Options Skew Risk Premium

How to measure and harvest it

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Global Quantitative and Derivatives Strategy

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See page 30 for analyst certification and important disclosures, including non-US analyst disclosures.

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Executive summary

This reports focuses on the possibility of isolating and trading risk premia associated with cross-asset options markets smiles, and more specifically with the skew parameter. The note follows-up on previous research more specifically dedicated to vol convexity premia.

The report is organized as follows. The first part covers the more general and theoretical aspects:

- A general framework for highlight smile parameters risk premia is introduced, with some significant innovations related to term structure effects and to decomposing the risk premium related to skew or spot/vol correlation parameters.
- We isolate a skew premium, related to the Vanna Greek letter, as an implied vs. realized difference of the product of spot/vol correlation, vol and vol-of-vol.
- We find that, across different assets, the signs of the ex-post estimate of the skew risk premium and of the PnL of the strategy aimed at harvesting that risk premium are generally well aligned – the skew risk premium is a sensible driver of the PnL of skew-sensitive strategies.
- High-level implications of vol smile premia on generic option structures are reviewed for illustrative purposes.

The second part is entirely dedicated to empirical findings and backtests, carried out in the FX space. It is broken down into two sub-sections, covering:

- The adequacy of the PnL interpretation, with an emphasis on the newer interpretations of TS effects, is tested on vol convexity strategies, for which previous research had been already released.
- The newer topic of identifying and trading the skew risk premium is presented in depth, with the empirical analyses providing support to the newer theoretical results as introduced in the first section.

The Appendix section then sheds additional light on some theoretical aspects which are not essential for a high-level understanding of the topic, while Conclusion summarizes the main findings and future avenues of research.

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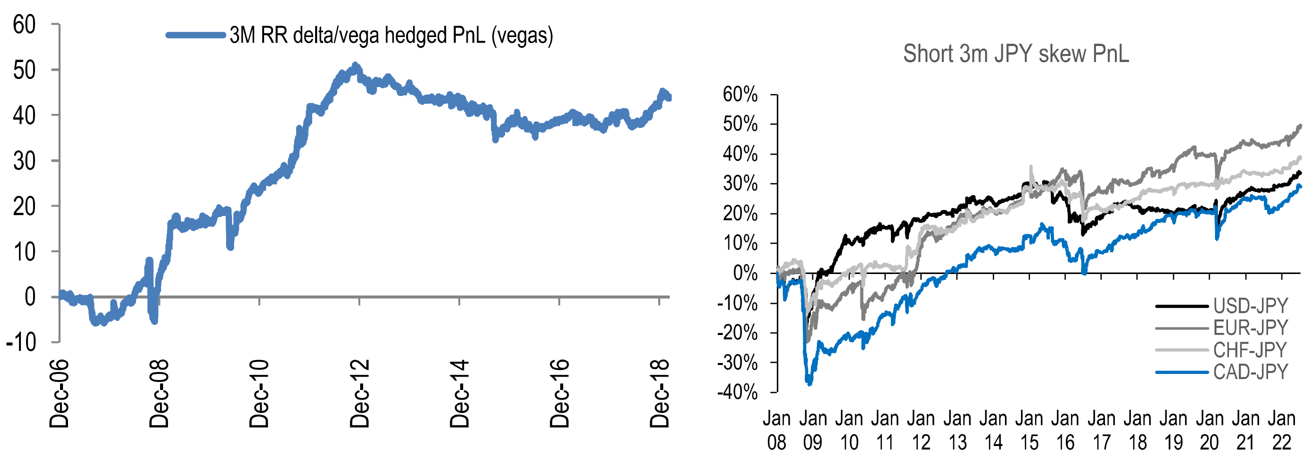
Introduction

Finding sources of de-correlated returns is crucial for reducing the volatility and the directional risks associated with investable portfolios. Within the Equities space, availability of a large number of underlying securities, deep liquidity, and solid academic research have allowed the growth of the factor-based business over the past few decades in particular. The inclusion of risk premia strategies (see for instance *Quantitative Perspectives on Cross-Asset Risk Premia*, Tzotchev et al, July 2022) within multi-asset portfolios has become much more common over the past decade, on the back of the diversification benefit offered by the alternative strategies over their traditional, long-only counterparts.

Within the volatility space, where the number of liquid assets is scarcer, maximising the diversification benefits involves looking for orthogonal sources of PnL drivers across the tradeable assets. This task typically involves looking for trading strategies that are for the most part sensitive to one specific pricing parameters, and then maximising the number of parameters that allow such a mapping via a trading system. Previous research by the team covered harvesting risk premia on cross-asset volatilities and vol convexity parameters, which allowed a decent de-correlation benefit. Vol curves and skews appear as the next available building blocks for expanding the number of available, de-correlated sources of returns (alpha in the best case scenarios).

Exhibit 1: Proxy PnL of skew-harvesting strategy on European Equities and FX



Source: J.P. Morgan Quantitative and Derivatives Strategy

Within the Equities space, a negative skew (puts cost more than calls) is a permanent feature post the 1987 flash crash; empirical observations linked to the performance of skew-sensitive trades suggest skew pricing might be on average too wide, hinting at the presence of a risk premium that could be harvested. Previous research from the Equity Derivatives Strategy team reviewed the notion of a skew risk premium that a systematic long Vanna trade. Can capture. Exhibit 1 shows the time series of proxy strategies aimed at "capturing" the skew risk premium as embedded in European Equity derivatives market (chart from *Understanding Skew Trading Strategies*, Silvestrini et al, Mar 2019) and in the FX space.

In the note we will tackle the question "is it possible to isolate a skew premium" from both a theoretical and a practical angles, by showing: a) what combination of market parameters related to the skew can be more directly associated with a risk premium; b) the adequacy between ex-ante estimation premium vs. ex-post realized PnLs; and c) a class of simple trading strategies that systematically harvest skew risk premium over time. For the present application, empirical analyses / backtests will be carried out in the FX market only.

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Isolating risk premia for the smile parameters

The starting point of this study is based on a note from last year (Trading the vol-of-vol risk premium, Ravagli et al, Feb 21) whose purpose was to discuss the multiple opportunities that a premium on the so-called vol-of-vol parameter offers to investors. With this note we aim to expand the previous findings, especially as far as the possibility of identifying a premium on the skew parameter is concerned. Given that the technical aspects involved are non-trivial, and that formal rigor would require a dedicated treatment on its own, in the following we will aim at striking a compromise, by introducing a robust and intuitive framework, supported by both pricing first principles and empirical analyses.

For a payoff $O(S,K,\tau,\sigma(S,K,\tau))$, where S is the spot value, K the strike, σ is the implied vol of maturity $\tau = T - t$; σ_0 is the fixed Expiry ATM volatility. We introduce first order:

$$Delta \equiv \frac{\partial O}{\partial S} \; ; \; Vega \equiv \frac{\partial O}{\partial \sigma_0} \; ; \; Theta \equiv \frac{\partial O}{\partial t}$$

And second order Greek letters as:

$$Gamma \equiv \frac{\partial^2 O}{\partial S^2} = \frac{\partial Delta}{\partial S} \; ; \; Volga \equiv \frac{\partial^2 O}{\partial {\sigma_0}^2} = \frac{\partial Vega}{\partial \sigma_0} \; ; \; Vanna \equiv \frac{\partial^2 O}{\partial S \partial \sigma_0} = \frac{\partial Vega}{\partial S}$$

Within the framework, ATM vols and smile parameters are treated as the relevant functional variables. As such, Greeks such as Vega and Volga are defined via the sensitivity to ATM, and not the option's actual, implied volatility. If/when Vega terms can be neglected, the PnL function of a delta-hedged option can be generally expanded as:

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

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

Without entering in unnecessary technicalities, the expansion above is rather general, and stems from the algebraic possibility of breaking down the Theta of the option as the sum of three terms associated to the three second order Greeks, by adjusting the parameters $\rho_{BE}, \sigma_{BE}, \upsilon_{BE}$ (an even more general expression would replace squares σ_{BE}^2, υ_{BE}^2 with quantities not forced to be positive *a priori*). The strike-independence of the breakeven parameters would grant the additivity of the Greeks for a portfolio relative to those of its constituents. The formula generalizes the well-known expression for the interplay between Theta and Gamma when other Greeks are neglected:

$$\Delta PnL = \frac{1}{2} S^2 Gamma \left(\left(\frac{\delta S}{S} \right)^2 - \sigma^2 \delta t \right)$$

What matters for trading purposes is the interpretation of the three breakeven parameters in the formula above. In order to obtain a starting point for the definition of the market-based BE quantities above, one needs to introduce some assumptions on the dynamics of vol surface and market variables with passing of time, spot moves, changes in implied vols (ATM).

If one assumes a purely diffusive process, goes into the limit of short maturities, expands at leading order near the smile (in terms of moneyness), assumes a flat vol curve and considers zero

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rates and skew, expressions for these breakeven parameters can be obtained in a compact form. Under these limits, in particular that of zero skew, the break-even parameters can be calculated as:

$$\sigma_{BE} = \sigma_0;\ \upsilon_{BE} = \upsilon$$

where υ is the vol-of-vol parameter as obtained via a stochastic volatility (SV) calibration of the smile. A previous Risk Magazine research report (*Isolating a Risk Premium on the Volatility of Volatility*, Ravagli, Risk Magazine, Dec 2015) discussed how, under certain limits, all SV models could be equivalent for the purpose.

When the skew is non-vanishing, the expansion from the smile leads to rather convoluted expressions for the breakeven parameters, especially the vol-of-vol one, which become hard to interpret. Taking into account explicitly term structure effects on vols and smile parameters would make expressions even more complicated. However, were $\upsilon_{BE} = \upsilon$ to hold even under the non-vanishing skew case (something which is not immediate to prove), it would naturally derive that $\rho_{BE} = \rho$, where ρ is again the spot/vol correlation parameter as obtained via a stochastic volatility calibration of the smile, above (see the Appendix). The following expansion would then be valid:

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

$$+ S\sigma_0 Vanna \left(\left(\frac{\delta S}{S} \right) \left(\frac{\delta \sigma_0}{\sigma_0} \right) - \rho \upsilon \sigma \delta t \right)$$

So, while the "educated guess" $\rho_{BE} = \rho$ is generally consistent with stochastic volatility models dynamics, a semi-empirical validation of the formula via data is mandatory, something which will be carried out in the following sections. The expansion above leads to a very natural interpretation of a skew or Vanna premium $Vanna_{RP}$ as:

$$Vanna_{RP} = \left(\left(\frac{\delta S}{S} \right) \left(\frac{\delta \sigma_0}{\sigma_0} \right) - \rho \upsilon \sigma \delta t \right) = (\rho_R \upsilon_R \sigma_R - \rho \upsilon \sigma) \delta t$$

where ρ_R is the high-frequency (over δt) estimate of correlation between spot and ATM volatility of fixed Expiry. The formula above suggests that the mismatch between implied and realized spot/vol correlation is not directly tradeable, but the combination $(\rho_R \upsilon_R \sigma_R - \rho \upsilon \sigma)$ is. A following section will share some light on this matter. Such a decomposition above would allow interpreting the time decay of an option as the sum of three separate contributions, directly attributable to well-known second order risks:

$$Theta = -\frac{1}{2} S^2 Gamma\ \sigma_{BE}^2 \delta t - \frac{1}{2} {\sigma_0}^2 Volga\ \upsilon_{BE}^2 \delta t - S\sigma_0 Vanna\ \rho_{BE} \upsilon_{BE} \sigma_{BE} \delta t$$

Vega contributions could be neglected under the strict short-maturity limit, but are generally to be accounted for. One can similarly introduce Greeks which measure an option's sensitivity to change in implied parameters such as skew and vol convexity.

The previous reports naturally introduced the notion of a vol surface dynamics, assuming which ATM pillars can be treated as independent variables based on which the rest of the surface is expected to move. A self-consistent smile model would quantify by how much smile parameters are expected to change for a move in implied vols. In practice, it is convenient to treat moves in smile parameters as independent from those in ATM vols and to compute corresponding PnLs accordingly. Here we pursue this empirical approach by introducing two new Greek letters beyond Vega, $Vega_{Skew}, Vega_{Fly}$ for the purpose:

$$Vega_{Skew} \equiv \frac{\partial O}{\partial Skew} \Delta Skew \; ; \; Vega_{Fly} \equiv \frac{\partial O}{\partial Fly} \Delta Fly$$

such that

$$Vega_{Skew\ PnL} = Vega_{Skew} \Delta Skew \; ; \; Vega_{Fly\ PnL} = Vega_{Fly} \Delta Fly$$

Absent an analytical expression for these Greeks, one can resort to a numerical computation, being aware that the latter might not necessarily be consistent with a given model dynamics. With the caveats above in mind, it appears sensible to test for the numerical validity of a PnL expansion as below, which groups term by term first and second order sensitivities related to the same smile parameter:

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

$$+ \frac{1}{2} \sigma_0{}^2 Volga \left(\left(\frac{\delta \sigma_0}{\sigma_0} \right)^2 - \upsilon_{BE}^2 \delta t \right) + Vega_{Fly} \Delta Fly +$$

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

Based on the expansion, it appears clearly how the Theta and related second-order Greeks are the terms most responsible for the long-term PnL generation of a given strategies, while the first order Greeks can be steady contributors to the PnL volatilities. A relative assessment of the two contributions, for instance addressing the relative sensitivity to the time to maturity, will be presented in the following sections. A recent paper (*Linking the performance of vanilla options to the volatility premium*, Daviaud et al, Risk, 2022) allowed interpreting Vega effects as mostly responsible for contributing to the PnL volatility of options trades which are held until Expiry.

Having neglected term-structure effects, the expansion above does not take into account the observed scaling on the vol-of-vol term structure, which exhibits a marked and structural inverted shape. When it comes to the standard Gamma vs. Vega interplay, our previous research report discussed how explicit term structure effects could be factored in the premium term and extracted out of explicit Vega sensitivities as:

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

where α stands for the term structure slope. One could envisage that similar corrections might impact the Volga premium term in the PnL equation, with the “Corrective term” reflecting the inverted vol-of-vol term structure.

$$\frac{1}{2} \sigma_0{}^2 Volga \left(\left(\frac{\delta \sigma_0}{\sigma_0} \right)^2 - \upsilon^2 \delta t + Corrective\ term \right) +$$

One can resort to first principle calculations taking term structure effects into account both in the Theta and in the Greeks. Within the boundary of the underlying formalism, whereby ATM vol and

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then smile's skew and convexity are treated as dynamic variables, this involves inverting the sensitivities to the flies with those to the curvature parameter b of the smile expansion, and/or on the implied vol-of-vol, which introduce an explicit maturity-dependence. One tentative scaling between curvature and (25delta) flies based on empirical observations as:

$$Fly \approx 3\tau{\sigma_0}^3 b$$

allows calculating changes in the curvature parameter as:

$$\frac{\partial O}{\partial b}\Delta b = Vega_{Fly}\Delta Fly + Vega_{Fly} * \ Fly * \frac{\Delta t}{\tau}$$

The above expression consists of two terms, one dependent on the changes of the fly parameter and one explicitly dependent on the time to maturity. From the expression one can clearly see how the relevance of the second term over the first becomes more marked for short maturities, when the term-structure effect is stronger. By working out the functional relation between $Vega_{Fly}$ and $Volga$, one can account for changes in the vol-of-vol premium due to the time-dependent effects as highlighted above.

More details on the calculations are shared in the Appendix. These effects will be covered more extensively in future research notes. We will come back to these aspects when reviewing the actual comparison with data in the following sections. One important aspect to stress here is that, given that the PnL_π for a portfolio π can be broken down as the sum of the PnL for its constituents, the same decomposition holds for an options portfolio, after cumulating Greeks across the portfolio's constituents ($Greek_\pi = \sum_i Greek_i$):

$$\Delta PnL_\pi = \frac{1}{2}S^2 Gamma_\pi\left(\left(\frac{\delta S}{S}\right)^2 - \sigma_{BE}^2\delta t\right) + Vega_\pi\Delta\sigma_0 +$$

$$+\frac{1}{2}{\sigma_0}^2 Volga_\pi\left(\left(\frac{\delta\sigma_0}{\sigma_0}\right)^2 - \upsilon_{BE}^2\delta t\right) + Vega_{Fly,\pi}\Delta Fly +$$

$$+ S\sigma_0 Vanna_\pi\left(\left(\frac{\delta S}{S}\right)\left(\frac{\delta\sigma_0}{\sigma_0}\right) - \rho_{BE}\upsilon_{BE}\sigma_{BE}\delta t\right) + Vega_{Skew,\pi}\Delta Skew$$

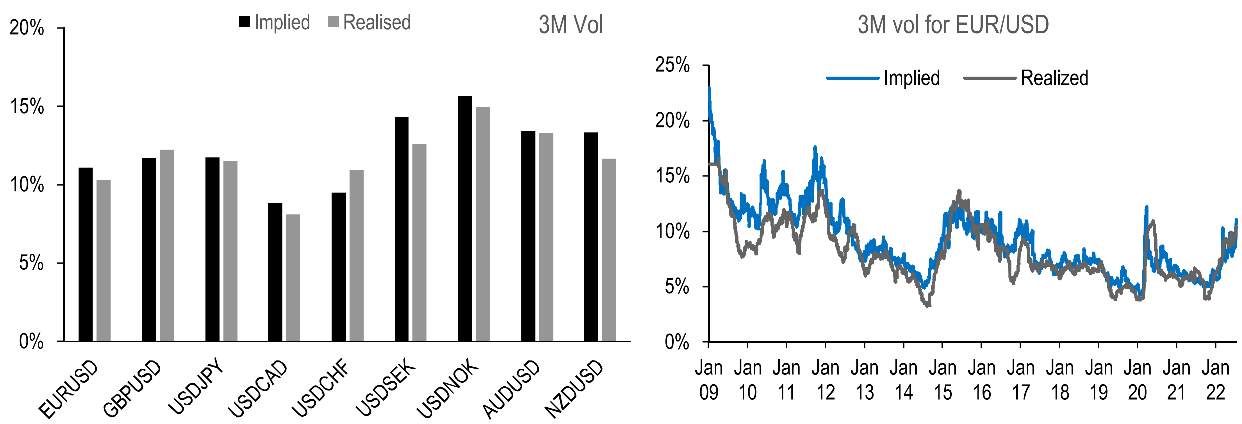
Having introduced the theoretical formalism, we now move on to some practical notions of premia across different market parameters, before addressing the adequacy of the expressions above vs. actual data in the final section of the note.

Vol premium – a general introduction

The concept of volatility risk premium is well-known among market practitioners and refers to the empirical observation that implied volatility tends to trade above the future realization of volatility as experienced by the underlying market. This additional risk premium is well understood by the natural propensity of investors to protect their portfolios ahead of market downturns, and willing to pay a negative expected return premium in returns for the benefit of such a protection. As a consequence, short-volatility strategies across asset classes are normally profitable and can add value for yield-enhancement purposes within multi-asset diversified portfolios, by going beyond the specific audience of options experts.

A couple of charts are informative for describing the "mechanics" behind vol premia. A recent snapshot (Exhibit 2, LHS) of implied and realized vols show how the two are typically close to each other, with implieds slightly above (backward-looking) realized vols. Over the long run, vol premia amount to less than 5% on average of the level of implied vols. A case study for EUR/USD (Exhibit 2, RHS) show that the two measures of volatilities tend to be close to each other over time, with implied typically overshooting realized by a modest margin.

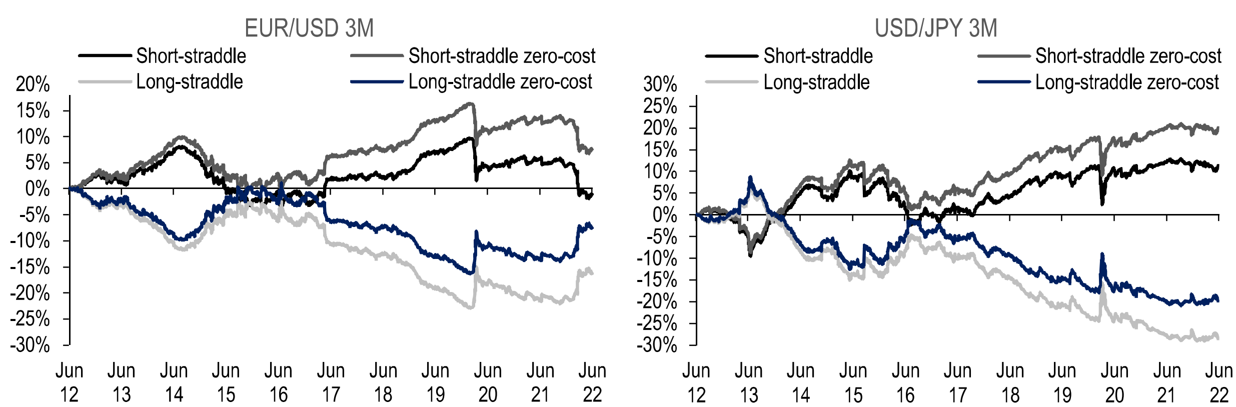
Exhibit 2: A snapshot of 3M implied vs. realized vol as of July 2022 across USD/G10 and EUR/USD time-series case study.



Source: J.P. Morgan Quantitative and Derivatives Strategy

Vol swaps allow the most direct implementation of the volatility premium theme, by offering a PnL which is proportional to the realized volatility at expiry – the strike, which is related to the implied vol at inception. Variance swaps rely on the same concept but via a quadratic (not linear) sensitivity on the premium. Both implementations are granted to offer a 100% agreement between ex-post estimates of the premium and PnL. Other exotic products allow a similar exposure to the vol premium, granting further flexibility (forward starting, breaking down realized volatility for up vs. down moves etc.).

Exhibit 3: Time series of short- and long-vol strategies via delta-hedged plain straddles over time.



Source: J.P. Morgan Quantitative and Derivatives Strategy

Delta-hedged plain vanillas like straddles are also commonly used for the purpose, although the implementation involves some potential slippage due to the path-dependence of the Greeks and in particular of Gamma and Theta, the main drivers of the PnL. The time series for two case studies (Exhibit 3) mirrors decently the ex-post estimation of the premia. The notion of a vol premium is reflected by the upward and downward sloping zero-cost PnL time series for short- and long-vol respectively; trading costs introduce an element of asymmetry between short and long vol

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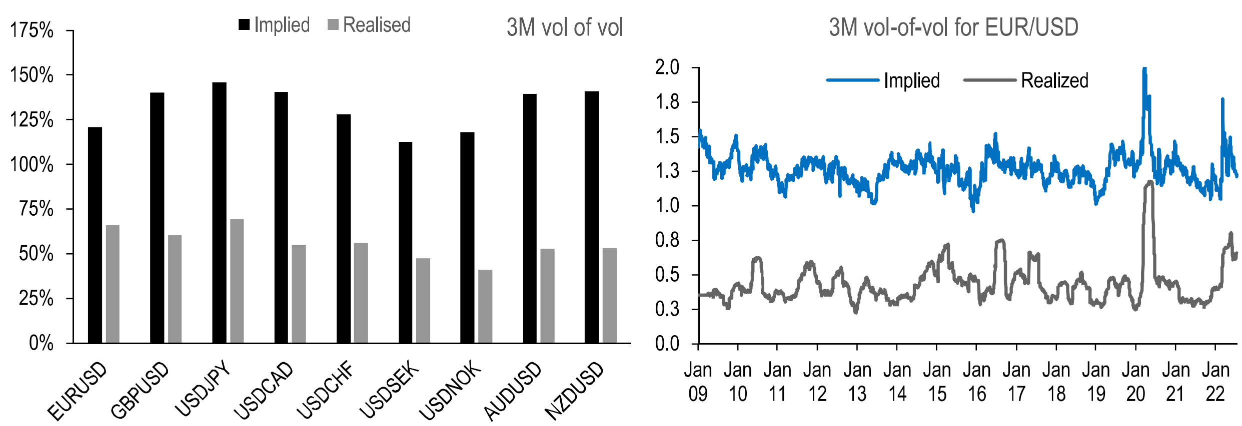
respectively. We can see that, especially after accounting for costs, a passive long-volatility position is subject to a heavy and persistent time-decay.

Vol-of-vol premium – a general introduction

The concept of vol-of-vol premium is definitely less bread and butter and easily accessible by a wide audience than was the case for the vol premium. Previous research reports were aimed at sharing light on the subject and draw conclusions relevant for a wide audience beyond dedicated vol traders. Amongst the most general applications of the vol convexity premium are the recommendations to use straddles for vol-buying and strangles for vol-selling purposes.

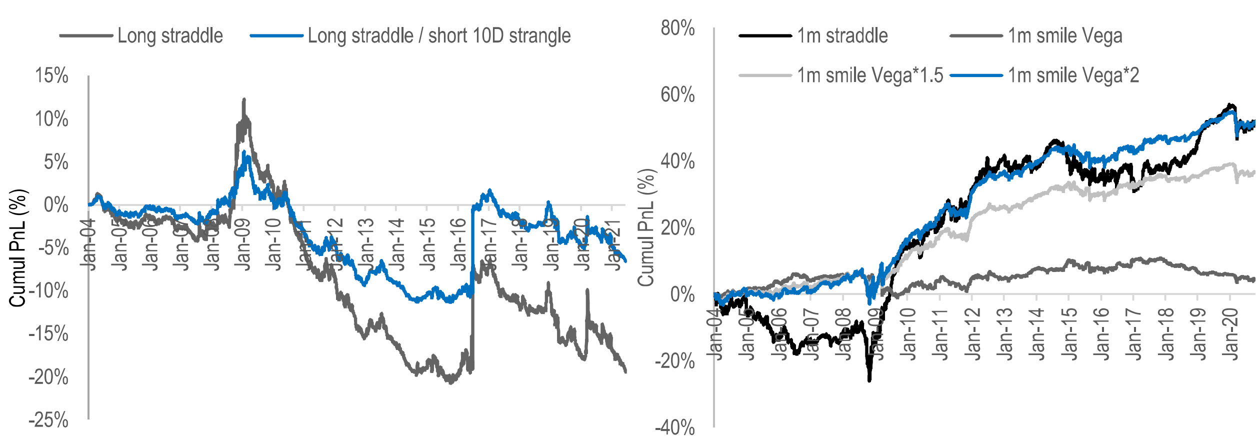
Exhibit 4: A snapshot of 3M implied (SABR) vs. realized vol-of-vol as of July 2022 across USD/G10 and EUR/USD time-series case study.



Source: J.P. Morgan Quantitative and Derivatives Strategy

Broadly speaking, the concept of vol-of-vol premium is related to the notion of a consistent gap between measures of implied and realized vol-of-vol. Previous research reports introduce a more precise definition of the quantities involved. We can see from the chart (Exhibit 4) that the measure of implied vol-of-vol overshoots significantly that of realized vol-of-vol. The result holds across different assets (see USD/G10 FX pairs, Exhibit 4, LHS) and over time (see EUR/USD, Exhibit 4, RHS). One resulting practical implication is that the wider premium as associated with OTM options can be captured opportunistically with suitable constructs.

Exhibit 5: Two constructs (one defensive LHS for GBP/USD, one risk-on RHS for EUR/USD) benefiting from the vol-of-vol premium.



Source: J.P. Morgan Quantitative and Derivatives Strategy

Two constructs, with a risk-off (on GBP/USD, Exhibit 5 LHS) and a risk-on (on EUR/USD, Exhibit 5, RHS) bias, are presented below respectively. The first one is a long straddle position that reduces time decay by selling OTM strangles in a suitably chosen combination of notionals (equal option notional). The second one is a long straddle / short strangle combination which results in a short-vol profile on the back of the scaling of the two legs (+1/-1.5 and +1/-2 in Vega notionals); the resulting portfolios are associate with comparable long-term returns but with less volatility than for the short-straddle trade.

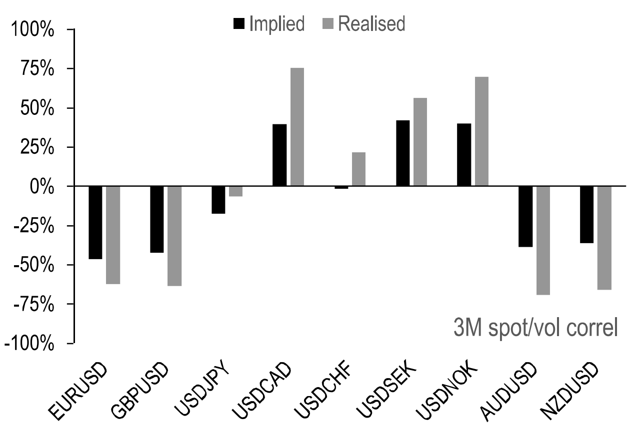
The richness of OTM vols can be therefore beneficial to both vol buyers and sellers. Our previous report discussed a wealth of other possible constructs that benefit from the elevated vol convexity. One general comment is that, beyond the most basic implementations, vol convexity trading goes beyond the day-to-day needs of investors who are not options-dedicated. One general problem is that short vol-convexity portfolios require dynamic management as spurious / path-dependent effects tend to kick-in during the life of the products.

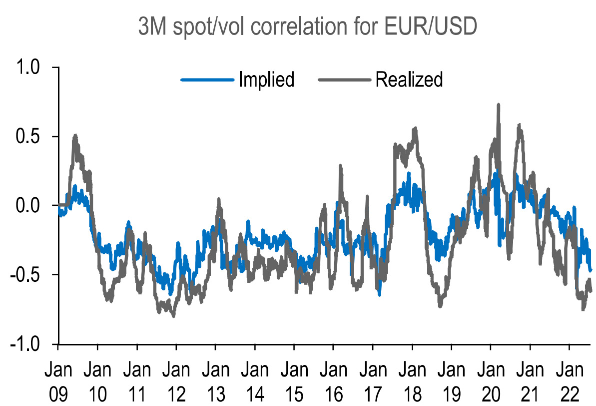
Skew premium – a general introduction

Risk-reversals and more generally skew-sensitive products are commonly employed by a wide group of market players, and for different purposes (advantages over for forwards for hedging needs, depending on market pricing; vol carry collection; opportunistic trading of skew relative to forward points etc.). Compared to vol-convexity just reviewed, the spurious and path dependent effects are less marked, which calls for a less intensive monitoring of the trades.

More details on the performance of skew-sensitive products are going to be reviewed later in the piece. As we have already done for vol and vol-of-vol, we start by asking ourselves the question how skew premia can be estimated. The comparison of implied and realized spot/vol correlation is displayed on Exhibit 6. Both a recent snapshot across assets (LHS) and the time series case study for EUR/USD (RHS) show that the two measures are "close" to each other, with the realized estimate being typically more volatile than the implied one. At the time of writing, realized spot/vol correlation tends to outperform (in absolute value) the implied measure, hinting that long risk-reversal trades should be performing.

Exhibit 6: A snapshot (as of July 2022) of 3M implied and realized spot/vol correlation across USD/G10 and one time-series case study (for EUR/USD).





Source: J.P. Morgan Quantitative and Derivatives Strategy

However, the use of the more accurate assessment of the terms actually entering the skew premium, involving

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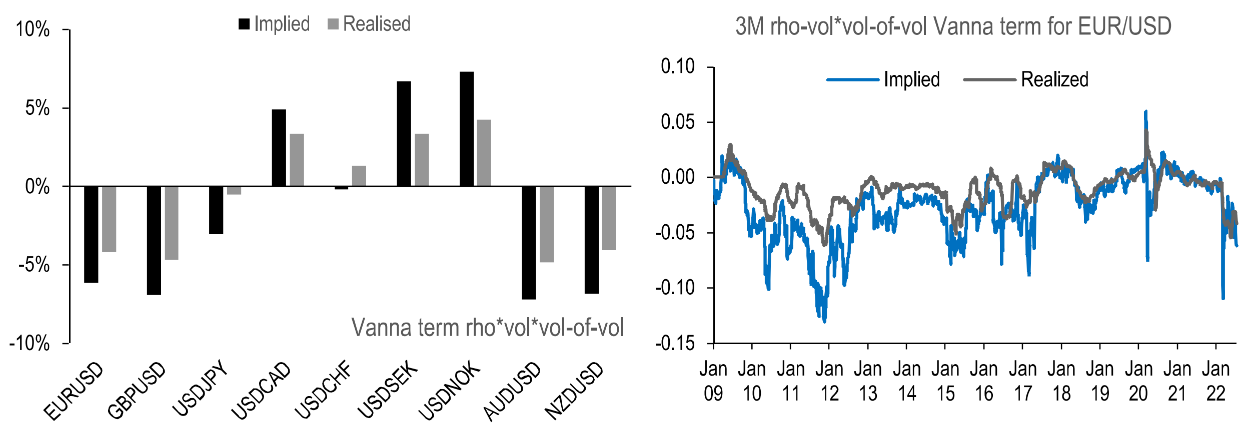
$$Vanna_{RP} = (\,\rho_R v_R \sigma_R - \rho v \sigma)\delta t$$

portrays a rather different picture. Being boosted by the implied vol and vol-of-vol correction, the implied term now is expected to be wider. In other words, the vol and vol-of-vol premia that were reviewed earlier, in particular the latter (see Exhibit 4), do have a magnifying effect on the actual term that enters the skew premium at least based on the formulas. The comparison of the corresponding terms, on the same underlying assets as in Exhibit 6, is displayed below (Exhibit 7). The latest snapshot (LHS) is no longer indicative of an outperformance of the realized parameter over the implied one, and therefore this no longer suggests that the long skew trade should be performing. The time series comparison (RHS) is instead better supportive of the notion that a premium between implied and realized skew could be isolated.

Exhibit 7: The notion of the skew premium changes considerably after taking into account vol and vol-of-vol terms beyond spot/vol corr, snapshot (as of July 2022) and time-series case study (for EUR/USD).



Source: J.P. Morgan Quantitative and Derivatives Strategy

We have just presented a general overview on the possibility of identifying risk premia on smile parameters beyond vols themselves, supported by some intuitive and easy to grasp concepts that most investors should be familiar with, and by empirical evidences. In the following section, we'll investigate further the comparison between estimates of the premia and corresponding actual PnLs, allowing to assess whether an ex-ante proxy of a premium of a smile parameter can have an actual correspondence on the PnL of a trading position. We'll dig a bit deeper in some technicalities that were left purposely aside for the high-level overview but which will become important when dealing with the nitty-gritty aspects (sometimes unavoidable) associated with options trading.

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Empirical drivers for smile strategies' PnLs

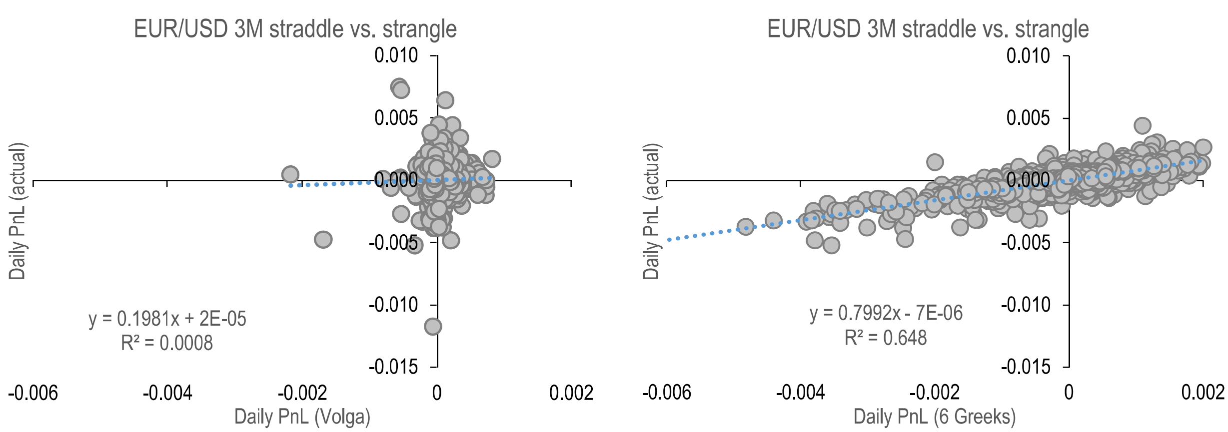
The purpose of this section is to assess how well the theoretical attribution of Greeks PnLs of the first section is matched by empirical analyses. While our previous report focused mostly on the vol-of-vol parameter, the novel element of discussion here is going to regard the skew. An additional element of innovation will discuss how much of a strategy PnL can be attributed to a given premium parameter and the related second-order Greek vs. the impact of the fluctuations on the corresponding smile parameter via the related first-order Greek.

We first test the theoretical framework to vol convexity strategies, where previous research has been already released, before reviewing the novel case of skew strategies. For the sake of brevity, and for explaining to readers the actual mechanism of PnL generation, we just consider a limited set of case studies for each smile strategies, with data since Jan 2008. A more comprehensive review of vanilla and exotic trading strategies directly exposed to the skew risk premium will be released in the future. Similarly, while the current note considers the FX market as the benchmark case for empirical analyses, future research will review historical analyses in the cross-asset space.

Vol convexity strategies – PnL drivers

In this section we review a few practical examples with plain vanilla constructs for the interpretation of FX vol convexity strategies PnLs via the relevant Greeks. As discussed earlier, for each construct the relevant Greeks are computed by cumulating over the underlying vanilla constituents. We review here PnLs related to 3M straddle vs. strangle trades, in equal Vega notionals, by covering, for illustrative purposes, just a limited subset of relevant case studies on the matter. As the goal is not that of introducing a trading strategy here (the possibility of trading the vol-of-vol premium in presence of trading costs was covered in our earlier note), but rather that of understanding PnL drivers, analyses are carried out assuming zero trading costs. PnLs are computed for the strategy that cumulates positions on a daily basis, and therefore refer to a whole set of options with different Expiries. In agreement with the formulas of the previous section, the Greeks (and the corresponding PnLs) are re-calibrated via proxies of fixed Expiry (i.e., shrinking time to maturity) ATM vol and of SABR-calibrated smiles.

Exhibit 8: Zero-cost PnL of EUR/USD vol convexity strategies well captured by its description via the relevant Greeks, not by Volga alone.



Source: J.P. Morgan Quantitative and Derivatives Strategy

We start with a case study on EUR/USD (Exhibit 8). The scatter plots compare daily PnL for the strategy (y axis) vs. that obtained via the Greeks: just Volga (LHS) and Volga, Gamma, Vega, Vanna plus smile rebalancing $Vega_{Skew}, Vega_{Fly}$ ones (RHS). The sole Volga Greek is not useful

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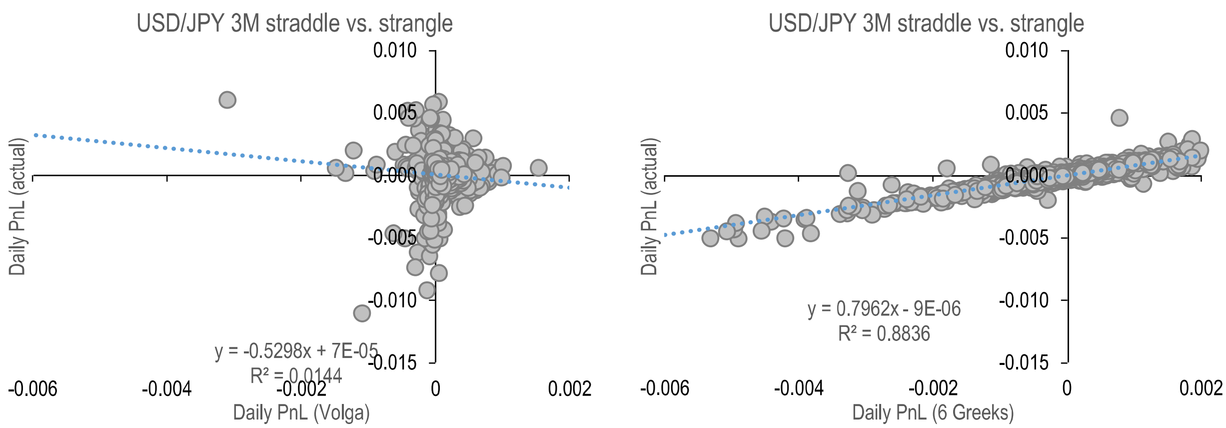
for describing the daily PnL of the strategy, as the effect of the other "spurious" Greeks becomes important after inception. The description of the PnLs via the six Greeks is satisfactory, with elevated R2 coefficients. The inclusion of the smile rebalancing effects via $Vega_{Skew}, Vega_{Fly}$ adds value to the PnL interpretations. The case study on USD/JPY (Exhibit 9), same settings as for EUR/USD, confirms the validity of the PnL interpretation via the six Greeks and the usefulness of measuring sensitivities to changes in the smile parameters. R2 coefficients based on the long-term PnL analyses are elevated, at almost 90%. In both cases, measuring Vega sensitivities via the change in ATM rather than the fixed strike (i.e., the option's actual) implied vols are associated with higher R2, which adds an empirical validation of the formalism pursued.

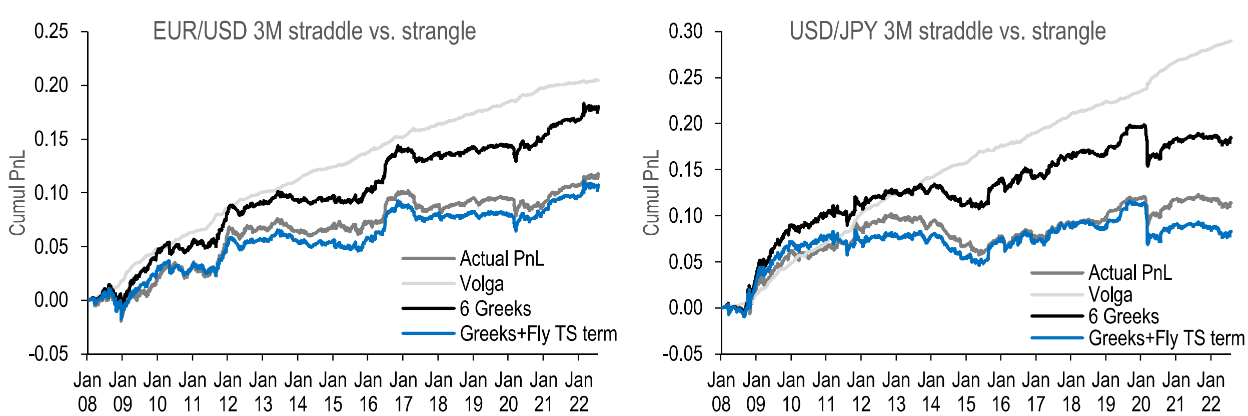
Exhibit 9: Zero-cost PnL of EUR/USD vol convexity strategies well captured by its description via the relevant Greeks, not by Volga alone.



Source: J.P. Morgan Quantitative and Derivatives Strategy

So far the term-structure correction term for the vol-of-vol were left aside, the reason being that the calculation hinges on a proxy / ansatz on the maturity-scaling which would require further theoretical justifications and additional checks, to be addressed in future research notes. Still, in the next couple of slides we will test the empirical adequacy of the term-structure correction term. Its added value in terms of higher R2 coefficients in the scatter plots above would be very modest (less than 1%) for both cases considered, relative to the benchmark case encompassing just Volga and the six Greeks (second order ones + Vega + $Vega_{Skew}, Vega_{Fly}$ smile adjustments).

Exhibit 10: Inclusion of the term-structure adjustment allows a closer match between long term time series of actual vs. Greeks-based PnLs.



Source: J.P. Morgan Quantitative and Derivatives Strategy

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Exhibit 10 considers the time series of actual PnL and Greek-related PnLs for the EUR/USD and USD/JPY constructs. We first highlight the significant mismatch between actual PnL and Volga-related PnL: the latter term exhibits a smooth upward slope but, because of the spurious sensitivities introduced by the other Greeks, is not the sole PnL driver during the life of the options. Adding the three other “standard” Greeks and the two new smile adjustments allows obtaining a closer description of the PnL via the expected sensitivities, still with some mismatch from the actual PnL. We stress that, during the “life” of the options (at inception constructs are Vega-neutral), Vega, and Gamma contributions to the PnL can be non-negligible. Similarly, the constructs can be associated with some significant Vanna exposure, especially when the pricing of the skew deviates markedly from zero (as in the case of USD/JPY and JPY-crosses).

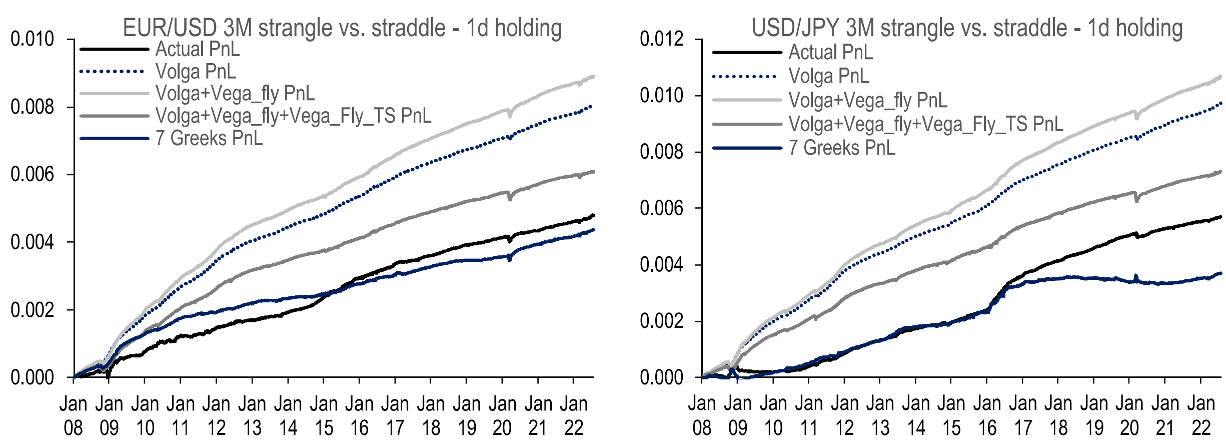
The inclusion of the term-structure correction appears to bring significant value, with much closer PnL time series, offering a semi-empirical validation of the term-structure scalings as introduced earlier. Still, we will leave it to future research to provide with a sounder test of the term-structure correction of the Volga premium as introduced in the Appendix:

$$\frac{1}{2}\sigma_0{}^2 Volga\left(\upsilon_{Real}{}^2 - \upsilon_{imp}{}^2 + \frac{Fly}{3\sigma_0\tau}\right)\Delta t$$

The 1d holding period is one final case study worth exploring. The reason why this latter case study is illustrative is that impact of spurious Greeks is contained, so that the PnL should represent the portfolio’s exposure as expressed by the constraints on the Greeks at inception (in other words, pure short Volga). We consider the actual strategy under the zero cost limit for the sole purpose of PnL attribution. As such a daily rebalanced strategy would be totally unfeasible in practice from a cost standpoint, one would need to set rules for rebalancing an options portfolios when the impact of spurious Greeks becomes excessive.

Indeed, for the 1d holding period case study (Exhibit 11, for EUR/USD LHS and USD/JPY RHS), we witness a much tighter agreement between actual and Volga PnL, as actual PnL is also a smooth upward sloping curve. This confirms the appeal of the short-Volga portfolios in the first place, and also the need of keeping the impact of the other spurious Greeks under control. We also notice that the correction via the $Vega_{Fly}$ term, which was helpful in terms of improving the R2 / descriptive power of the regression, introduces a drift which pushes the Greek-based description further away from the actual PnL.

Exhibit 11: Volga is a much better driver for the strategy’s PnL for short holding periods. $Vega_{Fly}$ and term-structure corrections further help in obtaining an accurate description of the actual PnL.



Source: J.P. Morgan Quantitative and Derivatives Strategy

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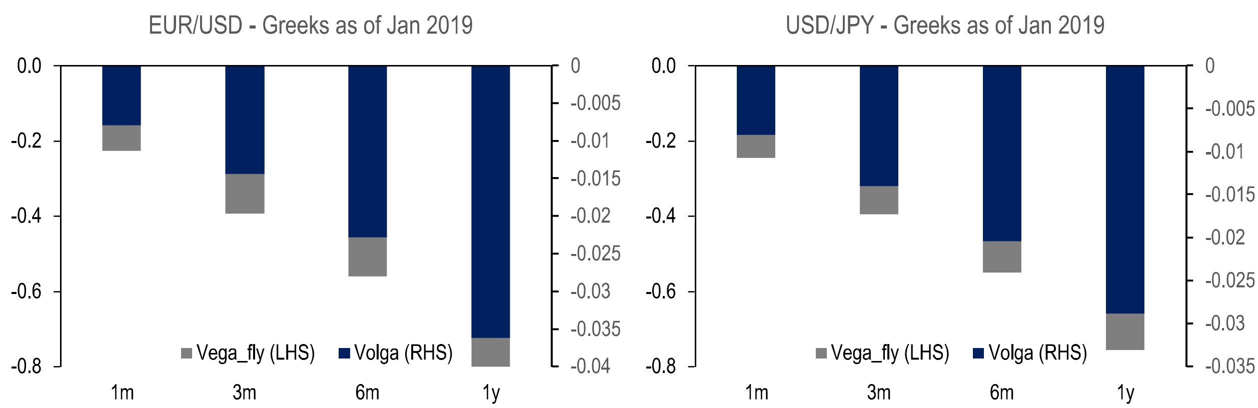
By putting all technicalities aside, this mismatch can be mostly attributed to an inadequate treatment of term-structure effects. It is then comforting to see that the term-structure correction based on a proxy scaling for the vol-of-vol allos for a much closer agreement of PnL time series, in particular for the EUR/USD case (LHS chart). For the USD/JPY case (RHS chart), the description of the time series of the 1d holding PnL via the six Greeks and the term structure correction is excellent until mid-2016 and less accurate after that. Whether the effect could be attributed to an eccessive PnL-decay due to the term-structure correction or to an inaccurate estimate of the other Greeks (or to additional exposures not reviewed here) remains to be tested in future analyses. We also stress that the Vega-neutral structure does not impose additional constraints on the portfolio's Greeks, implying a general exposure of the resulting portfolio to changes in market parameters over time.

Given the structurally inverted vol-of-vol curve, it is confirmed how a dedicated treatment of term-structure corrections is crucial when it comes to vol-convexity strategies. The topic will be explored more in detail in future reports, where possibly a functional expression for the maturity scaling will be motivated by first-principle arguments. As the maturity sensitivity of the spot/vol correlation parameter does not exhibit at first a structural pattern as it does for the vol-of-vol case, we will neglect such corrections in the following part of the note, dedicated to skew trading strategies (yet, as briefly discussed in the Appendix, the vol-of-vol term structure could still introduce a skew term-structure effect to be accounted for).

Exhibit 12: II vs. I order vol-of-vol Greeks – maturity dependence as of inception date (1/1/2019).

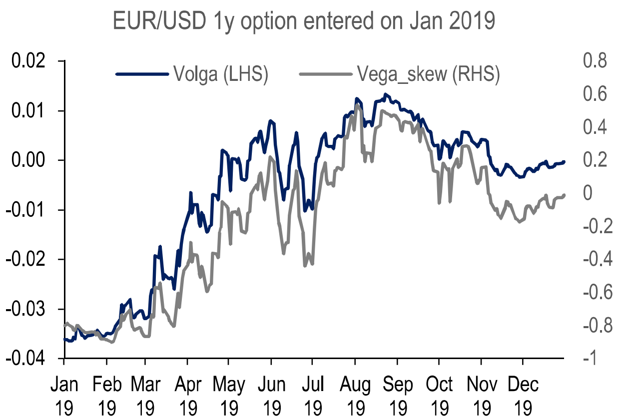


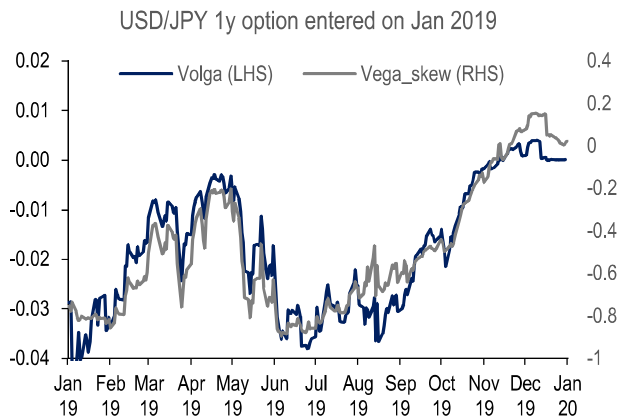
Source: J.P. Morgan Quantitative and Derivatives Strategy

We conclude the coverage of vol convexity strategies by commenting on the maturity-sensitivity of the relevant Volga and $Vega_{fly}$ Greeks, which can teach us a few relevant things. The empirical analysis is applied to two case studies, of EUR/USD and USD/JPY 1y option setups (straddle vs. strangle as before), for different maturities as of inception date (1 Jan 2019, (Exhibit 12). The two Greeks are computed numerically. What we understand is that, first, as it is expected from analytical expressions, the Volga Greek letter rises (in absolute value) with the time to maturity (i.e., it declines as the option approaches Expiry, all else being equal), with the $Vega_{fly}$ Greek exhibiting the same sensitivity to the maturity parameter. The behaviour of the two Greeks across the two currencies is fairly comparable. Second observation, for the two case studies, the two Greeks appear to be roughly proportional to each other, meaning that maturity and spot/smile effects are modest. As discussed in the Appendix, these results are consistent with the expected scaling $Vega_{Fly} = \frac{Volga\ \sigma_0}{6}$.

Exhibit 13 considers instead the Greeks computed following the evolution of market parameters over the life of the options over the period. While the general pattern of the previous chart is confirmed (i.e., both Greeks decrease in absolute value as time to maturity is reduced), the chart also shows the spurious effect mentioned earlier at play: the two Greeks, negative at inception, flip sign as spot and volatility variables change during the life of the options. This is a reminder of the difficulty of imposing a short-Volga constraints to active options portfolios.

Exhibit 13: II vs. I order vol-of-vol Greeks – maturity dependence as time passes by.





Source: J.P. Morgan Quantitative and Derivatives Strategy

As the vol-of-vol premium appears to be wider at the front-end of the curve (see our previous note), short maturities constructs are relatively more exposed to the premium driver, whereas long maturity ones are better suited for playing a re-pricing of the implied vol convexity parameter. The impact of term structure corrections is expected to be stronger at the front-end of the curves, calling for a more careful estimation of the premium for short-dated options. A more comprehensive discussion of the functional expressions for both smile rebalancing Greeks, of term-structure effects and of the related assumptions for the underlying spot/vol dynamics will be deferred to future research notes. Also, as discussed the question of how to best tackle vol-sensitivities sensitivities by using as pivots ATM or fixed strike vols will require further research.

As a whole, the results herein presented confirm the adequacy of the description of the PnL drivers for a set of vol-of-vol strategies that were covered in previous reports. The novel adjustments on the term-structure effects appear to add value from the perspective of having a tighter explanation of the PnLs. These observations are a promising starting point ahead of the analyses, carried out in the final part of the note, on skew risk premia strategies.

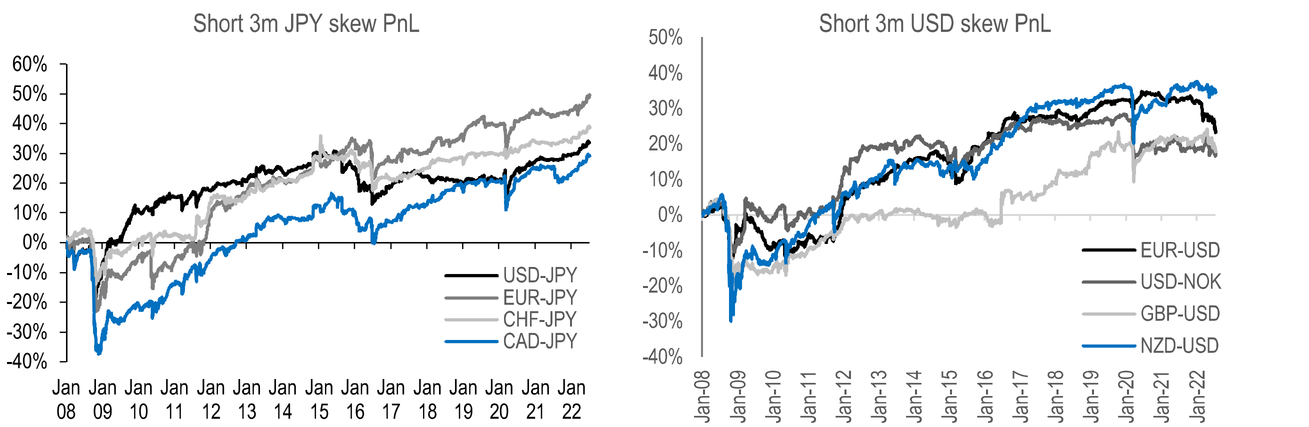
Skew strategies – PnL drivers

We now review the empirical results on skew-premium harvesting strategies, allegedly the main element of innovation covered within the report. In the following, we will just cover a limited subset of relevant backtests within the FX market, by following-up with a more detailed coverage (across asset classes, products, maturities etc.) in the near future. Skew-sensitive ratio spreads strategies in FX were covered in a previous research report (*All weather ratio spreads excel when primed with risk on/off filter*, Jankovic et al, 2020). A previous report (*What can option implied skew tell us about bond equity correlation?*, Cheng, 2021) inferred a proxy measure of Equity/Bond correlation from market prices of implied skews, assuming the CAPM relationship.

The ultimate safe haven status of the Yen within the currencies market is currently being challenged by the YCC program as enforced by BoJ for boosting inflation, which has led to sharp drops in the currency's value this year despite the sharp downturn of Equity markets. That said, JPY, followed by USD, are the two most representative examples of currencies where the sign of the skew is to some extent persistent over time, mirroring the mechanism at play for Equities. The two case studies we cover within FX are 3M risk-reversals for JPY- and USD-crosses. Positions are cumulated and delta-hedged daily, and held until Expiry. The two legs of the riskies have the same unit of Vega at inception. As discussed earlier, given the linearity of the Greeks of a portfolio relative to its constituents, the same notion of harvesting a skew risk premium can be applied at other vanilla and exotics constructs that are skew-sensitive.

A snapshot of skew collecting strategies in FX is presented below (Exhibit 14), for JPY (LHS) and USD (RHS) crosses, including transaction costs. The setup involves selling systematically JPY and USD calls and buying puts. Strictly speaking, market convention refers to selling the skew as positioning for a tighter deviation between calls and puts pricing (i.e., for a drop of the absolute value of the skew, regardless of the sign). Therefore, our backtests will be informative of skew premium collection if the sign of the riskies is structurally in favour of JPY and USD calls over puts. Still, a high-level analysis from the backtests points to the possibility of extracting a skew premium out of the FX space, at least for the most liquid G10 space (EM currencies are slightly less liquid and suitable for smile strategies). Strategies in the charts embed the impact of realistic trading costs.

Exhibit 14: Case studies of short JPY (LHS) and USD (RHS) skew (i.e., selling JPY and USD calls and buying the puts) strategies – time series



Source: J.P. Morgan Quantitative and Derivatives Strategy

In the next two tables we dig deeper across JPY and USD crosses for getting a tighter sense of the drivers behind the PnLs just displayed, by comparing performance measures with estimates of the skew premia. The tables compare long-term (since 2008) averages of implied and realised parameters, and performance measures for the strategies selling the skew (or, more precisely, JPY and USD calls over puts). In the tables, implied rho refers to the average of spot/vol correlation parameter over time (as averaged over all daily estimates for all options entering the book), while its realized counterpart averages all daily realized spot vol correlations. The same is done for the "skew" terms $\rho \upsilon \sigma$ and $\rho_R \upsilon_R \sigma_R$. For this historical analysis of the premia, we do not take into account the δt terms that would attribute higher weight to weekends over weekdays – the effect will be taken care of in the PnL attribution via the Greeks. As it was done earlier, Greeks and proxy of spot/vol correlations are adjusted on the running estimate of fixed expiry ATM volatility.

The results for the JPY-crosses (Exhibit 15) confirm a good agreement between the estimates of the skew premium and the PnL generated by the corresponding strategies. AUD/JPY and NZD/JPY are the two sole cases where the estimate of the premium, which would favour selling JPY calls over puts, is not matched by a positive sign of the corresponding PnL. Beyond transaction costs, we will analyse later more in detail the possible reasons for such a mismatch. In all the other cases, the strategy generates a positive PnL, supported by a premium on the skew for doing so. This is a first starting point towards the validation of the formula which allows linking an expected PnL to a risk premium on the skew parameter.

Exhibit 15: Summary of the statistics for the strategy selling JPY-x skew (selling JPY calls, buying JPY puts)

	Spot/vol correlation (rho)			*Skew (rho*vol*vol-of-vol)*			*Performance measures*		
ccy	Imp rho	Real rho	Diff	Imp skew	Real skew	Diff	Ret	Vol	Sharpe
USD/JPY	-22.5%	-14.6%	-7.9%	-5.2%	-3.2%	-2.1%	2.3%	6.0%	0.38
EUR/JPY	-32.2%	-22.4%	-9.8%	-8.1%	-4.4%	-3.7%	3.4%	6.2%	0.54
GBP/JPY	-33.1%	-19.8%	-13.3%	-9.1%	-4.8%	-4.4%	3.3%	7.9%	0.42
CHF/JPY	-19.5%	-14.6%	-4.8%	-4.4%	-1.2%	-3.2%	2.4%	5.4%	0.45
CAD/JPY	-32.0%	-23.5%	-8.5%	-8.6%	-4.9%	-3.7%	2.2%	6.6%	0.33
NOK/JPY	-35.1%	-22.9%	-12.2%	-10.4%	-5.6%	-4.8%	0.2%	10.5%	0.02
SEK/JPY	-33.8%	-21.4%	-12.5%	-9.8%	-4.7%	-5.1%	7.8%	14.9%	0.52
AUD/JPY	-40.7%	-30.7%	-10.0%	-12.4%	-8.1%	-4.2%	-1.2%	8.8%	-0.13
NZD/JPY	-38.8%	-24.4%	-14.5%	-12.1%	-6.6%	-5.5%	-1.6%	16.4%	-0.10

Source: J.P. Morgan Quantitative and Derivatives Strategy

The results for the USD-crosses (Exhibit 16) are qualitatively aligned. For all USD/G10 crosses, the estimate of the premium and the PnL (costs included) have all the same sign, with the exception of USD/CHF. The premium is in all cases supportive of selling USD calls, with the exception of USD/JPY, where we have seen in Exhibit 15 that the skew premium favors selling JPY calls over puts. The skew premium estimate is better aligned than the spot/vol correlation premium in explaining the sign of the PnL for USD/CAD. The average PnL generated by the strategy is generally tighter than for JPY-crosses, along with a tighter proxy of the estimate of the skew premium. These results are so far comforting in our interpretation of the drivers of skew-related strategies.

Exhibit 16: Summary of the statistics for the strategy selling USD-x skew (selling USD calls, buying USD puts).

	Spot/vol correlation (rho)			*Skew (rho*vol*vol-of-vol)*			*Performance measures*		
ccy	Imp rho	Real rho	Diff	Imp skew	Real skew	Diff	Ret	Vol	Sharpe
EUR/USD	-16.6%	-13.2%	-3.4%	-3.2%	-1.9%	-1.3%	1.7%	4.3%	0.39
USD/JPY	-22.5%	-14.6%	-7.9%	-5.2%	-3.2%	-2.1%	-4.1%	6.0%	-0.68
GBP/USD	-24.5%	-20.8%	-3.7%	-4.8%	-3.0%	-1.8%	1.2%	5.2%	0.24
USD/CHF	-3.3%	5.2%	-8.5%	-0.6%	-1.2%	0.6%	0.1%	5.0%	0.02
USD/CAD	21.9%	25.5%	-3.6%	3.5%	2.8%	0.7%	0.0%	3.2%	0.01
USD/NOK	24.1%	19.9%	4.3%	5.4%	3.5%	1.9%	1.1%	4.8%	0.22
USD/SEK	22.2%	16.7%	5.6%	4.7%	2.5%	2.2%	0.7%	4.1%	0.17
AUD/USD	-32.3%	-27.4%	-4.9%	-7.5%	-5.3%	-2.2%	0.6%	10.6%	0.05
NZD/USD	-30.3%	-22.3%	-8.0%	-7.4%	-4.2%	-3.1%	2.4%	7.6%	0.31

Source: J.P. Morgan Quantitative and Derivatives Strategy

Another aspect worth stressing is that, for both groups of currencies as covered above, our accurate estimate of the skew premium is wider than for the comparison of implied and realized spot/vol correlations. It appears confirmed that the “corrective” terms, thanks to the premia in vol and vol-of-vol parameters, make it easier to isolate and harvest a premium on the skew.

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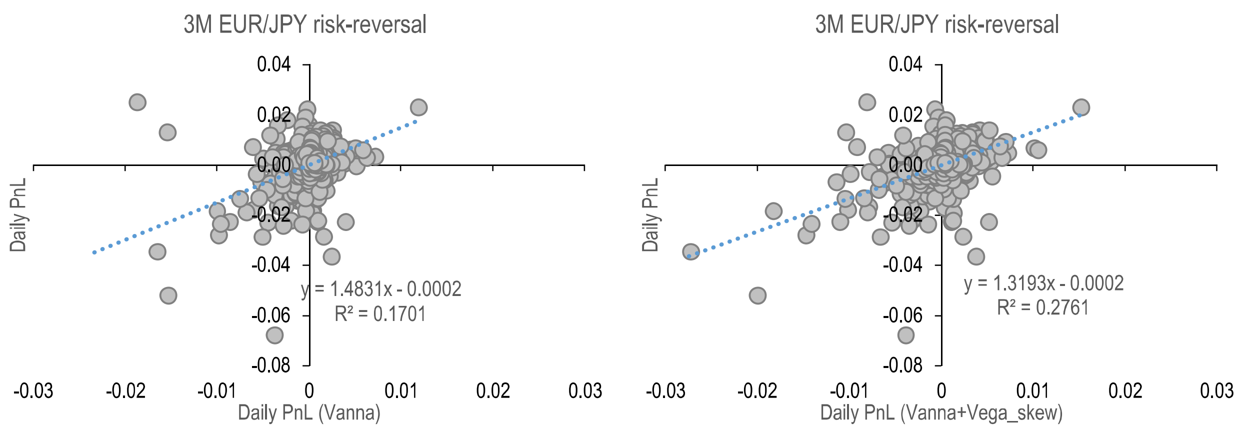
We now move on to a more granular analysis of specific case studies in order to highlight the drivers at play. We start from the analysis of EUR/JPY risk-reversals PnL (CHF/JPY would lead to similar results). We first compare the daily PnL of the strategies with the proxy PnL from the Vanna (Exhibit 17, LHS) and Vanna and $Vega_{Skew}$ (Exhibit 17, RHS) Greeks. While the sole Vanna Greek is associated with a rather limited R2, the efficacy of the description of the PnL is significantly improved when adding the $Vega_{Skew}$ axis to it.

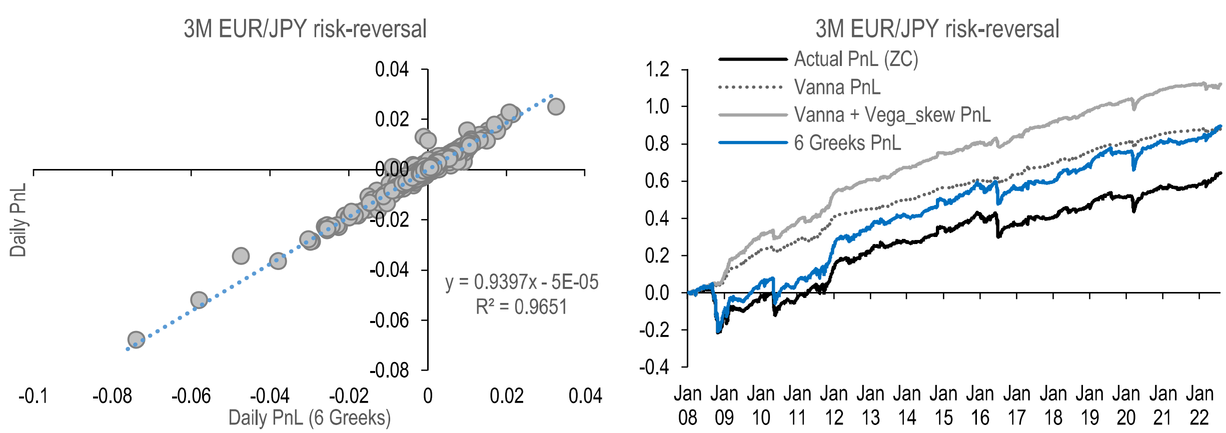
Exhibit 17: How much of PnL is captured by Vanna and $Vega_{Skew}$ Greeks – case study for EUR/JPY



Source: J.P. Morgan Quantitative and Derivatives Strategy

The addition of the remaining four Greeks (Exhibit 18, LHS) leads to an almost perfect description of the PnL, with Gamma and Vega associated with R2 coefficients of around 40% and 60%, respectively. Still, while the fluctuations of daily PnL is largely influenced by the Vega and Gamma sensitivities, the long-term PnL (Exhibit 18, RHS) is mostly driven by the positive trend from the skew-specific Greeks.

Exhibit 18: Adding the other Greeks helps obtaining a closer description of the PnL. PnL time series for EUR/JPY



Source: J.P. Morgan Quantitative and Derivatives Strategy

We then consider AUD/JPY, one of the few cases where there is a mismatch between skew premium and sign of the PnL. As for EUR/JPY, the two skew-related Greeks help describing the PnL up to R2 of less than 20% (Exhibit 19). Again, the use of the six Greeks allows an almost perfect description of the PnL with R2 of 98% (Exhibit 20 LHS). Contribution from vol-convexity Greeks (Volga and $Vega_{Fly}$) are very contained.

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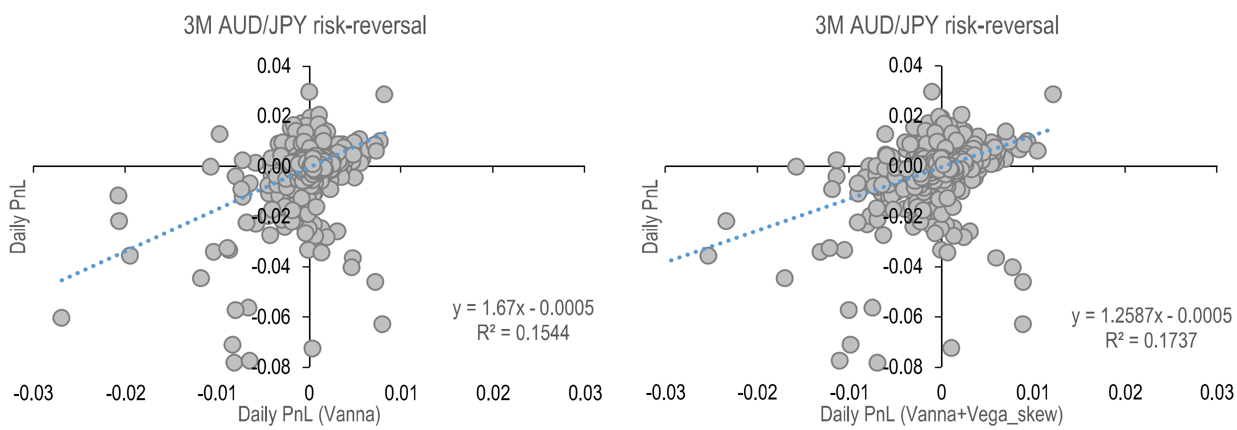
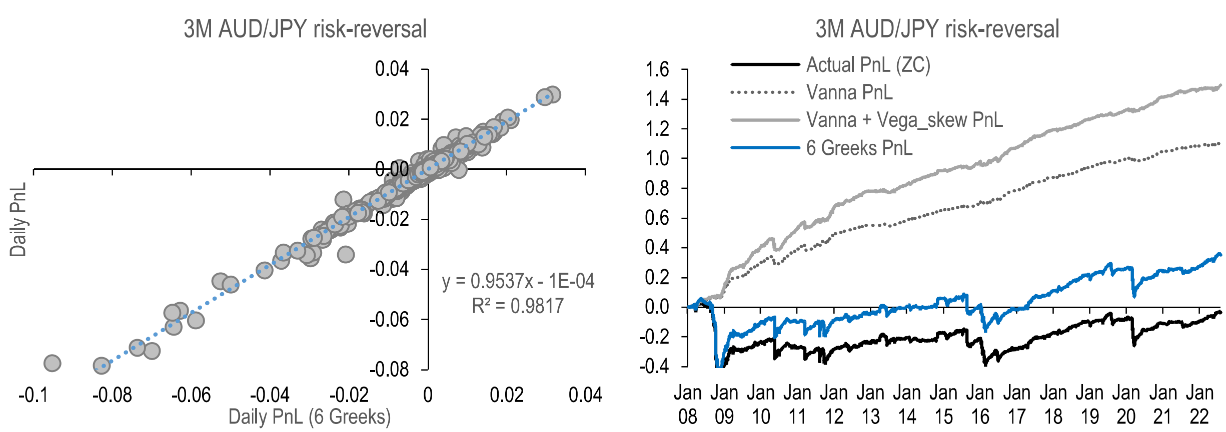
Exhibit 19: How much of PnL is captured by Vanna and $Vega_{Skew}$ Greeks – case study for AUD/JPY



Source: J.P. Morgan Quantitative and Derivatives Strategy

The comparison of cumulative PnL time series (Exhibit 20, RHS) is insightful for showing the drivers at play. While, as before, the PnL from Vanna and $Vega_{Skew}$ is steadily upward sloping, it is almost perfectly balanced by a corresponding negative trend from both Gamma and Vega. Out of the two, Gamma largely dominates over Vega (roughly in 4:1 relative amounts) as a source of negative PnL for this pair over time. Similar results are found for NZD/JPY.

Exhibit 20: Adding the other Greeks helps obtaining a closer description of the PnL. PnL time series for AUD/JPY



Source: J.P. Morgan Quantitative and Derivatives Strategy

A similar pattern is at play on USD/CHF. The average sign of the skew and of the skew premium would be supportive of selling CHF, not USD calls. Yet, the positive PnL as associated with the sale of USD/CHF riskies (selling USD calls and buying puts) is explained by the countering effect due to Gamma and Vega Greeks, and this despite the large drop of PnLs on January 2015 (when SNB removed the peg of CHF to EUR). As discussed earlier, strictly speaking the strategy that sells the skew should take into account fluctuations in the sign of the risk-reversals, something that will be explored in future research notes.

USD/NOK is yet another case where sign of the skew premium and of the PnL are aligned. As with EUR/JPY, Vanna and $Vega_{Skew}$ combined allow explaining around 20% of the daily variability in PnL (Exhibit 21), with the explanatory power rising to ~85% when including the other four Greeks as well (Exhibit 22, LHS).

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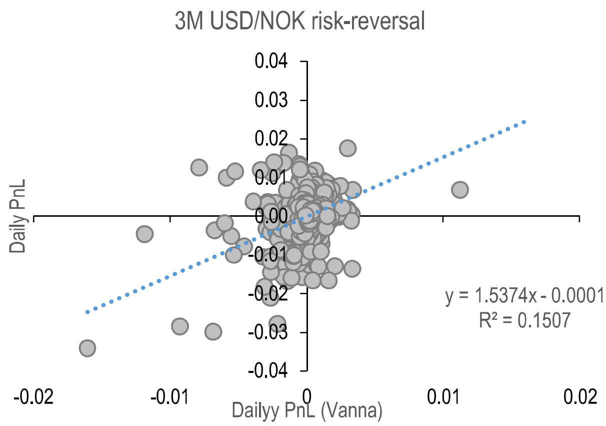
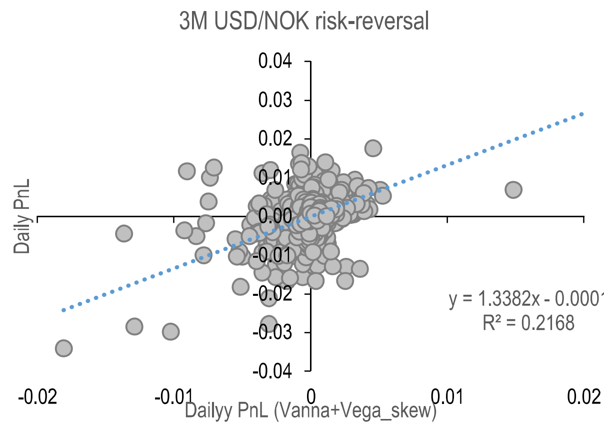
Exhibit 21: How much of PnL is captured by Vanna and $Vega_{Skew}$ Greeks – case study for USD/NOK

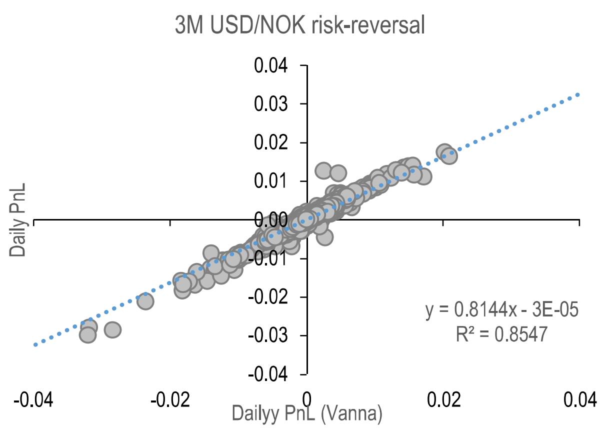


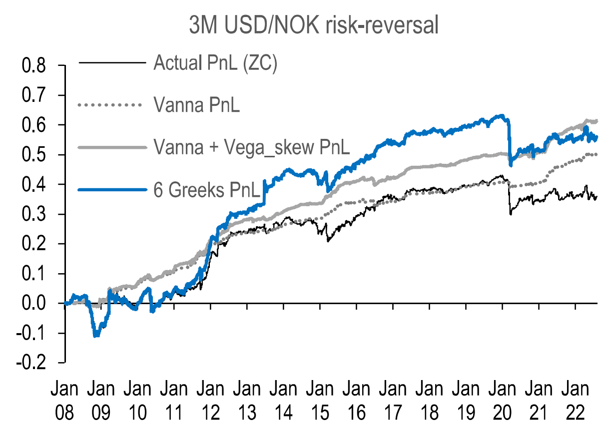


Source: J.P. Morgan Quantitative and Derivatives Strategy

As before, while Gamma and Vega (R2 of around 45% for both) have more of an impact in explaining the variability of daily PnL, the long-term trend in the risk-reversal trade PnL is mostly explained by the skew premium the position is naturally harvesting (Exhibit 22, RHS).

Exhibit 22: Adding the other Greeks helps obtaining a closer description of the PnL. PnL time series for USD/NOK.





Source: J.P. Morgan Quantitative and Derivatives Strategy

The empirical results of this section teach us that, generally, our interpretation of the PnL drivers of skew-exposed strategies are accurate. In particular, our novel estimate of skew premium via the implied vs. realized interplay of a term which involves the product of spot/vol correlation, vol and vol-of-vol is well supported by the empirical analyses. We have seen that generally the skew-harvesting trade tends to accumulate a steady, positive PnL via the Vanna Greek, but is sensitive to the other exposures such as Gamma and Vega. The new $Vega_{Skew\ as}$ introduced in the report brings value to the interpretation of the PnLs, and particularly at times where pricing of the skew lingers around zero and is possibly subject to large fluctuations; however, compared to the Vanna axis, it is more associated with a volatility than a drift in PnLs.

Also, we find that harvesting skew premium is an easier task than for the corresponding vol convexity parameter. This is due to essentially three main effects: 1) stability of the premium over time thanks to the vol and vol-of-vol adjustment; 2) modest impact of trading costs; and 3) relatively contained impact of "spurious" Greeks relative to the ones directly exposed to the skew.

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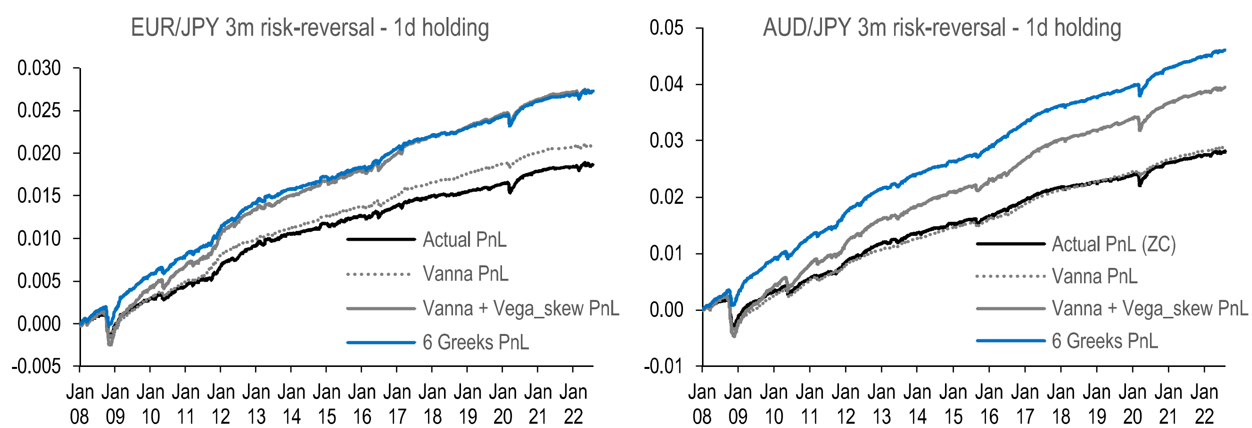
Regarding this latter aspect, we have tested that, while typically second order relative to Vanna, impact of Gamma and Vega can be significant. However, the signs of these exposures for a given risk-reversal trade are heavily path dependent, and can change depending on the path followed by spot, volatility variables and passing of time. As such, these Greeks are more associated with driving the volatility than with long-term trends themselves of risk-reversal PnLs. Still, as the skew premium associated with the Vanna Greek appears as significant, and on most occasions rather stable over time, it would be appealing to structure pure Vanna trades, insulated from other Greeks, mirroring for the skew the sensitivity that a Variance swap allows on realized volatility.

We highlight below a couple of aspects that will be worth exploring in future notes. The smile expansion that helped highlighting premia on the smile started from the assumption of zero interest rates on both currencies. Previous research (*FX Derivatives - EM vol has peaked for now*, Sandilya, Sep 18) showed that the inclusion of carry / rates differential terms can be significant when dealing with delta-hedged risk-reversals, granting a positive time-decay for long or short risk-reversal trades depending on the interplay between skew vs. forward points pricing. Such corrections could be particularly relevant when dealing with high-beta currencies such as AUD and NZD where interest rates have been historically higher than for low-beta currencies such as JPY.

Furthermore, as we have seen for the convexity strategies, taking into account an explicit term-structure correction could be beneficial for obtaining a more granular description of the PnLs via first-principle arguments. In fact, the formulas in the Appendix suggest that the vol-of-vol maturity scaling should have a corresponding impact of the skew. Such a correction was shown to be helpful (see Exhibit 11) for vol convexity PnL attribution purposes, by trimming the estimate of the premium in the smile parameter and bringing down the "theoretical" PnL and closer to the actual one. Its eventual inclusion would eventually allow checking whether any slippage in the calculation of the Greeks or on the estimation of the smile premia are responsible for the mismatches in PnL attribution. We will tackle more directly this topic in future research reports.

Exhibit 23: 1d holding – case studies on EUR/JPY and AUD/JPY risk-reversals



Source: J.P. Morgan Quantitative and Derivatives Strategy

Similarly as for the vol convexity case, considering 1d holding period can be informative of the genuine drivers of the structures before spurious Greeks kick-in. We carry out the investigation of EUR/JPY and AUD/JPY case studies (Exhibit 23). It is evident in both cases that the actual daily PnL follows very closely the Vanna PnL over time. If ever, there is in both cases some modest mismatch between actual and six Greeks PnLs, meaning that a perfect description would require a further tighter calibration. As an example, it remains to be assessed how much of this mismatch could be attributable to the (here disregarded) term structure effects.

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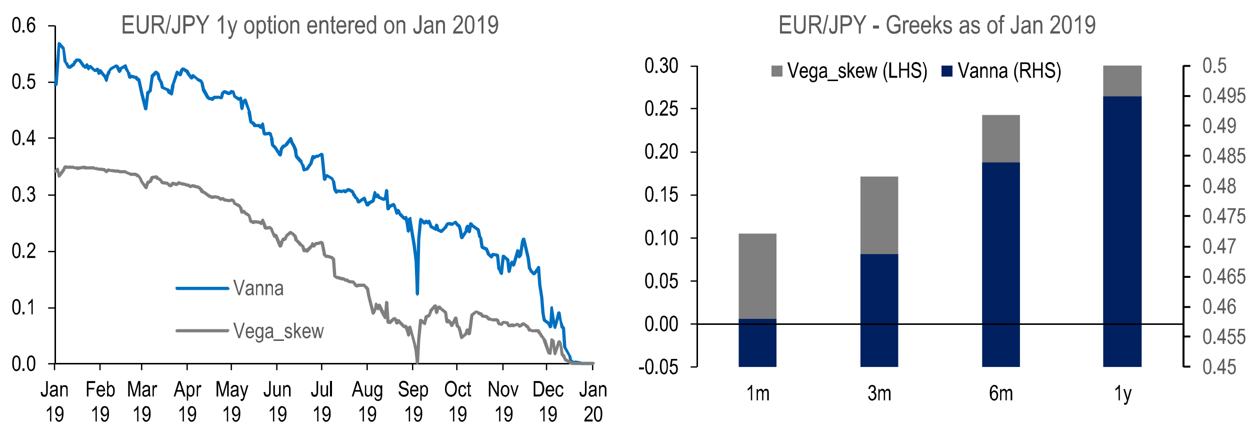
As we did for vol convexity, we now cover the maturity sensitivity of the two relevant skew-related Greeks. The case study on one existing option structure as entered on Jan 2019 and followed until Expiry (Exhibit 24, LHS) shows that at first sight the two Greeks display a similar behaviour over the life of the option, with the Vega_{Skew} converging towards zero near Expiry. The analysis of the Greeks for different maturities as of inception date (Exhibit 24, RHS) shows instead a linear sensitivity of Vega_{Skew} to the maturity, while Vanna shows tighter variations. At least within Black-Scholes, one can prove that that fixed-delta options converge to a fixed value of the Vanna in the limit of zero time to maturity. The observation suggests that, similarly as for the Gamma vs. Vega sensitivity, short-maturity options are best suited for taking a view on the skew premium (Vanna) while longer-dated ones are more exposed to the changes in the implied parameters (Vega_{Skew}). The review of products with different maturities would allow checking the relevance of the effect on actual case studies.

Exhibit 24: Maturity sensitivity of Vanna, $\text{Vega}_{\text{Skew}}$. Case study on EUR/JPY as of 2019.



Source: J.P. Morgan Quantitative and Derivatives Strategy

To conclude, the proposed framework offers a good starting point for understanding the main drivers behind skew-related strategies. In particular, our measure of the skew premium is positively correlated with the expected corresponding PnL. The Greek letter that we have introduced for accounting for changes in implied skew allows for a more granular description of the PnL, as it mostly responsible for explaining the latter's volatility. We have shown that the effect of spurious Greeks such as Gamma and Vega Greeks is non negligible and can be a significant driver of the volatility of the PnL. While the impact of the "spurious" Greeks is as significant, trading costs play less of a role for skew harvesting strategies relative to vol convexity ones. Also for the latter reason, the applicability of skew trading strategies tends to reach a broader audience than the ones on vol convexity which are more for dedicated vol-traders.

We have discussed that a couple of aspects that would deserve additional investigation for obtaining a closer description of PnLs would be: a) inclusion of explicit sensitivities to interest rates and b) accounting for term structure corrections.

Also, this note was mostly dedicated to a theoretical analysis of the skew premium. Future reports will share more light on relevant aspects for actual trading strategies, such as adding constraints on the Greeks of the traded portfolios, defining threshold levels for buying or selling the skew, by considering long/short strategies involving risk-reversals or other skew-sensitive products etc.

Concluding remarks with practical takeaways

We conclude with a few bullet points and practical takeaways for highlighting the main "selling points" of this note, especially as far as the implications for skew-trading are concerned.

Skew risk premium

A risk premium on the Skew or Vanna Greek letter can be introduced as:

$$Vanna_{RP} = \left(\left(\frac{\delta S}{S}\right)\left(\frac{\delta \sigma_0}{\sigma_0}\right) - \rho \upsilon \sigma \delta t\right) = (\rho_R \upsilon_R \sigma_R - \rho \upsilon \sigma)\delta t$$

As such, a self-consistent definition of a skew risk premium involves the implied vs. realized comparison of the product of vol, vol-of-vol and spot/vol correlation, and not just of the latter.

The PnL function related to the Vanna Greek and to the skew premium reads as:

$$Vanna_{PnL} = S\sigma_0 Vanna(\rho_R \upsilon_R \sigma_R - \rho \upsilon \sigma)\delta t$$

Main conclusions

- There is indeed a skew premium that can be harvested across asset classes
- The corrections due to vol-of-vol and vol make the skew premium wider if compared with the naïve outright comparison of implied vs. realized spot/vol correlation
- There is a long-term positive correlation between the sign of the premium (i.e., favouring selling calls or puts) and of the PnL of strategies aimed at harvesting that premium
- The interpretation of the PnL of skew-sensitive trades is further improved if, beyond Vanna, the sensitivity to changes of the implied skew parameter is measured via a dedicated Greek letter
- When pricing of the skew premium is wide enough, it is hard to position for a further widening of the skew premium, and the harvesting strategy is strongly supported
- The regime where skew pricing fluctuates around zero is the one better suited for playing large moves of the skew parameters, allowing to trade against the skew premium itself.
- The impact of spurious Greeks such as Gamma and Vega can be significant, and be the PnL main driver when large imbalances in such Greeks build up over the option's life

Tradeable solutions

The skew premium can be harvested by trading skew-sensitive products such as:

- Risk-reversals, call/put spreads, ratio spreads or outright calls/puts in the vanillas space
- Digitals, one-touches, conditional variance swaps in the exotic space

Conclusion

In the note, we have reviewed the possibility of attributing risk premia to vol parameters, and identifying structures that allow banking on these premia. As previous research had focused on the vol-of-vol or vol convexity parameter, here the main elements of innovation were focused in particular on the skew. We have shown that the skew risk premium involves the interplay between a realized vs. implied combination of spot/vol correlation, vol and vol of vol parameters.

For each smile parameter, we have highlighted the interplay between different drivers for the Carry (related to a second order Greek) and for the volatility (related to a first order Greek) of the corresponding PnL. For the skew, this involves the Vanna Greek vs. a measure of Vega sensitivity that relates to changes in implied skew pricing. Our interpretation of the ex-ante risk premia are well matched by the corresponding ex-post PnL, which allows a closer interpretation of performance drivers for structures that are sensitive to the smile parameters. The effect of spurious Greeks on vol-of-vol and skew trades was empirically tested.

We have also shown how to take into account term-structure corrections when empirical observations (as in the case of the markedly downward sloping vol-of-vol curve) suggests they should be significant, although additional research would be required for obtaining analytical expressions for the term-structure scalings consistent with first principles and the underlying dynamics. Our guess is that, by mirroring an effect already discussed on the interplay between Gamma and Vega terms for standard ATM vol trades, term-structure corrections can contribute to a widening or tightening of the naïve estimate of the corresponding parameter's risk premium.

For simplicity, we have tested the adequacy of the new formulas for isolating a skew risk premium by covering just a relevant subset within the FX space, that involving JPY-x and USD-x crosses: Yen skews are the most persistent (in favour of JPY calls over puts) within the currencies space, and those more akin to the features as shared by Equities. The empirical analysis suggests that a skew premium can be harvested out of the FX Options market, although possibly a wider skew premium can be possibly extracted out of Equities derivatives. For the vast majority of currency pairs considered, sign of the skew premium and of the PnL of the skew harvesting strategy are aligned, meaning that the former is a driver of the latter.

We have tried to keep the length of the report contained while overviewing both theoretical and practical relevant aspects. Therefore, there is much to follow up with in future research notes. It appears natural to broaden the scope of the coverage to other FX pairs where the sign of the skew can fluctuate more widely, and to assess the stability of the skew premium across asset classes. It would be worth testing the agreement of the premium formulas to other cases of skew-sensitive structures than just risk-reversals, as covered in the note. The interplay between second order and first order skew sensitivities for different maturities would need to be tested.

Perhaps most importantly, the main goal of the note was the possibility of isolating a risk premium related to the skew: additional work is required for building actual trading strategies, by sharing more light on the timing and on the structuring of the trades, and on the rules for rebalancing the portfolios for keeping the impact of spurious Greeks and of trading costs under control. On the more theoretical front, we could introduce term-structure corrections that are associated with the skew parameter and see if their inclusion to the description of actual PnLs.

Appendix – More on technical aspects

The two following sections add extra light on some technical aspects that were quickly presented throughout the note.

Understanding the breakeven term for the skew

We assume 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. After carrying out suitable expansions in the Greeks, and under the limits/assumptions presented in the previous sections, one can prove that the breakeven term for the spot/vol correlation is:

$$\rho_{BE} = \frac{2a\sigma_0}{\upsilon_{BE}}$$

As discussed earlier in the note, it would be cumbersome to prove analytically the equivalence $\upsilon_{BE} = \upsilon$ when the skew is not vanishing. However, by assuming that $\upsilon_{BE} = \upsilon$ holds, it is easy to prove that, within a class of standard stochastic volatility models such as SABR (*Managing Smile Risk*, Hagan et al, Wilmott, 2002) or Heston (*A closed-form solution for options with Stochastic Volatility with applications to Bond and Currency Options*, Heston, The Review of Financial Studies, 1993):

$$\rho_{BE} = \frac{2a\sigma_0}{\upsilon} = \rho$$

where ρ is the implied spot/vol correlation parameter.

Roll-over term in the vol-of-vol

Empirical analysis supplemented by first principles support a scaling like:

$$\nu = c\sqrt{\frac{Fly}{\tau * \sigma_0}}$$

where Fly stands for the 25delta Butterfly with time to maturity τ, σ_0 is the ATM vol of same maturity and c is a proportionality constant. At least under the zero skew limit, the following equality holds

$$\nu^2 = 3b{\sigma_0}^2$$

Which leads to the guess:

$$Fly = \frac{3\tau b{\sigma_0}^3}{c^2}$$

It then holds that:

$$\frac{\partial O}{\partial b} = \frac{\partial O}{\partial Fly}\frac{\partial Fly}{\partial b}$$

and that, based on the suggested scaling above:

$$\Delta b = (\frac{c^2 \Delta Fly}{3\tau{\sigma_0}^3} + \frac{c^2 Fly}{3{\sigma_0}^3}\frac{\Delta t}{\tau^2})$$

Which leads to:

$$\frac{\partial O}{\partial b}\Delta b = Vega_{Fly}\Delta Fly + Vega_{Fly} * \ Fly * \frac{\Delta t}{\tau}$$

By carrying out the explicit calculation of the $Vega_{Fly}$ term within the formalism, one finds a proportionality with the Volga Greek:

$$Vega_{Fly} = \frac{Volga\ \sigma_0}{6}$$

which leads to the following correction of the vol-of-vol premium formula due to term structure effects:

$$\frac{1}{2}{\sigma_0}^2 Volga\left({\upsilon_{Real}}^2 - {\upsilon_{imp}}^2 + \frac{Fly}{3\sigma_0\tau}\right)\Delta t$$

Future research will test more in depth the adequacy of such a correction when applied to actual estimations of the vol-of-vol premium, and in particular on the assumptions (like the scaling above $\nu \approx \sqrt{\frac{Fly}{\tau * \sigma_0}}$) that were instrumental in allowing a compact expression for the term-structure correction. For simplicity, in the numerical analyses carried out in the note, we have left the vol-of-vol term-structure correction:

$$Vega_{Fly} * \ Fly * \frac{\Delta t}{\tau}$$

as a separate term in the PnL expansion.

The vol-of-vol scaling could indirectly introduce a maturity sensitivity on skew exposures even if the ρ parameter does not exhibit a structural term-structure. After finding a functional relationship between risk-reversal and spot/vol correlation:

$$Risk - reversal = Risk - reversal\ (\rho, \sigma_0, \dots)$$

One could repeat the calculations above and isolate such a time-dependent effect via the ν-scaling. The topic will be reprised in future research notes.

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Risks of Common Option Strategies

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Put Sale: Investors who sell put options will own the underlying asset if the asset's price falls below the strike price of the put option. Investors, therefore, will be exposed to any decline in the underlying asset's price below the strike potentially to zero, and they will not participate in any price appreciation in the underlying asset if the option expires unexercised.

Call Sale: Investors who sell uncovered call options have exposure on the upside that is theoretically unlimited.

Call Overwrite or Buywrite: Investors who sell call options against a long position in the underlying asset give up any appreciation in the underlying asset's price above the strike price of the call option, and they remain exposed to the downside of the underlying asset in the return for the receipt of the option premium.

Booster : In a sell-off, the maximum realized downside potential of a double-up booster is the net premium paid. In a rally, option losses are potentially unlimited as the investor is net short a call. When overlaid onto a long position in the underlying asset, upside losses are capped (as for a covered call), but downside losses are not.

Collar: Locks in the amount that can be realized at maturity to a range defined by the put and call strike. If the collar is not costless, investors risk losing 100% of the premium paid. Since investors are selling a call option, they give up any price appreciation in the underlying asset above the strike price of the call option.

Call Purchase: Options are a decaying asset, and investors risk losing 100% of the premium paid if the underlying asset's price is below the strike price of the call option.

Put Purchase: Options are a decaying asset, and investors risk losing 100% of the premium paid if the underlying asset's price is above the strike price of the put option.

Straddle or Strangle: The seller of a straddle or strangle is exposed to increases in the underlying asset's price above the call strike and declines in the underlying asset's price below the put strike. Since exposure on the upside is theoretically unlimited, investors who also own the underlying asset would have limited losses should the underlying asset rally. Covered writers are exposed to declines in the underlying asset position as well as any additional exposure should the underlying asset decline below the strike price of the put option. Having sold a covered call option, the investor gives up all appreciation in the underlying asset above the strike price of the call option.

Put Spread: The buyer of a put spread risks losing 100% of the premium paid. The buyer of higher-ratio put spread has unlimited downside below the lower strike (down to zero), dependent on the number of lower-struck puts sold. The maximum gain is limited to the spread between the two put strikes, when the underlying is at the lower strike. Investors who own the underlying asset will have downside protection between the higher-strike put and the lower-strike put. However, should the underlying asset's price fall below the strike price of the lower-strike put, investors regain exposure to the underlying asset, and this exposure is multiplied by the number of puts sold.

Call Spread: The buyer risks losing 100% of the premium paid. The gain is limited to the spread between the two strike prices. The seller of a call spread risks losing an amount equal to the spread between the two call strikes less the net premium received. By selling a covered call spread, the investor remains exposed to the downside of the underlying asset and gives up the spread between the two call strikes should the underlying asset rally.

Butterfly Spread: A butterfly spread consists of two spreads established simultaneously – one a bull spread and the other a bear spread. The resulting position is neutral, that is, the investor will profit if the underlying is stable. Butterfly spreads are established at a net debit. The maximum profit will occur at the middle strike price; the maximum loss is the net debit.

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