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Interest Rate Derivatives

Trading Principal Factor Volatility

- Short gamma strategies are a popular overlay employed by fixed income market participants in pursuit of positive carry as well as uncorrelated returns. But thanks in part to the growth of such strategies, as well as greatly reduced mortgage hedging demand, volatility premia are likely lower, and the risk adjusted performance of such strategies is somewhat less compelling. This begs the question - are there other, perhaps more nuanced, gamma strategies where an attractive and systematic edge exists? One avenue that we believe shows promise is the trading of the volatility of principal factors
- Principal component analysis is a tool that is very familiar to fixed income market participants, and is commonly utilized to reduce the dimensionality of highly correlated market variables - such as yields at different maturity points. Yield changes are commonly expressed as a combination of moves stemming from a level factor (or the first principal factor), a curve or twist factor (the second principal factor), and so forth. These factors are uncorrelated by design, so the squared volatility of yields at any given maturity point can be decomposed into a weighted combination of the squared volatilities of each factor
- This unbundling of the volatility of any given yield into factor volatility components can be used to isolate exposure to the volatility of any given principal factor. If we assume that third and higher order principal factors are small enough to ignore (which is usually the case empirically), then the volatility of (say) 2s and 10s can both be unbundled into weighted combinations of the volatilities of the first and second factors, but with different weights. Thus, we can in general find a suitable weighted combination of (say) 6Mx2Y and 6Mx10Y swaption straddles that isolates exposure to the volatility of the first (or second) principal factor, as desired. To our knowledge, this is a novel application of principal components that has not been explored before
- Such "factor vol" trades are ultimately simply weighted combinations of vanilla swaptions. But is there a way to characterize the performance of such trades so that it depends on some notion of "implied" versus "realized" factor volatility? Indeed there is - if we use forward looking "implied" principal components (which we have discussed in detail elsewhere) to construct such trades, we can show that returns from such trades track the difference between implied and realized factor vol
- Why do this? History appears to suggest that implied second-factor vol is typically rich while implied first-factor vol is consequently cheap, making such nuanced factor-vol trades promising as a theme
- Finally, our approach has relative value implications. Numerous instrument pairs can be used to create exposure to the volatility of a given factor, but their corresponding implied vol spreads must be statistically similar, providing a basis for relative value analysis

US Rates Strategy

Srini Ramaswamy AC
(1-415) 315-8117
srini.ramaswamy@jpmorgan.com

Ipek Ozil
(1-212) 834-2305
ipek.ozil@jpmorgan.com

Philip Michaelides
(1-212) 834-2096
philip.michaelides@jpmchase.com

Arjun Parikh
(1-212) 834-4436
arjun.parikh@jpmchase.com
J.P. Morgan Securities LLC

See page 14 for analyst certification and important disclosures.

Srini Ramaswamy AC (1-415) 315-8117
srini.ramaswamy@jpmorgan.com
J.P. Morgan Securities LLC
Ipek Ozil (1-212) 834-2305
ipek.ozil@jpmorgan.com

Philip Michaelides (1-212) 834-2096
philip.michaelides@jpmchase.com

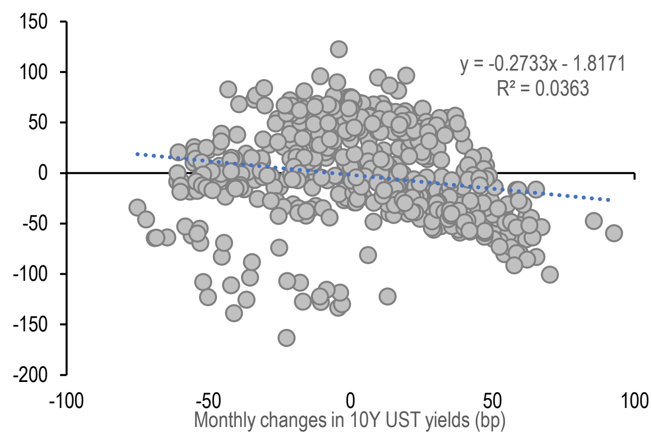
Arjun Parikh (1-212) 834-4436
arjun.parikh@jpmchase.com

Trading Principal Component Volatility

Over the years, volatility strategies have become popular as an avenue to seek returns that are typically less correlated to the returns from fixed income more broadly. In particular, the selling of short expiry swaption straddles has become a popular overlay strategy that is typically profitable on average, but also not significantly directional in nature. The case for this rests on something like the observation one can make from **Figure 1** - returns from selling 3Mx10Y swaption straddles, in this case, have been fairly uncorrelated to changes in 10Y yields, meaning that a properly sized short gamma strategy can add some diversification benefit to a fixed income portfolio. But returns from selling straddles are not always positive - indeed, over much of the past two years, short gamma positions have not been profitable on average, and have had rather poor distributional properties (**Figure 2**). For instance, average returns from selling 3Mx10Y swaption straddles have been essentially close to zero over the past two years, thanks to the frenetic pace of Fed hikes and the prolonged period of policy uncertainty that we have experienced. Of course, this just means that active management of gamma positions is essential, which comes as no surprise to anyone utilizing such strategies.

Figure 1: Returns from selling 3Mx10Y swaption straddles have been fairly uncorrelated to changes in 10Y yields

Monthly rolling returns from selling 3Mx10Y swaption straddles* (bp of notional) versus monthly changes in 10Y UST yields (bp); 7/5/2022 - 7/1/2024



Source: J.P. Morgan.
*Options are assumed to be delta hedged daily, and rolled monthly. Ignores transaction costs

Figure 2: Outright short gamma returns are not always positive, and can have rather poor distributional properties

Percentile statistics on rolling 1 month unscaled returns (bp of notional) as well as normalized returns (unitless) from selling 3Mx10Y swaption straddles*; 7/5/2022 - 7/1/2024

Rolling 1M Returns from selling 3Mx10Y straddles		
Attribute	Unscaled return	Normalized Return
Worst	-163.2	-3.5
10th %ile	-57.4	-1.2
Median	-3.6	-0.1
Average	-3.2	-0.1
90th %ile	58.5	1.2
Max	122.5	2.6
Std. Dev	46.9	1.0

Source: J.P. Morgan.
*Options are assumed to be delta hedged daily, and rolled monthly. Ignores transaction costs

One approach to trying to enhance performance of gamma strategies is to fine-tune fair value assessments and actively manage volatility positions from the long as well as short side, based on deviations from fair value. Other approaches involve trading volatility of one tail versus another (e.g., 6Mx2Y volatility versus 6Mx10Y) or even broader implied volatility differentials by taking fair-value views on those spreads. These are all worth pursuing - indeed, in our regular weekly research publications, we routinely strive to find trades of all of these types, as and when opportunities present themselves.

But it is always of interest to consider whether it is possible to find a better edge, a strategy which improves upon outright short gamma strategies in the sense of boosting the risk adjusted return characteristics. In other words, **is there yet another way that hasn't yet been fully explored**? In this section, **we open the door to an entirely new class of relative value trades, that is based on a decomposition of volatility in any**

Srini Ramaswamy [AC] (1-415) 315-8117
srini.ramaswamy@jpmorgan.com
J.P. Morgan Securities LLC
Ipek Ozil (1-212) 834-2305
ipek.ozil@jpmorgan.com

Philip Michaelides (1-212) 834-2096
philip.michaelides@jpmchase.com
Arjun Parikh (1-212) 834-4436
arjun.parikh@jpmchase.com

given forward rate into portions that stem from the volatility of each principal component driving rate moves.

The outline of this paper is as follows. **First**, we start with a brief overview of principal component analysis and define a notion of factor volatility (or principal component volatility). We also discuss why we use forward-looking implied principal component analysis for trading principal component volatility instead of more traditional estimates of historical principal component volatility. **Next**, we describe our approach to isolating exposure to one principal component volatility, while hedging out another and demonstrate that by appropriately weighting swaptions, we are indeed able to generate exposure to the difference between *ex-post* realized factor volatility minus *ex-ante* implied factor volatility. **Third**, we answer the question of why an investor may want to do this and demonstrate that generating exposure to PC1 or PC2 volatility has generally tended to outperform outright volatility positions, except in certain instances, which we also discuss. We also discuss softer considerations that must be borne in mind when utilizing our approach to constructing exposure to factor volatility. **Finally**, we discuss a natural extension of our framework that can be used to evaluate relative value between swaptions of different tenors.

Principal Component Analysis - a brief review of selected concepts

Principal component analysis is widely understood and used in financial markets. For instance, it is common to express changes in yield levels across different tenors as the sum of (i) changes stemming from moves in a "level" factor or the first principal component, (ii) additional changes stemming from a "curve" factor or the second principal component, and (iii) so on. This is illustrated in **Figure 3**. In this example, changes in 2-, 5-, 10- and 30-year yields are expressed as a weighted combination of changes stemming from the first, second, third and fourth principal components. (Since we use only 4 points on the curve in this illustration, there are no more than 4 possible principal components).

Figure 3: Using principal components to decompose one day's change in yields across the curve - an illustration

An illustration of the decomposition of actual yield changes in benchmark swap yields (bp) in the 2-, 5-, 10- and 30-year sectors, as a weighted combination of a level factor (PC1), a curve factor (PC2), and higher order factors (PC3 and PC4).

	ΔY		PC1		PC2		PC3		PC4
2Y	28		6.9		2.9		0.3		0.2
5Y	25	**= w_1 ***	7.2	**+ w_2 ***	0.3	**+ w_3 ***	-0.2	**+ w_4 ***	-0.6
10Y	20		6.4		-1.3		-0.6		0.4
30Y	13		5.1		-2.8		0.6		0.0

→ **$w_1 = 3.4$** **$w_2 = 1.6$** **$w_3 = 0.1$** **$w_4 = 0.7$**

Source: J.P. Morgan.
* For each principal component, we define its loadings on the 2Y, 5Y, 10Y and 30Y sector to be the impact (in bp) of a 1-sigma move in that component on 2Y, 5Y, 10Y and 30Y rates respectively. For a more detailed explanation, see i-PCA: Implied Principal Component Analysis (12/6/2022). The weights may be thought of as random variables, whose realized values were 3.4, 1.6, 0.1 and 0.7 on the particular day shown above. In the scaling of principal components shown above, each weight is designed to have an implied standard deviation of 1. From this, we may also define a notion of implied factor volatility. The implied PC1 volatility, for instance, can be defined as the square root of $(6.9^2 + 7.2^2 + 6.4^2 + 5.1^2)/4$. *Ex-post* realized PC1 volatility may be calculated similarly, by using an ex-*post* historical estimation of principal components

We use this illustration to first develop a better understanding of principal components before moving on to discussing the volatility of principal components. Our aim here is

Srini Ramaswamy AC (1-415) 315-8117
srini.ramaswamy@jpmorgan.com
J.P. Morgan Securities LLC
Ipek Ozil (1-212) 834-2305
ipek.ozil@jpmorgan.com
Philip Michaelides (1-212) 834-2096
philip.michaelides@jpmchase.com
Arjun Parikh (1-212) 834-4436
arjun.parikh@jpmchase.com

not to provide an elaborate and comprehensive discussion of PCA, but merely discuss some of the key aspects that will be specifically relevant to our purposes in this paper. We touch upon this below.

Variable shift, from correlated observables to uncorrelated "hidden" factors

Traditionally, market participants focus on observable market variables, which are of course random in nature. Thus, it is perfectly reasonable to think of 2Y, 5Y, 10Y and 30Y yields as being random, with some drift and volatility that characterizes the random behavior. But what one cannot do is treat these random variables as independent, because of the considerably high degree of correlation between yields in different maturity points.

But Figure 3 also naturally suggests a different lens with which to view market variables. If we take the column vectors "PC1", "PC2", "PC3", and "PC4" (i.e., the principal component vectors) as given, then the changes in yields in 2s, 5s, 10s and 30s are entirely determined by the weights w_1, w_2, w_3 and w_4. In other words, it is perfectly fine for us to view the (unseen) weights as the true random variables here. On the particular day illustrated in the Figure, we could say that w_1 took on the value 3.4, w_2 took on the value 1.6, and so on, instead of saying that 2-year yields rose by 28bp, 5Y yields rose by 25bp, etc. Thus, the source of randomness moves from observables (yield levels) to the weights (or the realizations of the first factor, the second factor, and so on). This is indeed the point - **the principal component vectors are estimated so as to make the factor realizations uncorrelated random variables.** We will use this property later.

Scaling, numerical significance and a useful notion of factor volatility

A visual scan of Figure 3 reveals that the entries in PC1 (also called the factor loadings) are generally larger in magnitude than the entries in PC2, and so on. When correlations between the actual observables are high (which is the case in fixed income markets), then such an ordering in decreasing order of significance is generally possible as an empirical fact. Also, in our illustration, we have chosen to scale the principal component vectors in such a manner that the hidden factors (i.e., the weights, which must be thought of as random variables) have a standard deviation of one.

Thus, the volatility of each weight is simply one, at least *ex-ante*. But it is not useful to think of the volatility of each factor as being one. After all, a unit move in the first factor would move yields by 6.9bp in the 2Y sector, 7.2bp in the 5Y sector and so on, while a unit move in the fourth factor would move yields by rather negligible amounts across the curve. Instead, a more useful notion of the **volatility of the first factor is to think of it as the product of (i) the standard deviation of** w_1 (which is simply 1 by construction at inception) and **(ii) the root-mean-square of the loadings** (i.e., the square root of $(6.9^2 + 7.2^2 + 6.4^2 + 5.1^2)/4$). The squares and square roots are an unfortunately necessary distraction, but the intuition is that this measure of volatility combines both the volatility of each factor (i.e., the standard deviations of the weights) with the corresponding impact on market variables (i.e., the principal component vector loadings).

Finally, for the more mathematically curious reader, **this notion of factor volatility corresponds to the square root of the corresponding *eigenvalue* from a so called *eigenvalue decomposition***, divided by the number of variables included (see *Technical*

Srini Ramaswamy [AC] (1-415) 315-8117
srini.ramaswamy@jpmorgan.com
J.P. Morgan Securities LLC
Ipek Ozil (1-212) 834-2305
ipek.ozil@jpmorgan.com

Philip Michaelides (1-212) 834-2096
philip.michaelides@jpmchase.com

Arjun Parikh (1-212) 834-4436
arjun.parikh@jpmchase.com

Appendix 1). This is one way to calculate principal component vectors, although there are other (closely related) decompositions that can be used.

Backward/forward looking principal components and historical/implied principal factor volatility

There is the important question of how to estimate the principal component vector loadings illustrated in Figure 3. Typically, this is done by choosing a desired amount of history, and factorizing the historical covariance matrix. For instance, for our example, we might use (say) 3 months of historical data on changes in 2-, 5-, 10- and 30-year yields, compute the historical covariance matrix, and factorize it using the above-mentioned eigenvalue decomposition to compute principal components. This would give us principal components that are unavoidably backward looking. Thus, our measure of factor volatility would also essentially give us a measure of backward looking historical factor volatility.

But historical factor volatility doesn't tell us anything about what is being priced into the options market. **If our ultimate goal is to develop a way to trade factor volatility, we will need a way to calculate forward looking *implied factor volatility*, that we can then use to decide whether to create long or short exposure to factor volatility. This serves as a measure of what is priced in for future factor volatility, and is essential for any factor vol trading strategy.**

Fortunately, we have addressed the question of estimating forward looking implied principal components before. Details can be found in our earlier note on this topic (see i-PCA: Implied Principal Component Analysis). But the essence of our approach to creating implied principal components is as follows. **First**, we note that principal components are computed by merely factorizing the covariance matrix, as we noted above. This is typically done using a historical covariance matrix, but if we could somehow obtain a forward looking implied covariance matrix, we can use the exact same factorization to obtain forward looking implied principal components. Thankfully, since covariances depend on volatilities and correlation coefficients, all we need to calculate an *implied* covariance matrix is *implied* volatilities and *implied* correlations. These are available from the swaptions market and the Yield Curve Spread Options market, respectively. **Thus**, it is straightforward to estimate an implied covariance matrix and thereby obtain implied principal components, both of which are forward looking (see *Technical Appendix 1*).

Finally, we can also calculate our measure of factor volatility for a given factor, using implied principal components. This will give us a notion of implied factor volatility. **Much like we expect returns from selling (or buying) volatility to depend on the difference between *ex-ante* implied volatility and *ex-post* realized volatility, the analogous expectation when trading factor volatility is that returns should depend on the difference between *ex-ante* implied factor volatility and *ex-post* realized factor volatility**. This gives us a way to assess the effectiveness of such strategies in achieving its intended purpose.

Isolating exposure to the volatility of principal factors

We begin by stressing that **trading the volatility of principal factors is not the same as volatility trades constructed based on a PCA-based analysis of the implied volatility surface**. Indeed, PCA has even been used to characterize moves in ATMF

Srini Ramaswamy [AC] (1-415) 315-8117
srini.ramaswamy@jpmorgan.com
J.P. Morgan Securities LLC
Ipek Ozil (1-212) 834-2305
ipek.ozil@jpmorgan.com

Philip Michaelides (1-212) 834-2096
philip.michaelides@jpmchase.com

Arjun Parikh (1-212) 834-4436
arjun.parikh@jpmchase.com

implied volatility at various points on the vol surface, much as in the case of the yield curve, and such analyses can be used to construct hedge ratios in trades with multiple legs on the vol surface. But this is not what we are referring to here. Instead, recall that **one purpose of PCA is to shift one's viewpoint from thinking about observable market variables** (i.e., yield levels at various points on the curve) **to hidden factors** (thinking of the weights in Figure 3 as market variables). **In the context of volatility trading, we wish to develop the analogous shift, from trading the volatility of observable variables (e.g., 5Y swap yields) to trading the volatility of an unobservable hidden factor** (e.g., the volatility of, say, the second principal factor). Of course, we would expect any such trade to be implemented using the traditional tradable instruments (swaptions on 5- and 10-year yields, for instance).

As far as we are aware, the trading of the volatility of principal components remains an unexplored area. Specifically, we address two questions:

- How can an investor trade the volatility of (say) just the first principal component, as opposed to trading the total volatility of (say) 10Y swap yields?
- Why should an options market participant consider such a strategy?

We develop the intuition behind this approach here. To begin, Figure 3 illustrates the idea that moves in 5Y yields, or moves in 10Y yields, can be expressed as a weighted sum of moves in PC1, PC2, and so on, where each weight is uncorrelated to the other. In other words, and as noted earlier, instead of thinking of yield changes in 5s or 10s as being correlated random variables with their own volatility, we may instead think of the weights w_1, w_2, w_3 and w_4 as uncorrelated random variables with some volatility of their own, but this volatility will manifest as volatility in observable yields. Also, as an aside, empirically only the first and second principal components are usually significant in US Rates markets, and we ignore the third component and beyond for ease of exposition. Thus, as a direct consequence of the decomposition illustrated in Figure 3, it follows that the squared volatility of 10Y rates (or 5Y rates) can be expressed as a weighted sum of the squared volatility of each principal component. Slightly more loosely speaking, the total volatility of 10Y yields (say) can be unbundled into a portion that comes from the volatility of the first principal component, and another portion that comes from the volatility of the second principal component. (Technically, it is the square of the volatility that can be unbundled, but we take liberties with the language here to enhance readability).

The same would of course be true for a different point on the curve - the volatility of 5Y rates also can be similarly unbundled into portions that come from PC1 and PC2, but the relative proportions will likely be different. For instance, 5Y rates appear relatively unimpacted by swings in PC2, given the small loading for PC2 in the 5Y sector (Figure 3). Thus, the volatility of 5Y tails likely stems mostly from the volatility of PC1. This is not true for other points on the curve, such as 2s or 30s, for instance.

Logically, then, we ought to be able to combine a (say) 6Mx10Y straddle (which gives exposure to the volatility of PC1 as well as PC2), versus selling a carefully chosen amount of 6Mx5Y straddles (which mostly carries exposure to the volatility of PC1 given the small loading for PC2 in the 5Y tenor), to isolate exposure to the volatility of the second principal component. More generally, **by combining volatility positions on different tails using carefully constructed hedge ratios, we ought to be able to isolate long or short exposure to the volatility of any desired principal component**. In general, given that we are ignoring the third and additional principal factors due their

Srini Ramaswamy [AC] (1-415) 315-8117
srini.ramaswamy@jpmorgan.com
J.P. Morgan Securities LLC
Ipek Ozil (1-212) 834-2305
ipek.ozil@jpmorgan.com

Philip Michaelides (1-212) 834-2096
philip.michaelides@jpmchase.com
Arjun Parikh (1-212) 834-4436
arjun.parikh@jpmchase.com

typically-small significance, **we can combine swaption straddles on two different tails to isolate exposure to the volatility of one factor while hedging out the volatility of the other**. **Constructing such trades is simply an exercise in calculating the appropriate vega weighting on the two legs relative to each other.**

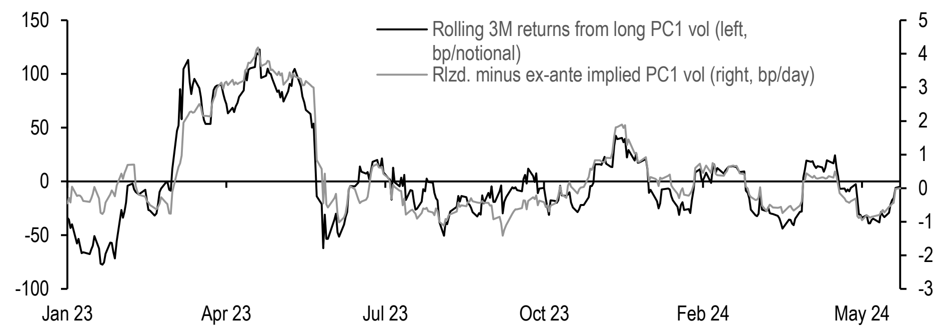
This is the essence of our approach, the mathematical details of which are detailed in *Technical Appendix 2*. Also, as already noted, **we use implied principal components in solving for the vega weights used in constructing such trades**. This allows us to calculate a notion of implied factor volatility that we can use to assess whether it is too high or too low, and thus decide on trade direction.

Does this work?

In other words, **are the returns from such a strategy in fact correlated to ex-*post* realized factor volatility minus the ex-*ante* implied factor volatility**? **Figure 4** demonstrates that this is indeed the case. Rolling 3M returns on such a strategy that used 6Mx5Y and 6Mx30Y swaption volatility to isolate long exposure to volatility of the first principal component has indeed closely tracked the differential between subsequent realized PC1 volatility and the implied PC1 volatility at inception.

Figure 4: Returns from a strategy designed to isolate long exposure to PC1 volatility are indeed explained by the differential between *ex-post* realized factor volatility and the *ex-ante* implied factor volatility

Rolling 3M returns from a long PC1 volatility position constructed using 6Mx5Y and 6Mx30Y swaption straddles* (left, bp/notional), versus the difference between *ex-post* realized PC1 volatility and *ex-ante* implied PC1 volatility ** (right, bp/day) , Jan 2023 - June 2024



Source: J.P. Morgan.
* Weights on 6Mx5Y and 6Mx30Y straddles are chosen to isolate exposure to PC1 while hedging exposure to PC2 using the methodology outlined in *Technical Appendix 2*. Options are delta hedged daily, and rolled monthly, and transaction costs are ignored.
**PC1 volatility is calculated as described above as the square root of the sum square of the first principal component loadings divided by the number of variables. *Ex-post* realized PC1 volatility uses 3-months of history

Why do this?

In our view, trading factor volatility is not merely an intellectual curiosity. It is worthwhile because (i) **the approach results in trades that are no more complex than volatility spreads, just weighted in a different way**, and (ii) **there does appear to be an edge to be had in unbundling overall volatility into its factor-level components**. One way to see this latter point is to examine the fraction of total variation explained by each principal component. Recall that the ratio of each factor's eigenvalue, divided by the sum of all eigenvalues, is the fraction of overall variation explained by each factor (*Technical Appendix 1*). Of course, in the case of forward looking implied principal components, this statement is to be interpreted in a forward-expectation sense, i.e., the implied markets expect a certain fraction of overall variation to come from the first

Srini Ramaswamy AC (1-415) 315-8117
srini.ramaswamy@jpmorgan.com
J.P. Morgan Securities LLC
Ipek Ozil (1-212) 834-2305
ipek.ozil@jpmorgan.com

Philip Michaelides (1-212) 834-2096
philip.michaelides@jpmchase.com

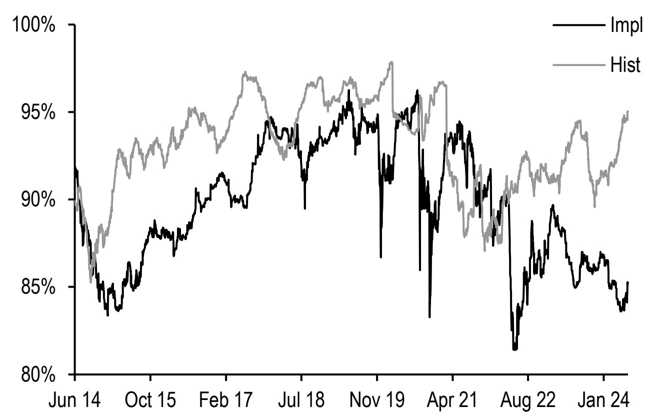
Arjun Parikh (1-212) 834-4436
arjun.parikh@jpmchase.com

principal component, and so on.

Figure 5 shows a relatively long time series of (i) the historical fraction of variation explained by the first principal component, using rolling 6M backwards looking history, as well as (ii) the implied fraction of variation explained by the first principal component, calculated from 6M expiry swaptions and YCSOs. The latter has been lagged by 6 months, so as to make the two directly comparable. The difference between the two is shown in **Figure 6**. As can be seen, the historical fraction of variation stemming from the first component has almost always been greater than the corresponding *ex-ante* implied fraction. **This suggests that the volatility of the first principal factor is structurally underpriced, relative to the volatility of the second principal factor**. In other words, **selling PC2 volatility is likely to outperform selling volatility overall**. On the other side, **buying PC1 volatility might be expected outperform outright long volatility positions**.

Figure 5: The percent of total variation expected to be explained by the first implied principal component has tended to be lower than the fraction that was subsequently actually explained by the first historical principal component...

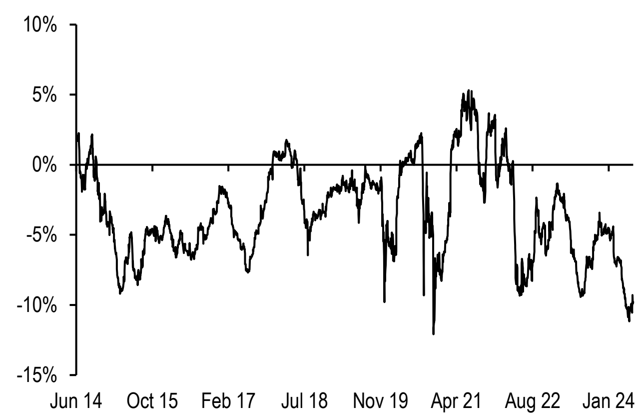
Percent variation* explained by the first historical principal component (using 6-month history) and the percent variation expected to be explained by the first implied principal component (lagged by 6 months to facilitate comparison) , past 10 years



Source: J.P. Morgan.
*Calculated as the ratio of the eigenvalue corresponding to the first implied/historical principal component to the sum of all eigenvalues, for a detailed description of our implied PCA framework, see i-PCA: Implied Principal Component Analysis

Figure 6: ...and this difference has been mostly negative in recent years

Difference between implied (lagged by 6 months) and historical (using 6-month history) percent variation explained by the first principal component*, past 10 years



Source: J.P. Morgan.
*Calculated as footnoted in Figure 5

Empirical evidence does support the idea that selling volatility of the second factor outperforms selling volatility overall. This is seen in the results tabulated in **Figure 7**. In this exhibit, we examine 5 different strategies - (i) selling PC1 volatility, (ii) selling PC2 volatility, and (iii), (iv) and (v) selling outright volatility in 5-, 10- and 30-year tails. We note that the first two strategies were constructed using 5- and 30-year tails as legs in the trades. All of these trades rely on monthly option rolls and daily delta hedging. As can be seen, selling PC2 volatility has on average (over the past three years) produced positive returns, with lower 10th percentile losses and better 90th percentile gains than all the other strategies. (All returns have been normalized by their individual strategy-specific standard deviation of returns, so as to make this comparison possible).

Srini Ramaswamy [AC] (1-415) 315-8117
srini.ramaswamy@jpmorgan.com
J.P. Morgan Securities LLC
Ipek Ozil (1-212) 834-2305
ipek.ozil@jpmorgan.com

Philip Michaelides (1-212) 834-2096
philip.michaelides@jpmchase.com
Arjun Parikh (1-212) 834-4436
arjun.parikh@jpmchase.com

Similarly, we must ask if our approach to constructing long exposure to PC1 volatility also outperforms outright long volatility strategies. This, too, is indeed the case, with one caveat that we soon discuss. This is already somewhat evident from Figure 7, which also includes returns from selling PC1 volatility. As can be seen there, selling PC1 volatility is the single worst strategy in that mix, which corroborates the notion that implied PC1 volatility is typically cheap. But we include a fuller comparison in **Figure 8**, where we examine 3 outright volatility strategies (rolling 3M returns on outright longs in 6Mx5Y, 6Mx10Y and 6Mx30Y swaption straddles delta hedged daily and reset each month) with three strategies designed to create long exposure to PC1 volatility (using 6Mx2Y and 6Mx30Y, 6Mx5Y and 6Mx30Y, and 6Mx10Y and 6Mx30Y instrument-pairs respectively). As can be seen, **the long-PC1-vol strategies appear to indeed outperform outright long vol strategies**, **but there are two exceptions to discuss**. **First**, a strategy of being long 6Mx5Y volatility outright appears to produce returns that are as good as the long-PC1 strategies. This is an exception that is actually easy to understand. Over this period of time, the second principal component has had relatively small loadings in the 5Y sector; this means that a long 6Mx5Y swaption volatility position is very nearly the same as a long PC1-vol position. Thus, this result is neither a coincidence nor is it surprising. **Second**, while long-PC1-vol strategies constructed using the 5s/30s and 10s/30s instrument pairs have performed well, the 2s/30s pair has not and instead has the worst distribution of returns in the entire exhibit. This is likely because of stability issues. Because the past two years have brought forth an aggressive hiking cycle with rapidly shifting Fed expectations, principal component loadings in the 2Y sector have not been as stable as they have been further out the curve. Thus, a strategy involving the 2Y leg likely has experienced more noise because of factor-loading instability. We discuss this below (see section on *Softer Considerations*).

Figure 7: Selling second principal component volatility can be a worthwhile endeavor, as return characteristics suggest

Selected statistics* regarding rolling 3M returns from 5 different delta hedged short volatility strategies**, 6/15/2021 - 6/14/2024; bp/notional

		Normalized 3M rolling return stats from selling:				
		PC1 vol	PC2 vol	6Mx5Y	6Mx10Y	6Mx30Y
Normalized Stats	Min	-3.3	-3.5	-3.3	-3.1	-3.0
	10th %ile	-1.9	-0.9	-1.8	-1.9	-1.7
	Median	-0.3	0.2	-0.3	-0.4	-0.3
	Average	-0.5	0.2	-0.5	-0.5	-0.3
	90th %ile	0.6	1.4	0.6	0.8	0.9
	Max	1.5	3.1	1.6	1.8	2.3
	Std. dev	1	1	1	1	1
Raw	Std. dev	50	57	51	79	152

Source: J.P. Morgan.
* Values shown have been normalized by dividing by each strategy's rolling returns by its standard deviation over the past three years, so as to facilitate comparison across strategies. The standard deviation is shown separately for completeness
** Strategies designed to isolate exposure to PC1 and PC2 volatility use 6Mx5Y and 6Mx30Y swaption straddles as the two legs (see *Technical Appendix 2*). All strategies assume daily delta hedging and monthly rolling of the options.

Figure 8: Long PC1 volatility strategies have generally outperformed outright long vol strategies, with two notable exceptions that are insightful to examine

Selected statistics* regarding rolling 3M returns from longs in 6Mx5Y, 6Mx10Y and 6Mx30Y swaption straddles delta hedged daily and three strategies designed to create long exposure to PC1 volatility**, 6/15/2021 - 6/10/2024; bp/notional

		Outright long straddles			Long PC1 volatility using		
		6Mx5Y	6Mx10Y	6Mx30Y	2s / 30s	5s / 30s	10s / 30s
Normalized Stats	Min	-1.6	-1.8	-2.3	-2.0	-1.5	-1.7
	10th %ile	-0.6	-0.8	-0.9	-1.1	-0.6	-0.8
	Median	0.3	0.4	0.3	-0.1	0.3	0.4
	Average	0.5	0.5	0.3	-0.1	0.5	0.5
	90th %ile	1.8	1.9	1.7	0.7	1.9	1.9
	Max	3.3	3.1	3.0	3.3	3.3	2.8
	Std. dev	1	1	1	1	1	1
Raw	Std. dev	51	79	152	31	50	61

Source: J.P. Morgan.
*Values shown have been normalized by dividing by each strategy's rolling returns by its standard deviation over the past three years, so as to facilitate comparison across strategies. The standard deviation is shown separately for completeness
**Strategies designed to isolate exposure to PC1, while hedging PC2 using specified 6M expiry swaption straddles as two legs, with the weightings calculated as outlined in *Technical Appendix 2*. All strategies assume daily delta hedging and monthly rolling of options.

Softer Considerations

As we have described it so far, we can effectively use any pair of two tails to construct a volatility trade that isolates exposure to the volatility of a given principal factor. **But are**

Srini Ramaswamy AC (1-415) 315-8117
srini.ramaswamy@jpmorgan.com
J.P. Morgan Securities LLC
Ipek Ozil (1-212) 834-2305
ipek.ozil@jpmorgan.com

Philip Michaelides (1-212) 834-2096
philip.michaelides@jpmchase.com

Arjun Parikh (1-212) 834-4436
arjun.parikh@jpmchase.com

all pairs created equal? If not, **what other considerations must an investor contemplate in choosing a suitable pair?**

There are at least two softer, but important, considerations to bear in mind when choosing a pair of tenors to construct the trade with, and they both have to do with the relative stability of factor loadings. **First**, consider constructing a trade using 5- and 10-year tails that creates long exposure to the volatility of the first factor, while hedging out exposure to the second factor. As the second principal component vector shown in Figure 3 suggests, the loadings of the second principal component on 5s and 10s are numerically rather small, suggesting that the ratio of the two might be highly unstable from day to day. Intuitively, the hedge ratio that removes exposure to second factor vol might be expected to depend on this ratio, and therefore constructing such a trade using the 5- and 10-year points might result in the retention of PC2 vol exposure. Thus, such a trade is likely an example where relative-coefficient instability might cause significant deviation from intended performance. One natural extension of this observation is that **it will likely be easier to create trades that offer long or short exposure to PC2-vol (while hedging out PC1 volatility) as opposed to doing the opposite**. Indeed, **hedging out PC2-vol exposure while retaining PC1-vol exposure will likely require a more careful selection of instruments so as to mitigate coefficient instabilities**.

A second way in which coefficient stability can come into play is because of regime shifts. As Figure 8 highlights, using 2Y tails as one of the legs in combination with 30s (as the second leg) has produced returns that are worse than implementations using other tails. This is likely because factor loadings in short tails have been less stable (relative to loadings on longer tails) during this unprecedented hiking cycle that has dominated the backdrop in recent years.

The takeaway from these two observations is rather straightforward - our approach to creating exposure to factor volatility ultimately relies on stable estimation of those factors, and is only as good as that estimation. Should regime shifts and/or poor choice of tenors result in instability of the relative loadings, the strategy is unlikely to perform as intended. This is an important consideration that should be borne in mind when choosing a pair of tenors to construct such trades.

Relative Value Applications

Even if an investor has no desire to create exposure to the volatility of principal factors, such a framework is nevertheless useful for relative value analysis purposes. Consider, for instance, two different ways to create long exposure to PC1 volatility: (i) buying 6Mx10Y versus selling 27.5% of the vega risk in 6Mx2Y, or (ii) simply buying 6Mx5Y, since the loading on 5s from PC2 is close to zero. Assuming this hedge ratio has been somewhat stable in recent months, it is reasonable to expect the implied vol spreads corresponding to these two different implementations to be well correlated to each other. This is indeed the case (**Figure 9**), but recently the -0.27:1.0 weighted 6Mx2Y/6Mx10Y implied volatility spread had significantly richened relative to 6Mx5Y implied volatility, although it is now converging back to fair value (**Figure 10**).

This is an illustration of a broader idea. In general, **we may create long exposure to PC1 volatility using a number of suitably vega weighted swaption straddle pairs. All of those implied vol spreads may be expected to be statistically similar, and deviations, if significant, will likely represent a relative value trading opportunity**.

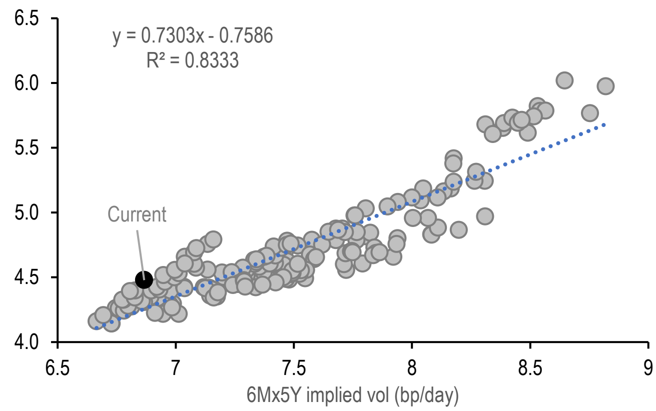
Srini Ramaswamy AC (1-415) 315-8117
srini.ramaswamy@jpmorgan.com
J.P. Morgan Securities LLC
Ipek Ozil (1-212) 834-2305
ipek.ozil@jpmorgan.com

Philip Michaelides (1-212) 834-2096
philip.michaelides@jpmchase.com
Arjun Parikh (1-212) 834-4436
arjun.parikh@jpmchase.com

The same would be similarly true for the various ways in which we could create long PC2-vol exposure. Thus, even for an investor who does not desire a more nuanced unbundling of volatility views, **our approach offers a scheme to assess relative value between swaptions of different tenors**.

Figure 9: The implied vol spreads corresponding to two different implementations of long PC1 vol exposure have been well correlated to each other ...

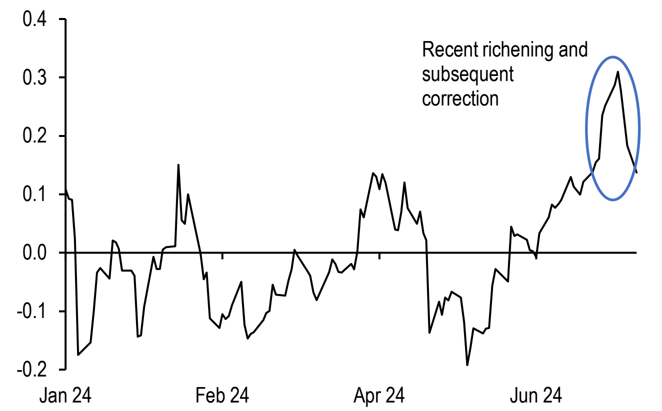
6Mx10Y minus 0.275*6Mx2Y implied vol regressed against 6Mx5Y implied vol, 10/10/2023 - 7/8/2024; bp/day



Source: J.P. Morgan.

Figure 10: ... and deviations appear to be small and quick to correct

Residual from regression of 6Mx10Y minus 0.275*6Mx2Y implied vol against 6Mx5Y implied vol, 1/8/2024 - 7/8/2024; bp/day



Source: J.P. Morgan.

Conclusion

In conclusion, in this paper we have described an approach to trading the volatility not of rates, but of the principal factors that compose the volatility of rates. Our approach is based on viewing the volatility of swap yields as stemming from weighted combinations of the volatility of principal factors, and then using carefully vega-weighted swaption pairs to isolate exposure to principal factor volatility. We have shown that such strategies can be effective in achieving their intended purpose of tracking factor volatility. Moreover, we think such strategies hold promise given the apparent structural richness of implied second-factor volatility. Lastly, even to an investor who does not wish to trade principal factor volatility, the approach still likely offers value as it can be used as a means to assessing relative value across different tenors in the swaptions market.

Srini Ramaswamy [AC]
(1-415) 315-8117
srini.ramaswamy@jpmorgan.com

Technical Appendix 1

Technical Appendix 1: Implied and Historical Principal Components

1) To get an **implied covariance matrix**, denoted $\boldsymbol{C_{imp}}$ (and illustrated using 2Y, 5Y, 10Y, and 30Y rates), we simply enter squared vols in the diagonal elements. For the off-diagonal elements, we write the product of the implied correlation (from the YCSO market) and the two implied vols. For instance, the covariance between rates r_i and r_j would be $\boldsymbol{Cov(r_i, r_j) = \rho_{(r_i r_j)}\sigma_{r_i}\sigma_{r_j} = \frac{1}{2}(\sigma^2_{r_i} + \sigma^2_{r_j} - \sigma^2_{r_j - r_i})}$.

Thus we get $\boldsymbol{C_{imp}} = \begin{bmatrix} \boldsymbol{\sigma^2_2} & \cdots & \frac{1}{2}(\boldsymbol{\sigma^2_{r2} + \sigma^2_{r30} - \sigma^2_{r30-r2}}) \\ \vdots & \ddots & \vdots \\ \frac{1}{2}(\boldsymbol{\sigma^2_{r2} + \sigma^2_{r30} - \sigma^2_{r30-r2}}) & \cdots & \boldsymbol{\sigma^2_{30}} \end{bmatrix}$.

2) This implied matrix can now be factorized to yield implied principal components. This is done by performing an eigenvalue decomposition on the implied covariance matrix to back out unique eigenvalues $\{\boldsymbol{\lambda_i}\}$ and associated eigenvectors $\{\vec{\boldsymbol{v}}\}$. This is typically written as $\boldsymbol{C_{imp} = PDP^T}$ where D is a diagonal matrix with the eigenvalues and the columns of P are the associated eigenvectors. It is also traditional to sort the eigenvalues in descending order.

3) After that, we compute the matrix $\boldsymbol{V = P\sqrt{D}}$. The columns of this matrix gives our **implied principal components**, and are scaled to reflect a sense of magnitude. I.e., the first column represents the impact of a 1-sigma move in the level factor on rates in different tenors, the second column reflects the impact of a 1-sigma move in the second (or curve) factor, and so on.

4) In a similar vein, we can calculate a historical covariance matrix based on realized changes (over some estimation window) on swap rates. Once the historical covariance matrix is calculated, the process for calculating historical principal components is the same process as described in (2) and (3): $\boldsymbol{C_{hist} = PDP^T}$ where D is a diagonal matrix with the eigenvalues and the columns of P are the associated eigenvectors, and the columns of $\boldsymbol{V = P\sqrt{D}}$ gives the **historical principal components**.

5) Lastly, the ratio of the first eigen value to the sum of eigen values can be interpreted as the percent of total variance explained by the first factor. The ratio of the second eigenvalue to the sum of eigenvalues represents the percent of total variance explained by the second factor, and so on.

Srini Ramaswamy [AC]
(1-415) 315-8117
srini.ramaswamy@jpmorgan.com

Technical Appendix 2

Technical Appendix 2: An approach to trading Principal Factor Volatility

Let Δy_k denote the change in yield levels in some tenor k, on some day. Also suppose that we have estimated principal components, allowing us to write:

$$\boldsymbol{\Delta y_k} = \sum_i \boldsymbol{f^i}\, \mathrm{P}_{\boldsymbol{k}}^{\boldsymbol{i}} \quad (Equation\ 1),$$

where $\mathrm{P}_{\boldsymbol{k}}^{\boldsymbol{i}}$ denotes the loading of factor i on tenor k, and the summation is over all factors, indexed by i. Also, $\boldsymbol{f^i}$ denotes the "realization" of factor on the day in question.

Since the prinicipal components are estimated so as to make the $\boldsymbol{f^i}$s uncorrelated to each other, it follows from Equation 1 that:

$$\boldsymbol{\sigma}_k^2 = \sum_i \boldsymbol{\sigma}_{\boldsymbol{f}^i}^2 (\mathrm{P}_k^i)^2 \quad (Equation\ 2),$$

where the summation is, once again, over all principal factors, and $\boldsymbol{\sigma}_{\boldsymbol{f}^i}$ denotes the standard deviation of $\boldsymbol{f^i}$. Now, using the empirical observation that 2 factors generally suffice to explain the bulk of the variance in US Rates markets, we can write:

$$\boldsymbol{\sigma}_k^2 = (\mathrm{P}_k^1)^2 \boldsymbol{\sigma}_{\boldsymbol{f}^1}^2 + (\mathrm{P}_k^2)^2 \boldsymbol{\sigma}_{\boldsymbol{f}^2}^2 + \epsilon^2 \quad (Equation\ 3)$$

Differentiating Equation 3, we get: $\frac{\partial \sigma_k}{\partial \sigma_{f^1}} = (P_k^1)^2 \frac{\sigma_{f^1}}{\sigma_k}$ $(Equation\ 4)$ and $\frac{\partial \sigma_k}{\partial \sigma_{f^2}} = (P_k^2)^2 \frac{\sigma_{f^2}}{\sigma_k}$ $(Equation\ 5)$

Here on, we note that our principal component vectors are scaled so that, *ex-ante*, $\boldsymbol{\sigma}_{\boldsymbol{f}^1} = \boldsymbol{\sigma}_{\boldsymbol{f}^2} = 1$ $(Equation\ 6)$

Now consider a trade combining 2 vanilla swaptions, with the same expiry, in tenors k and j. The trade is denoted by the vol spread: $\mathrm{V} = \mathrm{w}_k \boldsymbol{\sigma}_{\boldsymbol{k}} + \mathrm{w}_j \boldsymbol{\sigma}_{\boldsymbol{j}}$ $(Equation\ 7)$.

Suppose we want this trade to isolate exposure to the vol of factor 1. Then, we desire, without loss of generality: $\frac{\partial V}{\partial \sigma_{f^2}} = 0, \frac{\partial V}{\partial \sigma_{f^1}} > 0, |w_k| = 1$ $(Equation\ 8)$

Combining Equations 5 and 8, and using the fact that $\boldsymbol{\sigma}_{\boldsymbol{f}^i} = 1$ on an *ex-ante* basis, we therefore desire: $\mathrm{w}_j = -\left(\frac{P_k^2}{P_j^2}\right)^2 * \frac{\sigma_j}{\sigma_k} * w_k$ $(Equation\ 9)$

Of course, we also want $|w_k| = 1$, which means we only need to determine the sign of w_k. We get this from the requirement that $\frac{\partial V}{\partial \sigma_{f^1}} > 0$ since we want long exposure to factor-one volatility.

If we define a new quantity: $\Omega^1 = (P_k^1)^2 - \left(\frac{P_k^2}{P_j^2}\right)^2 (P_j^1)^2$ $(Equation\ 10)$. Then we get: $w_k = sign(\Omega^1)$ $(Equation\ 11)$.

Very similarly, if we wish to create long exposure to the volaility of factor 2, while hedging the volatility of the first factor, we get the following:

$$\Omega^2 = (P_k^2)^2 - \left(\frac{P_k^1}{P_j^1}\right)^2 (P_j^2)^2 \ (Equation\ 12),\ w_k = \mathrm{sign}(\Omega^2)\ (Equation\ 13),\ w_j = -\left(\frac{P_k^1}{P_j^1}\right)^2 \frac{\sigma_j}{\sigma_k} * w_k\ (Equation\ 14).$$

Lastly, it will often be useful to compare different tenor pairs that can be used to create long exposure to (say) the volatility of the first factor. For instance, suppose $\mathrm{V} = \mathrm{w}_k \boldsymbol{\sigma}_k + \mathrm{w}_j \boldsymbol{\sigma}_j$ is designed to create long exposure to the first factor, but so is the trade $\mathrm{Y} = \mathrm{w_m} \boldsymbol{\sigma}_\mathrm{m} + \mathrm{w_n} \boldsymbol{\sigma}_n$ which simply uses two different tenors. If our intent is now to compare trades V and Y, we can no longer choose two weights to be of magnitude 1. Instead, we could calculate w_k and w_j as before, and so also calculate $\mathrm{w_m}$ and $\mathrm{w_n}$. But then, we would need to scale $\mathrm{w_m}$ and $\mathrm{w_n}$ by some multiple so that $\frac{\partial V}{\partial \sigma_{f^1}} = \frac{\partial Y}{\partial \sigma_{f^1}}$. This would result in no-longer-unit-scaled weights for the trade Y, but would make Y comparable to V for the purposes of relative value. For instance, if the carry cost of V is lower than Y, say, then an investor could "buy" V, "sell" Y, and have a positive carry position that should generally be well hedged.

Srini Ramaswamy AC (1-415) 315-8117
srini.ramaswamy@jpmorgan.com
J.P. Morgan Securities LLC
Ipek Ozil (1-212) 834-2305
ipek.ozil@jpmorgan.com

Philip Michaelides (1-212) 834-2096
philip.michaelides@jpmchase.com

Arjun Parikh (1-212) 834-4436
arjun.parikh@jpmchase.com

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Srini Ramaswamy AC (1-415) 315-8117
srini.ramaswamy@jpmorgan.com
J.P. Morgan Securities LLC
Ipek Ozil (1-212) 834-2305
ipek.ozil@jpmorgan.com
Philip Michaelides (1-212) 834-2096
philip.michaelides@jpmchase.com
Arjun Parikh (1-212) 834-4436
arjun.parikh@jpmchase.com

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