J.P.Morgan

European Rates Strategy
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Corrected Note (See page 11 for details)

Yield Curve Spread Options primer

Mechanics, fair value analysis, typical trades, and JPM analytics

- Yield curve spread options (YCSO) provide a clean way to express views on the yield curve and are exposed to the correlation between the underlying swap rates
- We discuss the pricing of a YCSO and its estimation of fair value using underlying swaptions and the correlation between the swap rates, including the convexity adjustment necessary to price CMS structures
- We highlight various types of trades implemented via spread options. We look at the following categories: *1)* Correlation trades; *2)* Carry trades (including delta-based trades and selling the "wedge" between YCSO and conditional curves using swaption); *3)* Conditional flies; and *4)* Delta-hedged pure curve volatility trade
- We present JPM analytics which help in identifying and analysing the attractiveness of these trades
- These reports are available on www.jpmm.com and their underlying data is available to clients via Dataquery®

Rates Strategy

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See page 11 for analyst certification and important disclosures.

Yield curve spread options primer

Yield curve spread options (YCSO) are options on the yield curve which is defined as the spread of two swap rates. Therefore, similar to a vanilla interest rate option which is used to express views on a single swap rate, the YCSOs can be used to express views on the spread of two swap rate (swap curve), thereby providing opportunities to investors for trading and hedging purposes.

These options primarily trade as OTC products and were popular prior to the financial crisis amongst a wide array of investors including hedge funds and real money. However, after their popularity plummeted during the financial crisis, investor interest on these products has been on the rise over the past few years. Liquidity in these products can now be described as good for standard options.

In this research note, **we focus on: *1)* the mechanics/pricing of these spread options; *2)* typical trades involving YCSOs; and *3)* J.P.Morgan analytics to identify potential trading opportunities and to provide a relative value framework**.

What is a Yield Curve Spread Option?

A yield curve spread option provides an attractive way to trade a view on the yield curve. These options are typically traded in the OTC market and the underlying is the spread between two swaps with different maturities. The payoff of a typical spread option is represented as:

Payoff of a curve cap (positioning for steepening): ***Max((Rate1 - Rate2)- Strike, 0)*Notional*.**

Payoff of a curve floor (positioning for flattening): ***Max(Strike - (Rate1 - Rate2), 0)*Notional***

Rate1 is the longer maturity leg and *Rate2* is the shorter maturity leg. Yield curve caplet (floorlet) is used to position for curve steepening (flattening) view. Other variants of this structure take place when the underlying is a weighted curve instead of the simple yield curve. For instance: *Max((Weight1*Rate1 - Weight2*Rate2) - Strike, 0)* for a caplet and *Max(Strike - (Weight1*Rate1 - Weight2*Rate2), 0)* for a floorlet. **The payout of a YCSO is linear in the level of the curve so that 1bp of the curve is equal to 1bp of notional**. Thus, for a notional exposure of €100mn in a vanilla 2s/10s curve caplet (1bp move is worth €10K), the payoff would be €500K (50bp * €10K/bp) if the 2s/10s curve settles at 50bp above the *Strike*.

Using different *Weights*, investors can design more bespoke versions of this product.

Exhibit 1: Various sectors of the swap curve have exhibited strong correlation amongst themselves recently
6M correlation of weekly changes between various swap rates; %

	2y	5y	10y	15y	20y	25y	30y
2y	100%						
5y	78%	100%					
10y	69%	97%	100%				
15y	66%	95%	99%	100%			
20y	65%	93%	99%	100%	100%		
25y	63%	92%	98%	100%	100%	100%	
30y	62%	92%	98%	99%	100%	100%	100%

Pricing a Yield Curve Spread Option

Given the structure of the option, the performance of an **YCSO is independent of the absolute level of interest rates and is entirely a function of the spread between these two rates**. Nevertheless, it is dependent on the correlation between these two rates. **Exhibit 1** shows that over the past 6M, various segments of the yield curve have exhibited strong correlation with the other segments (we have measured correlation using weekly changes of the underlying swap rates). The variance of the yield curve can be expressed as:

$$\sigma_{r1-r2}^2 = \sigma_{r1}^2 + \sigma_{r2}^2 - 2\rho\sigma_{r1}\sigma_{r2}$$

Where, σ_{r1}^2 is the variance of the rate *R1* (long maturity), σ_{r2}^2 is the variance of the rate *R2* (short maturity), and ρ is the correlation between these two rates. As seen, in addition to the variance of the individual swap rates, the correlation between these rates also forms a crucial component of the pricing of the spread options.

Convexity adjustment

In a plain vanilla swaption, the terminal payoff of the swaption depends on the *annuity* of the swap, which in itself decreases as yields move higher (**Exhibit 2**) (the swap is like a bond, an instrument with positive convexity). This gives a non-linear payoff profile to the swaption. The payoff of a payer swaption is defined as:

Payoff of a payer swaption: *Max[((Swap rate fixing - swaption strike) * Annuity * Notional amount), 0]*

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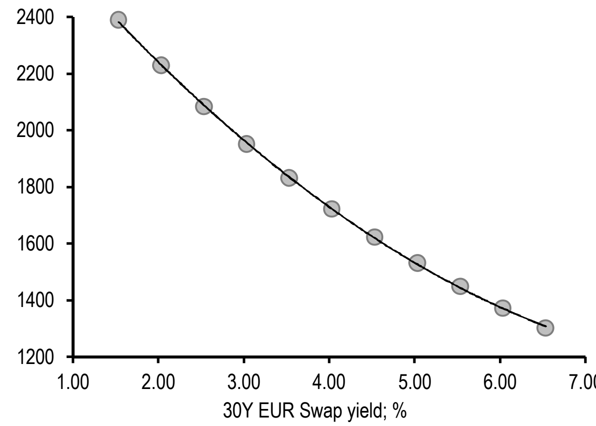
Exhibit 2: The annuity of a swap decreases with yields leading to a non-linear payoff profile to swaptions
30Y swap annuity versus 30Y swap yield; %



In contrast, the payoff of a single-look Constant Maturity Swap cap (where the underlying swap rate index is a constant maturity swap) is independent of swap duration and is *linear* by construction. Mathematically, this is expressed as:

Payoff of a single-look CMS cap: *Max[((Swap rate fixing - swaption strike) * Notional amount), 0]*

Therefore, if the cap and payer strike rates and premiums were equal, the cap would be a superior trade and would increasingly outperform as yields increased (**Exhibit 3** - a stylized representation of payoff of a 5Yx30Y payer and single-look cap). A dealer hedging the cap exposure via equivalent position in payer swaption would incur losses for large yield movements as the non-linearity of the payers would lead to its underperformance versus caps. Therefore, cap strikes, for the same premium, are set higher than payer strikes to account for the linearity (or lack of convexity) of the caps. This adjustment is known as the *convexity adjustment*. For instance, currently the *convexity adjustment* for the 5Yx30Y options is around 35bp. These convexity adjustments tend to be higher for structures with higher volatility and vice versa.

Single-look YCSO CMS option

YCSOs are generally European in nature and are typically based on constant maturity swaps. Similar to a single-look CMS cap, the payoff of a YCSO single-look cap is also linear in yields and is a function of the difference between the realized curve and the *Strike* of the YCSO at expiry. Therefore, these options trade using a convexity adjusted strike. For example, the at-the-money-forward of single-look CMS YCSO cap would

Exhibit 3: CMS caps, on the other hand, have a linear payoff. Therefore, CMS rates generally need to be adjusted higher compared to swap rates – this adjustment is called the "*convexity adjustment*"
Payoff from a 5Yx30Y and an equi-notional 5Yx30Y single-look caplet versus 30Y swap yield at option expiry; % of notional

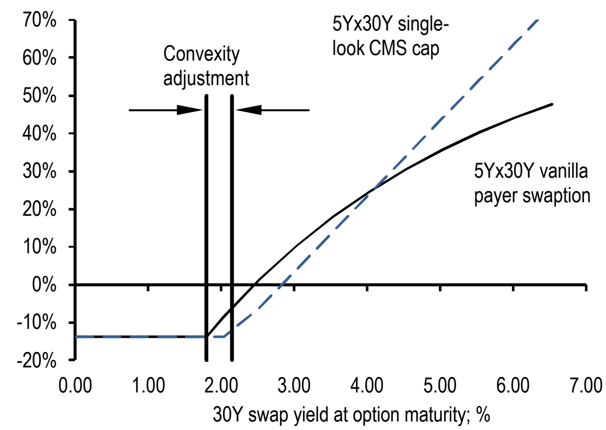


Exhibit 4: This convexity adjustment increases with the option expiry
Convexity adjustment for various spread options; bp

	Un-adjusted strike	CMS-adjusted strike	Difference
3Mx (2s/10s)	93	94	0
1Yx (2s/10s)	98	101	2
5Yx (2s/10s)	58	70	12
3Mx (10s/30s)	53	55	1
1Yx (10s/30s)	43	48	5
5Yx (10s/30s)	-8	11	18

account for the convexity adjustment of the individual legs and is defined as the convexity adjusted rate of the longer maturity swap minus the convexity adjusted rate of the shorter maturity swap. **Exhibit 4** shows the un-adjusted and CMS-adjusted strike for a small list of EUR spread options.

Exhibit 5 shows some typical single-look YCSO including current implied volatility, statistics on these implied volatility, and delivered volatility of the underlying CMS yield curve using various horizons. All the underlying data is available via Dataquery ®.

Trading strategies using Yield Curve Spread Options

In this section, we discuss typical trading strategies amongst investors using YCSOs and in some cases in combination with other products such as swaptions. In

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Exhibit 5: JPM analytics showing typical statistics on YCSOs is now available on www.jpmm.com – the "Yield Curve Spread Option market snap shot report"

Implied volatility, Delivered volatility, and correlation (both implied and realized) for some YCSOs; bp/day

					Imlied volatility 'bp/day			Delivered vol; bp/day			Implied correlation			Realized correlation	
Ref Crv	Mat	Prem	Fwd	ATMF*	Current	1D chg	1M chg	10D	1M	3M	Current	1D chg	1M chg	Real+	Wtd++
2Yx5Y	3m	12	34	34	1.9	0.0	0.0	1.6	1.4	2.0	68%	2%	0%	90%	90%
2Yx5Y	6m	18	37	38	2.0	0.0	0.0	1.6	1.4	2.0	69%	0%	-1%	92%	91%
2Yx5Y	9m	22	40	40	2.0	0.0	-0.1	1.5	1.3	2.0	71%	0%	1%	94%	92%
2Yx5Y	12m	25	42	42	2.0	0.0	-0.1	1.5	1.3	2.0	71%	-1%	-2%	95%	92%
2Yx5Y	2y	30	45	46	1.7	0.0	-0.2	1.2	1.2	1.7	87%	0%	1%	98%	93%
2Yx5Y	3y	35	43	45	1.6	0.0	0.0	0.9	1.2	1.6	91%	0%	0%	98%	93%
2Yx5Y	5y	41	33	38	1.5	0.0	0.0	0.7	0.7	0.9	95%	0%	0%	100%	94%
2Yx10Y	3m	22	97	97	3.6	0.0	-0.1	3.1	2.8	4.0	37%	1%	-14%	78%	79%
2Yx10Y	6m	32	100	101	3.6	0.1	0.0	2.9	2.7	3.9	42%	-2%	-16%	81%	80%
2Yx10Y	9m	38	102	103	3.5	0.0	-0.1	2.8	2.6	3.8	51%	-1%	-10%	85%	82%
2Yx10Y	12m	42	103	105	3.3	0.0	-0.1	2.7	2.5	3.7	58%	-1%	-9%	88%	83%
2Yx10Y	2y	52	99	104	2.9	0.0	-0.2	2.0	2.0	2.9	74%	0%	0%	95%	85%
2Yx10Y	3y	61	88	95	2.7	0.0	-0.1	1.3	1.6	2.3	79%	0%	0%	95%	85%
2Yx10Y	5y	74	59	71	2.6	0.0	0.0	0.7	0.7	0.8	84%	0%	0%	99%	86%

* CMS adjusted ATMF for the spread option.
+ Calculated as 1M correlation of daily changes of the underlying swap rates.
** Calculated as the average of the correlations of daily changes underlying forward swap rates. See text for more details.

addition, we also discuss and present J.P.Morgan analytics which can be used to identify and analyse trades using YCSOs. Broadly, we categorize the most popular types of trades into four categories:

1) **Correlation trades**: YCSOs have inherent exposure to yield curve correlation by construction. Therefore, in theory, we could trade individual swaptions against YCSOs to isolate the exposure to correlation and hence use these combinations to express view on curve correlations.
2) **Carry trades**: There are several variants of carry trades that can be constructed using YCSOs. This category of trades also includes trades that are implemented for range-targeting (cap spread or floor spread), yield enhancement (selling YCSOs against conditional curve trades initiated via swaptions), etc.
   a. Delta-based trades
   b. YCSOs versus conditional curve trades using swaptions
3) **Trading conditional flies**: We can use combinations of YCSOs to replicate exposure of a fly. For instance, buying a 2s/5s curve cap versus selling a 5s/10s curve caps. This is equivalent to that of conditional belly cheapners (5Y cheapening against 2Y and 10Y).
4) **Delta-hedged pure curve volatility trade**: These trades are designed to express view on YCSO implied and/or delivered volatility.

We discuss each of these in detail below.

Correlation trades

A long YCSO position has an inherent short correlation exposure - the yield curve volatility decreases with increase in correlation and vice versa. Therefore, by carefully selecting the weights of a combined YCSO/swaption trade, we can isolate the exposure to correlation. The weights of the swaptions are chosen such that the YCSOs exposure to the short and the long maturity rates are hedged by the corresponding swaption. Mathematically, the partial vega's of the YCSO can be expressed as:

$$Vega_S = vega_{YCSO} * (\sigma_S - \sigma_L \rho)/\sigma_{YCSO}$$

$$Vega_L = vega_{YCSO} * (\sigma_L - \sigma_S \rho)/\sigma_{YCSO}$$

where, $Vega_S$ ($Vega_L$) is the sensitivity of the YCSO premium to changes in implied volatility the short (long) maturity leg and $Vega_{YCSO}$ is the sensitivity of the YCSO premium to changes in curve volatility itself.

With the partial vega exposures and the vega exposure of the underlying swaptions, we can calculate the notional exposures needed for the short maturity and the long maturity swaptions to trade against the YCSO position to isolate the correlation exposure.

In **Exhibit 6** we show a list of YCSOs along with their implied and recent realized correlation (measured as averages of the various forwards which are 3M apart). Our measure of the realized correlations on the curve is a

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more accurate way which takes into account the correlation of the various forwards. To this effect, the realized correlations shown are not necessarily simple correlations for the various forwards. For example the 1Y correlation for options with 3M expiry shows the correlation between the daily changes of the 3M forward rates. Thus, for 3Mx(2s/10s), it is defined as the correlation of daily changes of 3Mx2Y and daily changes of 3Mx10Y swap rate over the past 1Y. Lets denote this correlation as *Corr(1Y, 3Mx2Y, 3Mx10Y)*. However, for option expiry with 12M, it is calculated as the simple average of the following four correlations: *Corr(1Y, 3Mx2Y, 3Mx10Y)*, *Corr(1Y, 6Mx2Y, 6Mx10Y)*, *Corr(1Y, 9Mx2Y, 9Mx10Y)*, and *Corr(1Y, 12Mx2Y, 12Mx10Y)*. This weighted correlation, in our view, is a more accurate representation of the underlying correlation for long dated forwards.

We also show the notionals required for the left and right swaptions needed to trade against selling €1000mn exposure in the YCSO to isolate the correlation exposure. These notionals are calculated using the vega exposures calculated above.

Exhibit 6 shows that the YCSO market is currently underpricing the delivered correlation. Alternately, if the correlation is cheap, this means that the YCSO is trading rich to fair value. However, does this constitute a trade, especially based on macro considerations? The drawback of any realized metric is that they are backward looking by construction. Currently, we would not consider the YCSOs based on implied and realized correlation differential. We illustrate via an example.

Let us consider the 3Mx(2s/10s) spread option. The implied correlation is around 45%. Realized correlation is between 60% to 80%, depending on the time frame used for calculation – YCSO is rich. **Exhibit 7** shows the evolution of the rolling 6M correlation between 2Y and 10Y EUR swap rates over the past 15Y. As seen, this correlation is itself variable; for instance, during the period between the ECB's last rate cut in September 2014 and the yield sell-off of 2Q15, this correlation collapsed to its historic lows (10%). This makes intuitive sense as the front-end of the EUR rate curve is expected to remain anchored under the weight of stable ECB policy rates and high excess liquidity whereas the long end of the curve remains hostage to macro and international developments. In our view, current level of realized correlation still remains too high for the 2s/10s curve and is not supported by macro considerations and we would be cautious in fading the apparent richness of the YCSO, based on correlation measure.

Exhibit 6: The "Trading Correlation Report" can be used to identify discrepancies between implied and realized correlation. It also shows the notional required on the swaptions to trade against the spread option to isolate the correlation exposure

Implied correlation, realized correlation, and notional weights required on the swaption legs to replicate the total vega exposure on the YCSO

			Realized correlation*			Notional weight; €mn		
Structure	Option Expiry	Implied correlation	1M	3M	6M	YCSO	Left	Right
2s/5s	3M	64%	87%	80%	75%	-1000	-57	116
2s/5s	12M	72%	92%	88%	85%	-1000	-33	101
2s/10s	3M	46%	79%	71%	64%	-1000	-63	69
2s/10s	12M	62%	85%	80%	77%	-1000	-73	60
2s/20s	3M	55%	75%	66%	60%	-1000	-102	36
2s/20s	12M	54%	81%	76%	73%	-1000	-67	47
2s/30s	3M	40%	72%	64%	59%	-1000	-60	33
2s/30s	12M	43%	79%	74%	72%	-1000	-13	39
5s/10s	3M	89%	96%	96%	96%	-1000	-35	30
5s/10s	12M	91%	97%	97%	97%	-1000	-32	28
5s/20s	3M	62%	94%	93%	93%	-1000	-19	36
5s/20s	12M	67%	95%	94%	94%	-1000	-8	38
5s/30s	3M	71%	92%	91%	91%	-1000	-33	22
5s/30s	12M	67%	93%	93%	93%	-1000	-11	27
10s/30s	3M	91%	99%	98%	98%	-1000	-7	9
10s/30s	12M	90%	99%	98%	98%	-1000	1	9

* Calculated using averages of forward swap rates.

Exhibit 7: Correlation between swap rates changes over time and thus YCSOs can be used to express views on the evolution of these correlations

Rolling 6M correlation between weekly changes in 2Y swap rate and 10Y swap rate; past 15Y; %

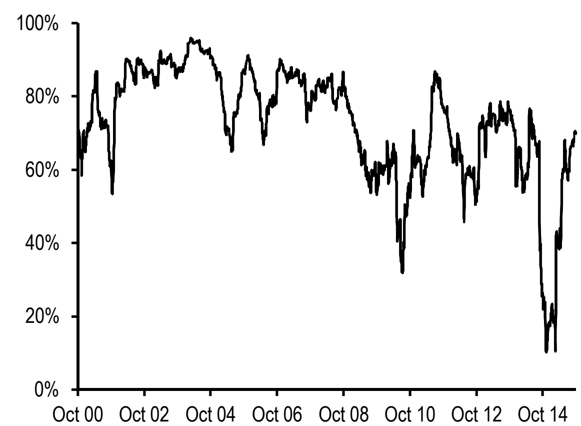

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Exhibit 8: Carry trades – JPM analytics on using spread options to position for a roll down (or roll up) the curve

Various structures using floors and caps with current cost, projected payoff at maturity if current carry is realized, and yield bounds for 6Mx(2s/10s) floors and 6Mx(10s/30s) curve option; bp

Stucture		Strike	Contract	Cost (bp)	Projected payoff (bp)	Curve bounds (bp) Lower	Upper
Floors (curve flatteners); 2s/10s curve; 6M options; spot curve at 92.6bp							
Outright	ATMF	100.7	+1	16.0	8.2	-	84.7
Spread	ATMF/ATMF-10	100.7/90.7	+1/-1	4.5	8.2	-	96.2
1x2	ATMF/ATMF-10	100.7/90.7	+1/-2	-7.0	8.2	73.7	107.7
Ladder	ATMF/ATMF-10/ATMF-20	100.7/90.7/80.7	+1/-1/-1	-3.5	8.2	67.3	104.2
Butterfly	ATMF/ATMF-10/ATMF-20	100.7/90.7/80.7	+1/-2/+1	1.0	8.2	81.7	99.8
Caps (curve steepeners); 10s/30s curve; 6M options; spot curve at 60bp							
Outright	ATMF	56.2	+1	9.0	3.8	65.3	-
Spread	ATMF/ATMF-10	56.2/66.2	+1/-1	4.2	3.8	60.4	-
1x2	ATMF/ATMF-10	56.2/66.2	+1/-2	-0.7	3.8	55.5	76.9
Ladder	ATMF/ATMF-10/ATMF-20	56.2/66.2/76.2	+1/-1/-1	1.8	3.8	58.1	84.4
Butterfly	ATMF/ATMF-10/ATMF-20	56.2/66.2/76.2	+1/-2/+1	1.6	3.8	57.8	74.6

YCSO implied correlation versus midcurve implied correlation

A midcurve option also has exposure to correlation between swap rates. We produce daily analytics highlighting the implied and realized correlation between swap rates as priced via the midcurve options.[1] However, a cursory comparison between the implied midcurve correlations and YCSO correlations shows that they trade at different levels; the implied correlation of the YCSO will typically be lower than the midcurve one. The explanation is that it is rather easy to conjure up cases where the correlation between the swap rates remains low in which scenario the swap curve shows high volatility (YCSO volatility is inversely proportional to the realized correlation between the two swap rates) whereas intermediate forward (uses for midcurve volatility), for example, are not volatile. Consider a scenario where the 10Y swap rate increases by 5bp whereas the 5Y swap rate moves up by 10bp (a bear flattening scenario). The 5Y5Y forward swap rate (the rate on which the midcurve option is based) is unchanged (the 5Y5Y can be roughly estimated as 2*10Y - 1*5Y). However, the 5s/10s curve has moved 5bp. Another reason for the lower YCSO implied correlation is the fact that YCSOs are based on CMS rates whereas midcurves are based on swap rates. Because of vol-of-vol, CMS vols are generally much higher compared to swap vols and hence the same should apply to their spreads suggesting lower correlation between the underlying CMS rates.

[1] See *Midcurve options primer: Mechanics, fair value analysis, typical trades*, and JPM analytics by Khagendra Gupta, 5 May 2015.

Carry trades

Similar to regular swaptions (vanilla and midcurves), we can use YCSOs to express outright or leveraged curve views and/or to earn carry on the curve. We illustrate two different ways to express carry trades:

1) *Curve range targeting and*
2) *Selling YCSO versus conditional curve trades* expressed via swaptions.

We discuss each of these in details below.

Trades for range targeting

We can use a combination of YCSOs to express a view that the curve is expected to stay in a tight range while earning the positive carry on the curve. For example, buying floor spreads (ATMF/ATMF-10bp) would be a way to earn the around +8bp of carry in the 2s/10s curve flatteners (6M forward curve is at 101 whereas spot curve is at 93). Similar to swaptions, YCSOs we can also use YCSOs to express leveraged views such as positioning for 1x2s or ladders. **Exhibit 8** shows a list of such directional trades (using caps and floors including outright YCSOs, 1x2s, ladders, flies, and condors) along with their expected payoff at option expiry. We produce daily analytics showing the current cost and expected P&L for a small sample of these trades which are available on www.jpmm.com. We highlight that leveraged structures may be attractive to initiate; however, they could also result in large losses. For instance, as shown in Exhibit 8, buying the floor 1x2 on 2s/10s curve would result in a net credit of 7bp.

However, the structure will start losing if the spot 2s/10s curve drops below 73.7bp and the losses could be large; the flattest level of the 2s/10s curve over the last year is around 36bp - just prior to the summer sell off.

Selling the YCSO/conditional curve trade "wedge"

During periods when the curve volatility is trading rich, we can sell spread options and hedge the curve exposure via adding conditional curve trades (not necessarily structured to be zero cost at inception). In an environment where the yield curve exhibits a strong directionality to one of the tails (say the long end of the curve), the payout from the conditional curve exposure is offset by the losses in the spread option leaving the initial premium uptake as the carry component. The conditional curve trade is initiated via swaptions or via single-look caps/floors.

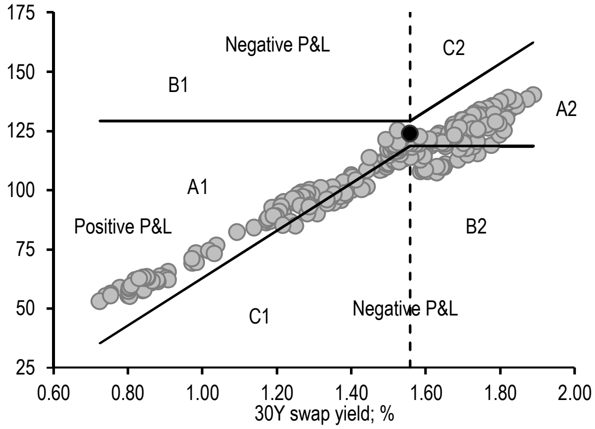
We first illustrate the structuring of these trades via an example. For instance, assume we want to initiate a 2s/10s bear steepeners and sell the 2s/10s curve cap against it. Assuming a PVBP ratio of the 2Y and 10Y swaps of 1:5, we buy €100mn ATMF 3Mx10Y payers and sell €500mn ATMF 3Mx2Y payers against it. This trade is not premium neutral at inception as the implied volatilities are different. The total risk exposure in such a trade is around €100K/bp. Therefore, we would need to sell €1bn notional of an ATMF 2s/10s curve cap against it. If we tweaked the strikes of the payers to make the bear steepener zero cost at entry, then this would result in a give up in terms of entry point and hence the strike of the curve cap should be adjusted accordingly.

Alternately, we can also initiate this strategy using single-look caps and curve caps. Since the payout of these caps is not dependent on the annuity of the underlying swap, we would need equi-notional exposure in all the options. Thus, for a risk exposure of €100K/bp, we would structure the trade by buying €1bn notional of single-look 3Mx10Y cap, selling €1bn notional of single-look 3Mx2Y cap, and selling €1bn notional of single-look 3Mx(2s/10s) curve cap.

We explain the working of this strategy via an example. **Exhibit 9** shows the region of positive and negative P&L for initiating a 5s/30s bear-steepeners (via 3M payers, buying 3Mx30Y payer and selling 3Mx5Y payer in a DV01 ratio) and selling the 3Mx(5s/30s) single-look curve cap against it, at option expiry. The scatter plot shows the recent 1Y relationship between the 5s/30s curve and 30Y swap yield. We divide the area into six

Exhibit 9: Carry trades – Selling the "wedge" as a carry trade; curve option wedges, when appropriate, could be an attractive source of carry

EUR 5s/30s spot swap yield curve versus 30Y swap yield and regions of positive and negative P&L for 5s/30s bear steepeners* constructed using 3M ATMF payers versus selling 3Mx(5s//30s) single-look curve cap; past 1Y; bp



* Trade: Long 3Mx30Y payer, short 3Mx5Y payers and short 3Mx(5s/30s) YCSO caps.
A1: All the options expire worthless; P&L initial premium
A2: All options expire in the money; P&L from bear steepener is off-set by losses from the YCSO; P&L initial premium
B1: Curve bull steepens; Swaptions expire worthless; losses due to YCSO in the money
B2: Curve bear flattens resulting a loss from swaptions; YCSO expire worthless
C1: Curve flattens aggressively; 3Mx30Y expire worthless but 3Mx5Y is in the money causing losses; YCSO expire worthless
C2: Curve steepens aggressively – higher 30Y yields but lower 5Y yields have rallied; P&L from long 3Mx30Y does not fully offset losses from YCSO.

regions. **Exhibit 10** shows the heat map for the P&L under various rate and curve scenarios, which is in line with the schematic representation of Exhibit 9, but also shows that P&L in regions A1 and A2 are broadly similar which is equal to the initial credit. We find it instructive to explain the various scenarios and the associated P&L in each region.

In region A1, the curve flattens in a rally; the payers and the caps all expire worthless leaving initial premium uptake as the net P&L. The upper breakeven line (the horizontal line) is then the ATMF curve plus initial intake, expressed in bp of yield. In region A2, the curve steepens in a sell-off; 30Y increases more than 5Y and the curve beta to 30Y is less than 1 (both 30Y and 5Y yields increase). The P&L from the bear steepening exposure is exactly offset by the losses of the spread option, leaving the initial intake as the P&L.

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Exhibit 10: A "heat-map" of the total P&L from selling the "wedge" shows that the maximum P&L in regions A1 and A2 is restricted to the initial credit. Therefore, these types of trades are generally preferable when the curve directionality is expected to remain stable

Heat map of total P&L from being long 3Mx30Y payer, short 3Mx5Y payers and short 3Mx(5s/30s) YCSO caps (all options are struck at ATMF); bp of yield

		10Y yield; %															
		1.20	1.24	1.28	1.32	1.36	1.40	1.44	1.48	1.52	1.56	1.60	1.64	1.68	1.72	1.76	1.80
5s/30s curve; bp	175	-46	-46	-46	-46	-46	-46	-46	-46	-46	-46	-42	-38	-34	-30	-26	-22
	170	-41	-41	-41	-41	-41	-41	-41	-41	-41	-41	-37	-33	-29	-25	-21	-17
	165	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-32	-28	-24	-20	-16	-12
	160	-31	-31	-31	-31	-31	-31	-31	-31	-31	-31	-27	-23	-19	-15	-11	-7
	155	-26	-26	-26	-26	-26	-26	-26	-26	-26	-26	-22	-18	-14	-10	-6	-2
	150	-21	-21	-21	-21	-21	-21	-21	-21	-21	-21	-17	-13	-9	-5	-1	3
	145	-16	-16	-16	-16	-16	-16	-16	-16	-16	-16	-12	-8	-4	0	4	5
	140	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-7	-3	1	5	5	5
	135	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-2	2	5	5	5	5
	130	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	3	5	5	5	5	5
	125	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5
	120	5	5	5	5	5	5	5	5	5	1	1	1	1	1	1	1
	115	5	5	5	5	5	5	5	4	0	-4	-4	-4	-4	-4	-4	-4
	110	5	5	5	5	5	5	3	-1	-5	-9	-9	-9	-9	-9	-9	-9
	105	5	5	5	5	5	2	-2	-6	-10	-14	-14	-14	-14	-14	-14	-14
	100	5	5	5	5	1	-3	-7	-11	-15	-19	-19	-19	-19	-19	-19	-19
	95	5	5	4	0	-4	-8	-12	-16	-20	-24	-24	-24	-24	-24	-24	-24
	90	5	3	-1	-5	-9	-13	-17	-21	-25	-29	-29	-29	-29	-29	-29	-29
	85	2	-2	-6	-10	-14	-18	-22	-26	-30	-34	-34	-34	-34	-34	-34	-34
	80	-3	-7	-11	-15	-19	-23	-27	-31	-35	-39	-39	-39	-39	-39	-39	-39
	75	-8	-12	-16	-20	-24	-28	-32	-36	-40	-44	-44	-44	-44	-44	-44	-44

In region B1, the curve steepens in a rally, or 5Y yield have declined more than 30Y. Both the swaptions expire worthless whereas a short position in the spread options results in loss. Similarly, in region B2, the curve flattens in a sell-off, or 5Y yield increases more than 30Y. The spread option expires worthless. However, this *bear-flattening* of the curve will result in losses from the swaption. In both these cases, the initial uptake provides a cushion for the losses and these losses start to accumulate only after the curve exceeds this level. This gradual decline of total P&L can be easily seen in the heat map of Exhibit 10.

In region C1, the curve flattens as 30Y yields rally. However, the curve beta is greater than 1 with respect to 30Y yield. In other words, 5Y yields have increased. The curve cap and the 30Y payer will both expire worthless while short position in 5Y payer will result in a loss. Similarly, in region C2, the curve steepens when 30Y yields have increased but with a beta greater than 1; 5Y yields have declined. The gains from being long 30Y payers (5Y payers will expire worthless) will not be sufficient to offset the losses from being short the curve cap resulting in overall loss.

In conclusion, such a strategy relies on the fact that the curve directionality remains strong to long-end yields with a beta less than 1, as has been the case recently.

Trading conditional flies

In an environment where the yield curve is directional to yields (the curve fly exhibits a strong directionality to the body and the yield curve exhibits strong directionality to one of its leg), we can use YCSOs to replicate conditional curve exposure. For instance, to initiate a 2s/5s/10s bear-belly cheapener (5Y cheapening in a sell-off which is typically expressed in swaption space via buying payers on 5Y and selling payers on 2Y and 10Y), we can buy 2s/5s single-look CMS curve caps against selling 5s/10s single-look CMS curve cap against it. We highlight that this structure does not have any directionality as the payout is not dependent on the level of rates. Alternately, we can buy two-unit of 2s/5s curve cap versus selling one unit of 2s/10s curve cap. The

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overall exposure in both these variants results in short belly versus wings. **Exhibit 11** shows a schematic diagram on the resulting yield curve exposures from these variants.

These variants are sometimes preferred for their overall better carry profile. **Exhibit 12** shows a snapshot of our analytics that is available on www.jpmm.com which presents several of these structures. In addition to overall carry profile in the trade, we also show zero-cost entry point for these trades which are obtained by tweaking the strike of one of the spread options to match the premium of the ATMF strike of the other spread option (we account for the net notional exposure for the alternate variant as well).

Delta-hedged pure curve volatility trades

We can express YCSOs to express views on the volatility of the swap curve itself. Exhibit 5 shows the current implied volatility, delivered volatility, and gamma carry for short curve gamma positions (implied volatility minus delivered volatility) for various curve straddles. In Dataquery® we have available time series implied volatility for several liquid curve options. As is the case with regular swaptions, the gamma (adjusted for time decay) P&L is a result of the difference between inception implied volatility and subsequent delivered volatility; the vega P&L is a function of the changes in implied volatility. In addition, we also have the contribution from correlation. We highlight that, the difference between implied and realized correlation also plays a dominant role in the overall gamma P&L, as shown in the following equation, which shows the gamma P&L after adjusting for theta. **Exhibit 13** shows the cumulative delta-hedged return series from buying 3Mx(2s/30s) USD curve caps since the beginning of the 2015; we assume that the options are delta-hedged are everyday and that options are re-struck at the beginning of each month.

Exhibit 11: YCSOs can be used to proxy conditional fly exposure
Schematic representation to illustrate the usage of YCSOs to initiate conditional butterfly exposure;

	2Y	5Y	10Y	Exposure
Using vanilla swaption				
2Y	-1			
5Y		+2		
10Y			-1	
Net exposure	-1	+2	-1	2*5Y - (2Y + 10Y)
2s/5s and 5s/10s curve caps				
Buy 1 unit of 2s/5s curve caps	-1	+1		
Sell 1 unit of 5s/10s curve caps		+1	-1	
Net exposure	-1	+2	-1	2*5Y - (2Y + 10Y)
2s/5s and 2s/10s curve caps				
Buy **2** units of 2s/5s curve caps	-2	+2		
Sell **1** unit of 2s/10s curve caps	+1		-1	
Net exposure	-1	+2	-1	2*5Y - (2Y + 10Y)

Exhibit 12: The "Replicating Conditional Butterfly using YCSOs" can be used to identify zero-cost entry points and the total carry for these trades
Zero-cost entry points (using caps and floors) and total carry to expiry for such trades; bp

									ATM (CMS adj)		Zero cost entry level (caps)			Zero cost entry level (floors)			Total carry (bp)	
Structure	Spot	Fwd (un adj)	Fwd (cms adj)	Curve carry	Curve 1	Curve 2	Curve 1	Curve 2	Curve 1	Curve 2	Curve 1	Curve 2	Entry level	Curve 1	Curve 2	Entry level	Caps	Floors
Using variant 1																		
1s/5s/10s	-29.0	-24.0	-24.0	5.0	1s/5s	5s/10s	Buy	Sell	37.4	61.4	37.4	66.1	-28.7	37.4	57.1	-19.7	0	5
1s/5s/30s	-85.0	-76.0	-78.0	7.0	1s/5s	5s/30s	Buy	Sell	37.4	115.4	37.4	131.7	-94.3	37.4	99.7	-62.3	0	5
1s/10s/30s	37.0	46.0	45.0	8.0	1s/10s	10s/30s	Buy	Sell	98.8	53.9	98.8	45.5	53.3	98.8	62.2	36.6	-9	0
2s/5s/10s	-31.0	-28.0	-28.0	3.0	2s/5s	5s/10s	Buy	Sell	33.4	61.4	33.4	63.2	-29.8	33.4	59.7	-26.3	-1	2
2s/5s/30s	-87.0	-80.0	-82.0	5.0	2s/5s	5s/30s	Buy	Sell	33.4	115.4	33.4	127.6	-94.2	33.4	103.5	-70.1	0	3
2s/10s/30s	35.0	42.0	41.0	6.0	2s/10s	10s/30s	Buy	Sell	94.8	53.9	94.8	45.9	49	94.8	61.8	33	-8	-1
5s/10s/30s	5.0	8.0	7.0	2.0	5s/10s	10s/30s	Buy	Sell	61.4	53.9	61.4	53.2	8.2	61.4	54.6	6.8	-2	1
10s/20s/30s	48.0	47.0	47.0	-1.0	10s/20s	20s/30s	Buy	Sell	50.4	3.6	50.4	-0.6	51	50.4	8	42.4	-2	-3
Using variant 2																		
1s/5s/10s	-29.0	-24.0	-24.0	5.0	1s/5s	1s/10s	Buy x 2	Sell	37.4	98.8	37.4	56.7	18	37.4	65.9	8.8	-5	5
1s/5s/30s	-85.0	-76.0	-78.0	7.0	1s/5s	1s/30s	Buy x 2	Sell	37.4	152.7	37.4	118.7	-44	37.4	112.1	-37.4	-2	9
1s/10s/30s	37.0	46.0	45.0	8.0	1s/10s	1s/30s	Buy x 2	Sell	98.8	152.7	98.8	31.9	165.6	98.8	75.8	121.8	-22	-7
2s/5s/10s	-31.0	-28.0	-28.0	3.0	2s/5s	2s/10s	Buy x 2	Sell	33.4	94.8	33.4	53.1	13.7	33.4	69.5	-2.7	-7	-1
2s/5s/30s	-87.0	-80.0	-82.0	5.0	2s/5s	2s/30s	Buy x 2	Sell	33.4	148.8	33.4	113.9	-47	33.4	116.8	-50	-4	4
2s/10s/30s	35.0	42.0	41.0	6.0	2s/10s	2s/30s	Buy x 2	Sell	94.8	148.8	94.8	32.5	157.2	94.8	75.2	114.4	-20	-9
5s/10s/30s	5.0	8.0	7.0	2.0	5s/10s	5s/30s	Buy x 2	Sell	61.4	115.4	61.4	42.9	79.9	61.4	64.7	58.1	-10	-5
10s/20s/30s	48.0	47.0	47.0	-1.0	10s/20s	10s/30s	Buy x 2	Sell	50.4	53.9	50.4	-7.6	108.3	50.4	14.9	85.8	-6	-9

We get exposure to bear belly cheapeners using caps and bull belly richeners using floors.

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$$Gamma-Theta = \frac{1}{\sigma_{r1-r2,impl}} * (\sigma^2_{r1-r2,real} - \sigma^2_{r1-r2,impl})$$

$$= (\frac{1}{\sigma_{r1-r2,impl}}) * [(\sigma^2_{r1,real} + \sigma^2_{r2,real} - 2 * \rho_{real} * \sigma_{r1,real} * \sigma_{r2,real}) - (\sigma^2_{r1,impl} + \sigma^2_{r2,impl} - 2 * \rho_{impl} * \sigma_{r1,impl} * \sigma_{r2,impl})]$$

$$= (\frac{1}{\sigma_{r1-r2,impl}}) * [(\sigma^2_{r1,real} - \sigma^2_{r1,impl}) + (\sigma^2_{r2,real} - \sigma^2_{r2,impl}) - 2 * \rho_{real} * \sigma_{r1,real} * \sigma_{r2,real} - 2 * \rho_{impl} * \sigma_{r1,impl} * \sigma_{r2,impl}]$$

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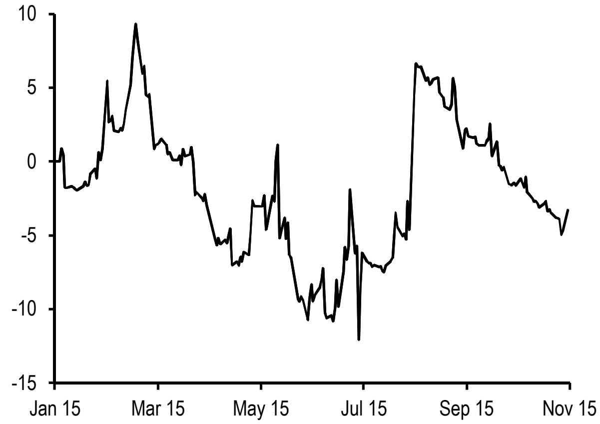
Exhibit 13: Buying 2s/30s USD curve gamma would have yielded mixed results this year

Cumulative returns from buying USD 2s/30s curve gamma delta-hedged on a daily basis using the underlying curve; since 1 Jan 2015; bp of notional



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Corrected Note: Exhibit 3 corrected to show 5Yx30Y in the chart

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