

PCA Unleashed

Interest Rate Strategy

Research Analysts

Marion Pelata
+44 20 7883 1333
marion.pelata@credit-suisse.com

Panos Giannopoulos
+44 20 7883 6947
panos.giannopoulos@credit-suisse.com

Helen Haworth
+44 20 7888 0757
helen.haworth@credit-suisse.com

The application of PCA across European Rates markets

One of the main difficulties in today's environment is being able to visualize data easily. There is frequently too much information, too much news, and too much data! Thankfully, tools such as Principal Component Analysis (PCA) can help reduce complexity.

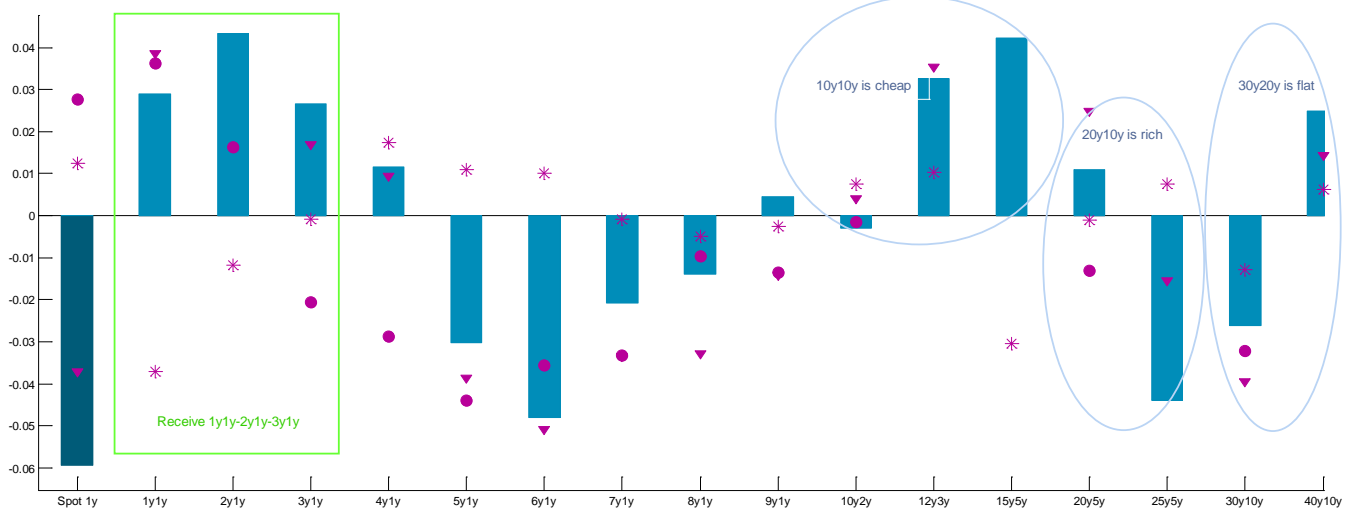
PCA is a well-known technique used to reduce complexity, visualize discrepancies, signal when to take profit and identify RV opportunities or cheap ways to express a macro view. It has been widely used to analyze the swap markets, but we find it equally useful for other markets, including vol space, money markets, and government bonds.

We provide an overview of the methodology and implementation of PCA through the use of practical examples. Current trades highlighted by our PCA framework include the following:

- 2s5s steepener in Netherlands
- 2s5s steepener in Spain
- Receive EUR 1s2s3s 1y fwd
- Pay EUR 10y10y-20y10y-30y20y
- GBP 30y10y-40y10y steepener
- Buy GBP 1m gamma on 10s and 30s

Residuals of EUR swaps, as of 22 October

BBar is residuals as of 22 October, triangle as of 19 October, circle as of a week ago and star as of a month ago.



Source: Credit Suisse

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Introduction: Reducing complexity

Principal Component Analysis (PCA) quantifies movements in a specific market and represents them as a combination of two to three driving factors, called principal components (PCs). For instance, investors often refer to movements in the yield curve in terms of three driving factors: level, slope, and curvature. PCA formalizes this viewpoint and allows us to evaluate when a sector of the yield curve has cheapened or richened beyond that prescribed by recent yield movements.

An entire sample's information can be represented in terms of structural changes – captured by the PCs – and noise. Should this noise be significantly different than zero, it highlights a possible dislocation within the dataset. This can be interpreted in conjunction with market views to see if there is an actionable trade opportunity.

In this publication, we describe what PCA is in simple terms and illustrate its use with practical examples – the mathematical background is based on basic linear algebra and is provided in the [Appendix](#).

PCA is well-known and frequently used in the swaps space; we have extended the analysis to other markets – including government bonds, volatility, basis swaps and futures – and find it equally useful. The framework can be used across markets to:

- **Highlight relative value opportunities.** For example, identify a rich or cheap sector of the yield curve, in which the relative valuation is independent of market direction.
- **Identify cheap ways of expressing a macro view.** For example our framework could highlight the cheapest point to go long on the curve.
- **Signal when it is time to take profit on a position.**

Investors can use PCA to implement a view based on these elements, set up portfolio-level decisions, including hedges isolating one or more of these drivers or focus on relative-value trades.

We run our PCA analysis across markets daily ¹ and use the results to help identify trade opportunities. Current trades highlighted by our PCA framework include the following:

- 2s5s steepener in Netherlands
- 2s5s steepener in Spain
- Receive EUR 1s2s3s 1y fwd
- Pay EUR 10y10y-20y10y-30y20y
- GBP 30y10y-40y10y steepener
- Buy GBP 1m gamma on 10s and 30s

¹ Please contact marion.pelata@credit-suisse.com for further information.

Methodology: Identifying the driving factors

The essence of PCA in the context of rates markets is that most yield curve movements can be represented as a set of two to three independent driving factors – the principal components (PCs) – along with their relative weightings.

PCA is a useful technique to remove redundant information contained in a large dataset, making it easier to interpret. In this section, we provide a top-level overview and explanation of the methodology based on examples for EUR swaps. Readers purely interested in the applications can skip this section and go directly to the next one.

More specifically, PCs are defined such that they explain the largest proportion of the overall variance of a dataset without any overlap. They can be seen as (uncorrelated) axes forming a new coordinate system. The new axes are known as **loadings**. The more an axis has explanatory power for the dataset, the larger the value of the corresponding weight.

By selecting just those PCs with the highest weights, it is possible to explain the majority of the dataset with a lot less complexity. We can therefore translate the original dataset into the new axes. These new coordinates are known as **scores**.

From our original dataset, we get three outputs: the loadings, their associated weights as well as scores. These outputs highlight the structural changes of our dataset, and therefore also its potential dislocations. As we outline in the [Applications](#) section, the latter can be used in different ways, potentially leading to trade opportunities. We begin by providing a basic overview of the methodology; the mathematical background is in the [Appendix](#).

Methodology

Data requirements

The framework behind PCA is relatively straightforward. The underlying data need to be correlated, mean-reverting, preferably non-overlapping, with sufficient points to ensure the robustness of the results.

In the past, this technique has been mostly used for swap markets. We find that the universe can easily be extended to other markets: from a set of different tenors across money markets to a set of sovereign bonds across Europe. As soon as the correlation among the data set is strong enough, PCA can be applied.

The dataset must be two-dimensional: we consider a set of instruments over a period of time; e.g., we collect time series for each instrument on a rolling window and update these levels on a daily basis.

Construction

We position the first axis in such a way that it accounts for the largest proportion of the data's variance. This axis will be called the first component (or first factor) and can be seen as a more accurate new angle, to observe our cluster of points. As it describes our data, it seems rather logical to say that it is built as a linear combination of our variables.

Each additional factor is calculated so that the contribution to the variance is cumulatively maximized. The second factor, for instance, will account for as much of the remaining variation as possible, given the first axis created. To be optimal and to have the least redundancy possible, we take each new axis orthogonal to previous ones, that is to say uncorrelated to them. In total, we can find as many (uncorrelated) components as we have variables. Each PC then contributes some unique information not provided by the others. In practice, we will use at most the first three PCs – these typically would account for 95% of total variance.

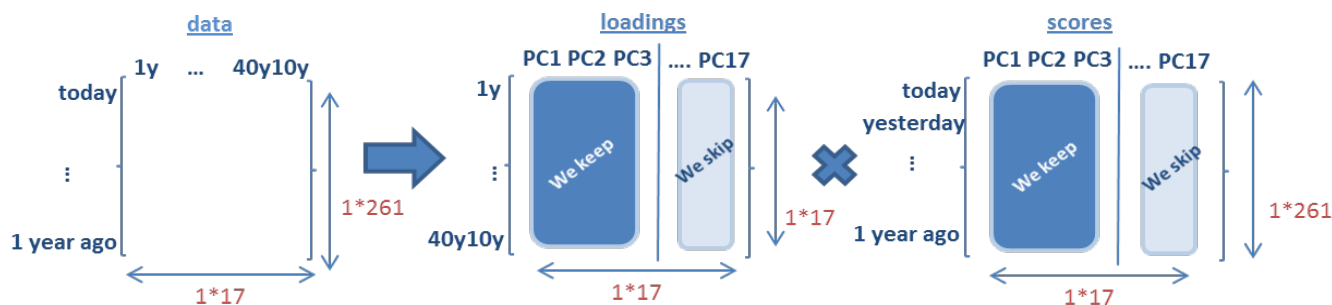
The standard linear algebra techniques used to compute the PCs are outlined in the Appendix. In short, PCA analyzes the covariance matrix of the dataset in order to capture as much variance as possible, with the fewest PCs possible. Axes created following this procedure – the loadings – will each have a certain length and an orientation. These are given, respectively, by the eigenvectors and eigenvalues of the diagonalized correlation matrix of our database (see [Appendix](#)). The eigenvalue is the standard deviation of the scores, while eigenvectors represent the loadings. The longer the length of the vector, (i.e., the larger the eigenvalue) the more information it contains and the more significant the associated PC will be.

In practice: the case of EUR swaps

As an example, we apply PCA to EUR forward swaps, with a 1-year timeframe and 17 different non-overlapping tenors (from 1y spot, 1y1y, 2y1y, etc. to 40y10y).

From our analysis, we get two outputs: the loadings (along with their weights) and the scores. Applied to our example, we show in Exhibit 1 the relative size of the two matrices created.

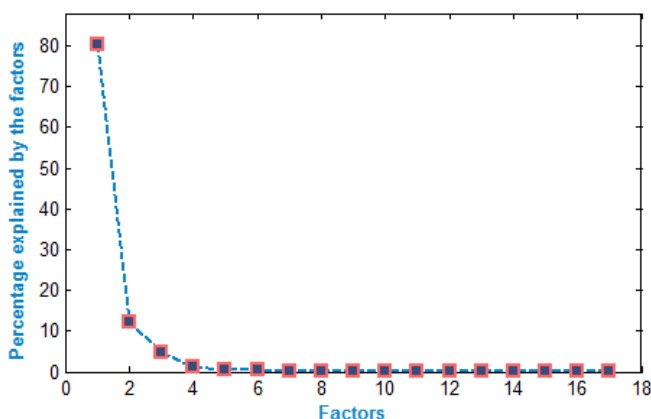
Exhibit 1: Size of loadings and scores relative to size of the data



Source: Credit Suisse

The loadings – also called factors or PCs – are classified by their relative weights, as shown in Exhibit 2. We decide to account for 95% of the overall dispersion and therefore consider the first three main drivers of our dataset. The first one – PC1 – explains more than 80% of the variance. The second and third factors (PC2 and PC3) explain 10.1% and 4.3%, respectively (Exhibit 2).

Exhibit 2: Percentage of overall variance explained



Source: Credit Suisse

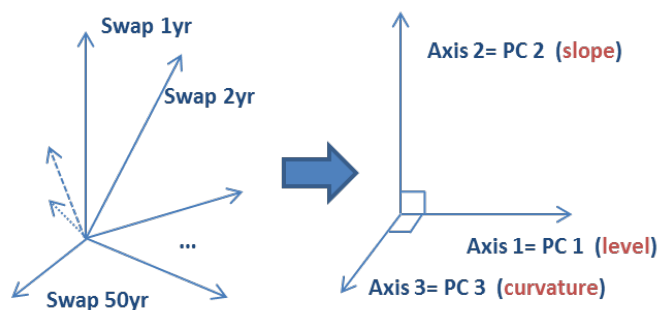
Reduction of dimensionality

The result is that we are able to substantially compress the information contained in our dataset. Rather than considering our entire set of variables, we can now express more than 95% of our overall variance – that is to say the information provided by the data – in terms of the main two or three PCs. By doing so, we reduce redundant information to consider just the most useful.

In Exhibit 3, we look at the transposition from a 17-dimensional cluster of points to a new system with only 3 coordinates. We reduced the data's dimensionality from 17 to 3 with very little information loss. If visualizing the data is first impossible, thanks to the fewer number of axes following the transformation, we can now represent the information graphically as well as model it in a simpler way.

In the next section we focus on the financial interpretation of these new axes. We find that they represent the level shift, the slope, and the curvature of the EUR swap term structure.

Exhibit 3: Simplified visualization when considering PCA on swap curve

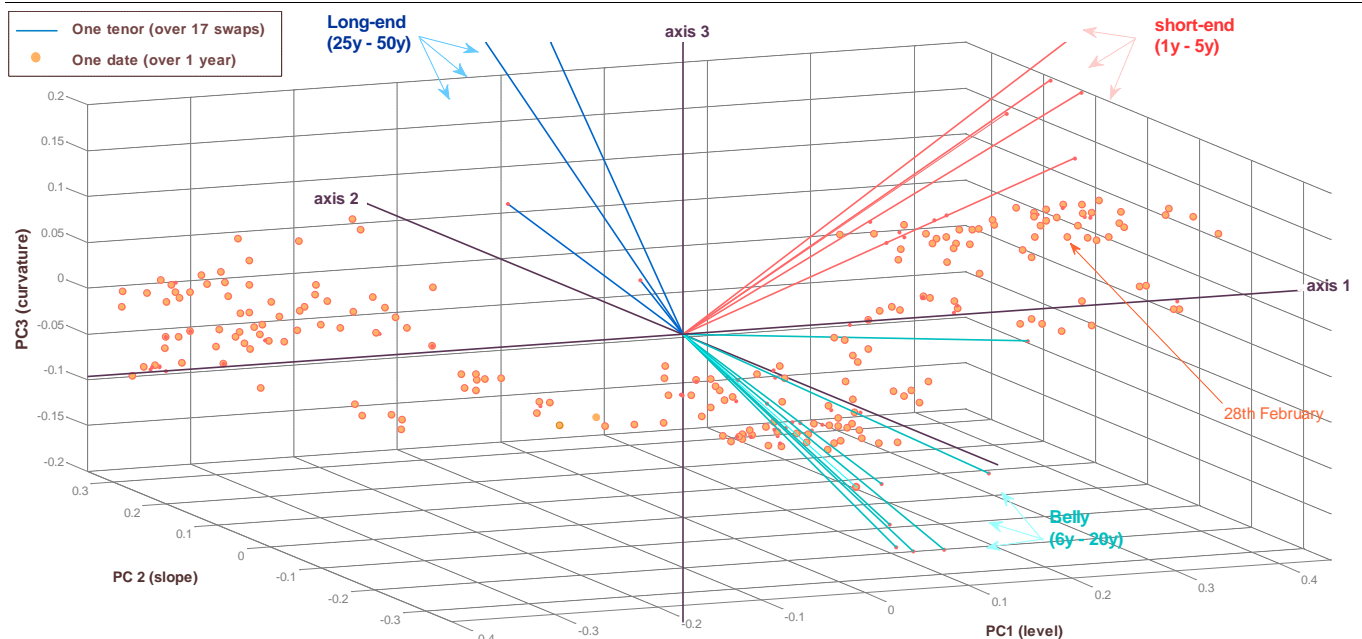


Source: Credit Suisse

Interpretation

We reduce the number of dimensions from 17 to 3 and consider only the first 3 columns of both the score and loadings matrices presented in Exhibit 1. An illustration of the result is presented in Exhibit 4.

Exhibit 4: Scatter plot of the new coordinate system: the first axis is the longest and explains the most the variance of the data



Source: Credit Suisse

We observe that each piece of data and each swap tenor has its representation in this new coordinate system – defined by the first three PCs. Market moves for each date are shown as points and swap tenors as lines.

For instance, we find that on 28 February, market changes can be represented within the new system by the following coordinates: [0.42 PC1, -0.35 PC2, -0.15 PC3]. That means that on this particular day, we can define the main moves in the EUR swaps market by our three drivers: a positive realization of PC1, a negative realization of PC2, and almost no effect from PC3. We will see that the components represent level, slope and curvature: so on this day, the EUR bear-flattened.

Similarly, the EUR swap 40y10y has a positive relationship to all three PCs. When levels shift higher and the curve steepens, the long-end grinds higher.

If the original dataset can be represented in this new coordinate system, it is worth pointing out that reciprocity exists. All new axes are constructed as a linear combination of the original variables.

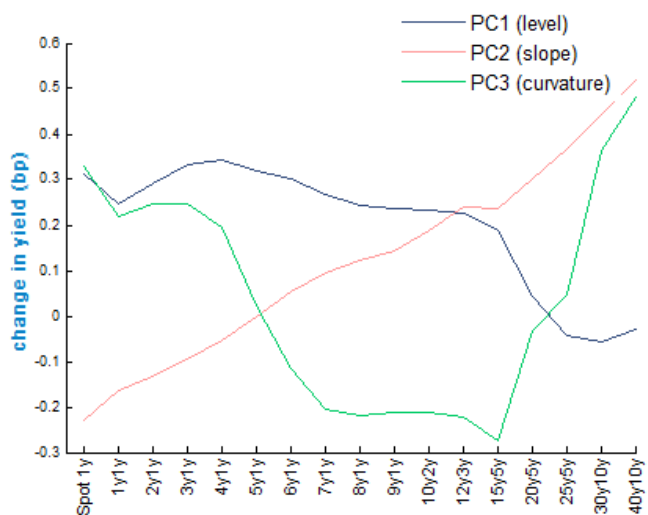
The main axis – PC1 – has the largest weight, which can be proxied by its length ([-0.4, 0.4] versus [-0.3, 0.3] and [-0.2, 0.2] for PC2 and PC3). We observe the mean-reverting property of our data, with the cluster being centred on a “new” zero.

As for the 17 swap forwards, their representation indicates how they contribute to each of the three principal components. We find that the tenors fall into three subsets: short-end, belly, and long-end. For instance, the short-end of the swap curve – from 1yr spot to 4yr1yr – has a positive contribution to both the first and third components, but contributes negatively to the construction of the second component.

EUR swaps: behind the first three components

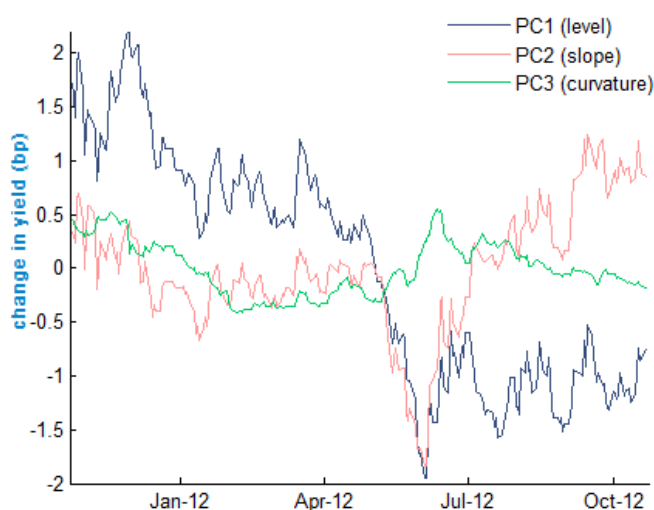
To have a better understanding of our data, we shift focus from our data to our score and loadings. We can identify a relationship between the original variables and the new coordinates. But we can go further in our analysis. In Exhibit 5 and Exhibit 6, we highlight the shape of our first three factors over time and the coefficients of our first three factors.

Exhibit 5: Shape of the three components: PCs are built as a linear combination of all tenors



Source: Credit Suisse, Credit Suisse Locus

Exhibit 6: PCs over time: PC1 highlights the general rally over the last year; PC2 the recent steepening



Source: Credit Suisse

From Exhibit 5, we observe that:

- The **first component** has positive coefficients for all the variables: it can be seen as a proxy for the level of yields and explains most of the dispersion.
- The **second one** has negative factors for the short-end that become more neutral at the belly and then positive at the long-end of the curve. It represents the slope of the swap curve: the short-end is anti-correlated to the long-end from this angle.
- The **third component** has positive coefficients for the short- and long-ends, while it has negative coefficients in the belly of the curve. This indicates that the axis distinguishes the relative impact on a point from a curvature effect.

The first main drivers of the swap curve can be seen as level, slope, and curvature.

It should be noted that the first component includes the slope and curvature changes that are correlated with yield level changes. With an upward move in rates, that is to say a positive realization of the first PC, we can see from Exhibit 5 that the change in yields (PC1) is greatest for shorter maturities (from 1y1y to 5y1y) and smallest for longer maturities (from 10y2y to 30y10y). Therefore, the short-end of the curve steepens and the long-end flattens (except the 40y-50y sector), increasing the hump in the intermediate sector of the curve.

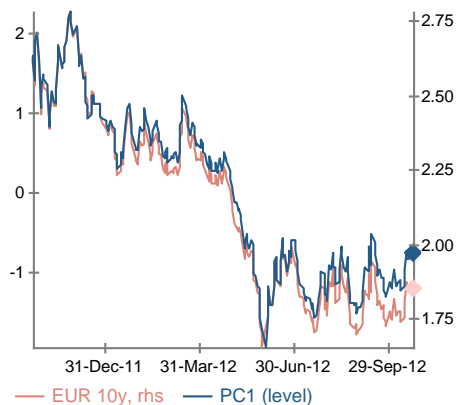
From this perspective, we see that bear-flattening seems to be more likely on average than bear-steepening. If yields move lower, the realization of the first PC will be negative, with bull-steepening (short-end flattens, long-end steepens) more likely than bull-flattening. This fact has been evidenced over the last year, as shown in Exhibit 6.

To a much lesser extent, the second and third factors also explain yield curve movements. For instance, a positive realization of PC2 will cause the short-end to grind lower (negative coefficients) and the longer maturities to move higher (positive coefficients). Looking at their shape, it also explains why bear-steepening as well as bull-flattening still occur in the current environment.

We can also verify these relationships by looking at the correlation against some of our actual data: 10y swap, 2s10s slope, and 2s15s30s curvature (Exhibits 7 - 9).

Exhibit 7: First factor

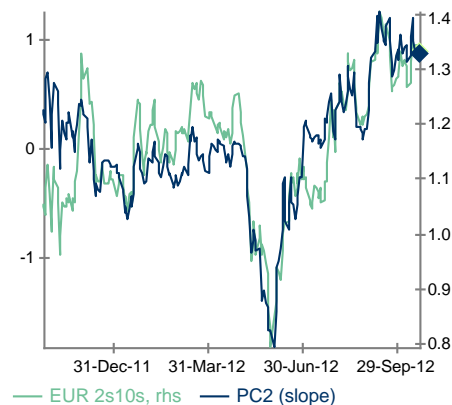
Correlated with yields, for instance the 10y sector.



Source: Credit Suisse

Exhibit 8: Second factor

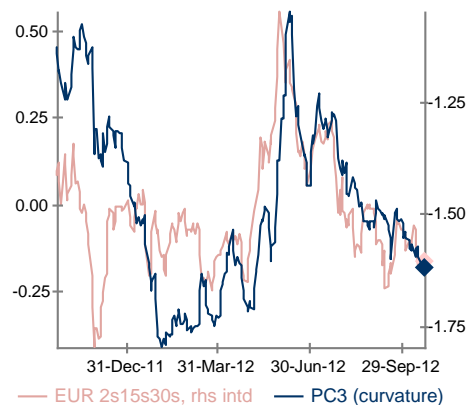
Correlated with slope, for instance the 2y-10y slope.



Source: Credit Suisse

Exhibit 9: Third factor

Correlated with curvature, for instance 2s15s30s fly.



Source: Credit Suisse

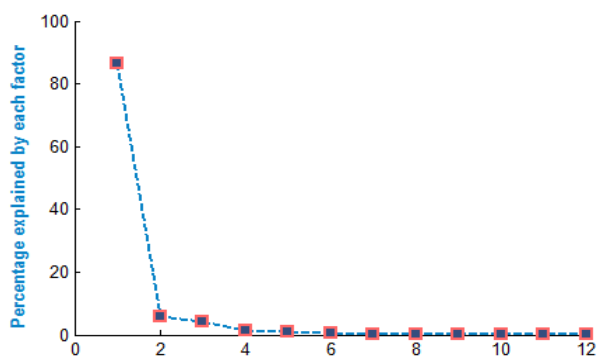
We can also observe from Exhibit 6 that yields have been rallying broadly over the time period shown, with the first PC decreasing over time. On the contrary, the second factor has been recently increasing, accounting for a steeper swap curve. Finally, we can see that there is no specific trend currently in terms of curvature, with the third factor fluctuating around zero. While this is not a dramatic piece of news, it is a nice way to illustrate what all investors know: the European swap curve has recently bull-steepened.

Further examples: core government bonds, gamma and FRA-Eonia bases

We can extend the analysis on euro swaps to other markets. Applying a similar methodology, we build the scores, the corresponding weights, and the loadings. In order to identify the main drivers, we concentrate on the first two outputs.

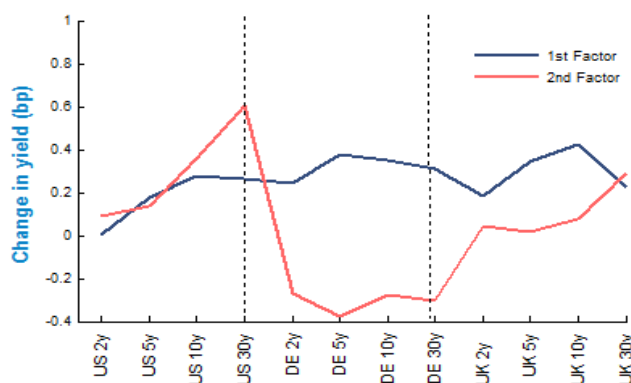
For core bonds (Exhibits 10 and 11), we find that the first factor explains more than 80% of the overall variance and can be interpreted as a level shift. The second and last factor we consider a curve impact, with coefficients increasing along with maturity. Given the smaller number of variables considered, we gauge enough information by considering only two factors. The third factor represents a curvature effect, but we have decided not to include it as a strategic decision, as it is more valuable for curvature effects to be captured as part of the residual (see section [Application](#)). Depending on the applications that we consider for PCA, we might choose at some point to include it.

Exhibit 10: Core bonds: relative factor weights



Source: Credit Suisse

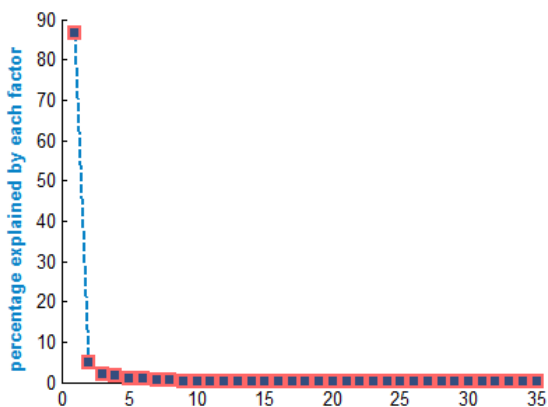
Exhibit 11: Core bonds: shape of the factors



Source: Credit Suisse

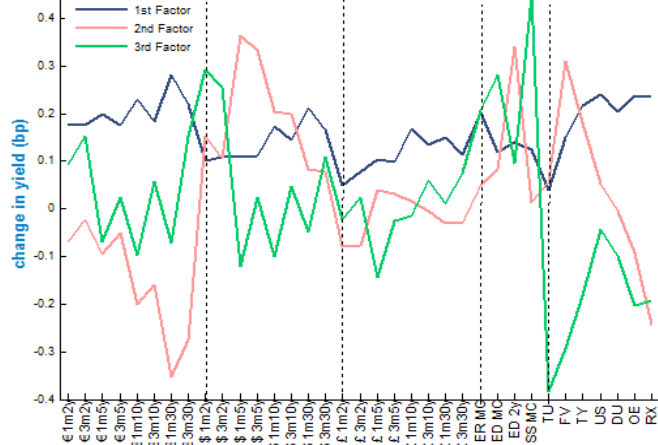
PCA factors for gamma are slightly less straightforward. Looking at Exhibits 12 and 13, we find that the first factor also explains a very large proportion of our dataset and corresponds to a level shift, with all coefficients positive. The second factor, accounting for 5% of the variance, is a shift between currencies, with euro space accounted as negative, US yields as positive, and UK as neutral. The third factor depends on the slope and decreases with maturity.

Exhibit 12: Gamma: relative factor weights



Source: Credit Suisse

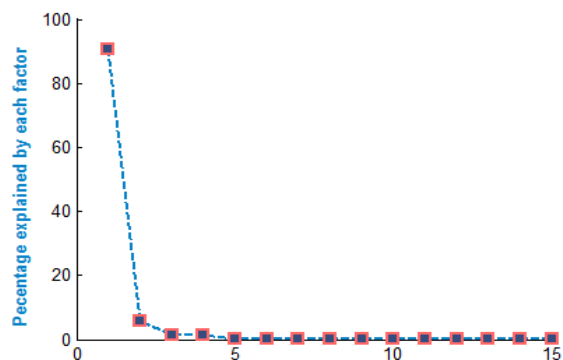
Exhibit 13: Gamma: shape of the factors



Source: Credit Suisse

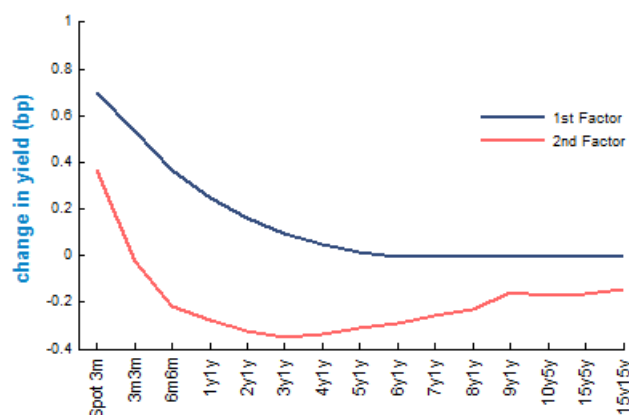
Finally, we focus on EUR FRA-Eonia bases. In Exhibits 14-15, we observe that again the first factor is the main driver of the analysis and represents both a level shift as well as the slope. Coefficients are all positive but decrease over time to maturity. The second factor represents the curvature effect. Similar to core bonds, we have decided not to consider the third factor.

Exhibit 14: FRA-Eonia bases: factor weights



Source: Credit Suisse

Exhibit 15: FRA-Eonia bases: shape of the factors



Source: Credit Suisse

PCA can therefore be used outside its usual market – swap term structures – and can be extended, while remaining robust, to many others. The next step, of course, is what to do with the outputs.

Applications: Implementing PCA

PCA is useful to reduce information contained in a big dataset, making it easier to interpret: points in a multidimensional space are projected onto a space of fewer dimensions. Not only we can reduce the number of dimensions considered, but we are now in a position to compare the original dataset with the reconstructed one, leading us to assess whether the pricing of each variable is fair relative to others, that is to say rich or cheap relative to what our PCA framework implies.

Having built a new dataset, we can compare the difference between the information provided by the original data and the reconstructed data. We define, for each date and each variable, a residual such that:

$$residuals_{ij} = data_{ij} - reconstructed_{ij}; i = 1:17; j = 1:261;$$

The residuals are simply the original data minus the fitted points. **They ought to be mean reverting and can be viewed as “noise”.**

A positive residual implies that the actual market value is higher than the theoretical one arising from our PCA framework and vice versa. Results can then be interpreted in light of macro views and market technicals to see if there is an actionable trade idea.

PCA has many uses

In rates markets, PCA is usually used to highlight potential rich/cheap opportunities in EUR swaps. In addition to extending PCA to other markets, we believe it is robust enough to have a much broader application.

1. **Residuals: identify rich and cheap value trades** Looking at relative value trades, we seek to enhance returns without taking a strong view on yield curve movements. By constructing curve-neutral portfolios, our goal is to outperform the market while being uncorrelated to it. Our new dataset is built such that the first three components represent the vast majority of yield curve movements. They are uncorrelated to one another and to the rest of the data that have yet to be explained. Thus, the residuals described above should be largely independent of market direction and can be used to assess relative valuation. If one residual is very positive on a particular day, while the surrounding points have negative residuals, then relative-value players might be tempted to enter a short-term butterfly position (pay wings, receive body).
2. **Residuals: identify best expressions of a macro view** The observation of our residuals give us a fair idea of the value of a particular point relative to others. Therefore, investors seeking to find the cheapest way to express a macro view might use PCA residuals to identify the cheapest entry point for their trade. In the example of a rally, it can be used to assess which point has rallied more than others and thus appears the best part of the curve to go short.
3. **Residuals: signal when it is time to take profit on a position** Tracking residuals is useful to identify the time to take profit on a position. For instance, should an investor have a short position on the EUR swap 5yr, the mean reversion of the associated residual from a negative to a positive level might be a fair signal to unwind the position.
4. **Loadings: assess risk** Duration is often used as a tool to assess market risk. It is a simple tool and assumes a one-to-one correlation between the changes in yields of different maturities. Even augmented by convexity, however, portfolios can be mismatched due to yield curve reshaping. For instance, duration doesn't capture the fact that 10s30s curves tend to flatten in a sell-off. PCA can provide an efficient and

yet easy way to assess exposure to the yield curve, as it includes not only the first PC that is usually a proxy for a level shift but also two additional driving factors (2nd and 3rd PCs). In practice, we find that the overall variance of a position on a yield curve can be constructed as a linear combination of the variance of the scores (see [Appendix](#)), making it straightforward to assess any variation.

5. **Loadings: create hedging ratios** PCs can be viewed as risk factors and the objective is to keep the portfolio exposure to PCs within acceptable bounds. This can be done using hedge ratios, which are calculated through linear algebra (see [Appendix](#)) based on both the loadings and eigenvalues. For instance if a position is immune to both the first and second factors, then it has no exposure to any linear combinations of these 2 PCs. For example, if an investor aims to be long 5yr Spain versus Italy while being neutral to yield shifts, PCA can provide a robust hedging ratio.
6. **Loadings: manage portfolios** More broadly, PCA can be used to help manage portfolios. We do not go into detail on this particular point here, but it is worth highlighting the extensive use that can be made of PCA. As outlined previously, PCA loadings can be used to hedge positions against one or more PCs as well as assessing risk. Looking at return attribution, the management of one portfolio can also be simplified thanks to the PCA, allowing investors to understand the breakdown on their P&L based on each individual PC. For instance, generating the return due to the first component alone allows an understanding of whether the portfolio is mishedged to this component.

More interestingly, the tool can be used to generate realistic yield curve scenarios. This set of scenarios can be used to assess both the performance and risk of portfolios, as well as the potential impact of a certain macro view.

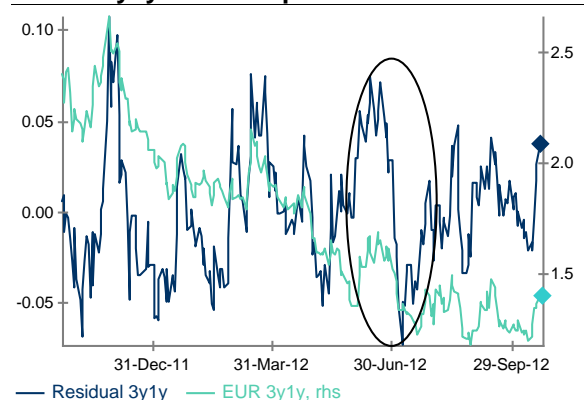
As strategists, our focus is more towards trade generation than portfolio management and so we now explore the use of residuals in more detail.

Using residuals to highlight discrepancies

We believe our interpretation of the first three factors is now clear. By considering the residuals, we can highlight patterns where a specific tenor does not follow the common factors currently driving the other maturities.

In Exhibit 16, we consider the residuals of the 1yr rate, 3yr forward, over the last year. We observe that the swap rate rallied dramatically at the beginning of July (while the residual has indeed been mean-reverting). Without the PCA tool, it's harder to assess whether a similar move has been observed with other tenors and to what extent. The residuals allow us to reach such a conclusion. We can see that during the same period the residual had a dramatic move (16bp) and went from positive to negative. That implies that the 3y1y swap was initially too high relative

Exhibit 16: Residual versus underlying data for the 3y1y EUR swap



Source: Credit Suisse

to other tenors, according to the PCA analysis. Following the sharp rally, we can conclude that, at first sight, the 4yr sector of the European swap curve now seems fairly priced.

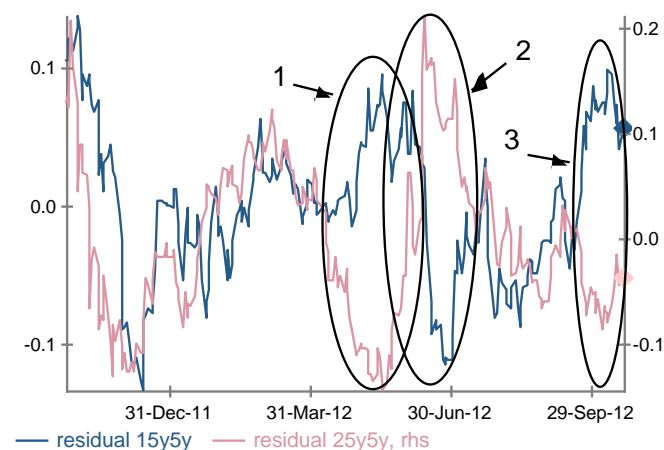
Thus, it provides some additional information on where a tenor stands relative to others. However, it doesn't indicate whether this discrepancy is due to some market inefficiencies or due to changes in structural demand, and care must always be used when interpreting PCA signals. They indicate dislocations, but that does not always mean there is a related trade.

For instance, looking at the 20yr-30yr sector in the European curve, we find that the residuals have been highly diverging (on occasions) since April (see Exhibit 17). But there were no trading opportunities necessarily – this change in the curve was due to structural reforms being implemented in Europe as described in [2 July, drivers of the EUR long end](#) publication and [EST 05th Oct, Talking the OMT Talk](#).

As shown in Exhibit 17, we find three separate periods in which 15y5y and 25y5y residuals have opposite signs. The first period is in May and probably represents unwinding of positions in 10s30s. The second period is June, when the FTK II reform was announced. The DNB discount curve was then not expected to use market rates past 20yr, consequently decreasing demand for this part of the curve. Finally, the third period is September, with the announcement that market rates 20yr+ might still play a role in calculating the discount curve.

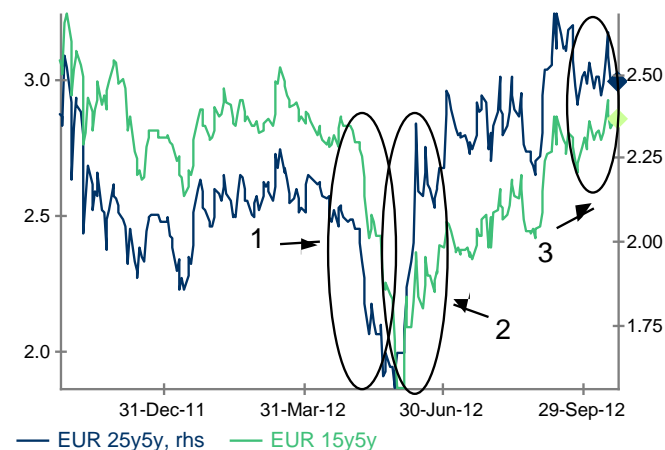
Looking at Exhibits 17 and 18, we highlighted these three phases: cheapening of the 20yr sector relative to the 30yr; 1st announcement and inversion of trends; 2nd announcement and re-inversion: cheap 20yr, rich 30yr. Thus, in this example, highly diverging residuals are a result of financial reforms and not of market inefficiency leading to a trade opportunity.

Exhibit 17: Divergence in long-end residuals partly due to DNB rules reforms and not reflecting any trade opportunities



Source: Credit Suisse

Exhibit 18: EUR long-end has rallied pre-announcement, sold off post-announcement (Jun) and was muted after the second announcement (Sep)



Source: Credit Suisse Locus

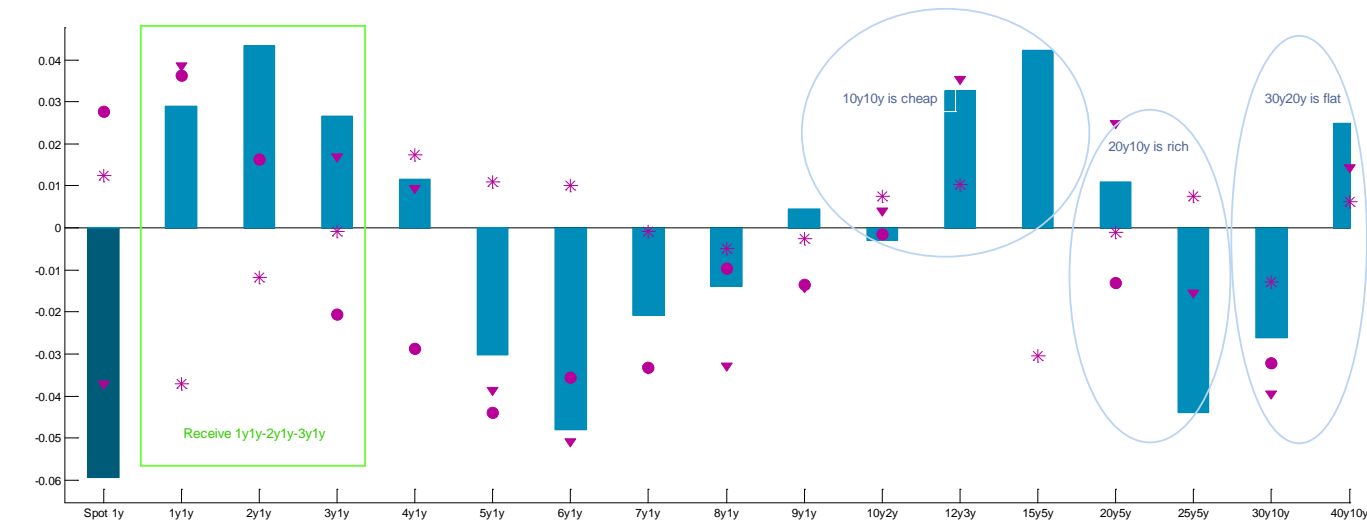
Another way to observe residuals and potential opportunities is to observe the latest residuals available rather than the time series of each variable. Exhibit 19 allows us to see the shape of the entire swap term structure and directly account for yield, slope, and curvature effects. More interestingly, it allows us to highlight interesting signals, as discussed in the following section.

Current PCA-generated trade opportunities

Receive EUR 1s2s3s 1y fwd and Pay EUR 10y10y-20y10y-30y20y

Exhibit 19: Residuals of EUR swaps, as of 22 October

BBar is residuals as of 22 October, triangle as of 19 October, circle as of a week ago and star as of a month ago.

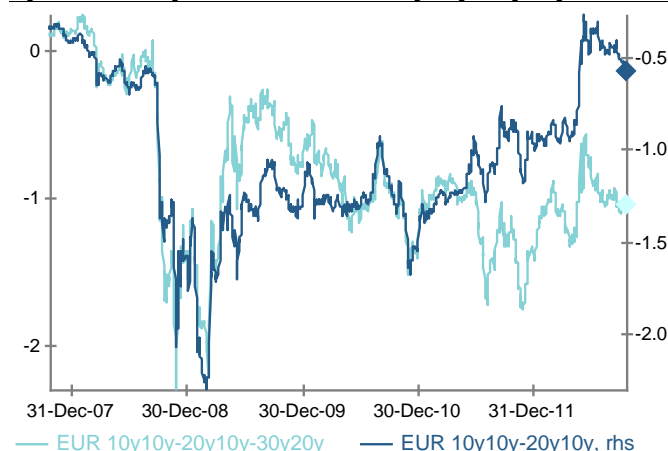


Source: Credit Suisse

Exhibit 19 provides a snapshot of the EUR swaps residuals as of 19 October. Note that residuals are built such that they represent the data minus the reconstructed data. Thus, positive residuals imply that current yields are cheap relative to what PCA implies.

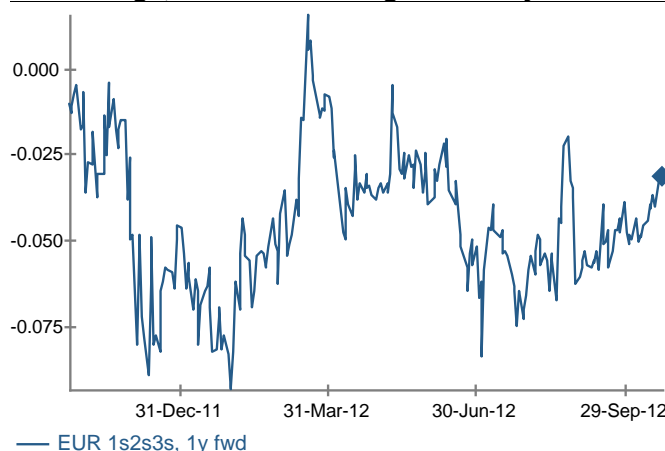
A possible trade to consider arising from this chart is to enter flies in EUR long-end. We find that the 10y10y swap – which is the weighted average of 10y2y, 12y3y, and 15y5y swaps – is cheap on a relative basis. On the other hand, we find that 20y10y is rich while the very long-end of the curve (30y20y swap) is relatively fair (see Exhibit 20). Overall, as highlighted in [EST, 5 October](#), we expect the curvature in these forwards to become less negative and hold to our recommendation of paying the fly.

Exhibit 20: The belly of the 10y10y-20y10y-30y20y fly is still very rich relative to 10y10y-20y10y



Source: Credit Suisse

Exhibit 21: EUR 1s2s3s 1y fwd is at the upper range of the range; we think the range will likely hold



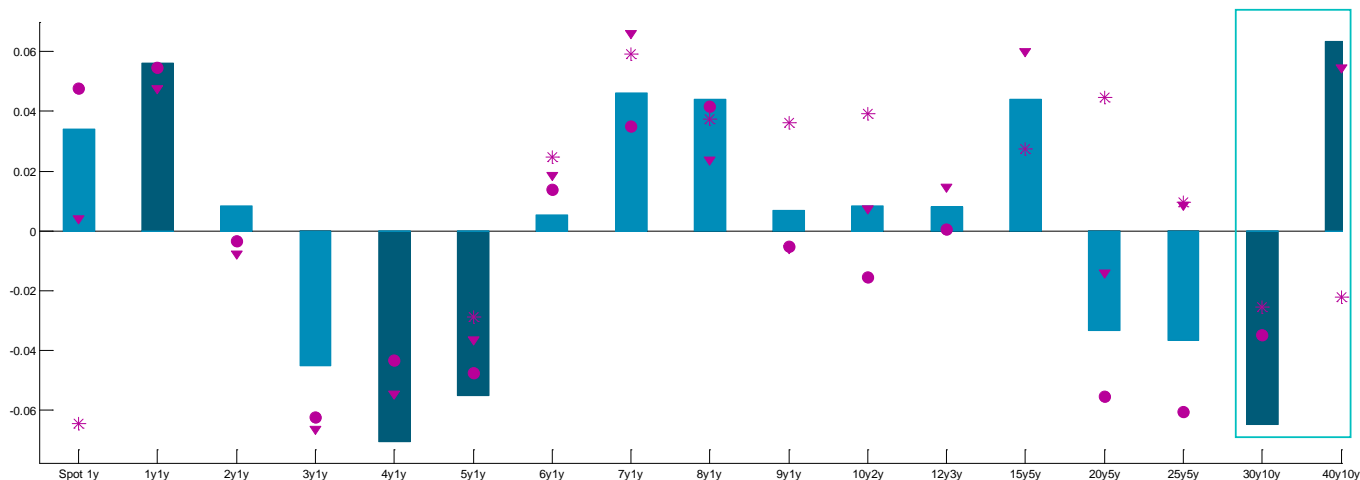
Source: Credit Suisse

Another interesting part of the curve is the very short-end, in particular 1s2s3s 1yr forward. As written in a [Trade note, 22 October](#), we find that greens have recently sold off too much relative to reds and blues (see Exhibit 21). The latest residuals highlight this trend: the short-end is cheap on a RV basis, but we don't have a strong view in terms of outright yields. On the contrary, we think the recent range of that fly (-7bp/-2 bp) will hold.

GBP 30y10y-40y10y steepener

Exhibit 22: Residuals of the spread EUR-GBP swaps, as of 22 October

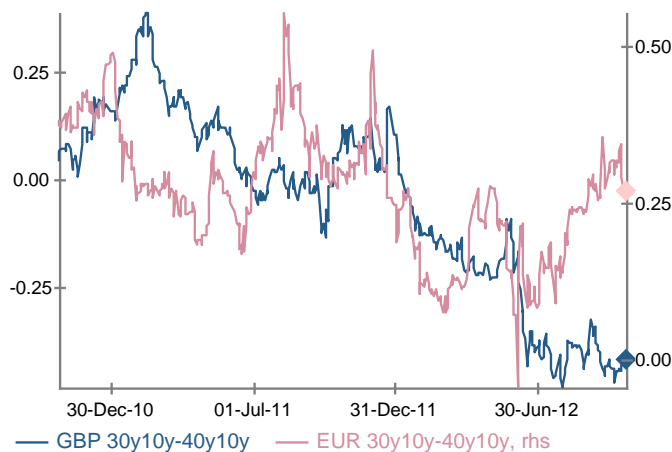
BBar is residuals as of 22 October, triangle as of 19 October, circle as of a week ago and star as of a month ago.



Source: Credit Suisse

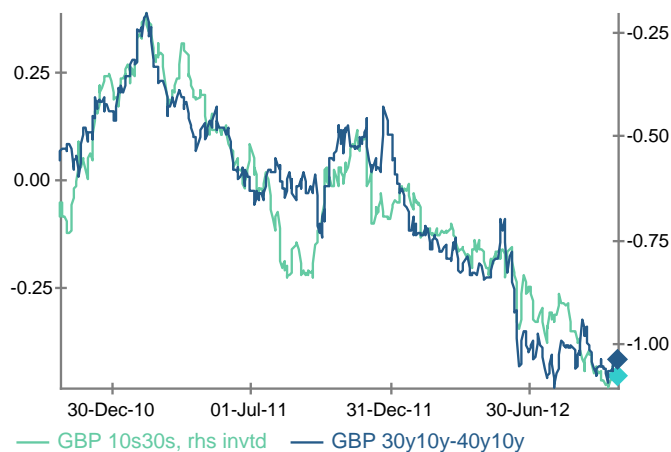
We recommended in [EST, 27 July](#) a GBP 30y10y-40y10y steepener. As shown in Exhibit 22, EUR-GBP spread residuals are too high in the 40y10y sector and too low in the 30y10y sector. In Exhibits 23 and 24, we find that the recent steepening in the 10s30s GBP curve is correlated with a flattening of the 30y10y-40y10y slope, which is out of line relative to EUR.

Exhibit 23: GBP 30y10y-40y10y is still close to all-time flattest levels and is out of line with EUR



Source: Credit Suisse

Exhibit 24: GBP 30y10y-40y10y has been flattening while 10s30s has been steepening

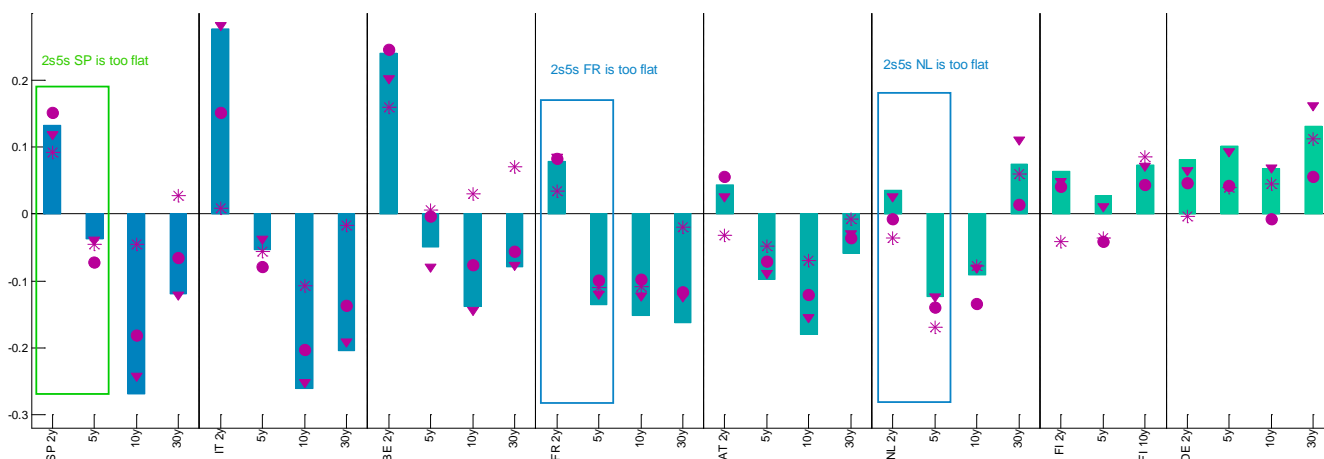


Source: Credit Suisse

2s5s steepener in Netherlands; 2s5s steepener in Spain

Exhibit 25: Residuals of the European bond yields, as of 22 October

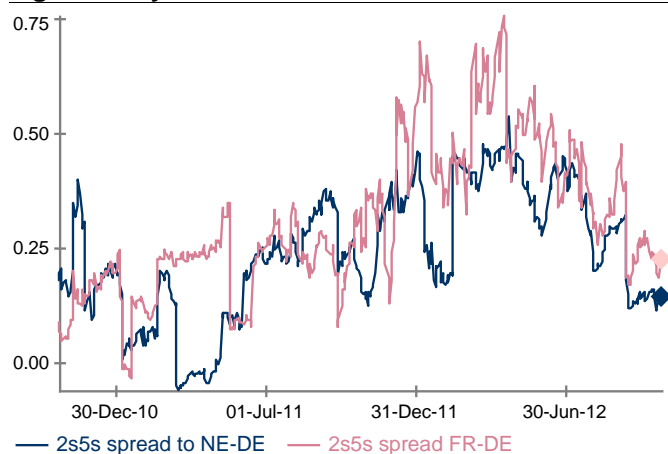
Bar is residuals as of 22 October, triangle as of 19 October, circle as of a week ago and star as of a month ago.



Source: Credit Suisse

Exhibit 25 provides a snapshot of the relative value of European bond yields. We find 2s5s curves too flat in both the Netherlands and France, as written in the [EST, 19 October](#) and highlighted in Exhibit 26.

Exhibit 26: The spread with Germany has tightened significantly for both Netherlands and France



Source: Credit Suisse

Exhibit 27: Spanish 2s5s curve is as steep as Italy



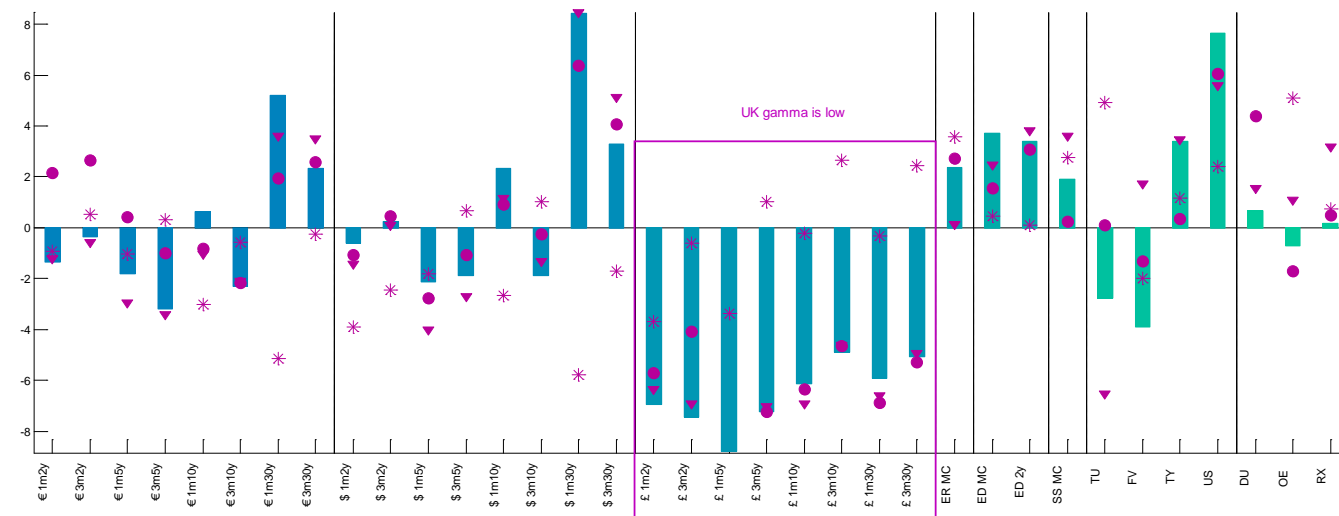
Source: Credit Suisse

Exhibit 25 also highlights the recent flattening of the 2s5s Spanish curve following the ECB's announcement to intervene in bond markets. We discussed this trade in [EST, 12 October](#). We think the curve should be steeper in Spain (see Exhibit 27) relative to a risk-reward perspective.

Buy GBP 1m gamma on 10s and 30s

Exhibit 28: Residuals of Gamma, as of 22 October

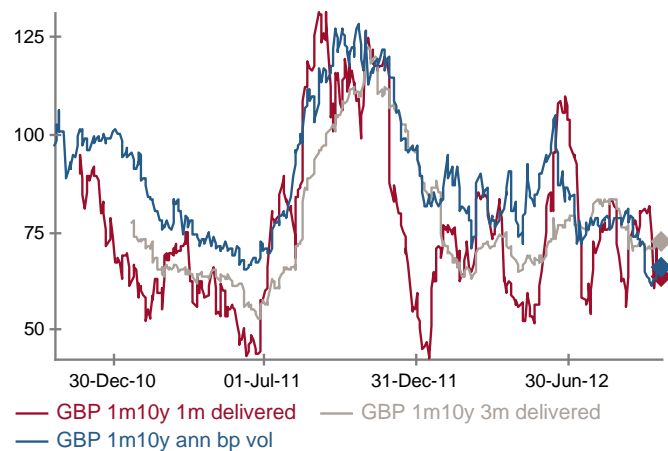
Bar is residuals as of 22 October, triangle as of 19 October, circle as of a week ago and star as of a month ago.



Source: Credit Suisse

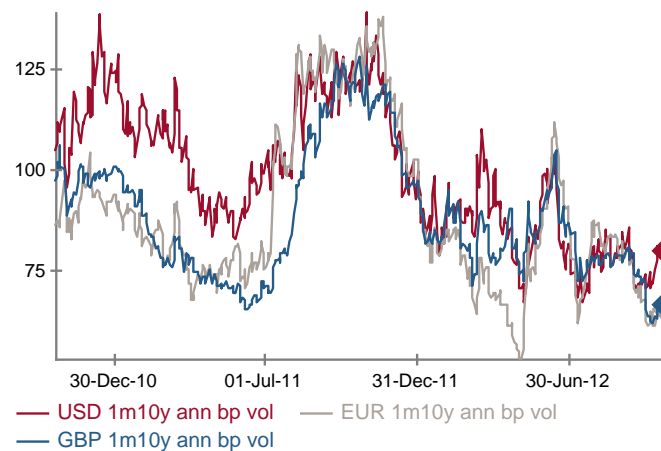
UK gamma (1m expiries in particular) has fallen to very low levels relative to historical implied, delivered, and likely delivered vol in the next month, as written in the [EST, 12 October](#) and highlighted in Exhibits 29 and 30. We suggest buying gamma to position for the uncertainty into the November MPC meeting, as we believe yields would sell off quite aggressively on a no QE decision. We believe the extension of QE in that meeting is a closer call than what is priced in by the market.

Exhibit 29: GBP 1m10y implied vol is trading below 1m and 3m delivered vol



Source: Credit Suisse Locus

Exhibit 30: GBP gamma has sold off in line with EUR



Source: Credit Suisse

Other applications: Hedging

Investors might be looking to hedge against a specific driver by finding the best hedge ratio between two positions, or alternatively to ensure they don't have exposure to a specific driver within their portfolio. Investors will often want to neutralize (hedge) an existing complicated portfolio against movements in the first, second and/or third factor. Or they would want to construct a curve trade that is factor one neutral (or a fly trade that is factor one and factor two neutral).

Hedging (neutralizing) an existing large portfolio

A large existing portfolio of swap trades will have bucket exposure to each individual forward. The PCA model can help to sum up the total exposure to factor one two and three and could suggest a single trade that would neutralize the portfolio in terms of specific factor movements.

Often, investors tend to sum up the DV01 exposure so as to assess their outright market exposure. This is not quite right. A simple portfolio with a long in 50k/bp in 5y swap versus 25k/bp in 2s and 10s would be flat in terms of outright DV01. However, as belly of the curve tends to outperform in a rally, the portfolio would outperform in a rally (and hence isn't really market neutral). The PCA model takes into account the relative exposure of each forward tenor to each factor and thus can be used to sum up the total exposure to each factor. This exposure can then be neutralized with a single trade if the investor no longer wishes to take a view on that factor.

Details can be seen in Exhibit 31.

Exhibit 31: Trades to neutralize exposure to each PC

	Existing position (k/bp)	PC1 loadings	PC2 loadings	PC3 loadings	Exposure to PC1	Exposure to PC2	Exposure to PC3	Hedging against PC1	Hedging against PC2	Hedging against PC3
Spot 1y	-10	0.3110	-0.23	0.33	-3.11	2.30	-3.30			
1y1y	23	0.2469	-0.16	0.22	5.68	-3.78	5.00		-74.01	-32.14
2y1y	89	0.2929	-0.13	0.25	26.07	-11.92	21.81			
3y1y	-64	0.3335	-0.09	0.25	-21.34	6.07	-15.77			
4y1y	-57	0.3415	-0.05	0.19	-19.46	3.09	-11.04			
5y1y	12	0.3205	0.00	0.02	3.85	-0.03	0.26	50.19		
6y1y	-24	0.3006	0.05	-0.12	-7.21	-1.25	2.78			
7y1y	63	0.2682	0.10	-0.21	16.90	6.00	-12.99			
8y1y	18	0.2431	0.12	-0.22	4.38	2.19	-3.93			
9y1y	-79	0.2346	0.14	-0.21	-18.53	-11.22	16.72		78.75	28.80
10y2y	47	0.2345	0.19	-0.21	11.02	8.75	-10.04			
12y3y	-21	0.2273	0.24	-0.22	-4.77	-5.00	4.67			
15y5y	-68	0.1874	0.24	-0.27	-12.74	-16.15	18.69			
20y5y	22	0.0422	0.30	-0.03	0.93	6.67	-0.70			
25y5y	-55	-0.0441	0.37	0.05	2.42	-20.24	-2.51			
30y10y	-17	-0.0559	0.44	0.36	0.95	-7.55	-6.19			-21.10
40y10y	36	-0.0305	0.52	0.48	-1.10	18.74	17.29			
Net	-85	3.4537	2.03	0.65	-16.09	-23.34	20.76	0	0	0

Source: Credit Suisse

Hedge ratios

Investors can also use the PCA loadings and weights to calculate the best hedge ratios between two securities. Note that in this case, we have shifted towards having no exposure to a specific PC, rather than accepting its underlying risk but hedging against all others. The calculation is provided in the [Appendix](#) for hedge ratios against PC1 as well as against a combination of PC1 and PC2.

In Exhibit 32, we provide hedge ratios on EUR swaps, for PC1 only. In other words, they represent the relative positions an investor should have in two securities in order to have no exposure to PC1 (which is effectively the level of the yield curve). For example, if an investor is long 100k/bp in 1y1y and wishes to hedge with the belly of the curve, then going short 95k/bp in 9y1y would be an appropriate position as outlined in Exhibit 32.

Exhibit 32: Implied hedge ratios against the first PC

In line: consider beta unity; in column: consider 1 unity.

	Spot 1y	1y1y	2y1y	3y1y	4y1y	5y1y	6y1y	7y1y	8y1y	9y1y	10y2y	12y3y	15y5y	20y5y	25y5y	30y10y	40y10y
Spot 1y	1.00	0.81	0.99	1.15	1.18	1.09	1.02	0.93	0.87	0.85	0.90	0.95	0.85	0.38	0.12	0.10	0.27
1y1y	1.24	1.00	1.23	1.42	1.46	1.35	1.27	1.15	1.08	1.05	1.11	1.18	1.05	0.48	0.15	0.13	0.33
2y1y	1.01	0.81	1.00	1.16	1.19	1.10	1.03	0.94	0.88	0.86	0.91	0.96	0.86	0.39	0.13	0.10	0.27
3y1y	0.87	0.70	0.86	1.00	1.02	0.95	0.89	0.81	0.76	0.74	0.78	0.83	0.74	0.33	0.11	0.09	0.23
4y1y	0.85	0.69	0.84	0.98	1.00	0.92	0.87	0.79	0.74	0.72	0.76	0.81	0.72	0.33	0.11	0.09	0.23
5y1y	0.92	0.74	0.91	1.06	1.08	1.00	0.94	0.86	0.80	0.78	0.83	0.87	0.78	0.35	0.11	0.09	0.25
6y1y	0.98	0.79	0.97	1.12	1.15	1.06	1.00	0.91	0.85	0.83	0.88	0.93	0.83	0.38	0.12	0.10	0.26
7y1y	1.08	0.87	1.07	1.24	1.27	1.17	1.10	1.00	0.93	0.91	0.97	1.02	0.91	0.41	0.13	0.11	0.29
8y1y	1.15	0.93	1.14	1.32	1.35	1.25	1.18	1.07	1.00	0.98	1.03	1.09	0.98	0.44	0.14	0.12	0.31
9y1y	1.18	0.95	1.17	1.35	1.38	1.28	1.20	1.09	1.02	1.00	1.06	1.12	1.00	0.45	0.15	0.12	0.31
10y2y	1.11	0.90	1.10	1.28	1.31	1.21	1.14	1.04	0.97	0.95	1.00	1.06	0.95	0.43	0.14	0.11	0.30
12y3y	1.06	0.85	1.04	1.21	1.24	1.15	1.08	0.98	0.92	0.90	0.95	1.00	0.90	0.40	0.13	0.11	0.28
15y5y	1.18	0.95	1.17	1.35	1.39	1.28	1.21	1.09	1.02	1.00	1.06	1.12	1.00	0.45	0.15	0.12	0.31
20y5y	2.61	2.10	2.58	2.99	3.06	2.83	2.67	2.42	2.26	2.21	2.34	2.47	2.21	1.00	0.32	0.27	0.70
25y5y	8.02	6.47	7.94	9.21	9.43	8.71	8.21	7.45	6.96	6.81	7.20	7.60	6.81	3.08	1.00	0.82	2.14
30y10y	9.78	7.88	9.68	11.22	11.49	10.61	10.00	9.08	8.48	8.30	8.77	9.26	8.29	3.75	1.22	1.00	2.61
40y10y	3.75	3.02	3.71	4.30	4.41	4.07	3.83	3.48	3.25	3.18	3.36	3.55	3.18	1.44	0.47	0.38	1.00

Source: Credit Suisse

Appendix

Mathematical background:

In order to use principal component analysis, we followed the steps outlined in Exhibit 33 .

1. $X = [x_{ij}]$, $i \in [1, n]$, $j \in [1, m]$ represents the raw data, with n being the number of dates considered and m the number of underlying variables. As we need to consider mean-reverting variables, we define the mean of sample: $\bar{X} = m^{-1} \sum_{j=1}^m X_j$. We will now consider: $Y = [y_{ij}]$, $i \in [1, n]$, $j \in [1, m]$ with $y_{ij} = x_{ij} - \bar{x}_i$.

Exhibit 33: Steps of a PCA process

Step 1: Centre data (and normalize when considering CDS data)

Step 2: Calculate the covariance matrix Σ

Step 3: Find a Matrix P such that $P\Sigma P'$ is a diagonal matrix

Step 4: Select the meaningful components (=eigenvectors)

Step 5: Create a reconstructed dataset

Step 6: Compare old and new datasets

Source: Credit Suisse

2. The covariance matrix is defined as:

$\Sigma = E \left[(X_i - E(X_i)) (X_j - E(X_j)) \right] = E[Y^T \cdot Y]$, which is a diagonal symmetric matrix with non-negative numbers in the diagonal.

3. We can now apply eigendecomposition to the covariance matrix Σ . We know that Σ can be factorized such that : $\exists P, \exists D: P^T \Sigma P = D \Rightarrow \Sigma = Y^T Y = P \cdot D \cdot P^T$ with P the eigenvector matrix and D the diagonal matrix whose diagonal elements are the corresponding eigenvalues. $D_{ii} = eigenvalue_i$, $i \in [1, m]$
4. Thus, D can be rewritten as: $D = \delta^T \delta \Rightarrow Y^T Y = P \cdot \delta^T \delta \cdot P^T \Rightarrow Y = \delta \cdot P^T$. We find our original data can be rewritten as the product of two matrices: the **scores** (δ) and the **loadings** (P).

Note that P is our matrix of eigenvectors, where eigenvectors and eigenvalues are ranked by order of significance. The information provided by each eigenvector i - that is to say its variance - is given by the relative weight of its eigenvalue: $D_{ii} / m^{-1} \sum_{j=1}^m D_{jj}$. Thus, the more the vector is dispersed (i.e long), the more it has an explanatory power over the variables.

5. We can project our data to our new coordinates system and reduce the dimensionality. We define $\tilde{\delta}$ and \tilde{P}^T as the loadings and scores for the first three factors only. We then have, for three factors: $\tilde{Y} \cong \tilde{\delta} \cdot \tilde{P}^T$.
6. Thus, to get the coordinates of the fitted points in terms of the original coordinate system, we multiply each PC coefficient vector by the corresponding score (and add back in the mean of the data).
7. Finally, we are able to look at the residuals, such that:

$$residuals = Y - \tilde{Y} = X - \bar{X} - \tilde{Y} = data - reconstructed (-mean)$$

Other findings:**Computing hedge ratios on two securities:**

In order to find, the best hedge ratios between two securities x and y , we solve $\min_{\gamma \in \mathbb{R}} \text{Var}(x - \gamma y)$ with γ being the hedge ratio we are looking for.

x and y can be written as a linear combination of loadings and scores:

$$x(t) = c_1(t) * u_1^x + c_2(t) * u_2^x \text{ and } y(t) = c_1(t) * u_1^y + c_2(t) * u_2^y \text{ for each } t \in [1, 252]$$

If we consider the first component only, we find:

$$\gamma = \frac{u_1^x}{u_1^y}$$

If we consider the first and second component, we find:

$$\gamma = \frac{u_1^x \cdot u_1^y \cdot (\lambda_1)^2 + u_2^x \cdot u_2^y \cdot (\lambda_2)^2}{(u_1^y)^2 \cdot (\lambda_1)^2 + (u_2^y)^2 \cdot (\lambda_2)^2}$$

Variance of the PnL of a portfolio:

We have: $x(t) = \sum_{p=1}^K c_p(t) * u_p^x, \forall t \in [1, 252]$. Thus $\text{Var}(x) = \sum_{p=1}^K (\lambda_p)^2 * (u_p^x)^2$

INTEREST RATE STRATEGY

Eric Miller, Managing Director
Global Head of Fixed Income and Economic Research
+1 212 538 6480
eric.miller.3@credit-suisse.com

US RATES

Carl Lantz, Director
US Head
+1 212 538 5081
carl.lantz@credit-suisse.com

Ira Jersey, Director
+1 212 325 4674
ira.jersey@credit-suisse.com

Scott Sherman, Vice President
+1 212 325 3586
scott.sherman@credit-suisse.com

Michael Chang, Vice President
+1 212 325 1962
michael.chang.2@credit-suisse.com

Carlos Pro, Associate
+1 212 538 1863
carlos.pro@credit-suisse.com

William Marshall, Analyst
+1 212 325 5584
william.marshall@credit-suisse.com

EUROPEAN RATES

Helen Haworth, CFA, Director
European Head
+44 20 7888 0757
helen.haworth@credit-suisse.com

Michelle Bradley, Director
+44 20 7888 5468
michelle.bradley@credit-suisse.com

Sabine Winkler, Director
+44 20 7883 9398
sabine.winkler.2@credit-suisse.com

Panos Giannopoulos, Director
+44 20 7883 6947
panos.giannopoulos@credit-suisse.com

Thushka Maharaj, Vice President
+44 20 7883 0211
thushka.maharaj@credit-suisse.com

Florian Weber, Associate
+44 20 7888 3779
florian.weber@credit-suisse.com

Marion Pelata, Analyst
+44 20 7883 1333
marion.pelata @credit-suisse.com

US DERIVATIVES

George Oomman, Managing Director
Derivatives Head
+1 212 325 7361
george.oomman@credit-suisse.com

TECHNICAL ANALYSIS

David Sneddon, Managing Director
+44 20 7888 7173
david.sneddon@credit-suisse.com

Christopher Hine, Vice President
+1 212 538 5727
christopher.hine@credit-suisse.com

Pamela McCloskey, Vice President
+44 20 7888 7175
pamela.mccloskey@credit-suisse.com

Cilline Bain, Associate
+44 20 7888 7174
cilline.bain@credit-suisse.com

David Robertson, Analyst
+44 20 7888 7172
david.robertson@credit-suisse.com

PARIS

Giovanni Zanni, Director
European Economics – Paris
+33 1 70 39 0132
giovanni.zanni@credit-suisse.com

SINGAPORE

Jarrod Kerr, Director
+65 6212 2078
jarrod.kerr@credit-suisse.com

TOKYO

Tomohiro Miyasaka, Director
Japan Head
+ 81 3 4550 7171
tomohiro.miyasaka@credit-suisse.com

Shinji Ebihara, Vice President
+81 3 4550 9619
shinji.ebihara@credit-suisse.com

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