vol swap leg in order to skew the payoff distribution lower and apply a short volatility tilt.

Exhibit 53: Backtest performance stats for 1Y S&P 500 short 1x variance vs. long vol swap for various vol swap leverage ratios

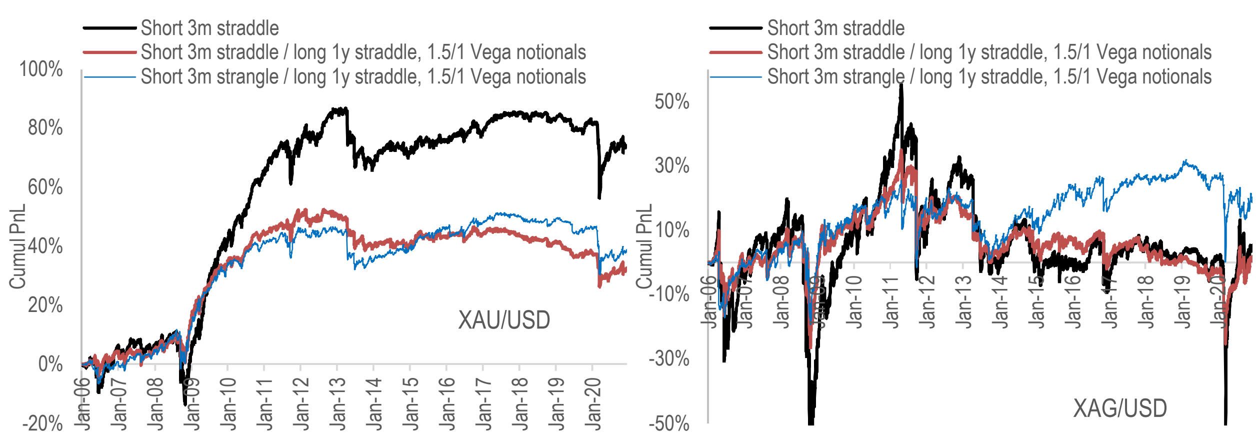
Vol swap leverage:	60%	70%	80%	90%	100%
Past 9Y					
Avg P/L (vega)	1.20	0.95	0.70	0.45	0.20
Median P/L (vega)	2.62	2.20	1.75	1.29	0.75
% positive	89%	89%	89%	80%	65%
Max loss (vega)	-15.1	-13.1	-11.2	-9.2	-7.2
Excluding pandemic					
Avg P/L (vega)	2.69	2.20	1.70	1.21	0.72
Median P/L (vega)	2.72	2.24	1.80	1.46	1.03
% positive	100%	100%	100%	89%	73%
Max loss (vega)	0.1	0.5	0.1	-1.1	-2.3

Source: J.P. Morgan Quantitative and Derivatives Strategy. No transaction costs are assumed

Precious Metals

Precious metals, and especially Gold and Silver, can prove as a reliable field for testing the richness of vol convexity in the commodities space, on the back of structural wings richness and reasonable liquidity. Backtests we consider cover the January 2006-November 2020 period. We assume 0.5 vol pts. for full width vol trading costs, and 3 bps for delta-hedging costs.

Exhibit 54: OTM options are a better source for extracting vol premium from precious metals smiles



Source: J.P. Morgan Quantitative and Derivatives Strategy

Pure smile strategies, as covered earlier in the piece, on XAU and XAG deliver decent results, trimming the typically large drawdowns associated with short straddle strategies (Exhibit 54).

However, the wider bid/ask spreads than for most liquid FX pairs would make it difficult to consider a fully systematic implementation of the theme.

Exhibit 55: Combination of calendar and smile strategies is associated with the best results in the long run

		Straddle		*Strangle*		*Calendar*		*Calendar+smile*	
FX pair	Maturity short	Ret	Sharpe	Ret	Sharpe	Ret	Sharpe	Ret	Sharpe
XAU-USD	1m	-1.6%	-0.08	5.3%	0.28	-5.5%	-0.44	1.4%	0.12
XAU-USD	3m	4.8%	0.48	5.2%	0.51	2.1%	0.34	2.5%	0.36
XAU-USD	6m	4.0%	0.61	4.2%	0.66	2.0%	0.59	2.3%	0.61
XAG-USD	1m	-12.5%	-0.31	-5.1%	-0.13	-9.1%	-0.36	1.1%	0.05
XAG-USD	3m	0.3%	0.01	0.9%	0.04	0.1%	0.01	1.2%	0.09
XAG-USD	6m	1.3%	0.08	1.5%	0.11	1.0%	0.13	1.0%	0.16

Source: J.P. Morgan Quantitative and Derivatives Strategy

As introduced for FX pairs, combining short smile convexity with calendar steepeners can boost the strategy's returns. For the sake of brevity, in Exhibit 55 we consider the following maturities for the calendar structures: 1m/3m, 3m/1y and 6m/2y. The long/short structures involve Vega notionals of 1.5/1 for the short leg over the long one. The general pattern is that the combination of smile and calendar effects leads to the highest risk-adjusted returns.

Conclusion

In this piece, we have provided an extensive review of vol convexity strategies, from both a practical and a theoretical standpoint. The main asset class covered was FX, given the deep liquidity and the typically symmetric and convex vol smiles; however, applications to Equity and Commodities markets were also discussed. This follows up on previous research as appeared in academic journals and as provided by JPM's QDS and FX vol research teams.

The general notion of a vol convexity premium was first addressed from a more theoretical standpoint, and later applied to a number of "concrete" case studies, involving plain vanilla (straddle vs. strangle with and without calendar component; ratio spreads) and exotics (vol vs. var swaps; options on VIX) structures.

The structural evidence of a vol convexity premium is validated by several empirical analyses. The takeaway relevant, in our view, to the widest spectrum of market professionals is that strangles should be preferred to straddles for vol-selling purposes, as implemented by several systematic programmes by both real-money and leveraged communities. Conversely, we think straddles are better suited for owning spot convexity on the back of a more contained exposure to the vol-of-vol premium.

In particular, the vol convexity premium appears wider for short-maturities, with higher trading costs at the very front-end of vol curves restricting the optimal range to 1m-3m maturities. In general, the elevated toll of trading costs for the long/short vol smile structures requires particular attention, preventing the possibility of accessing the vol convexity premium in its purest form, and requesting a compromise between exposure to the premium and impact of costs.

Several aspects deserve additional investigation. In the piece, we have adopted conservative assumptions regarding the rebalancing frequency of the options portfolios aimed at reducing the impact of trading costs. A suitable trading algorithm, as applied to the portfolio of live option positions, could determine the sizing of the new trades to be added for keeping a desired exposure on vol convexity, while reducing the issue of spurious sensitivities and Greeks path-dependency.

"Timing" signals, as discussed already in the context of ratio spread structures, could be applied more systematically across short vol convexity structures, and reviewed accordingly. In particular, a framework capable of determining allocations in the vol convexity space could prove extremely useful for building optimal portfolios, ideally in long/short format.

The timing of the trades should also be put in relation to market liquidity conditions. First, one could assess the interplay between drying up of liquidity conditions and an increased risk of vol convexity crashes. Also, given the elevated impact of costs, rather than trading systematically vol convexity as we have assumed in the piece, it would be much more realistic do to so opportunistically when a privileged access to liquidity market is permissible (for instance, when banks give away "axes"). Such opportunities could allow for a broadening of the audience of players in the convexity space beyond dedicated professionals.

The technicality of the subject could suggest further pricing work towards the computation of the optimal Greeks to be used for obtaining the cleanest exposure to the vol convexity premium, reducing as much as possible spurious sensitivities.

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Appendix I – Smile dynamics and volvol premium

In this section, we provide with a sketch of the steps required for obtaining the compact formula for the vol-of-vol premium mentioned throughout this piece. For more details, we refer to the academic piece listed amongst references[3]. We start from the following functional expression for the smile near the money:

$$\sigma(x,\sigma_0) = \sigma_0(1 + a(\sigma_0)x + \frac{b(\sigma_0)}{2}x^2)$$

Where σ_0 is the ATM vol of maturity $\tau = T - t$ and $x = logK/S$ the log-moneyness. This expansion is generally consistent with pure stochastic-volatility dynamics. Greeks can be obtained by taking into account smile adjustments from the expression above, under the limit of zero rates, short maturities/near the money, and assuming a flat volatility curve. For instance, the adjusted Delta can be derived as:

$$Delta = Delta|_{BS} + \frac{\partial Vega}{\partial \sigma}\frac{\partial \sigma}{\partial S} = Delta|_{BS} + Vega|_{BS}\frac{\partial \sigma}{\partial x}\frac{\partial x}{\partial S} = Delta|_{BS} - Vega|_{BS}\sigma_0\frac{a+bx}{S}$$

Similarly, for Theta, Gamma and Volga Greeks one gets ($d_+ = (x + \frac{\sigma^2}{2}\tau)/(\sigma\sqrt{\tau})$):

$$Theta \equiv \frac{\partial V}{\partial t} = -\frac{Sn(d_+)}{2\sqrt{\tau}\sigma_0}{\sigma_0}^2\left(1 + ax + \frac{b}{2}x^2\right)$$

$$\frac{1}{2}S^2 Gamma \equiv \frac{1}{2}S^2\frac{\partial^2 V}{\partial S^2} = \frac{1}{2}S^2\frac{\partial Delta}{\partial S} = \frac{Sn(d_+)}{2\sqrt{\tau}\sigma_0}\left(1 - 3ax + (6a^2 - \frac{5}{2}b)x^2\right)$$

$$\frac{1}{2}{\sigma_0}^2 Volga \equiv \frac{1}{2}{\sigma_0}^2\frac{\partial^2 V}{\partial {\sigma_0}^2} = \frac{1}{2}{\sigma_0}^2\frac{\partial Vega}{\partial \sigma_0} = \frac{Sn(d_+)}{2\sqrt{\tau}\sigma_0}x^2$$

The functional expression above shows how Volga rises for OTM options and declines with maturity for a fixed moneyness x. However, if one considers that log-moneyness rises with maturity, one would find that Volga for fixed-delta OTM strikes rises with maturity, too.

The formulas above show how the Volga plays for vols a similar role that Gamma plays for spot - a long Volga position benefits from quadratic fluctuations in vol levels that cannot be hedged by trading Vega. As long Gamma is a desirable feature, but associated with a negative time decay, so is in principle long Volga, with an even heavier Theta bleed.

The PnL function can be expanded as:

$$\Delta PnL = \frac{1}{2}S^2 Gamma\left(\left(\frac{\delta S}{S}\right)^2 - \sigma_{BE}^2\delta t\right) + \frac{1}{2}{\sigma_0}^2 Volga\left(\left(\frac{\delta\sigma_0}{\sigma_0}\right)^2 - \upsilon_{BE}^2\delta t\right) +$$

$$+ S\sigma_0 Vanna\left(\left(\frac{\delta S}{S}\right)\left(\frac{\delta\sigma_0}{\sigma_0}\right) - \rho_{BE}\upsilon_{BE}\sigma_{BE}\delta t\right)$$

In the limit of vanishing skew, the breakeven term for the Volga reduces to:

[3] Isolating a risk premium on the volatility of volatility, Ravagli, Risk magazine, Dec 2015

$$\upsilon_{BE}^2 = 3\sigma_0 \frac{\partial^2 \sigma}{\partial x^2}|_{x=0} = \nu^2$$

With ν being a universal proxy of implied vol-of-vol under a class of stochastic volatility models, which leads to the compact formula for the Volga exposure to the differential of squared implied and realized vol-of-vol.

Appendix II – Stochastic volatility models

In stochastic volatility models (SVM), the log-normal process followed by the spot market under Black-Scholes:

$$\frac{dS}{S} = (\mu\, dt + \sigma dW_S)$$

Is modified by a term which specifies a dynamics of the volatility term itself. In the simplest SVM, SABR[4] (Stochastic Alpha Beta Rho), volatility process is also log-normal:

$$\frac{d\sigma}{\sigma} = \alpha dW_\sigma \; ; \; \rho dt =< dW_S dW_\sigma >$$

The model is fully specified by two additional parameters, $\sigma(0) = \sigma_0$ and β. $\beta = 1$ corresponds to the log-normal dynamics for the spot variable as considered above whereas σ_0 approximates the pricing of ATM volatility for the calibration date. Within SABR, the parameters α, ρ are directly interpreted as implied vol-of-vol and spot/volatility correlation. The model can easily provide with a good calibration of a fixed-maturity smiles, across different asset classes, but struggles to adjust to a full surface/set of different maturities. As different values of the model's parameters are required to calibrate different maturities, the model is not internally consistent for pricing exotic products that are sensitive to the whole surface dynamics.

In the Heston model[5], the stochastic process is expressed for the variance and not the volatility:

$$d\sigma^2 = \kappa(\theta - \sigma^2)dt + \alpha dW_{\sigma^2} \; ; \; \rho dt =< dW_S dW_{\sigma^2} >$$

κ plays the strength of mean reversion of variance towards its long-run value θ. The extra parameter (5 vs. 4, for SABR with β not set to 1) grants the Heston model additional flexibility in calibrating vol curves other than fixed-maturity smiles, therefore proving to be better internally consistent than SABR when pricing exotics. One can recover an analogy between SABR and Heston smile parameters after some stochastic calculus.

The two models above are amongst the most popular in the SVM space, but several others were developed by the academic community. In recent years, Dupire-like *local* volatility models[6] were mixed with stochastic dynamics granting an agreement between smile-dependent products and barrier options. Some of the models allow for approximate compact formulas for pricing of implied volatility surfaces based on model parameters. Common across models is the fact that higher vol-of-vol parameters lead to higher smile convexity and higher OTM vols over ATM ones.

[4] Hagan et al, Managing Smile risk, 2002
[5] Heston, A closed-form solution for options with Stochastic Volatility with applications to Bond and Currency Options, 1993
[6] Dupire, Pricing with a Smile, 1994; Derman, Miller, The Volatility Smile, 2006

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Appendix III – Pricing Variance/Volatility swaps

Variance and Volatility swaps are exotic products that allow betting directly on the future level of volatilities (see more details in Bossu, 2006). Their payoffs at expiry are:

$$Var_{PO} = N_{Var}(\sigma_R^2 - K_{Var});\ Vol_{PO} = N_{Vol}(\sigma_R - K_{Vol})$$

N_{Var}, N_{Vol} are the variance and volatility notionals for the two contracts. The choice of $N_{Var} = N_{Vol}/(2 * \sqrt{K_{Var}})$ allows interpreting N_{Vol} as the corresponding Vega (Vol) notional for the var swap trade. Depending on how payoff is specified, realized vol parameter can include or not mean return over the sample σ_R. By assuming means are not subtracted (standard choice):

$$\sigma_R^2 = \frac{252}{n}\sum_{i=1}^{n} {r_i}^2$$

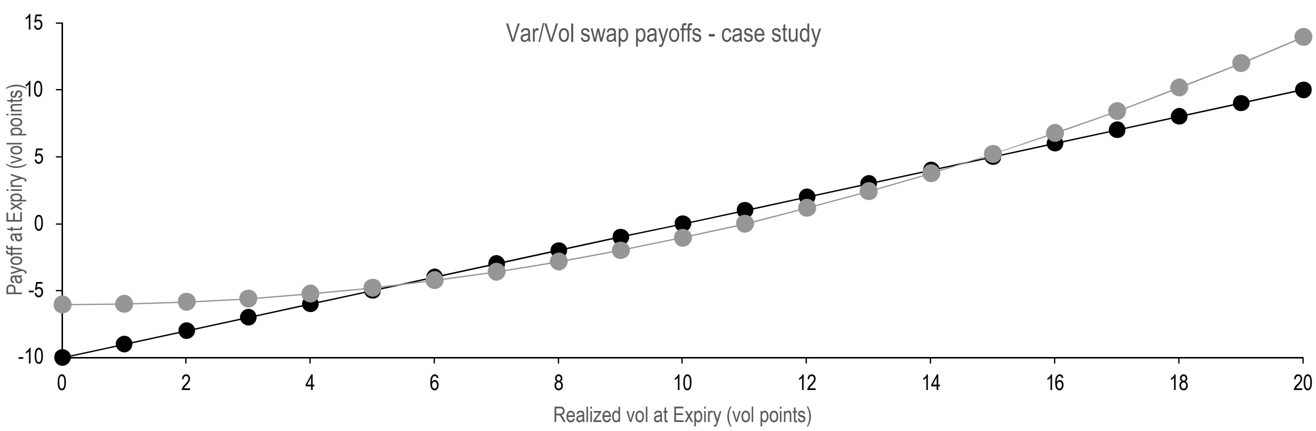
Therefore, if held until expiry, the products allow expressing a view on the future level of realized variance/volatility during the life of the products, relative to the strikes as set at inception. In this setup, the products allow expressing a view on the variance/volatility premium directly. If unwound before expiry, mark-to-market formulas (not displayed here) show that near inception payoffs are mostly exposed to Vega-like sensitivities to changes in implied parameters (i.e., strikes). Hence, for $t \ll T$ (where t is time elapsed after inception and T is initial maturity), payoffs can be traded for expressing a view on future levels of implied vols/smiles rather than future realized volatilities.

We have seen earlier that because of Jensen's inequality, in presence of vol fluctuations one has:

$$E(\sigma_R^2) > E(\sigma_R)^2\ \rightarrow \delta_K = \sqrt{K_{Var}} - K_{vol} > 0$$

For the "standard" scaling of the two payoffs $N_{Var}/N_{Vol} = 1/(2 * K_{Vol})$, Exhibit 56 shows the two payoffs, in vol points, as a function of realized vol at expiry σ_R.

Exhibit 56: Variance/Vol swaps payoffs – a case study when ATM vol is at 10%



Source: J.P. Morgan Quantitative and Derivatives Strategy

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We have seen that pricing of Var swap depends only on static smile properties, i.e. shape of volatility smile, and that closed formulas under different pricing models are available. In the $\beta = 1$ SABR model (with), one has:

$$K_{var} = \frac{1}{T}\frac{{\sigma_0}^2}{\upsilon^2}(exp(\nu^2 T) - 1)$$

Under Heston model the formula is:

$$K_{Var} = \frac{({\sigma_0}^2 - \theta)}{\kappa T} e^{-\kappa T} + \theta$$

As for the pricing of the vol swap there is in principle no closed formula, one can rely on Monte Carlo simulations, as displayed in the body of the piece, for showing a sensitivity to Vol swap strikes to pricing parameters. By exploiting the additivity of variance property, the marked-to-market value of the contract can be written down via the compact formula:

$$Var_{MtM} = N_{Var}\left(\sigma_{t,T}^2 - K_{Var}\right);\ \sigma_{t,T}^2 = t/T(\sigma_{R,t}^2) + \frac{T-t}{T}(K_{Var,t} - K_{Var})$$

Where $\sigma_{R,t}^2$ is the accrued realized variance and $K_{Var,t}$ the strike at time t of the var swap with expiry T . Similarly, by introducing a suitable expression for $\sigma_{t,T}$ (depending on pricing assumptions), the MtM value of the Vol Swap contract can be written down as:

$$Vol_{MtM} = N_{Vol}\left(\sigma_{t,T} - K_{Vol}\right)$$

Appendix IV – Vol/Var swap RV as a vol-of-vol trade

By assuming a SABR dynamics with parameters $\sigma_{imp}, \upsilon_{imp}$ we have seen that:

$$K_{vol} \equiv E_{imp}(\sigma_{real}) \cong \sigma_{imp}\ ;\ K_{var} \equiv E_{imp}({\sigma_{real}}^2) = {\sigma_{imp}}^2\left(1 + \frac{\nu^2{}_{imp}T}{2}\right)$$

One can now apply statistical world expectations to the payoffs above, by assuming still a SABR dynamics but with different statistical parameters, $\sigma_{stat}, \upsilon_{stat}$:

$$E_{stat}(Var_{PO}) = N_{Var}(E_{stat}(\sigma_R^2) - K_{Var});\ E_{stat}(Vol_{PO}) = N_{Vol}(E_{stat}(\sigma_R) - K_{Vol})$$

With $E_{stat}(\sigma_R^2) = {\sigma_{stat}}^2\left(1 + \frac{\nu^2{}_{stat}T}{2}\right)$ and $E_{stat}(\sigma_R) \cong \sigma_{stat}$.

One gets for the RV payoff, with $N_{Var} = \alpha\ N_{Vol}$, after a Taylor expansion assuming $\sigma_{imp} \cong \sigma_{stat}$:

$$E_{stat}(RV_{PO}) \cong\ N_{Vol}((\sigma_{stat} - \sigma_{imp}) + \alpha(({\sigma_{imp}}^2 - {\sigma_{stat}}^2) + {\sigma_{imp}}^2 T/2(\nu^2{}_{imp} - \nu^2{}_{stat})))$$

By approximating further ${\sigma_{imp}}^2 - {\sigma_{stat}}^2 \cong 2\sigma_{imp}(\sigma_{imp} - \sigma_{stat})$, one gets:

$$E_{stat}(RV_{PO}) \cong N_{Vol}((\sigma_{stat} - \sigma_{imp}) +\ 2\alpha\sigma_{imp}(\sigma_{imp} - \sigma_{stat}) + \alpha{\sigma_{imp}}^2 T/2(\nu^2{}_{imp} - \nu^2{}_{stat}))$$

By choosing $2\alpha\sigma_{imp} = 1$ (at first order in Taylor equivalent to $\alpha = 1/(2\sqrt{K_{Var}})$, one gets:

$$E_{stat}(RV_{PO}) \cong N_{Vol}\ \alpha\sigma_{imp}{}^2 T/2(\nu^2{}_{imp} - \nu^2{}_{stat}) = N_{Vol}\sigma_{imp}T/4(\nu^2{}_{imp} - \nu^2{}_{stat})$$

A more general approximate pricing within SABR/Stochastic Volatility models (Skalli, Youssfi, 2013) would support a scaling like:

$$K_{vol} = \sigma_{imp}(1 + \alpha\ \sigma_{imp}\ \ \upsilon^2{}_{imp}\ \tau)\ ;\ \sqrt{K_{var}} = \sigma_{imp}\left(1 + \beta\ \sigma_{imp}\ \ \upsilon^2{}_{imp}\ \tau\right)$$

$$\delta_K = \sigma_{imp}\upsilon_{imp}{}^2\tau\ (\beta - \alpha)$$

The aforementioned piece (Skalli, Youssfi, 2013) considers $\alpha = \frac{1}{12}, \beta = \frac{1}{4}$. For a general choice of α, β, at the lowest order in the expansion, one would have the following adjustment to the RV formula as below:

$$E_{sta}(RV_{PO}) = N_{Vol}\sigma_{imp}\tau(\beta - \alpha)(\upsilon^2{}_{imp} - \upsilon^2{}_{sta})$$

which shows how in first approximation the Var/Vol swap RV trade is a pure "vol-of-vol play".

The formula above is valid at first order in α, β and at zero-th order in $\Delta\sigma = \sigma_{imp} - \sigma_{stat}$. By expanding at order 1 in $\Delta\sigma$ one gets:

$$E_{sta}(RV_{PO}) = N_{Vol}\tau(\sigma_{imp}(\beta - \alpha)\left(\upsilon^2{}_{imp} - \upsilon^2{}_{sta}\right) + \Delta\sigma(\upsilon^2{}_{sta}(\beta - \alpha) + \beta\left(\upsilon^2{}_{sta} - \upsilon^2{}_{imp}\right)))$$

One can therefore expect that, in case of large mismatches between implied and sample realized vols, the RV trade will be exposed to such "spurious" factor and end up not being a pure vol-of-vol play. In fact, the expression above can be broken down as the sum of three terms, one related to pure vol-of-vol premium (left), one to pure vol premium (middle) and one a combination of the two (right). The payoff is expected to be negatively impacted in case of large mismatches between implied and sample realized volatility (i.e., large and negative $\Delta\sigma$). Also, the sensitivity on "model" parameters α, β appears more marked than for the no vol premium ($\Delta\sigma = 0$) case as investigated above. By neglecting the cross term, the expression becomes slightly more compact:

$$E_{sta}(RV_{PO}) \cong N_{Vol}\tau(\beta - \alpha)(\sigma_{imp}\left(\upsilon^2{}_{imp} - \upsilon^2{}_{sta}\right) + \Delta\sigma\ \upsilon^2{}_{sta})$$

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