Trading synthetic EUR forward volatility

JPM analytics for valuing forward volatility using swaptions

- We present a simplified framework to analyze forward volatility structures which are created synthetically using a triangle of swaptions and assuming a correlation of 1 between the two swap rates
- We present a list of synthetic forward volatility structures, their estimated value using vanilla swaptions and correlation of 1, and some statistics over the past 6M
- We have developed analytics that generate these statistics for EUR and GBP on a daily basis and is available in the *Euro/UK Interest Rate Volatility Package*
- Currently in EUR, on a 6M z-score valuation basis, we find 2Yx1Yx10Y forward volatility attractive to sell and 7Yx1Yx20Y forward volatility attractive to buy

Rates Strategy

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Trading synthetic EUR forward volatility via swaptions

When the ECB cut the deposit rates to -20bp last September and signaled that they would keep policy rates on hold for the foreseeable future and that any further monetary easing would likely occur by varying the size, pace, and composition of the balance sheet, implied volatility declined sharply across the curve reaching its multi-year lows. For instance, 3Mx10Y implied volatility declined to about 2.8bp/day in 4Q14, almost reaching its historical lows.

However, since Draghi hinted at potential QE in December, implieds have generally increased in the long-end of the curve even after accounting for the recent decline in implieds over the last couple of weeks. For instance, 3Mx30Y implied volatility is now at 4.3bp/day versus early December level of 3.4bp/day and interim highs of 5.4bp/day. More interestingly the volatility curve has steepened sharply across tails; the (1Yx30Y – 1Yx10Y) implied volatility spread has increased about 0.8bp/day since the December 2014 meeting.

This steepening of the volatility surface across tails has occurred in conjunction with an increase in the volatility of 30Y implieds (vol – of – vol) (**Exhibit 1**). The front-end of the curve has remained relatively sticky exhibiting low beta to long end volatility. With the swap curve being directional to the long end - flattening in a rally and steepening in a sell off, volatility has moved further out the curve. Intermediate and long-end forwards have exhibited large volatility and the forward volatility surface, especially those involving ultra-long tails, has anecdotally received lot of investor focus recently.

To recap, forward volatility agreements can be used to obtain volatility exposures on a forward looking basis. These structures do not have any delta or gamma exposures as the strikes are not set until the option expiry. For instance, in a long 1Yx2Yx5Y forward volatility agreement, the investor will enter into a 2Yx5Y swaption (swaption maturity is 2Y and underlying tenor is 5Y) in 1Y (expiry of the forward volatility agreement). The strike of this structure is set at option expiry in 1Y time.

Forward volatility structures, by themselves, are relatively illiquid especially in EUR and GBP. Investors can, however, replicate exposure to these forward rates

Exhibit 1: The steepening of the volatility surface across tails has occurred in conjunction with an increase in the volatility of 30Y implieds

1Yx30Y – 1Yx10Y implied volatility spread (lhs) and 1M delivered volatility of 1Yx30Y implied volatility (rhs); since 1 Jan 2015; bp/day

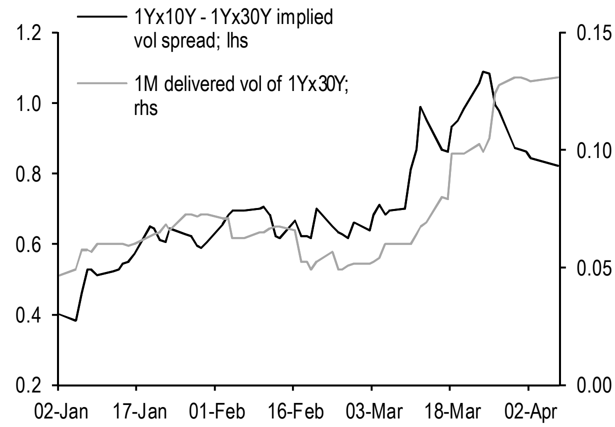
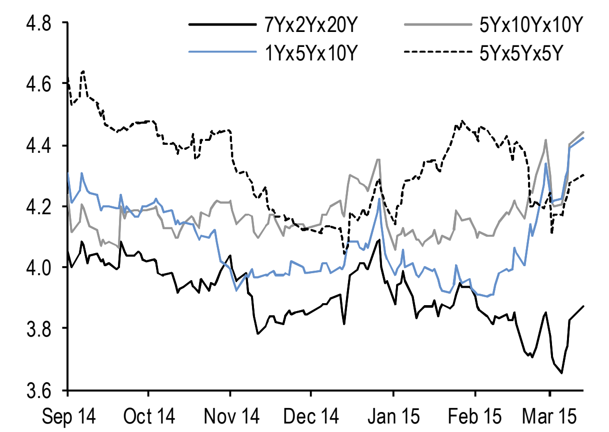


Exhibit 2: We can replicate forward volatility exposures using a triangle of swaptions and assumption about the correlation of the underlying rates

7Yx2Yx20Y, 5Yx10Yx10Y, 1Yx5Yx10Y, and 5Yx5Yx5Y forward volatility; past 6M; bp/day



* Forward volatility replicated using a triangle of swaptions and assuming correlation of 1.

via swaptions (the grey box presents the arithmetic explaining this replication). **In this note, we present a framework to analyze forward volatility structures which are created synthetically using swaptions**. As seen, in synthetically replicating the forward volatility (the actual forward volatility product remains illiquid), **we use a triangle of swaptions and a correlation between swap rates**. In our analysis below, we **assume that the correlation between various forward swap rates is 100%** (see below for more discussion on this). **Exhibit 2** shows the evolution of a selected forward volatility structures using this framework.

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For instance, a long position to the 1Yx2Yx5Y forward volatility structure can be replicated via:

1) long position in 3Yx5Y swaptions
2) long position in 1Yx2Y swaptions
3) short position in 1Yx7Y swaptions. These long and short exposures with 1Y expiry options also provide a long exposure to the correlation between 2- and 7-year swap rates.

The last two swaptions essentially give exposure to the underlying midcurve structure (see grey box for details).

The most common way of positioning for a forward volatility is via trading these underlying swaptions in an equi-notional way. Doing so, will leave the structure long vega and marginally short gamma by construction (actual forward volatility agreements do not have any gamma exposures). **Exhibit 3** shows the net vega and gamma exposures of a synthetically replicated 1Yx2Yx5Y forward volatility agreement. In this table, we also show the vega/exposure of the forward vol if constructed using *adjusted* notionals as opposed to equi-notionals, as is the more popular way of implementing these structures.[1] At current level of rates, the adjusted notionals are close to being equi-notional and hence the sensitivities are also similar in both the cases. However, we highlight that, in an environment of high interest rates, this assumption may not be valid and could result in significant discrepancy between these two approaches.

The assumption of correlation between the underlying swap rates also plays a significant part in the determination of the forward volatility. As mentioned previously, by construction, this synthetic replication is long the correlation exposure between the underlying swaps. **Exhibit 4** shows the evolution of the synthetic forward volatility under various levels of correlation between the 2- and 7-year swap rates. Our assumption of a 100% correlation gives us an upper estimate of the underlying actual structure. In **Exhibit 5**, we show the recent realized correlation between the 2- and 7-year swap rates over the past few months.

In **Exhibit 6**, we present a list of forward volatility structures, their estimated value using vanilla swaptions and correlation of 1, and some statistics over the past 6M. Specifically, we look at the 6M Z-score to identify structures that appear attractive on valuation (both to buy and sell). The extent of richness is more exaggerated for

[1] The adjusted notionals are calculated after adjusting for the annuity of the underlying swap. In the expression for forward volatility, we should originally add the variances based on their annuity weights and not time based weights as shown in the grey box. However, for simplicity, we assume time based weights. For instance, adjusted notional of the 3Yx5Y leg would then be annuity of 3Y swap/3.

Exhibit 3: By construction, this synthetic replication also results in long vega and short gamma exposure

Vega and gamma exposures for the synthetic forward vol structure† and underlying triangle of swaptions;

	Bpvega*	Gamma**
3Yx5Y	10.1	419
1Yx2Y	2.6	617
1Yx7Y	8.8	1244
Forward vol using equinotional exposure	3.9	-208
Forward vol using *adjusted* notional exposure	3.9	-206

†: We compare the sensitivities under two scenarios. First, we assume that we use equi-notional amount of each swaption as is the more popular way of implementing these structures. Second, we use actual notionals needed to replicate exposure –see footnote 1 for more explanation).
* Change in option premium in bps of notional per 0.1bp/day change in implied vol.
**10000*Change in option delta due to 1bp shift in rates; expressed in currency units.

Exhibit 4: These synthetic replication of forward volatility leaves us with an exposure in correlation between the swap rates

1Yx2Yx5Y forward volatility calculated at three different assumptions of correlation between the 2- and 7-year swap rates; past 1Y; %

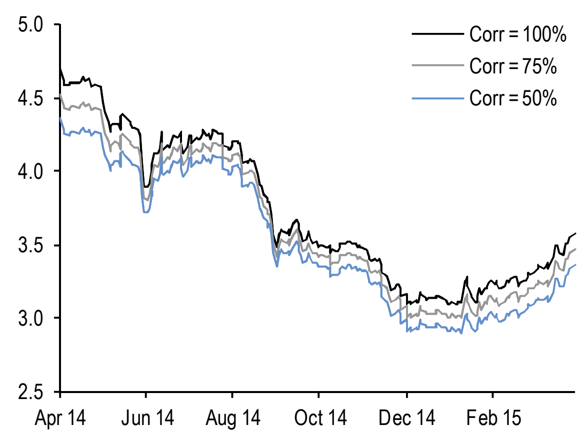
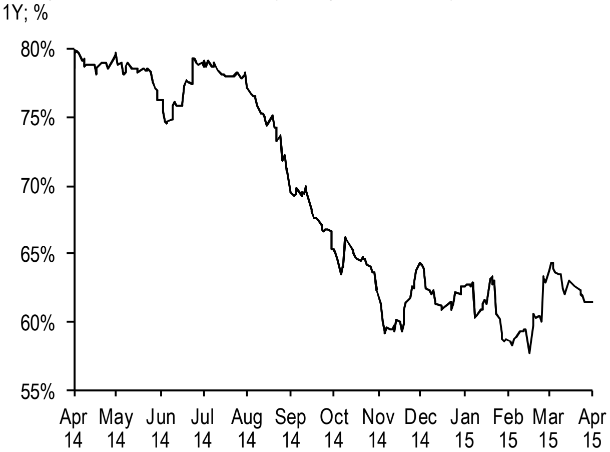


Exhibit 5: In practice, realized correlation is generally not at 100% and our calculation gives us an upper bound

Rolling 6M correlation between daily changes of 2- and 7-year swap rates; past 1Y; %



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Expressing forward volatility using vanilla swaptions[2]

The forward volatility (index F in equations below) may be expressed in terms of vanilla swaption (index E in equations below) and a midcurve option (an option on the same forward rate as a vanilla swaption but expiring at some earlier time, index M in the equations below). For instance, consider a 3Yx5Y plain vanilla swaption; its implied volatility may be thought of as a weighted average of the:

1) volatility of the underlying forward yield over the 1st year of the option (which we can call the midcurve volatility, since the underlying forward rolls down from being 3-years forward to only 2-years forward as opposed to spot), and
2) volatility of the same underlying yield over the last two years of the options life (the period over which the underlying yield rolls from being 2-years forward to spot)

Arithmetically, this can be written as:

$$1 * \sigma^2_{M,1x2x5} + 2 * \sigma^2_{F,1x2x5} = 3 * \sigma^2_{E,3x5} \qquad \text{(I)}$$

with

$$\sigma^2_{M,1x2x5} = w_a^2 * \sigma^2_{1x2} + w_b^2 * \sigma^2_{1x7} - 2 * w_a * w_b * \sigma_{1x2} * \sigma_{1x7} * \rho \qquad \text{(II)}$$

where, $\sigma^2_{M,1x2x5}$ denotes the implied volatility of a midcurve that expires in 1Y but with the same underlying swap as the 3Yx5Y. σ_{1Yx2Y} & σ_{1Yx7Y} denotes 1Yx2Y and 1Yx7Y swaption implied volatility.
w_a is defined as (PVBP of 1Yx2Y swap)/(PVBP of 1Yx7Y - PVBP of 1Yx2Y);
w_b is defined as (PVBP of 1Yx7Y swap)/ (PVBP of 1Yx7Y - PVBP of 1Yx2Y);
ρ is the correlation between the 2Y and 7Y swap rate.
$\sigma^2_{F,1x2x5}$ denotes 1Y forward volatility on the 2Yx5Y volatility while $\sigma^2_{E,3x5}$ refers to the 3Yx5Y vanilla swaption volatility.

We deduce the expression of the forward volatility from (I) and (II):

$$\sigma^2_{F,1x2x5} = \left(\frac{1}{2}\right) * \left(3 * \sigma^2_{E,3x5} - \left(w_a^2 * \sigma^2_{1x2} + w_b^2 * \sigma^2_{1x7} - 2 * w_a * w_b * \sigma_{1x2} * \sigma_{1x7} * \rho\right)\right)$$

Therefore, synthetically, we can replicate forward volatility as a combination of three swaptions and a correlation between two swap rates. A pure forward volatility option is desirable for expressing pure vega views; these options do not have any delta and gamma exposure as their strikes are fixed only at option expiry. However, the synthetic portfolio has both delta and gamma exposures as the underlying options are traded with fixed strikes. While we can reduce the delta exposure by trading straddle, the synthetic structure is left with long vega/short gamma by construction.

The pricing of a 1Yx2Yx5Y forward vol contract, for instance, is determined by the implied volatilities of the 3Yx5Y, 1Yx2Y, and 1Yx7Y swaptions, as well as the correlation between 2- and 7-year swap yield. Equivalently, the risk exposure in a long 1Yx2Yx5Y forward option agreement position typically decomposes into:

- a long position in 3Yx5Y swaptions
- a long position in 1Yx2Y swaptions
- a short position in 1Yx7Y swaptions, and
- long exposure to the correlation between 2- and 7-year swaps.

structures combining front-end and ultra-long end of the curve as the volatility curve has steepened sharply across tails resulting in even larger increase in volatility of the forwards. Similarly, structures involving vega implieds on intermediate and longer tails appear attractive to buy.

According to our analytics, 2Yx1Yx10Y appears attractive to sell and 7Yx1Yx20Y appear attractive to buy. With the recent strong directionality of the swap curve (bull flattening and bear steepening), volatility has moved further out the curve and is likely to remain so. Therefore, we exercise caution in selling forward volatility structures with the underlying swap rate anchored at the ultra-long end of the yield curve.

Our analysis shows that these replicates are currently around 4 and 0.6 standard deviations above (below) their recent averages (as measured on a 6M basis), respectively. We highlight that these synthetic replicates have a residual delta and gamma exposure unlike pure forward volatility options (traded versus actual forward volatility agreements) which do not have these exposures as the strike is not set at inception. We can minimize

[2] See *US Interest Rate Derivatives* section of *US Fixed Income Markets Weekly*, 25 April 2008 for more details.

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Exhibit 6: We present a framework to evaluate forward volatility options using a triangle of vanilla swaptions and present a list of rich and cheap structures

Current level, 1Y statistics, 3M delivered volatility of the underlying forward and implied – delivered volatility; bp/day

		6M stats					
Structure	Level	Average	Max	Min	Zscore	3M delivered vol	Implied - delivered
2Yx2Yx20Y	4.1	3.6	4.1	3.4	4.0	4.4	-0.3
2Yx1Yx10Y	4.2	3.8	4.2	3.6	4.0	4.1	0.2
2Yx1Yx20Y	4.2	3.6	4.2	3.4	4.0	4.2	0.0
2Yx10Yx10Y	4.4	4.2	4.4	4.1	3.9	4.7	-0.3
7Yx10Yx20Y	3.6	3.3	3.6	3.2	3.8	4.5	-0.9
1Yx10Yx20Y	3.9	3.5	3.9	3.4	3.8	4.7	-0.8
1Yx10Yx10Y	4.5	4.2	4.5	4.1	3.8	4.7	-0.3
3Yx10Yx10Y	4.4	4.2	4.4	4.1	3.8	4.7	-0.3
2Yx10Yx20Y	3.7	3.5	3.7	3.3	3.7	4.7	-0.9
5Yx10Yx10Y	4.4	4.2	4.4	4.1	3.6	4.7	-0.3
7Yx1Yx20Y	3.8	3.9	4.1	3.6	-0.6	4.7	-0.8
7Yx2Yx20Y	3.9	3.9	4.1	3.7	-0.4	4.7	-0.8
5Yx5Yx5Y	4.3	4.3	4.5	4.0	-0.1	4.7	-0.4
3Yx5Yx5Y	4.1	4.1	4.4	3.8	0.1	4.8	-0.7
7Yx1Yx5Y	4.5	4.5	4.7	4.4	0.1	4.8	-0.3
3Yx2Yx5Y	4.0	4.0	4.4	3.7	0.2	4.6	-0.6
5Yx5Yx20Y	3.7	3.7	3.9	3.5	0.2	4.7	-1.0
5Yx2Yx20Y	3.7	3.7	4.0	3.5	0.3	4.6	-0.9
7Yx2Yx30Y	3.5	3.5	3.7	3.3	0.3	4.5	-1.0
5Yx2Yx5Y	4.3	4.3	4.4	4.1	0.4	4.8	-0.5

For example: We can replicate long position in 7Yx2Yx20Y forward volatility by *1)* long position in 9Yx20Y swaption, *2)* long position in 7Yx2Y swaption, *3)* short position in 7Yx22Y, and *4)* long correlation exposure between 2Y and 20Y swap rates. Forward implied volatility can be derived using the formula listed in the grey box.
All data as of COB: 7 April 2015.

delta exposure by trading straddles; however, gamma exposures will remain, especially for structures with shorter expiries. Therefore, we find it instructive to compare the forward volatility versus the recent delivered volatility of the underlying forward. Exhibit 6 also shows the gamma carry from short positions in these forward volatility structures. We prefer buying (selling) structures which appear cheap (rich) on an historical basis and also cheap (rich) when compared against the recent delivered volatility. Structures highlighted in the exhibit is cheap on a z-score basis are also currently cheap versus delivered volatility.

The forward volatility structures, especially those with long dated forwards, have exhibited a strong correlation to the underlying spot vanilla swaption. For example, the 1Yx10Yx10Y exhibits a strong relationship to 10Yx10Y swaption and are trading 0.1bp/day rich. In **Exhibit 7**, we show the recent regression beta, R-squared, and residual obtained from regressing forward volatility against vanilla swaptions.

Exhibit 7: Forward volatility generally exhibit strong correlation to spot swaption volatility; we highlight regression based residuals in our framework

Various forward and spot volatility and 6M stats from regressing forward volatility against spot volatility; bp/day

			6M regression stats to spot vol		
Structure	Fwd vol	Spot vol	Beta	R-squared	Residual*
2Yx2Yx20Y	4.1	4.2	0.2	22%	0.4
2Yx1Yx10Y	4.2	3.5	0.1	5%	0.5
2Yx1Yx20Y	4.2	4.1	0.2	30%	0.5
2Yx10Yx10Y	4.4	4.5	0.5	67%	0.1
7Yx10Yx20Y	3.6	4.0	0.3	30%	0.1
1Yx10Yx20Y	3.9	4.0	0.6	72%	0.1
1Yx10Yx10Y	4.5	4.5	0.6	82%	0.1
3Yx10Yx10Y	4.4	4.5	0.5	60%	0.1
2Yx10Yx20Y	3.7	4.0	0.4	32%	0.2
5Yx10Yx10Y	4.4	4.5	0.5	61%	0.1
7Yx1Yx20Y	3.8	4.1	-0.2	47%	0.0
7Yx2Yx20Y	3.9	4.2	-0.2	32%	0.0
5Yx5Yx5Y	4.3	4.1	0.5	29%	-0.1
3Yx5Yx5Y	4.1	4.1	0.9	57%	-0.1
7Yx1Yx5Y	4.5	2.3	0.1	0%	0.0
3Yx2Yx5Y	4.0	3.0	1.0	10%	-0.1
5Yx5Yx20Y	3.7	4.2	-0.3	18%	0.1
5Yx2Yx20Y	3.7	4.2	-0.3	41%	0.2
7Yx2Yx30Y	3.5	4.3	-0.1	18%	0.1
5Yx2Yx5Y	4.3	3.0	0.5	11%	0.0

* A positive number indicates that the synthetic replicate is rich and a negative number indicates cheapness.

We publish these analytics on a variety of EUR and GBP forward volatility structures on a daily basis as a part of the *EUR/UK Interest Rate Volatility Analytics Package*. Interested clients can request to receive this analytics package on a daily basis via email or access it on our website here.

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