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Global Rates Strategy

Reading the Yield Curve: Inferring Market Expectations of Central Bank Tightening

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- We present a methodology to infer market expectations of central bank policy tightening from core government yield curves
- In contrast to usual practice of simply reading these from the euro futures curves, we account for the uncertainty regarding the date of first tightening as well as time-varying term premium
- The US curve is pricing too early a start to the hiking cycle suggesting steepening positions
- A global comparison indicates too short a lag between tightening in the US versus UK suggesting short positions in Treasuries versus Gilts

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Reading the Yield Curve: Inferring Market Expectations of Central Bank Tightening

Investors confront steep yield curves in the G10 core markets. This is to be expected since we appear to be at the bottom of the rate cycle in most markets and certainly at or close to the lower bound in US, Europe, Japan and the UK. Inferring market expectation of the path of policy tightening is critical for expressing views on the yield curve.

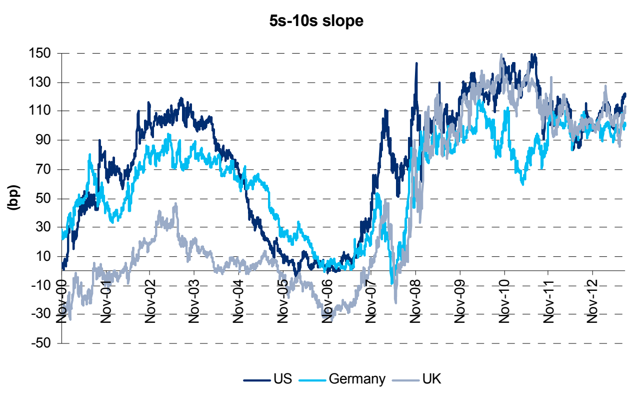
Steep yield curves suggest that investors expect policy rate increases at some point but a part of the steepness could also be due to the compensation invests demand for taking duration risk. Disentangling these effects is critical to inferring market expectations. In this research report, we propose and implement a methodology to infer market expectations of the central bank policy paths.

Our main conclusions are:

- *The treasury market is pricing too early a tightening cycle*: The probability of the first hike peaks in Q3 2014, around nine months sooner than consensus private sector forecasts as well the FOMC projections. This suggests steepening positions.[1]

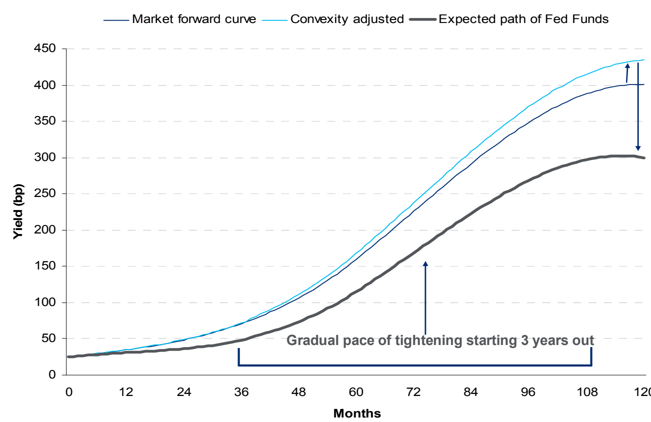
- *Too short a lag between tightening in the US vs UK*: A global comparison indicates that markets imply around a 6-momth lag between policy tightening in the US vs UK; our economic projections suggest a much longer lag given the slower economic recovery in the UK. We recommend short Treasury versus Gilt positions.[2]

Figure 1. Steep core government curves



Source: Citi Research, Bloomberg

Figure 2. A simple interpretation of forward short-rates is incorrect



Source: Citi Research

Note: We extract 3-month tenor forward rates form the Treasury par curve as of April 18th 2013. The adjustment for term premium is described in the appendix.

A simple interpretation of the Eurodollar strip is incorrect

A very simple way to infer the policy path is to read it off from the Eurodollar strip. For example, Figure 2 shows the path of 3-month tenor treasury rates at various

[1] Our US Rates Strategy team has suggested receiving the 2y2y rate versus paying 10y10y.

[2] Our Euro Rates Strategy team has suggested shorting 10-yr Treasuries versus Gilts.

forward dates (the thin, black line in the figure that lies in the middle).[3] Then the short rate expectation at any forward date could be read off from this curve. There are at least two problems with this interpretation.

(i) As discussed earlier, a part of the reason that the yield curve slopes up is because investors demand a premium for taking duration risk; the longer the maturity, the greater the premium required. The upward sloping par yield curve implies an even steeper curve of short-tenor forward rates. We can adjust the forward rates lower by our estimate of current term premium[4] to yield the flatter thicker line (Figure 2).

(ii) A 'static' interpretation of this adjusted curve would imply that the Fed tightens policy over a 7-year period. This would be a most unusual hiking cycle. The typical Fed hiking cycle has lasted less than two years. Even allowing for a slower pace of hikes given the long period of accommodation, a 7-year hiking cycle seems implausible. Policy makers and markets treat the start of a hiking cycle as a very significant step and are unlikely to do so unless they feel that the economy is very close to full employment. Protracted rate normalization is inconsistent with this mindset.

A more dynamic interpretation: the yield curve as a weighted average of alternative hiking paths

A more reasonable interpretation of the upward sloping forward curve is this: there is significant uncertainty around the start of the hiking cycle and the probability weighted average of these different paths yields the (term premium adjusted) forward rates. Figure 3 demonstrates the idea. There are three possible start dates to the first hike centered at end 2015; the central tendency of the FOMC's forecast of the start of rate normalization.[5] In each cycle, we project the rate hikes to be completed in three years topping out at 4% (the 'terminal rate'), consistent with the FOMCs projection of the steady state funds rate.

Note that the 'average' hiking path (the blue line) is flatter than any of the individual paths since it stretches between the first hike date of the earliest path and ends at the terminal point of the most distant hike path.

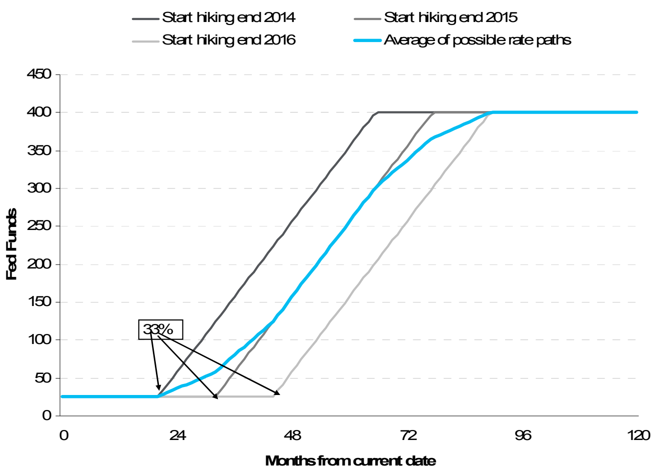
The average rate path can be used to generate a consistent yield curve; e.g. the 5-year tenor yield is the average of short rates over the five years with adjustments for term premium and convexity.

[3] For this exercise, we use 3-month tenor forward rates from the Treasury curve rather than the Eurodollar strip since we need short-rate expectations out to ten years.

[4] See appendix for details on estimating the current term premium

[5] See projections released with July FOMC meeting.

Figure 3. Uncertain start date flatten the forward curve



Source: Citi Research

Notes: the blue line represents the equally weighted average of the three paths

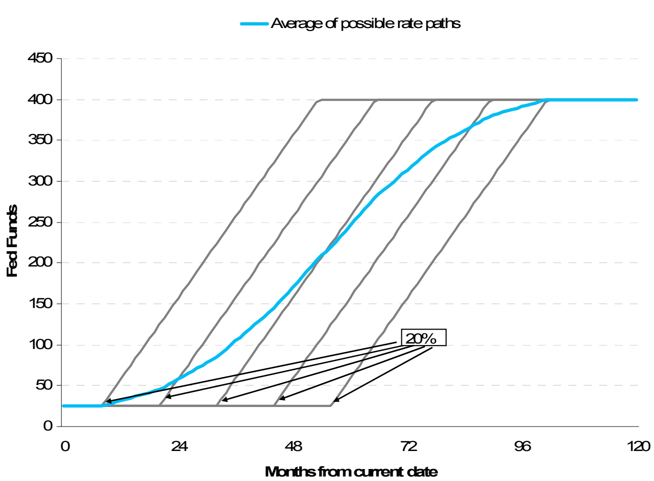
Figure 4. Fair value 5s10s steeper than market

	2y	5y	10y
Avg. short rate (bp)	26	87	229
Term premium & convexity adj. (bp)	6	27	75
Model yield (%)	**0.32**	**1.11**	**2.82**
Actual yield (%)	0.23	0.69	1.70
Earliest hike (mo.)	20	(end 2014)	
Median hike (mo.)	32	(end 2015)	
Terminal rate (bp)	400		

Source: Citi Research

Notes: Yield curve constructed based on rate path in figure on the left. Market yields are as of April 18th 2013

Figure 5. More uncertain start of hiking flattens the curve



Source: Citi Research

Notes: the blue line represents the equally weighted average of the five paths

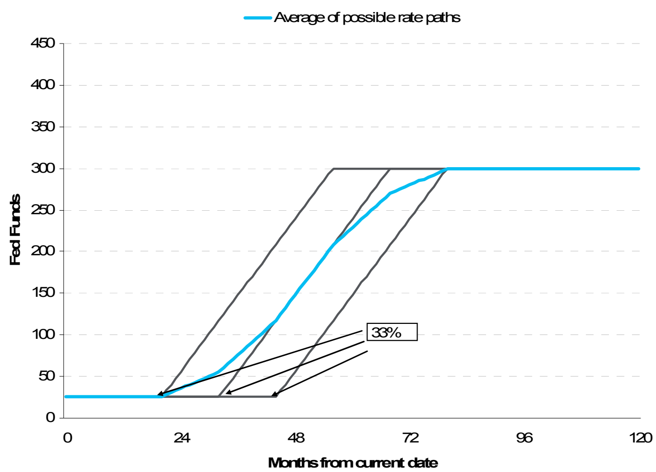
Figure 6. More uncertain start of hiking flattens the fair value curve

	2y	5y	10y
Avg. short rate (bp)	35	99	229
Term premium & convexity adj. (bp)	6	27	75
Model yield (%)	**0.41**	**1.23**	**2.82**
Actual yield (%)	0.23	0.69	1.70
Earliest hike (mo.)	8	(end 2013)	
Median hike (mo.)	32	(end 2015)	
Terminal rate (bp)	400		

Source: Citi Research

Notes: Yield curve constructed based on rate path in figure on the left. Market yields are as of April 18th 2013

Figure 7. Lower terminal rate flattens and lowers the curve



Source: Citi Research

Notes: the blue line represents the equally weighted average of the five paths

Figure 8. Lower terminal rate flattens and lowers the curve

	2y	5y	10y
Avg. short rate (bp)	26	82	185
Term premium & convexity adj. (bp)	6	27	75
Model yield (%)	**0.32**	**1.06**	**2.39**
Actual yield (%)	0.23	0.69	1.70
Earliest hike (mo.)	20	(end 2014)	
Median hike (mo.)	32	(end 2015)	
Terminal rate (bp)	300		

Source: Citi Research

Notes: Yield curve constructed based on rate path in figure on the left. Market yields are as of April 18th 2013

This particular set of paths produces a yield curve that is both higher than the observed curve on this date and steeper as well (Figure 4). To better match the curve, we can make the hike dates distribution more diffuse (use more paths, Figure 5) and/or lower the terminal rate (Figure 7). By matching the curve, we can infer the market's expectations of the Fed tightening path along these dimensions: the probability distribution of the first rate hike and the terminal rate.

A formal calibration exercise

We can formalize the ideas discussed in the previous section in a calibration process.

We calibrate to 3-month tenor rates at every quarterly forward date out to 10 years i.e. we have 40 rates to calibrate to[6]. Each such forward short rate can be decomposed into a

- *The expected short rate at that date*: this is driven by the path of Fed tightening. The key drivers – the probability distribution of the first hike and the terminal – are discussed below.

- *Term premium adjustment*: In general, forward short rates are higher than the expected short rates on forward dates since investors demand a premium for taking term risk. In this exercise, we estimate term premium at each forward date using a separate procedure (see appendix).

- *Convexity adjustment*: this is a relatively small adjustment and we do not discuss it in detail in this note.

[6] We prefer to use forwards extracted from the treasury curve rather than the swaps curve since treasury yields are a better proxy for Fed Funds.

The two drivers of the Fed policy path

The probability distribution of the first rate hike: In our pictorial exposition in figure 3, we considered alternate rate paths that were equally likely and centered at a mid 2015 start date. In fact, the probability distribution is likely more complicated than this. For one, not all paths are equally likely; the market is likely to assign very little probability to the first hike occurring imminently or in the very distant future. Second, the distribution is unlikely to be symmetric; the time to first hike cannot be less than zero but there could be a small probability of no hikes for a very long time. The lognormal distribution, characterized by a mean and standard deviation, is an appropriate probability structure for our purpose.

The terminal rate: This is the expected policy rate when the economy is at full employment[7] and inflation is close to the Fed's stated target of 2%. Since we expect that the unemployment rates will very likely normalize over the next five years, the terminal rate should anchor forward rates beyond that point.

The current read: US treasury curve is not steep enough!

Using these two levers to fit the Treasury curve on July 30th indicates (Figure 9 and Figure 10)

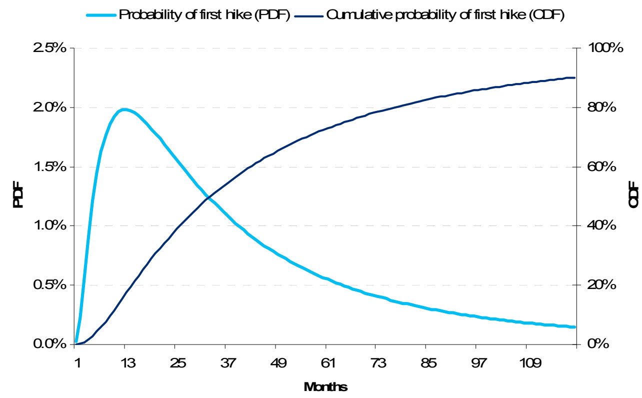
- *A terminal funds rate of 3.5%:* This is somewhat lower than the central tendency of 4% in quarterly FOMC projections and certainly lower than the terminal funds rate in the previous two hiking cycles. However, note that the terminal funds rate has been trending lower since the early 80s. Further, the average real funds rate has averaged around 1.5% over the last fifty years. Adding a projected 2.25% inflation rate suggests a steady-state funds rate of 3.75%. Given a much slower growth outlook than the past fifty years, a 3.5% funds rate is not implausible.

- *The most likely date of first hike is Q3 2014*: Figure 9 highlights two unusual features of the tightening path implied by the curve. First, the probability of the first hike date peaks at roughly 12 months or Q3 2014. This is at least nine months sooner than most private sector forecasts as well as the central tendency of FOMC's projections. Second, there is almost a 30% probability that no rate hikes occur for five years. This is an unusually pessimistic outlook for US recovery. Statistically speaking, the probability distribution peaks too soon (low mean) and has too long a right tail (high variance).

A more reasonable set of parameters which puts the peak hike date in mid 2015 and smaller variance suggests that the curve should be much steeper than it is currently (Figure 11 and Figure 12). Our US Rates Strategy team has reflected these views in a recent trade recommendation to receive the 2y2y rate versus 10y10y.

[7] i.e. the unemployment rate is close to NAIRU, currently judged by the FOMC to be 5.5%-6.0%.

Figure 9. Current yield curve implying probability of first hike peaks in twelve months



Source: Citi Research

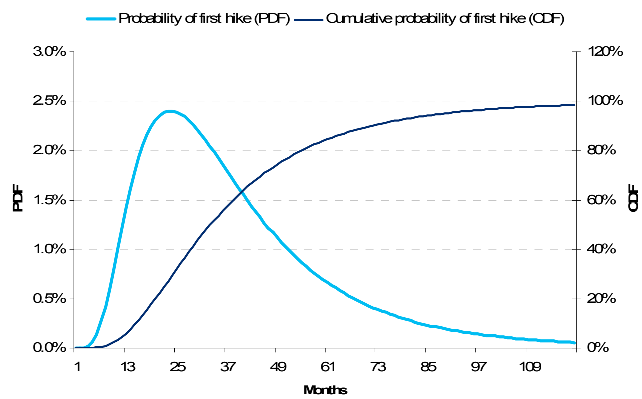
Notes: The probability distribution of first hike date based on calibration procedure described in the text. Market levels as of July 30th 2013.

Figure 10. Current yield curve implying probability of first hike peak in twelve months

	2y	5y	10y
Avg. short rate (bp)	21.0	98.8	177.3
Yield premium (bp)	6.6	40.6	93.7
Convexity adj. (bp)	0.2	3.3	15.1
Model yield (%)	0.27	1.36	2.56
Market (%)	0.33	1.37	2.58
	Mode	Median	
Hike Date (months)	12	34	
Terminal rate (bp)	350		

Source: Citi Research Notes: Parameter estimates based on calibration procedure described in the text. Market levels as of July 30th 2013.

Figure 11. Pushing back peak probability of hiking to mid 2015 …



Source: Citi Research

Notes: probability distribution of first hike date is altered to push back peak probability of hiking to mid 2015

Figure 12. …. Suggests that curve should be steeper

	2y	5y	10y
Avg. short rate (bp)	11.0	90.2	190.1
Yield premium (bp)	6.6	40.6	93.7
Convexity adj. (bp)	0.2	3.3	15.1
Model yield (%)	0.17	1.28	2.69
Actual yield (%)	0.33	1.37	2.58
	Mode	Median	
Hike Date (months)	24	34	
Terminal rate (bp)	350		

Source: Citi Research Notes: probability distribution of first hike date is altered to push back peak probability of hiking to mid 2015

A global perspective: A more distant tightening cycle in the Euro Area

A similar analysis using the German sovereign curve and the UK sterling provides an interesting comparison (Figure 13). Consistent with our more pessimistic economic outlook in the Euro area, markets are pricing a more distant tightening cycle – the probability of the first hike peaks in 32 months and the terminal rate is around 90 bp lower than in the US.

The sterling curve has room to reprice to be consistent with our economic views. In particular, note that the peak probability of first hike in the UK is only 5 months lagged versus the US. In our assessment, there should be at least a 24 month gap in the tightening cycles given the very slow recovery in the UK. This analysis underscores short US long UK positions, particularly in the three to five year parts of the curve.

Figure 13. Insufficient lag between the US-UK tightening cycle

Region	Terminal Rate	First Hile Probability Distribution (months)	
	(bp)	Mode	Median
US	350	13	34
EUR	260	32	41
UK	330	18	39

Source: Citi Research

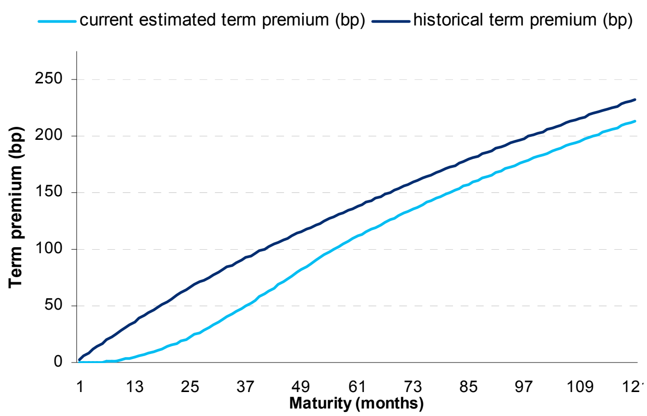
Notes: Parameter estimates from calibrating to current sovereign cash curves. Calibration procedure is defined in the text.

Appendix: Estimating Term Premium

Historically, investors have been compensated for taking duration risk; specifically, a position in longer tenor treasuries has outperformed t-bills (Figure 14 and Figure 15) - the longer the maturity/duration of the instrument, the larger the excess return over t-bills. There are two sources of excess return both linked to an upward sloping yield curve. The longer maturity not only earns more carry than t-bills, it also gets the benefit of rolldown return. The term premium (in returns) is much more than the difference in yield between the longer maturity treasury and t-bills.

Our assessment is that investors earn this premium for taking interest rate volatility risk and, by implication, the level of interest rate volatility should drive term premium. For example, if volatility is lower than it has been historically – as is the case for 2-year tails currently – then the required term premium should be lower as well. We scale the historical term premium by the ratio of current implied volatility to historical volatility and infer the required yield premium.

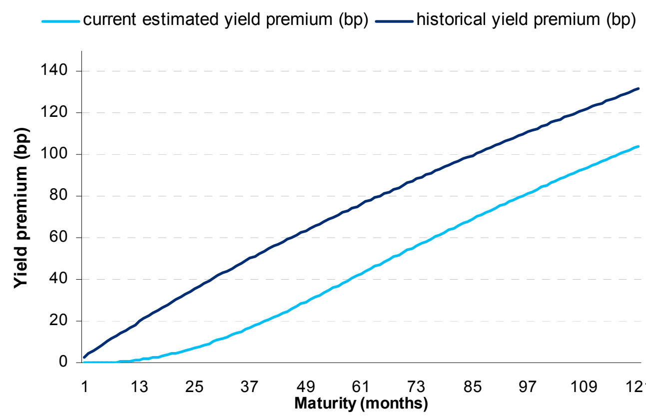
Figure 14. Low volatility at front-end has compressed term premium..



Source: Citi Research

Notes: Historical term premium is average historical excess return (1971 onwards) on long maturity treasuries versus t-bills. Historical averages are scaled based on current to historical volatility ratio to give current estimated term premium.

Figure 15. ... And the required yield premium as well



Source: Citi Research

Notes: Yield premiums are the excess yield required on longer maturity treasuries relative to t-bills to deliver expected excess returns consistent with the term premium numbers in the chart on the left.

Appendix A-1

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