Global Rates and FX Primer

FX Quant Primer

Bank of America Merrill Lynch

Primer

01 October 2018

One-stop shop for FX quant models

The FX Quant Trader is a one-stop weekly report on FX spot analysis using a quantitative approach. We publish every Monday night and the majority of the report is dedicated to presenting and discussing our proprietary FX quant models, summarizing different approaches in analyzing G10 and EM currencies.

We synthesize all these approaches to determine the latest trends in spot movements, to determine on-going market developments and to form a view on possible short-term FX moves, focusing in particular on weekly trading signals. Our models include cross-asset factor models, option and volatility insights for FX spot and flow analysis.

Cross-asset factor models

Cross-asset and macroeconomic factors are essential drivers of FX movements. FX markets may take more time to price in gradual equity rotations than central bank rate policy decisions over time. We use cross-asset drivers and traditional macroeconomic drivers to produce an optimal currency portfolio. Inputs in our model include carry, interest rate trends, rates momentum, equity momentum, and contrarian mean reversion. In particular, this report highlights our in-house OCTAVE and FORTE directional models, designed to produce an optimal currency portfolio.

Options and positioning signals

Following a sizable currency move (rally or a sell-off), investors face the dilemma of either chasing the move or fading it. The FX options market can provide valuable information about positioning and sentiment, and we have developed a framework called the Event analysis that uses the level of volatility, skew and term structure to help with such decisions. In addition, our positioning model uses moving average aggregation (MAA), Up/Down volatility (UD) and Residual Skew (RS) to help track spot directional trends and corrections.

Flow analysis

Tracking flows is an important but difficult aspect of currency analysis. Breaking down currency performance by time zones can help investors better understand the sources of key flows. For example, private cross-border portfolio investment flows or reserve rebalancing related flows at any given time can be important drivers of FX movement. In addition, as FX is traded around the clock, understanding liquidity in FX options by currency, time zone and tenor can be useful for investors considering strategic hedges or expressing a directional view. In addition, we use the Swap Data Repository (SDR) database for FX options, piecing together the entire database of over 4.5 million recorded FX options trades across time, tenor, currency and product type in searching for directional signals. We discuss how to apply time-zone and option flow to form directional views.

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Cross-asset factor model

Cross-asset and macroeconomic factors are essential drivers of FX movements. FX markets may take more time to price in gradual equity rotations than central bank rate policy decisions. We use cross-asset drivers and traditional macroeconomic drivers to produce an optimal currency portfolio. Inputs in our factor model include carry, interest rate trends, rates momentum, equity momentum, and contrarian reversals.

BofAML FORTE Model

FORTE is our directional model designed to produce an optimal currency portfolio based primarily on equity momentum with an additional blend of rates trends, rates momentum and short-term valuation considerations. The inputs in this model are the level of rates (carry), the change in rates, the change in national equity indices and deviation of spot from its moving averages, (short-term valuation). An earlier model, OCTAVE, has similar inputs but the methodology is different in how the data is processed.

FORTE prioritizes the equity signal by doing the first preliminary sort based on equity performance. This step identifies top 4 and bottom 4 FX pairs based on equities, among which the eventual 2 longs and 2 shorts are chosen from, respectively. The basic premise of the first sort is to capture positive correlations between persistent equity flows and FX. Global equity managers who track unhedged indices tend to keep equity positions unhedged to reduce tracking error. Equity managers with overweight positions tend to buy more when they receive inflows into their funds, which may support their currency. Strong performing equity markets reflect positive growth expectations as well as likely to encourage additional equity fund flows from global investors, which have to buy FX to buy equities outside their country.

FORTE then re-sorts these preliminary two (bullish and bearish) baskets of 4 currencies using a secondary metric that blends rates information to ensure that FX – equity positive correlation remains relevant. If, however, the central bank is easing (alternatively, hiking) aggressively, then the FX would tend to fall (alternatively, rise) as equities rise (fall), inducing a negative correlation. Conditioning on rates is meant to discourage FX trades on the basis of the wrong correlation and ultimately choose top 2 out of 4 bullish FX prospects as well as bottom 2 out of 4 bearish FX prospects.

In its portfolio, FORTE may buy or be neutral FX where equities are outperforming and sell or be neutral FX where equities are underperforming but it cannot sell FX with relatively strong equities or buy FX with relatively weak equities (unlike, for example, OCTAVE which averages its sorting factors).

FORTE is an equity-heavy model because the equity sorting happens first. Second, it incorporates rates information when rates market move in a material way. Rather than using a weighted average, it follows a non-parametric approach with two-step sorting. It stands to benefit in an environment when equities are an important driver of FX as well as incorporating information from rates market.

Model specification

Overall, FORTE rank is based mostly on equity rank, which is adjusted (resorted) when significant rates moves are present. The equity ranking is re-sorted by the filter-score, which combines the baseline equity ranking scorecard with z-scores of rates level, rates momentum and contrarian value.

Equity momentum is 12 month change and ranks 1 (highest) through 10 (lowest) assigned a scorecard as follows (3, 2, 1, 0.5, 0, 0, -0.5, -1, -2, -3). Based on the ranking, top 4 and bottom 4 currencies are baskets from which the equity and rates filter picks out the most attractive two to buy and sell, respectively.

A simple summation of equity scorecard plus z-score of 3 factors computed using the formula below:

$$FORTE\ portfolio\ filter\ score = equity\ scorecard + \sum_{1}^{n} z_i$$

Where n = number of factors (3 in this case), and the 1y z-score of each factor is computed using the formula below.

$$z_i = \frac{x_i - \bar{x_i}}{\sigma}$$

Where:
x_i is the value of the factor (4 factors in this case explained below)
z_i of corresponding factors

- Carry level
- 1 week rates momentum (1 weeks difference),
- 15 day contrarian value (15 day average FX divided by the latest spot)

$\bar{x_i}$ is the mean and σ is the standard deviation And standard deviation (σ):

$$\sigma = \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}}$$

Where:
σ = Standard Deviation
x = Variable for time series data point (each variable of the 4 data sources for each currency)
$\bar{x}$ = Mean value for variable of time series data
n = Number of data points for each variable

The FORTE filter score is used to resort top 4 and bottom 4 equity ranks separately. Thus, the top 1 ranked FORTE currency is the one that has the highest filter score among the top 4 equity ranks. The top 2 ranked FX has the 2nd highest filter score among the top 4 equity ranks and so on. The bottom ranked FORTE currency has the lowest filter score among the bottom 4 equity ranks and so on. FORTE goes long top 1 and top 2 and short bottom 1 and 2 (ranks 9 and 10). FORTE ranks 5 and 6 are neutral and equal to the equity rank.

Weekly signal

FORTE is designed to capture currency performance generated by equity flows. The model first ranks each currency from 1 to 10 based on 1 year equity performance. A secondary ranking also incorporates the 1 year z-scores of a) 2 year rates, b) 3 week currency cheapness, and c) 1 week rate momentum. For our optimal currency portfolio, we go long the two currencies in the top-four equity ranking that are the highest ranked by the secondary ranking. We go short the two currencies in the bottom-four equity ranking that are the lowest ranked by the secondary ranking (Table 1).

Table 1: FORTE is bullish USD/CHF, given equity divergence

	FORTE RANKING	Equity Ranking	Rate z-score	Cheapness z-score	Short-term Momentum z-score
JPY	1	3	1.8	2.2	0.6
USD	2	4	1.3	1.2	0.4
NOK	3	1	1.2	-1.4	-0.4
NZD	4	2	-1.7	-0.4	1.3
AUD	5	5	0.7	-0.4	1.8
CAD	6	6	1.7	0.0	1.1
SEK	7	7	2.6	-1.9	1.4
GBP	8	8	1.4	0.4	0.3
EUR	9	10	1.7	0.0	1.8
CHF	10	9	0.0	0.9	0.6

Data collected Monday 9/24/2018. The equity signal ranking is magnified or diminished by currency rates trend and currency cheapness 1 (bullish) to 10 (bearish).
Source: BofA Merrill Lynch Global Research

Model performance:

Systematic model FORTE produces a portfolio of currencies every week. FORTE goes long two currencies vs. short two currencies. The hit ratios shows the percentage of weekly portfolios when the combined long-short portfolio would have had a positive return.

We also calculate the average number of long signals above the funding cost for each model: the weekly close-to-close basis against an equally weighted basket of the currencies recommended to short. For example, if the Monday close to Monday close change of our top two ranked currencies in FORTE were 3% and 0.5% respectively, while each of our two short currencies rose 0.5%, then we would determine that 1 of our long currencies appreciated versus the equally weighted average of the shorts (Table 2).

Table 2: Historical performance for FORTE

FORTE history	2m	12m	Since inception (2014)
Portfolios initiated (#)	9	52	237
Portfolio return up (#)	4	28	128
Hit ratio for overall portfolio	44.4%	53.8%	54.0%
Long signals above funding cost (out of 2), avg	0.89	1.00	1.03

Rolling trade history of 2 months corresponds to last 9 weeks and 12 month history covers last 52 weeks. Since inception covers complete history since March 10, 2014 when FORTE was introduced
Source: BofA Merrill Lynch Global Research, Bloomberg

Systematic trades methodology and risks

Systematic trades in FORTE are assumed to be initiated at 5pm EST on Monday prior to date of publication, and closed at 5pm EST the subsequent Monday.

Performance tables are updated on a weekly basis. Performance does not reflect transactions costs, tax withholdings or any investment advisory fees. Had these costs been reflected, the performance of the portfolios would have been lower. The performance results are hypothetical in nature and do not reflect actual transactions. The performance of persons following systematic models will differ from the performance contained in this report for a variety of reasons, including differences related to incurring transactions costs and/or investment advisory fees, as well as differences in the time and price at which currencies were acquired and disposed of. Past performance is no guarantee of future results.

BofAML Octave Model

OCTAVE is our directional model designed to produce an optimal currency portfolio based on carry, rates and equity momentum and short-term valuation considerations. OCTAVE is the precursor to FORTE and averages its factors. The inputs in this model are the level of swap rates (carry), the change in swap rates, the change in national equity indices and deviation of spot from its moving averages, (short-term valuation) with which we rank each currency from 1 to 10. We then combine these signals using a

modified scorecard framework to arrive at an Overall Portfolio Indicator. Since two of the four averaged factor scores are based on rates (the level and change), OCTAVE is a rates-heavy model. It therefore stands to benefit in an environment when rates are an important driver of FX.

The methodology ranks G10 currencies using equities and rates performance for each country. The model is designed to achieve an optimal currency portfolio based on the level of swap rates (carry level), the change in swap rates (rates momentum), the changes in national equity indices (equity momentum) and deviation of spot from its moving averages (contrarian value).

The model relies on z-scores. We measure the dispersion of a dataset relative to its mean and calculate the square root of the variance by determining the variation between each data point relative to the mean. If the data points are further from the mean, there is higher standard deviation for the data set; thus, the more spread out the data, the higher the standard deviation.

Model speciation

Overall OCTAVE rank is a simple summation of z-score of 4 factors and scorecards based on ranked factors (Table 3), computed using the formula below:

$$OCTAVE\ Rank = \sum_{1}^{n} (z_i + s_i)$$

Where n = Number of factors (4 in this case), s_i is given by Fig 4.1.1 after each factor is sorted and the Z-score of each factor is computed using the formula below.

$$z_i = \frac{x_i - \bar{x_i}}{\sigma}$$

Where:

x_i is the value of the factor (4 factors in this case explained below)

z_i z-scores of corresponding factors

- Carry level and its 1y z-score,
- 2month Rates momentum (8 weeks percentage change) and its 1y z-score,
- 2month Equity momentum (8 weeks percentage change) and its 1y z-score and
- 2month contrarian value (44 day average FX/spot) and its 1y z-score. Contrarian value is only included when its |z|>1.

$\bar{x_i}$ is the mean and σ is the standard deviation

And standard deviation (σ) is computed as:

$$\sigma = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}}$$

Where:

σ = Standard Deviation

x = Variable for time series data point (each variable of the 4 data sources for each currency)

$\bar{x}$ = Mean value for variable of time series data

n = Number of data points for each variable

A similar procedure is used to create individual rank for each parameter and total of all Z scores gives the overall portfolio indicator and rank.

Table 3: OCTAVE scorecard for each of the four ranked factors

	Scorecard			
Rank	Equity Momentum	Carry Level	Rates Momentum	Contrarian Score
1	4	4	3	2
2	4	3	2	1
3	2	3	1	0
4	2	0	0	0
5	0	0	0	0
6	0	0	0	0
7	-2	0	0	0
8	-2	-3	-1	0
9	-4	-3	-2	-1
10	-4	-4	-3	-2

Source: BofA Merrill Lynch Global Research

Weekly directional signal

Our weekly directional model is designed to produce an optimal currency portfolio based on carry, momentum and valuation considerations. We rank each currency from 1 to 10. We combine these signals from the level of swap rates (carry), the change in swap rates, the change in national equity indices and deviation of spot from its moving averages, (valuation) using a modified scorecard framework, including z-scores, to arrive at a Combined Indicator. For our optimal currency portfolio, we go long the three currencies that are the highest ranked, funded by the three currencies that are the lowest ranked (Table 4).

Table 4: OCTAVE is bullish USD/CHF based on ordered carry, value and equities

	OCTAVE RANKING		Carry Ranking	Rate Trend Ranking	Equity Trend Ranking	Valuation Rank Contrarian
USD	1		1	2	3	4
CAD	2		2	1	6	5
JPY	3		7	6	1	1
NOK	4		5	7	2	9
AUD	5		3	8	7	2
SEK	6		8	3	5	10
NZD	7		4	10	4	3
GBP	8		6	5	10	6
EUR	9		9	4	9	7
CHF	10		10	9	8	8

Data collected Monday 9/24/2018. For each of the four OCTAVE components, every currency gets a rank from 1 (bullish) to 10 (bearish). Subscore is based on relative rank and z-scores.
Source: BofA Merrill Lynch Global Research, Bloomberg

Model Performance and Testing

Our systematic model OCTAVE produces a portfolio of currencies every week. OCTAVE goes long three currencies vs. short three. The hit ratios show the percentage of weekly portfolios when the combined long-short portfolio would have had a positive return.

We also calculate the average number of long signals above the funding cost for each model: the weekly close-to-close basis against an equally weighted basket of the currencies recommended to short. For example, if the Monday close to Monday close change of our top three ranked currencies in OCTAVE were -0.1%, 3% and 0.5% respectively, while each of our three short currencies rose 0.5%, then we would determine that one of our three long currencies appreciated versus the equally weighted average of the shorts (Table 5).

Table 5: Historical performance for OCTAVE

OCTAVE history	2m	12m	Since inception (2012)
Portfolios initiated (#)	9	52	343
Portfolio return up (#)	6	26	181
Hit ratio for overall portfolio	66.7%	50.0%	52.8%
Long signals above funding cost (out of 3), avg	1.78	1.46	1.56

Rolling trade history of 2 months corresponds to last 9 weeks and 12 month history covers last 52 weeks. Since inception covers complete history since March 5, 2012 when OCTAVE was introduced.
Source: BofA Merrill Lynch Global Research, Bloomberg

Systematic trades methodology and risks

Systematic trades in OCTAVE are assumed to be initiated at 5pm EST on Monday prior to date of publication, and closed at 5pm EST the subsequent Monday.

Performance tables are updated on a weekly basis. Performance does not reflect transactions costs, tax withholdings or any investment advisory fees. Had these costs been reflected, the performance of the portfolios would have been lower. The performance results are hypothetical in nature and do not reflect actual transactions. The performance of persons following systematic models will differ from the performance contained in this report for a variety of reasons, including differences related to incurring transactions costs and/or investment advisory fees, as well as differences in the time and price at which currencies were acquired and disposed of. Past performance is no guarantee of future results.

Implications: tracking factor sensitivity in FX movement

An example of how we use different variation of cross-asset models to understand current market dynamic is from our previous publication.

Cross-asset and macroeconomic factors are essential drivers of FX movements. We study the sensitivity of factors over time and highlight attractive holding periods by optimizing historical correlations. FX markets may take more time to price in gradual equity rotations than central bank rate policy decisions over time. However, we find that 2017 was a tough year to trade FX with a relative breakdown in historical relationships.

Using data up to Aug 2018, we find that cross-asset drivers are becoming more important for FX than traditional macroeconomic drivers in 2018 with rising sensitivity. Of the five FX drivers we looked at, equities have the strongest correlation with FX, followed by rates, terms of trade, inflation and unemployment.

Equities and rates as key drivers

To capture the importance of FX drivers, we looked at cross-sectional correlations within G10 between FX ranking and ranking of each factor. The idea is to look for relative currency outperformance as compared to the relative factor strength.

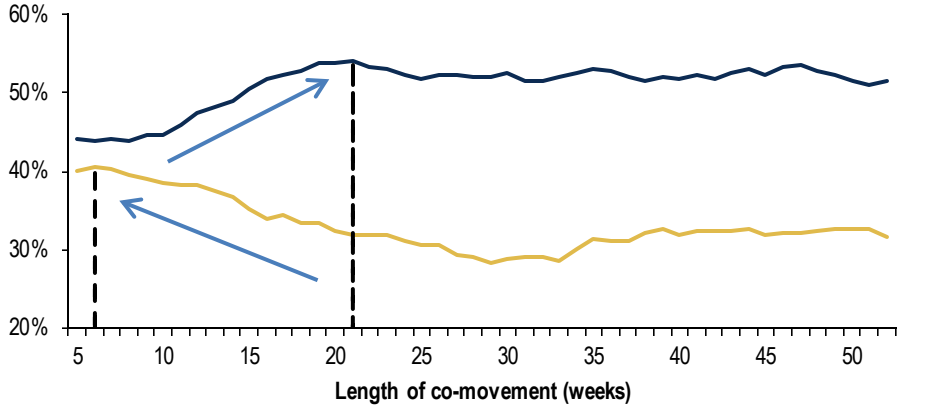
For equity performance, we looked at USD returns of MSCI country indices, focusing on six-month changes. For rates we look at cumulative changes of two-year rates, focusing on two-month changes. For FX returns of each country we look at BCWI (Bloomberg Correlation-Weighted Index) returns, giving us a G10 basket to reduce USD-dependency. For inflation rate, unemployment rate and terms of trade we focused on 12-month changes. For example, over the last six months European equities have underperformed the most in G10, while US equities have outperformed (in USD returns). As it turns out, EUR has indeed fallen since January.

Overall, our analysis suggests that equities and rates are some of the most important FX drivers. We looked at relative FX and factor ranking. The idea is to look for currency outperformance as compared to factor strength with the intuition that factors may reveal themselves on the extremes (high vs low), rather than pairwise for each currency where the differences may be insignificant.

Between equity and rates, we find that equity flows are more persistent than rates flows. FX markets may take more time to price in gradual equity rotations than central bank rate policy decisions. This analysis confirms this intuition (Chart 1). The rates-FX

correlation is the highest at shorter horizons and is declining from five weeks out, peaking at two months using monthly data. By contrast, the equity-FX correlation plateaus around 26-52 weeks, peaking at six months using monthly data.

Chart 1: Equity outperformance has lasting effects on FX



For each horizon length, we compute correlation of ranks between FX and factor (USD equity returns, 2y rates changes).
Source: BofA Merrill Lynch Global Research, Bloomberg

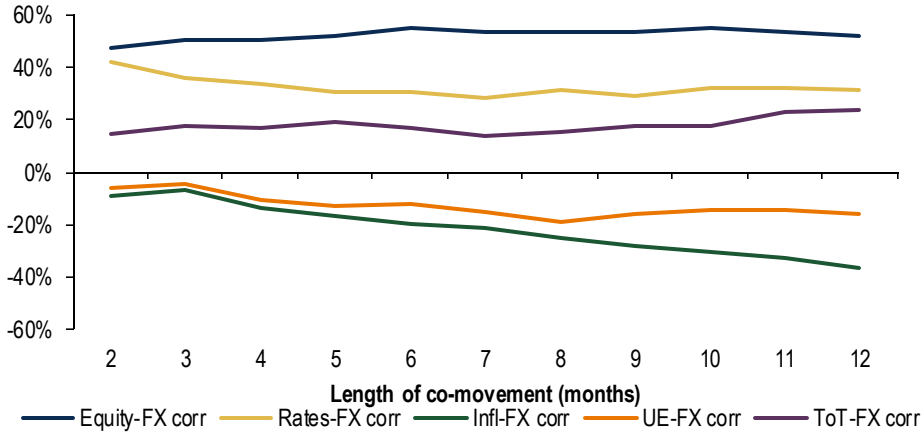
We believe asset class rotation as well as regional allocation changes may contribute to the cross-asset drivers. For instance, repatriation of foreign cash holdings by corporates into USD per tax reform allows for equity buybacks as well as domestic investments, supporting SPX. Additional inflows into US equities from foreign investors would also support USD if not fully hedged.

Traditional macro factors

Traditional macro factors are also important drivers in FX movements. We considered higher-frequency information captured by financial markets in country-level, cross-asset prices (equities and rates). Rates and equities reflect market sentiment mixed in with relative monetary policy and economic growth prospects.

Here we look at the slower-frequency traditional macroeconomic factors: unemployment rate, inflation rate and terms of trade. These capture relative business cycle, relative price changes and international trade. Improving terms of trade shows positive correlation with FX, while a rise in inflation and unemployment rates shows negative correlations with local FX (Chart 2). Since the traditional macro drivers are slow moving, it is not surprising that the co-movement is stronger over longer time-frames (12 months).

Chart 2: Long-term FX horizons correlate better with macro and equities than with rates

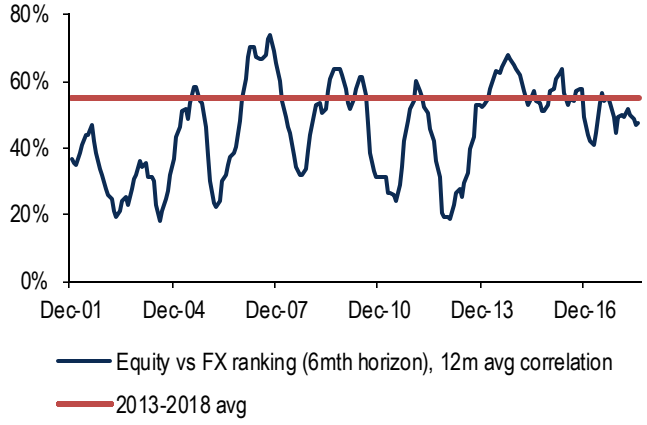


For each horizon length, we compute correlation of ranks between FX and factor (USD equity returns, 2y rates changes, YoY inflation changes, unemployment rate changes, and terms of trade changes).
Source: BofA Merrill Lynch Global Research

Sensitivity of FX factors over time

Factor analysis shows that equity vs FX ranking on a six-month horizon is on average 55% correlated with the declines in 2011, 2013 and 2017 in recent years. The current correlation is slightly below the historical average around 47% (Chart 3). FX-rate ranking correlation declined back in 2013 and 2017, with current correlation approaching historical mean around 40% (Chart 4).

Chart 3: FX vs equity ranking correlation



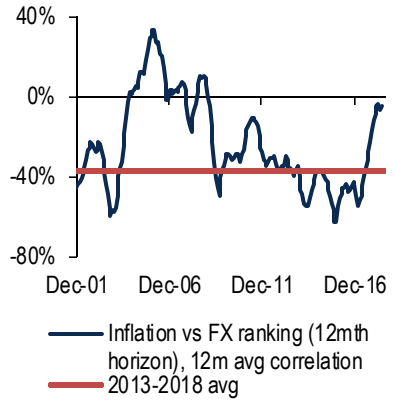
Source: BofA Merrill Lynch Global Research, Bloomberg

Chart 4: FX vs rate ranking correlation

Source: BofA Merrill Lynch Global Research, Bloomberg

Macroeconomic factors have been a historically important driver of FX movements, though their sensitivities have declined in recent years. Factor analysis shows that inflation vs FX ranking correlation on a 12-month horizon is on average -36%. The current correlation is close to 0, indicating inflation is less of an important driver in affecting FX movements (Chart 5). FX-unemployment ranking correlation declined in 2015 and peaked in 2017, with current correlation close to 0 (Chart 6). FX terms of trade ranking correlation rose in 2016, with the current correlation declining below the historical average of 24% (Chart 7).

Chart 5: FX vs inflation ranking correlation

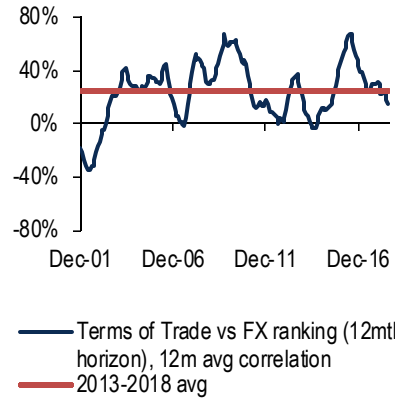


Source: BofA Merrill Lynch Global Research, Bloomberg

Chart 6: FX vs unemployment rate ranking correlation

Source: BofA Merrill Lynch Global Research, Bloomberg

Chart 7: FX vs. terms of trade ranking correlation



Source: BofA Merrill Lynch Global Research, Bloomberg

Options and positioning signal

Following a big currency move (rally or a sell-off), investors often face the dilemma of either chasing the move or fading it. We believe the FX options market can provide valuable information about positioning and sentiment, so we have also developed a framework called the Event analysis that uses the level of volatility, skew and term structure to help with such decisions. In addition, we also developed a three-input positioning model that gauges perceived positioning based on market forces rather than surveys. It uses moving average aggregation (MAA), Up/Down volatility (UD) and Residual Skew (RS) to track spot movement.

Event analysis

Our Event analysis framework consists of four general rules.

- Buy: a currency for which depreciation is accompanied by an increase in 1m vol and put skew, but whose 1y vol does not increase. Signal 1 reflects a "buy on dip", reflecting positive sentiment after a prior sell-off.
- Buy: a currency for which appreciation is accompanied by a relative inversion of the vol curve and a decline in put skew. Signal 2 shows "continuation" when options confirm spot gains.
- Sell: a currency for which depreciation is accompanied by a parallel shift higher across the vol curve. Signal 3 captures "risk premium unwind" after depreciation.
- Sell: a currency for which appreciation is accompanied by an increase in put skew. Signal 4 shows "contrarian" options with skew going against the spot.

These rules don't always produce a signal because the approach is meant to describe meaningful options market reaction following a 1% weekly move in spot. What can be said is that the signals are mutually exclusive and comprehensive. Generally speaking, this approach divides actionable market events into four categories: the spot either fell or gained last week and now the signal is to either buy or sell. Two inputs times two outputs is a set of four signals. The event analysis inputs are presented in a table below and a summary of views column shows the market implication, if any of the four signals was triggered (Table 6).

Table 6: Volatility analysis

Pair	17Sep18 Spot	Current Spot	1m vol	1m vol Chg	1y vol	1y vol Chg	1y - 1m Chg	1m skew pct Chg	Summary of views
EURUSD	1.1685	1.1782	6.82	0.27	7.36	-0.09	-0.36	2.59	No Signal EUR
USDJPY	111.89	112.59	6.44	0.17	8.15	0.01	-0.16	1.43	No Signal JPY
GBPUSD	1.3162	1.3134	9.60	1.02	9.66	0.15	-0.86	-5.12	No Signal GBP
USDCHF	0.9624	0.9607	6.22	0.35	7.19	0.18	-0.17	0.43	No Signal CHF
AUDUSD	0.7181	0.7265	8.34	-0.13	9.32	-0.22	-0.09	1.01	No Signal AUD
USDCAD	1.3028	1.2922	7.28	0.36	7.82	0.09	-0.27	-0.36	No Signal CAD
USDSEK	8.9111	8.8000	9.32	0.67	9.66	-0.19	-0.85	-2.22	Bullish SEK
USDNOK	8.1709	8.1418	8.60	-0.29	9.48	-0.06	0.23	-1.47	No Signal NOK
NZDUSD	0.6580	0.6664	8.30	-0.37	9.52	-0.33	0.05	0.72	No Signal NZD
USDSGD	1.3717	1.3645	4.99	-0.25	4.97	-0.08	0.17	-1.21	No Signal SGD
USDKRW	1126.6	1115.3	7.61	-0.61	8.71	-0.40	0.21	-1.07	No Signal KRW
USDMXN	18.8407	18.8280	12.00	-1.16	13.35	-0.32	0.85	0.40	No Signal MXN
USDBRL	4.1381	4.0494	24.68	-4.77	18.09	-0.16	4.60	-2.31	No Signal BRL
USDTRY	6.2935	6.1545	27.84	-1.13	27.01	-0.66	0.47	-1.59	No Signal TRY
USDZAR	14.9145	14.2401	18.67	-0.93	18.91	-0.49	0.43	-0.60	No Signal ZAR

Data collected Monday 9/24/2018.

The table shows the 1-year percentile and 1-week change in 1m and 1y implied vol, the 1y-1m spread, and the 1m 25 delta risk reversal as a percentage of the ATM. For a currency with a put skew, the rules for generating the signal column are the following:

Bullish signal: [#1]. Spot change < -1%, 1m vol change > 0.5%, 1y vol change < 0.2%, 1m skew chg. < -2; [#2]. Spot change > 1%, 1y-1m change < -0.2%, 1m skew change > 2

Bearish Signal: [#1]. Spot change < -1%, 1m vol change > 1%, 1y vol change > 0.5%; [#2]. Spot change > 1%, 1m skew change < -2

Source: BofA Merrill Lynch Global Research

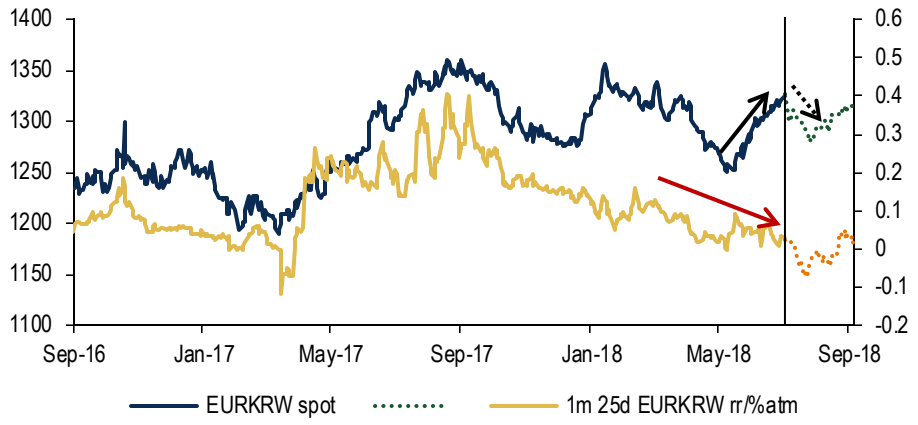
Skew reflecting risks to spot

As an example, we highlight at a few market scenarios where signals showed options skew confirming or contradicting spot trends at the time. On July 23, EUR/KRW was in uptrend with skew shifting to favor EUR/KRW puts.

Despite EUR/KRW uptrend, options investors were not looking for KRW to weaken (Chart 8). Historically, option market sentiment indicated by risk reversal shifts is a leading indicator for spot movement. In our view, the spot was likely to retrace lower follow bearish options signal, for example between February and May.

EUR/KRW uptrend has gone too far then and the model saw it reversing lower given the divergence between spot and skew (signal 4).

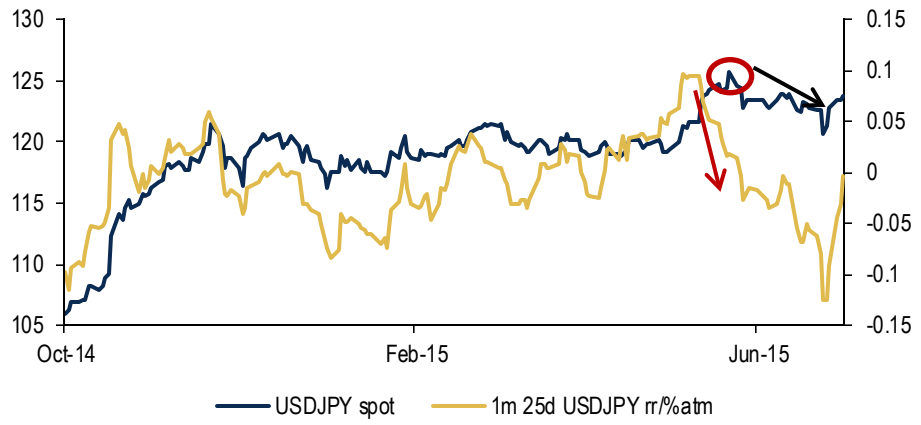
Chart 8: EUR/KRW skew divergence vs. spot marked a top on July 23, 2018



Source: BofA Merrill Lynch Global Research

Similarly, when USD/JPY marked a 15-year high on June 5, 2015, risk reversal had already made a high late May and was reversing lower (Chart 9). The options participants were ready to hedge its USD/JPY positions, seeing greater downside risks. In this example, the skew change was leading spot, which followed shortly after. That USD/JPY high has not been retested as of three years later in 2018.

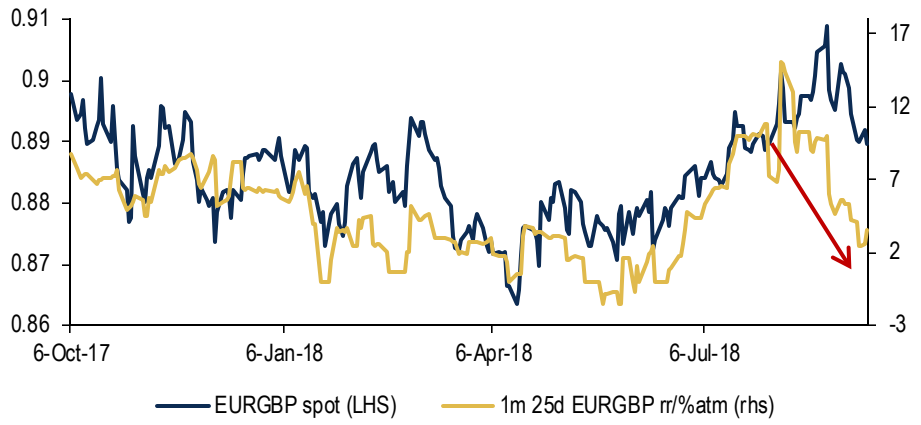
Chart 9: USD/JPY 15yr high was preceded by falling skew



Source: BofA Merrill Lynch Global Research

As an example of options suggesting continuation (signal 2), EUR/GBP skew has moved for puts just as the spot was selling off going into Sep 10 (Chart 10). A week later, the spot fell another leg lower.

Chart 10: EUR/GBP skew falling ahead of spot



Source: BofA Merrill Lynch Global Research

Model performance

We assess performance of the weekly Event analysis model from the start of the data: in 2003 for most pairs and since 2005 for NOK, SEK, CHF, MXN, HUF and TRY. In G10 we find that the contrarian signal 4 works especially well in G10, which has mean-reversion tendencies (Table 7). Event analysis has worked well for USD/CAD and underperformed for GBP/USD.

Table 7: Event analysis performance in G10

	Signal 1	Signal 2	Signal 3	Signal 4	Overall
EURUSD	57.7%	59.3%	54.5%	75.0%	58.7%
USDJPY	50.5%	39.0%	58.3%	62.5%	47.9%
GBPUSD	46.7%	40.9%	48.1%	100.0%	47.8%
AUDUSD	54.4%	55.0%	46.2%	40.0%	51.9%
NZDUSD	53.8%	52.9%	53.5%	60.0%	53.8%
USDCAD	80.0%	71.4%	59.1%	0.0%	62.9%
USDCHF	49.0%	58.8%	62.5%	0.0%	51.8%
USDSEK	50.0%	66.7%	45.8%	33.3%	51.0%
USDNOK	62.5%	45.5%	48.1%	66.7%	52.7%
G10	52.5%	50.3%	51.7%	57.1%	52.1%

Source: BofA Merrill Lynch Global Research

We perform a similar assessment for emerging markets below (Table 8). In emerging markets, we find that the "buy on dip" signal 1 works well, followed by the "contrarian"

signal 4, while continuation signal 2 has underperformed. For specific pairs, Event analysis has worked better for USD/PLN USD/HUF and USD/TRY, than for USD/SGD.

Table 8: Event analysis performance in EM

	Signal 1	Signal 2	Signal 3	Signal 4	Overall
USDMXN	50.0%	53.3%	44.2%	58.8%	48.8%
USDSGD	66.7%	27.3%	46.7%	80.0%	48.6%
USDHUF	50.0%	46.7%	52.4%	56.3%	52.1%
USDPLN	50.0%	43.8%	54.3%	66.7%	54.5%
USDKRW	62.5%	47.6%	45.7%	42.9%	47.6%
USDZAR	50.0%	66.7%	47.7%	54.2%	51.0%
USDTRY	50.0%	40.0%	52.1%	59.3%	52.2%
EM	64.3%	46.1%	49.1%	58.6%	50.8%

Source: BofA Merrill Lynch Global Research

Positioning analysis

Our preferred three measures of positioning are a moving average aggregation (MAA), Up/Down volatility (UD) and Residual Skew (RS)

MAA tracks momentum and trend maturity and is calculated as the percentage of moving average trading rules giving a buy signal for a given cross and a variety of moving averages. A high (low) percentage of buy signals suggests long (short) positioning in the pair is quite heavy.

Up/Down volatility and Residual Skew are measures of skewness in currency returns, which we view as an indirect reflection of positioning. A high (low) value of one or both of UD and RS in conjunction with a high (low) value of MAA suggests positioning is impacting price action, so a reversal is likely.

MAA as momentum

Momentum is a factor used for asset pricing to capture trending markets. FX is generally mean-reverting in the long run, but in the short term it can trend in one direction. The downtrend of EUR/USD back in 2014 and the uptrend in 2017 illustrate that a currency can move in a single direction for extended periods of time.

We have found evidence of momentum for G10-USD pairs that is statistically significant, though the overall lean is moderate. We found 52% of medium-term FX trends continued for another month since 2000 when measuring trend direction as the sign of a five-month spot change. Moreover, EURUSD momentum persisted for another four weeks 54% of the time. However, eventually, momentum became too strong and currencies mean reverted. In our view, the momentum risk premium has to do with the possibility of elevated drawdowns when the market is positioned the same way and becomes vulnerable to data surprises.

Market Implications using momentum signal

An example of how we use momentum positioning analysis to understand current market dynamics is from our previous publication using data up to May 2018,

Recently, USD has gained strong momentum, which also makes it vulnerable to sharp sell-offs after US data misses. This vulnerability was shown by its sudden correction following the soft CPI print last week. The cleanest historical signals on EUR, GBP, CAD and SEK saw trends continue more than 53.5% of the time (Table 11).

Medium-term FX trends tend to persist for another month

Momentum is a factor used for asset pricing that intends to capture the continuation of existing trends in the market. We used spot returns as a simple measure of momentum using varying lookbacks between one week and one year and checked whether the currency has maintained its direction afterward. We looked ahead between one week and twelve months (52 weeks), with a focus on the next 12 weeks, to get a sense of how persistent these trends are. We found that G10 trends from the preceding four to six months continued for another one to four weeks and started to mean-revert after two months (Table 9).

Table 9: Probability FX momentum continues in the same direction

Look ahead (week) \ Lookback (months)	0.25	1	2	3	4	5	6	12
1	51.0%	50.5%	50.8%	51.0%	51.2%	52.0%	51.8%	51.8%
2	51.0%	50.5%	50.8%	51.0%	51.2%	52.0%	51.8%	51.8%
3	51.0%	50.5%	50.8%	51.0%	51.2%	52.0%	51.8%	51.8%
4	50.4%	50.6%	50.8%	50.5%	51.7%	52.2%	51.9%	50.9%
8	50.4%	49.5%	50.5%	50.8%	51.0%	50.6%	49.9%	50.0%
12	50.4%	49.5%	50.5%	50.8%	51.0%	50.6%	49.9%	50.0%

EURUSD, GBPUSD, USDJPY, USDCHF, USDCAD, AUDUSD, NZDUSD, USDNOK, USDSEK since 2000, 40k daily observations.
Source: BofA Merrill Lynch Global Research, Bloomberg

Table 10: t-statistics for FX momentum

Look ahead (week) \ Lookback (months)	0.25	1	2	3	4	5	6	12
1	4.2	2.1	3.3	4.0	4.8	7.9	7.3	7.3
2	4.2	2.1	3.3	4.0	4.8	7.9	7.3	7.3
3	4.2	2.1	3.3	4.0	4.8	7.9	7.3	7.3
4	1.6	2.3	3.2	2.0	7.0	8.9	7.6	3.7
8	1.4	-2.1	2.0	3.2	4.2	2.2	-0.5	0.2
12	1.4	-2.1	2.0	3.2	4.2	2.2	-0.5	0.2

EURUSD, GBPUSD, USDJPY, USDCHF, USDCAD, AUDUSD, NZDUSD, USDNOK, USDSEK since 2000, 40k daily observations. t-test is constructed vs. null hypothesis of 50%.
Source: BofA Merrill Lynch Global Research, Bloomberg

FX momentum statistically significant

We performed a statistical test and found evidence of momentum for G10 USD pairs is statistically significant. Brief holding periods under a month are robust to varying measures of trends. Trends from six to five months ago are the most persistent and may last as long as three months, though the signals peaked after four weeks with t-statistics as high as 8.9 (Table 10).

For example, if EURUSD has been trending for four months, the 95% confidence interval of the trend to persist four weeks later is [53.6%, 56.5%] with a midpoint of 55%.

Table 11: Historical probability that the on-going trend continues (5m lookback)

Weeks ahead	1	2	3	4	8	12	16	20	24	28	32	40	52
EURUSD	53.6%	54.3%	53.5%	54.1%	52.8%	51.0%	52.8%	54.0%	54.0%	53.0%	52.0%	47.7%	43.2%
GBPUSD	52.9%	52.5%	52.6%	53.6%	54.5%	54.0%	53.3%	52.1%	52.1%	51.4%	50.4%	48.9%	46.3%
USDJPY	51.1%	50.2%	50.1%	49.7%	47.2%	47.0%	43.9%	46.4%	46.4%	47.9%	50.7%	54.9%	56.1%
USDCAD	51.9%	53.3%	52.3%	53.7%	52.5%	50.7%	49.7%	53.4%	53.4%	51.4%	51.6%	55.4%	55.9%
AUDUSD	52.4%	52.7%	52.6%	53.2%	51.8%	52.9%	53.2%	52.9%	52.9%	51.2%	51.6%	50.7%	52.9%
NZDUSD	51.2%	51.3%	50.8%	52.1%	51.6%	53.1%	52.0%	50.5%	50.5%	50.5%	51.8%	51.4%	53.0%
USDSEK	52.2%	52.6%	54.2%	55.0%	53.5%	54.3%	55.6%	53.9%	53.9%	52.4%	51.4%	49.2%	47.6%
USDNOK	50.0%	49.9%	48.4%	49.1%	48.3%	47.4%	49.3%	48.9%	48.9%	48.7%	48.8%	45.1%	45.6%
USDCHF	52.3%	51.3%	50.2%	49.3%	47.7%	44.6%	45.0%	45.5%	45.5%	46.0%	46.3%	45.5%	47.7%

Since 2000 FX momentum is calculated using spot change over last 5 months (lookback) and looking ahead up to 52 weeks.
Source: BofA Merrill Lynch Global Research, Bloomberg

MAA: Moving Average Aggregation

Another way to measure trends and momentum in our quant models is by constructing moving average aggregator. The daily MAA (Moving Average Aggregator) is the average of the 28 binary "signals" given by crossing short and long moving averages. It measures trend maturity and correlates closely with spec CFTC positioning.

For many investors, a conventional bullish signal for a currency pair occurs when: the short-dated moving average is crossing above the long-dated moving average. The MAA reaches 100% when 28 moving average pairs are bullish, while it reaches 0% when 28 pairs are bearish. Similarly, the MAA is at 50% when 14 out of 28 pairs are bullish and 14 other pairs are bearish.

Specifically, we take 8 raw data series (Bloomberg price field tickers below) are: PX_LAST (spot), MOV_AVG_5D, MOV_AVG_10D, MOV_AVG_20D, MOV_AVG_30D, MOV_AVG_50D, MOV_AVG_100D and MOV_AVG_200D. These 8 series are paired in all 28 possible ways as follows (Table 12):

Table 12: MAA averages moving average pairs to capture trend maturity

The 28 components of Moving Average Aggregator (MAA)		
PX_LAST vs MOV_AVG_5D	MOV_AVG_5D vs MOV_AVG_50D	MOV_AVG_20D vs MOV_AVG_100D
PX_LAST vs MOV_AVG_10D	MOV_AVG_5D vs MOV_AVG_100D	MOV_AVG_20D vs MOV_AVG_200D
PX_LAST vs MOV_AVG_20D	MOV_AVG_5D vs MOV_AVG_200D	MOV_AVG_30D vs MOV_AVG_50D
PX_LAST vs MOV_AVG_30D	MOV_AVG_10D vs MOV_AVG_20D	MOV_AVG_30D vs MOV_AVG_100D
PX_LAST vs MOV_AVG_50D	MOV_AVG_10D vs MOV_AVG_30D	MOV_AVG_30D vs MOV_AVG_200D
PX_LAST vs MOV_AVG_100D	MOV_AVG_10D vs MOV_AVG_50D	MOV_AVG_50D vs MOV_AVG_100D
PX_LAST vs MOV_AVG_200D	MOV_AVG_10D vs MOV_AVG_100D	MOV_AVG_50D vs MOV_AVG_200D
MOV_AVG_5D vs MOV_AVG_10D	MOV_AVG_10D vs MOV_AVG_200D	MOV_AVG_100D vs MOV_AVG_200D
MOV_AVG_5D vs MOV_AVG_20D	MOV_AVG_20D vs MOV_AVG_30D	
MOV_AVG_5D vs MOV_AVG_30D	MOV_AVG_20D vs MOV_AVG_50D	

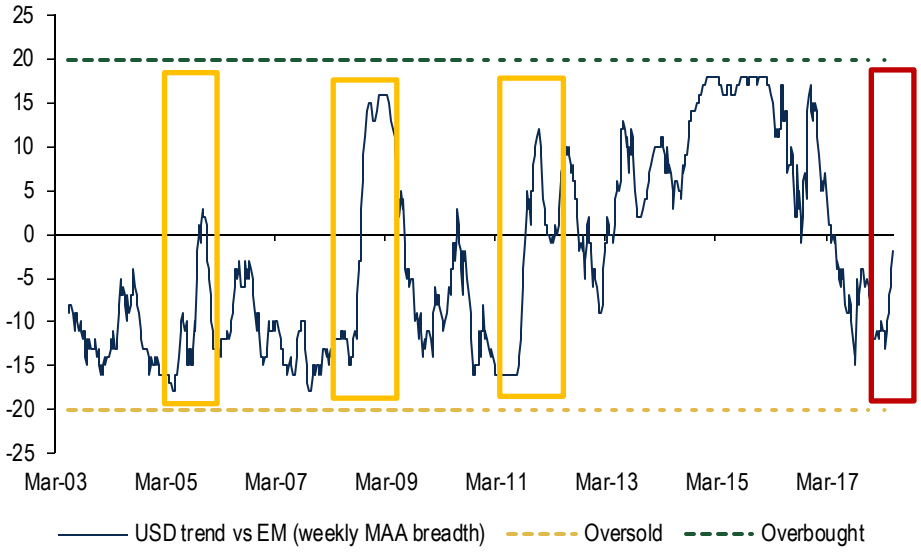
Source: BofA Merrill Lynch Global Research

Implications: MAA breadth captures broader USD trend vs. EM

An example of how we use moving average aggregator positioning analysis to understand current market dynamic is from our previous publication using data up to June 2018.

USD rally was about to take its toll on emerging market currencies, according to our weekly MAA (Chart 11). EM FX has topped out the week of 6 April when USD broadly descended against most pairs as investors kept buying emerging market currencies at that time. Over the last two months EM FX longs have been under pressure with USD recovering the most ground since the 2011 EM rout. Our indicator suggested the sell-off has been selective and localized so far (eg, USD/INR, UDS/TRY) given USD breadth remains slightly negative at that time. In addition, JPY was already peaking like in previous EM FX selloffs. Past episodes have taken four to six months to unwind trough to peak. The laggards early in June were USD/KRW, USD/ZAR and USD/EUR. Indeed, USD/ZAR has moved higher over the summer as EM positions were significantly reduced.

Chart 11: USD was set up for the biggest reversal rally against EM FX since 2011

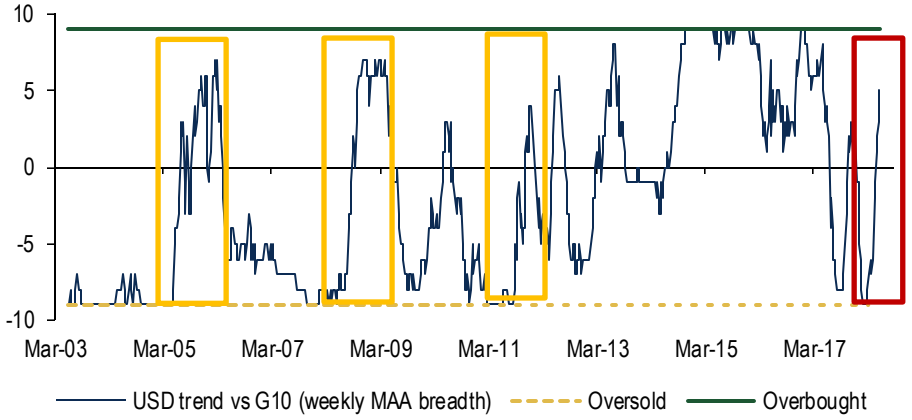


Source: BofA Merrill Lynch Global Research

Strong USD in G10 presented risks for EM

By June 2018, USD had already recovered from oversold levels into positive territory among G10 pairs (Chart 12). In other words, MAA cross-section shows there were more USD uptrends than downtrends in G10. USD bottomed out in February against G10 and in April against EM. Strong USD in developed markets was already weighing on emerging markets when the summer sell-off began.

Chart 12: USD had already turned a corner and recovered from oversold levels in G10

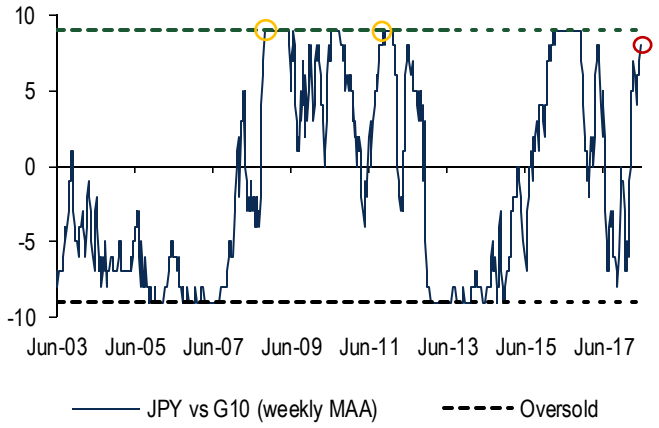


We construct USD trend vs. EM based on weekly moving average cross-overs in G10 for USDEUR, USDGBP, USDAUD, USDNZD, USDCAD, USDCHF, USDNOK, USDSEK and USDJPY. An uptrend has MAA>60% is worth +1, while a downtrend has MAA<40% is worth -1.
Source: BofA Merrill Lynch Global Research, Bloomberg

Strong JPY peaking, a warning for EM

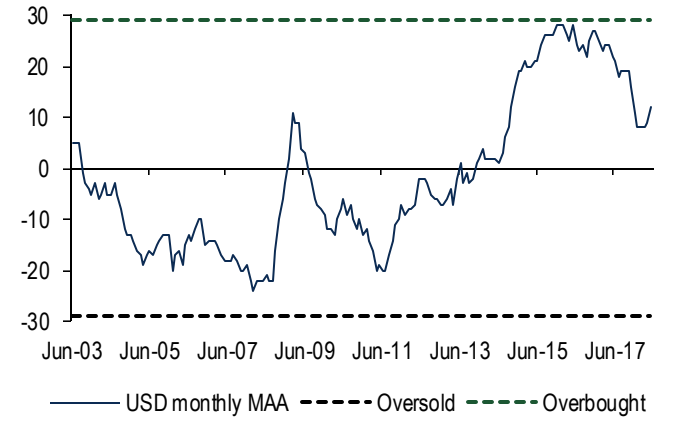
JPY was outperforming not just against USD, but also against other developed currencies. JPY as approaching peak trend strength, displaying its biggest rally since 2015 against other G10 pairs (Chart 13). This JPY strength was reminiscent of past EM FX selloffs, so we took this as additional confirmation of rising risks for EM longs against USD.

Chart 13: JPY vs. G10 approached peak trend strength, most since 2015



We construct JPY trend vs. G10 based on weekly moving average cross-overs in major currencies: JPYEUR, JPYGBP, JPYAUD, JPYNZD, JPYUSD, JPYCAD, JPYCHF, JPYNOK and JPYSEK.
Source: BofA Merrill Lynch Global Research, Bloomberg

Chart 14: Monthly MAA shows USD vs. Majors above long-term average



We construct USD trend vs. Majors based on monthly moving average cross-overs in major currencies: USDARS, USDBRL, USDCLP, USDCNY, USDCOP, USDCZK, USDHUF, USDINR, USDIDR, USDILS, USDMYR,USDMXN, USDPEN, USDPLN, USDRUB, USDSGD,USDZAR, USDKRW, USDTWD, USDTRY, USDEUR, USDGBP, USDAUD, USDNZD, USDCAD, USDCHF, USDNOK, USDSEK and USDJPY.
Source: BofA Merrill Lynch Global Research, Bloomberg

Long-term view USD trends

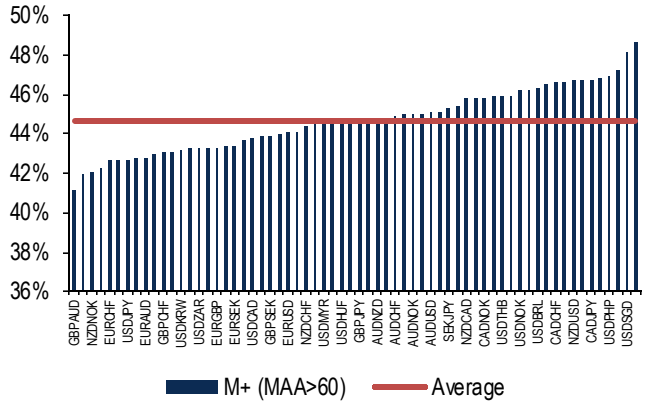
While we saw USD upside in the medium term heading into the midterms, we also considered long-term implications (Chart 14). Using monthly moving average cross-overs for USD vs 29 major currencies (EM and G10), the monthly USD trend strength is already at +12 out of 29, which is above its long-term average around 0. This suggested the USD rally may be overshooting its long-term trend and eventually mean revert lower, for example as the Fed is expected to reach the terminal rate in the coming years ahead.

MAA model performance

Mean reversion is more likely following extended positions. Despite conventional intuition that trends tend to be persistent, our analysis shows that a generic trend may dissipate when it is not impulsive, especially for G10 currencies. Stretched positions tend to accumulate and lead to turning points after strong directional trends. When the

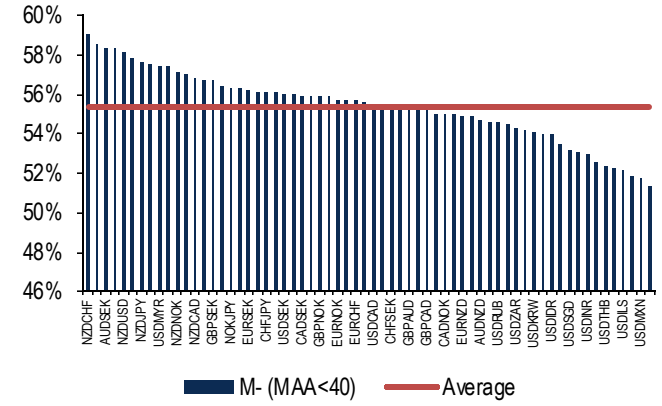
trend is up, on average only 44% of the time it leads to additional topside moving average crossing and lifting MAA a week later (Chart 15). Similarly, when the trend is down, 55% of the time the downtrend softens with a bounce a week later (Chart 16). Extended positions tend to be more sensitive to shocks in the opposite direction, leading to sizable likelihood of a reversal.

Chart 15: 44% of extended uptrends gain strength a week later



Source: BofA Merrill Lynch Global Research

Chart 16: 55% of extended down trends bounce



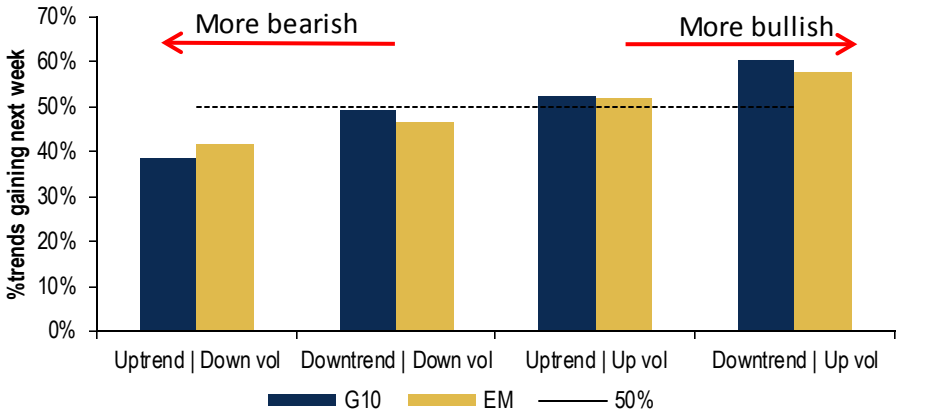
Source: BofA Merrill Lynch Global Research

Directional realized vol: Up-Down vol

When MAA is augmented by Up-Down volatility, which measures directionality of price action, the signals become more powerful (Chart 17). Higher volatility in direction of trend is bullish, while significant volatility against the trend is bearish.

We construct Up-Down vol as a spread of realized volatility between up and down days over the past month.

Chart 17: Up-down vol propels trends and assists timing reversals

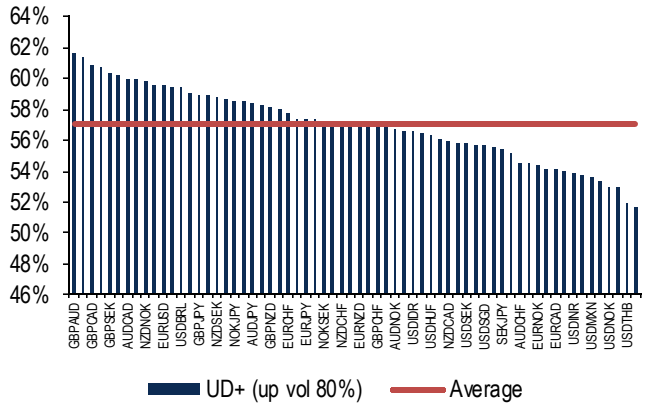


Source: BofA Merrill Lynch Global Research

Up-down vol model performance

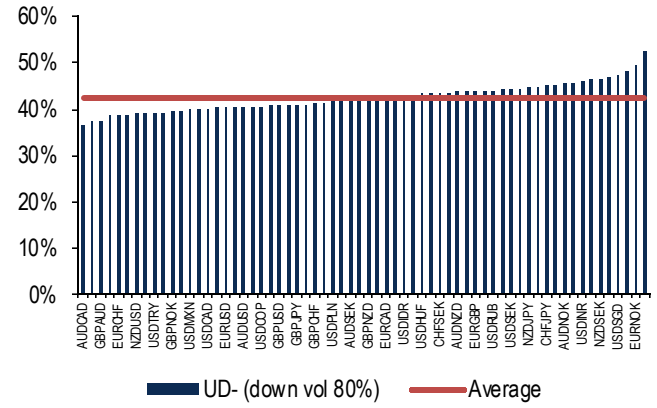
Trends are stronger following supportive volatility movements. By using 80% and 20% percentile as cutoffs for Up-Down vol, we find that a bullish Up-Down vol sees bounce 55% of the time (Chart 18). On the down side, we find bearish Up-Down vol sees bounce 42% of the time (Chart 19), meaning the price action is bearish 58% of the time.

Chart 18: Bullish Up-Down vol sees bounce 55% of the time



Source: BofA Merrill Lynch Global Research

Chart 19: Bearish Up-Down vol sees bounce 42% of the time



Source: BofA Merrill Lynch Global Research

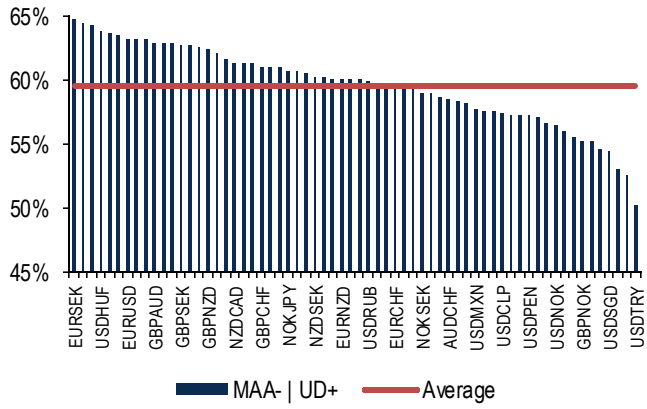
Continuation with favorable momentum: the trend is your friend

Trends tend to strengthen when a stretched trend and Up-Down vol agree with each other. On average, we find 52% of uptrends with upward momentum gain strength higher upside volatility, as compared to only 44% by conditioning on a mature trend alone. Conditioning on trend going down and volatility going down, we find that the trend gets more negative with only a 48% chance of a bounce. Trends tend to continue with favorable momentum measured by volatility direction. We find that "the trend is your friend" saying holds when supported by vol movements.

Heavy positioning: trend reversals

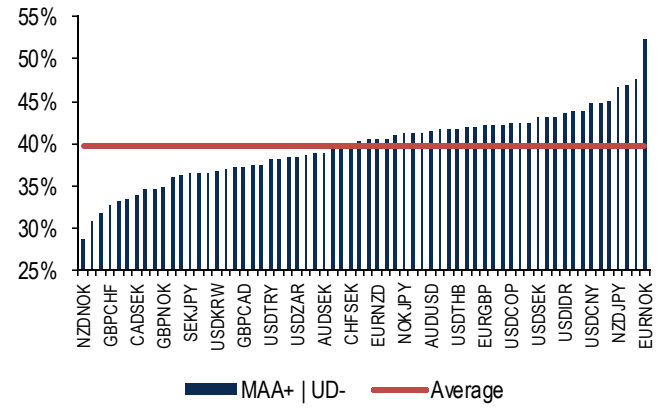
We use Up-Down vol to catch a falling knife in times of unexpected trend reversal. When the trend is down while upside volatility is high, we find that the chance of a bounce/reversal is higher. On average, we find 60% of downtrends with positive momentum bounce up (Chart 20). When the trend is up but downside volatility is high, we find that a sell-off/reversal lower is more likely to happen. On average, there are 40% of uptrends with negative momentum gain strength (Chart 21). Up-down vol is an indication aiding a trend breaking or continuing. Stretched trends tend to be supported when the direction of volatility agrees with the trends or reverted vice versa.

Chart 20: 60% of downtrends with positive momentum bounce



Source: BofA Merrill Lynch Global Research

Chart 21: 40% of uptrends with negative momentum gain strength



Source: BofA Merrill Lynch Global Research

Residual put Skew

Following the intuition of the Event analysis, we construct Residual put Skew as a residual of a regression of weekly changes in 1m 25d risk reversals (% atm) on weekly changes in spot over 6 month rolling window. Using a normalized cumulative sum of these residuals over the last month, we get a measure of contrarian and trend-following signals from skew. We then take 1 year percentile to normalize the RS indicator. The

model is not systematic but it highlights scenarios where signals show skew confirming or contradicting spot trends. The normalize the RS indicator so that low values reflect light positioning and excess demand for calls, while high values reflect excess demand for puts and relatively stretched long positioning.

Combine together: MAA, UD and RS

Our preferred three measures of positioning are moving average aggregation (MAA), Up/Down volatility and Residual Skew are measures of skewness in currency returns, which we view as an indirect reflection of positioning. A high (low) value of one or both of UD and RS in conjunction with a high (low) value of MAA suggests positioning is impacting price action, so a reversal is likely.

Contrarian signal: MAA, Up-Down vol and Residual Skew

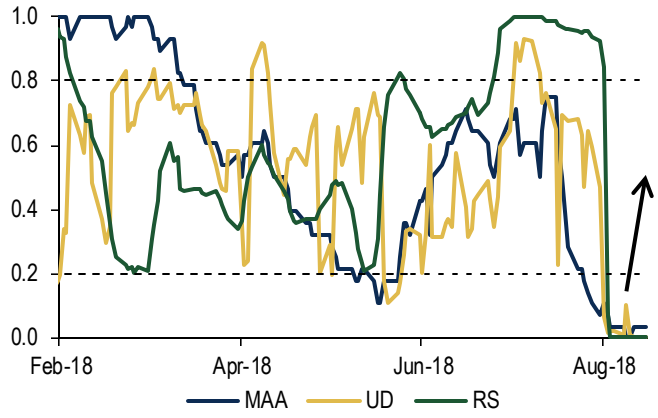
We plot Up-Down vol signal to coincide with positioning, normalizing higher values of UD as greater down vol corresponding to stops being hit on stretched long positions. The normalization we use is Raw U/D=100-[100/(1+UP/DOWN)], where UP and DOWN are realized vol for UP and DOWN days using a common rolling 1 month window. Then UD indicator as plotted between 0% and 100% is UD%=(100%-1y percentile of Raw U/D). Again, the inversion for UD% is for illustration of light positioning with low values and high positioning with high values of the normalized indicator.

On August 21, 2018, the model showed a bullish reversal signal for EUR/CAD. As US investors bought EUR the previous week, we were seeing bullish signals for EUR crosses. In particular, EUR/CAD was then flashing red with Moving Average Aggregator (MAA) trending down at 4%, while Up-Down vol and Residual skew were both extreme at 0th percentile, meaning a material risk of a bounce. While EUR/CAD has been previously trending lower, the volatility was then higher against the trend and the skew for puts has declined (Chart 22).

Continuation signal: MAA, Up-Down vol and Residual Skew

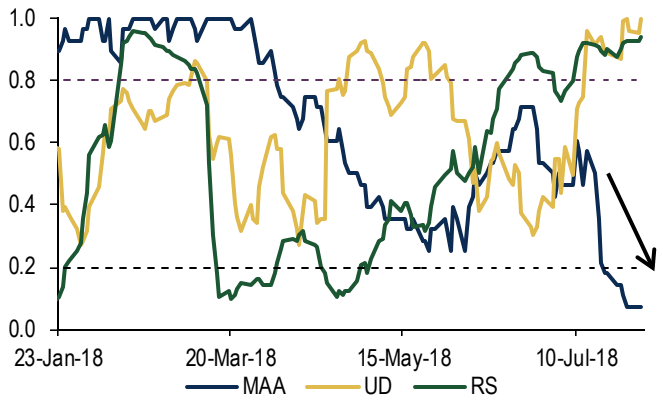
On July 31, 2018 the model showed a bearish continuation signal for GBP/CAD. CAD demand has picked up in local hours. In our view, this was incrementally bullish for CAD and may have reflected improving data surprises as well as possibly a less bleak outlook for Canada on NAFTA for the time being. Canadian GDP and retail sales for May came above consensus and our economists expect the Bank of Canada to hike in October. In addition, our positioning model was bearish GBP/CAD with elevated Residual put Skew (Chart 23).

Chart 22: EUR/CAD sets up for a bounce



Source: BofA Merrill Lynch Global Research, Bloomberg

Chart 23: GBP/CAD downtrend is in play



Source: BofA Merrill Lynch Global Research, Bloomberg

In the tables below, we combine MAA, Up-Down and Residual put Skew for all USD pairs (Table 13) as well as all EUR pairs in G10 (Table 14) and summarize the current trend direction (up, down or sideways) as well as risks of trends reversing.

Table 13: USD trends face headwinds with MAA turning sideways

	Trend	Risk of Reversal	MAA	UD	RS
EURUSD	↑	LOW	61	22	72
USDJPY	↑	MEDIUM	96	90	11
GBPUSD	↔	NO TREND	46	44	76
AUDUSD	↓	LOW	25	72	57
USDCHF	↓	LOW	14	23	40
USDCAD	↓	LOW	32	30	41
NZDUSD	↓	LOW	21	71	45
USDSEK	↔	NO TREND	46	73	9
USDNOK	↔	NO TREND	46	100	18

Uptrend has MAA > 60, downtrend MAA < 40. Uptrend reversal likely if MAA/UD/RS > 80, unlikely if UD,RS < 50. Downtrend reversal likely if MAA/UD/RS < 20, and unlikely if UD,RS > 50. UD and RS are 1y percentile and MAA is in %. Source: BofA Merrill Lynch Global Research

Table 14: Bullish EUR/NZD

	Trend	Risk of Reversal	MAA	UD	RS
EURGBP	↑	LOW	75	55	78
EURJPY	↑	LOW	75	37	45
EURUSD	↑	LOW	61	22	72
EURAUD	↑	LOW	89	79	40
EURCHF	↓	LOW	21	6	11
EURCAD	↓	LOW	39	13	20
EURNZD	↑	LOW	93	49	24
EURSEK	↔	NO TREND	46	96	23
EURNOK	↓	LOW	39	70	85

Uptrend has MAA > 60, downtrend MAA < 40. Uptrend reversal likely if MAA/UD/RS > 80, unlikely if UD,RS < 50. Downtrend reversal likely if MAA/UD/RS < 20, and unlikely if UD,RS > 50. UD and RS are 1y percentile and MAA is in %. Source: BofA Merrill Lynch Global Research

Flow analysis

Tracking flows is an important but also a difficult aspect of currency analysis. Breaking down currency performance by time zones can help investors better understand the sources of key flows. For example, private cross-border portfolio investment flows or reserve rebalancing related flows at any given time can be important drivers of FX movement. In addition, as FX is traded around the clock, understanding liquidity in FX options by currency, time zone and tenor can be useful for investors considering strategic hedges or expressing a directional view. We use Swap Data Repository (SDR) database, piecing together the entire database of over 4.5 million recorded trades across time, tenor, currency and product type in searching for directional signals.

Time zone trading patterns

Breaking down currency performance by time zones can help investors better understand the sources of key flows. We define the UK time zone as between 8am GMT and 1pm GMT. The US time zone is from 1pm to 12am GMT, and Asia's is from 12am to 8am GMT.

While it is intuitive to expect that locals incorporate data releases and other events into asset prices quicker than foreigners, it is not obvious which currency leg is more dominant. For example, is EUR/USD driven mostly by UK locals in the morning or by US locals later on? To measure this, we compare R^2 in a six-month regression of 24-hour spot returns on just a single time-zone return series. The time zone with the largest R^2 for each currency pair is thus the dominant one, capturing most of the spot trend. In addition, for each geographic region, we can sort currencies by its R^2 to identify truly local currencies.

US hours are golden

An example of how we use time zone analysis to understand current market dynamic is from our previous publication.

Using data up to July 2018, we identify the dominant geographic region (the US, UK or Asia) for each of the USD, EUR and JPY crosses in G10. We find that for 1H18, US hours have been dominant for 16 currency pairs, UK hours drove 6 pairs and Asia hours were most relevant for just 2 pairs out of 24 pairs in this analysis. This shows the market remains focused on US data, US politics and the Fed. Time-zone analysis shows USD is rising in US hours, EUR is falling in UK hours and JPY is falling in Asia. In addition, UK locals are bullish GBP and SEK, while US locals are bearish CAD on the crosses.

Essential time zones

Understanding flows is both the most important and most difficult aspect of currency trading. In our view, breaking down currency performance by time zones can help investors better understand the sources of key flows (e.g. the importance of private cross-border portfolio investment flows or reserve rebalancing related flows at any given time). We define the UK time zone as between 8am GMT and 1pm GMT. The US time zone is from 1pm to 12am GMT, and Asia's is from 12am to 8am GMT. This

corresponds to each region starting at 8am local in Tokyo, London and New York and captures local stock markets, local data releases and local central bank decisions.

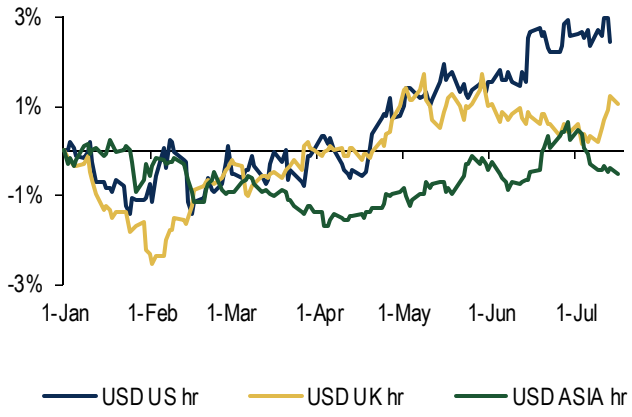
Who is local in a global world?

While it is intuitive to expect that locals incorporate data releases and other events into asset prices quicker than foreigners, it is not obvious which currency leg is more dominant. For example, is EUR/USD driven mostly by UK locals in the morning or by US locals later on? To measure this, we compare R^2 in a six-month regression of 24-hour spot returns on just a single time-zone return series. The time zone with the largest R^2 for each currency pair is thus the dominant one, capturing most of the spot trend. In addition, for each geographic region, we can sort currencies by its R^2 to identify truly local currencies.

USD rose in US hours

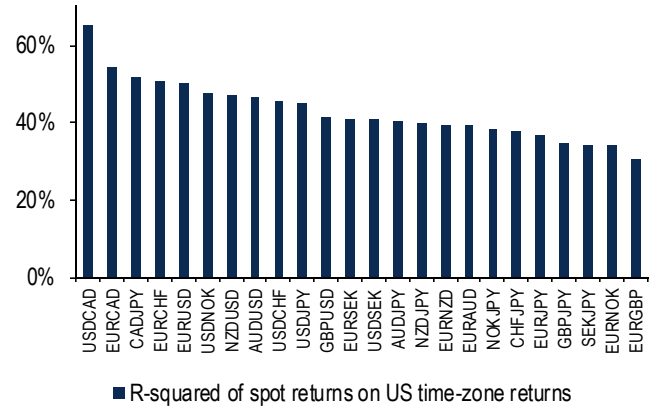
Time-zone analysis for BCWIUSD (Bloomberg Correlation-Weighted USD Index) shows USD rising sharply in local US hours (Chart 24). The top five locally traded currencies in US hours in 2018 are: USD/CAD, EUR/CAD, CAD/JPY, EUR/CHF and EUR/USD (Chart 25).

Chart 24: USD rising in US hours



Source: BofA Merrill Lynch Global Research, Bloomberg

Chart 25: FX pairs most active during US hours

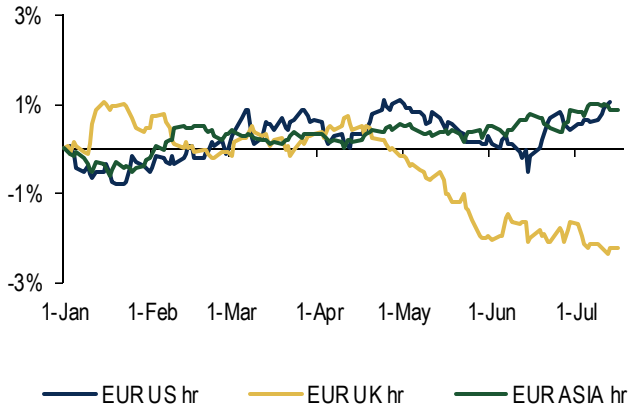


Source: BofA Merrill Lynch Global Research, Bloomberg

EUR fell in UK hours

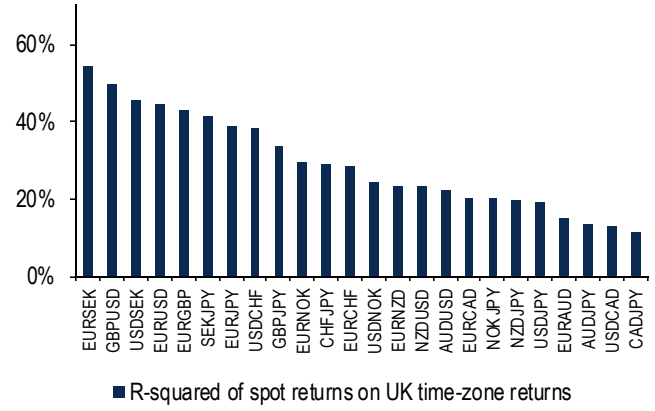
Time-zone analysis for BCWIGBP (Bloomberg Correlation-Weighted EUR Index) shows EUR falling sharply in local UK hours (Chart 26). The top five locally traded currencies in UK hours this year are: EUR/SEK, GBP/USD, USD/SEK, EUR/USD and EUR/GBP (Chart 27).

Chart 26: EUR falling in UK hours



Source: BofA Merrill Lynch Global Research, Bloomberg

Chart 27: FX pairs most active during UK hours

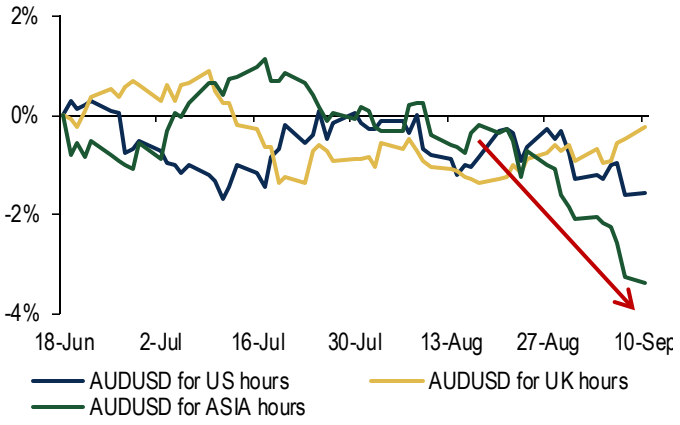


Source: BofA Merrill Lynch Global Research, Bloomberg

JPY fell in Asia hours

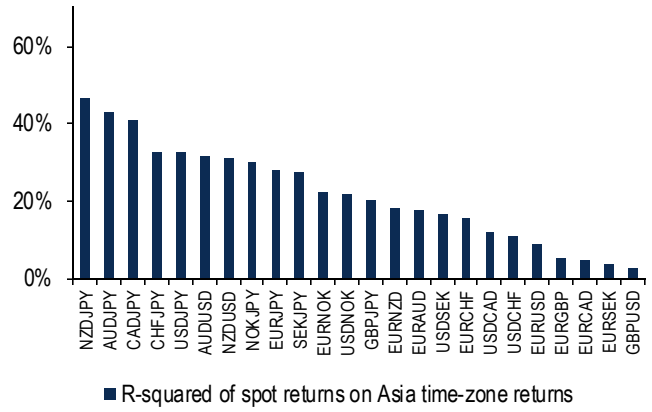
Time-zone analysis for BCWIJPY (Bloomberg Correlation-Weighted JPY Index) shows JPY falling sharply in local Asia hours (Chart 29). The top five locally traded currencies in UK hours this year are: NZD/JPY, AUD/JPY, CAD/JPY, CHF/JPY and USD/JPY (Chart 29).

Chart 28: AUD/USD is in free fall in local hours



Source: BofA Merrill Lynch Global Research

Chart 29: FX pairs most active during Asia hours



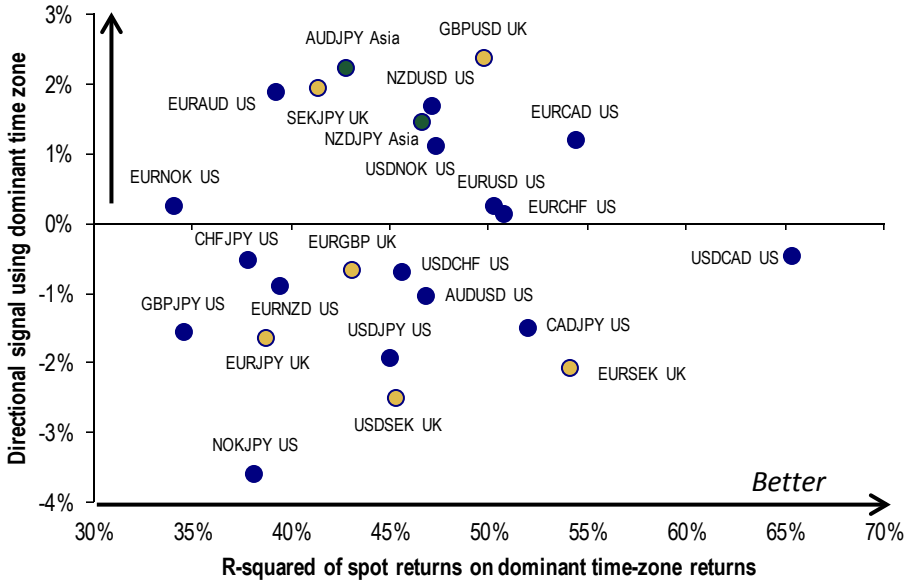
Source: BofA Merrill Lynch Global Research, Bloomberg

When in Rome, do as the Romans do

We highlight where the dominant regions disagree with the rest of the world.

Having identified the dominant time-zone region for each pair as the key main trend, we check for divergence between that region and noise trading in other regions. We regress cumulative 24-hour spot returns series on the dominant time-zone returns to see what the locals think of the currency (Chart 30).

Chart 30: US is the dominant time-zone in G10 FX, followed by UK and Asia



UK time zone as between 8am GMT and 1pm GMT. The US time zone is from 1pm to 12am GMT, and Asia's is from 12am to 8am GMT.
Source: BofA Merrill Lynch Global Research, Bloomberg

The top five locally traded currencies in US hours this year are: USD/CAD, EUR/CAD, CAD/JPY, EUR/CHF and EUR/USD.

The top five locally traded currencies in UK hours this year are: EUR/SEK, GBP/USD, USD/SEK, EUR/USD and EUR/GBP. The top five locally traded currencies in Asia hours this year are: NZD/JPY, AUD/JPY, CAD/JPY, CHF/JPY and USD/JPY.

SDR analysis

As FX is traded around the clock, understanding liquidity in FX options by currency, time zone and tenor can be useful for investors considering strategic hedges or expressing a directional view.

The Swap Data Repository (SDR) was created by the Dodd-Frank Act in 2013 and provides a level of transparency to the OTC FX options market. We look at this data to better understand the evolving landscape of FX liquidity with the caveat that it excludes trades between counterparties outside of the Dodd-Frank scope when neither is US based.

Dodd-Frank requires three types of reporting of swap transactions: SDR reporting, real-time reporting and historical swap reporting. Swap counterparties must report various information to new "swap data repositories" registered with the CFTC. Key information about swaps becomes public via SDRs. There may be delays for reporting large "block" transactions. This new database effectively permits the creation of option volume, the evolution and positioning by tenor, product type such as put-call ratio which has profound implications for FX markets.

Implications of option flow

We revisit the Swap Data Repository (SDR) database after 5 years since its inception, piecing together the entire database of over 4.5 million recorded trades across time, tenor, currency and product type. In our first endeavor, we focus on 2.5m vanilla trades and analyze the implication of the SDR database from four angles:

1. The SDR database assists execution by tracing the evolution of market share by currency pairs and product type.

2. The SDR helps understand hedging vs speculation dynamics by categorizing volumes of option traded by maturity.

3. The product type (call vs put) can serve as a preview of future spot movement.

4. Option volume gauges underlying volatility regime and turning points.

An example of how we use options flow analysis to understand current market dynamic is from our publication: FX & Vol Strategy Viewpoint: Show me the flow: SDR dive I 27 April 2018 computed using data up to April 2018.

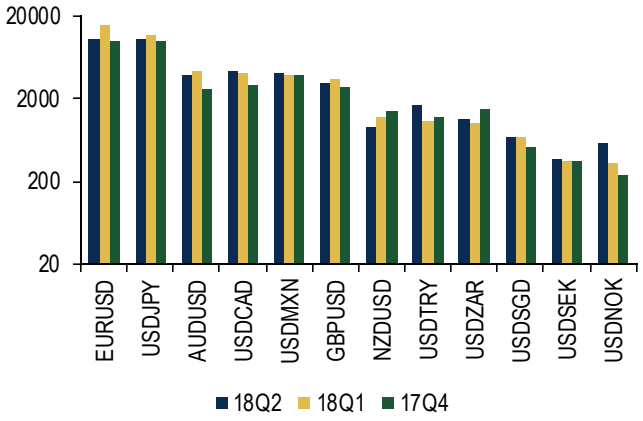
Trace the evolution of volumes

The SDR database can assist execution by tracing market share evolution by currency pairs and product type. Comparing volumes over the last three quarters, we see volume spiked in 18Q1 following the February equity market selloff. EURUSD, USDJPY, AUDUSD have shown larger-than-normal volume traded as the market speculates on sentiment and hedges for a potential meltdown in risk assets (Chart 31). The volume normalized in 18Q2 as the equity market stabilized and broad market risks declined.

By slicing options traded by tenor, 2018Q2 has seen increasing volume in short-term options for USDCAD, GBPUSD and USDSEK from the last quarter (Chart 32). The increasing volume in short-term CAD options indicates that NAFTA is traded as a short-term risk and that demand for longer-term hedges has fallen. The increase in short-term option volume for the GBP and SEK pair shows that near-term Brexit and Riksbank risks dominate the flow.

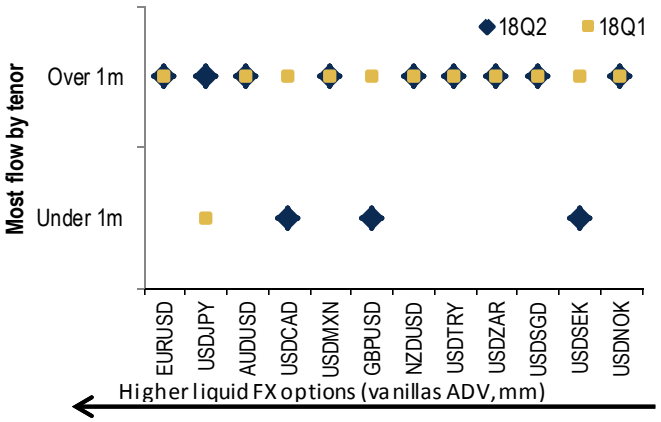
On the other hand, the most popular tenor was over 1 month in April for USDJPY vs. less than 1 month in 2018Q1, suggesting that in the first quarter investors speculated over equity market turbulence using the Yen as a "safe-haven" currency instead of putting on longer-term hedging. The rise in longer-term flow for Yen pairs in 18Q2 could be driven by US treasury yields breaking new levels and anticipating the next two hikes by the Fed later in 2018.

Chart 31: Spike in volumes in 2018Q1 (log scale, ADV mm)



Source: BofA Merrill Lynch Global Research, DTCC

Chart 32: Rising near-term risks in CAD, GBP and SEK



Source: BofA Merrill Lynch Global Research, DTCC

Flashpoints in FX options: NAFTA, oil and geopolitics

Looking at the overall market, the relative share of vanilla options on FX majors since 2013 when the SDR database was first recorded shows that EURUSD and USDJPY account for half of market share (Table 15). Unlike spot where EUR always exceeds JPY flows, in options EUR and JPY often change places for the most liquidity.

EURUSD market share increases over time whereas USDJPY market share decreases, possibly due to fading Abenomics after 2013, while ECB quantitative easing was having a bigger market impact in 2015 (Table 15). CAD and MXN increased market share recently, as NAFTA risk (intertwined with Mexico's election) becomes an important driver of FX movement. Upcoming OPEC meeting is captured by CAD and NOK gaining market share, while Syrian geopolitics and Turkey elections are captured by TRY gains.

Table 15: Relative market share of vanilla options on FX majors (all tenors combined)

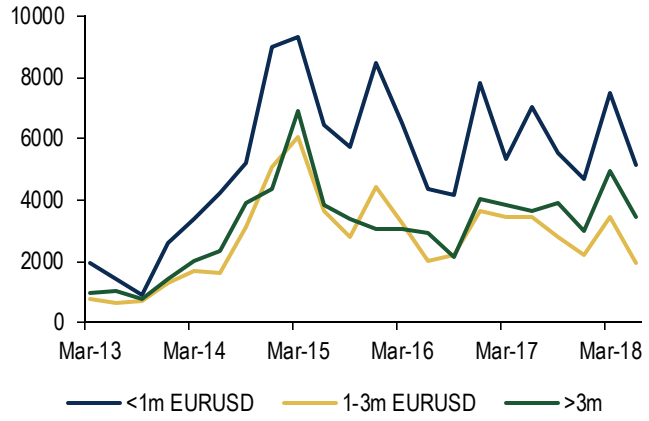
	18Q2	18Q1	17Q4	17Q3	17Q2	17Q1	16Q4	16Q3	16Q2	16Q1	15Q4	15Q3	15Q2	15Q1	14Q4	14Q3	14Q2	14Q1	13Q4	13Q3	13Q2	13Q1
EURUSD	25.0%	33.2%	26.3%	31.6%	35.7%	29.2%	32.1%	23.8%	24.7%	29.9%	44.4%	32.7%	36.0%	40.1%	32.3%	29.2%	28.3%	17.9%	18.9%	14.6%	13.3%	20.0%
USDJPY	25.5%	24.3%	26.8%	26.6%	23.5%	31.0%	29.6%	30.0%	24.5%	25.4%	19.9%	21.8%	25.8%	20.7%	34.5%	29.3%	26.4%	30.5%	40.5%	35.6%	43.8%	31.9%
AUDUSD	9.1%	9.2%	6.9%	8.1%	7.4%	7.4%	7.2%	9.2%	12.2%	11.5%	9.7%	12.2%	8.9%	9.9%	9.1%	9.8%	10.2%	11.7%	11.7%	15.4%	12.4%	8.5%
USDCAD	10.2%	8.4%	8.0%	9.3%	8.2%	7.6%	8.1%	9.1%	10.7%	12.1%	7.9%	11.7%	8.5%	10.1%	7.1%	10.3%	13.6%	18.7%	9.4%	6.2%	7.1%	6.9%
USDMXN	9.8%	8.0%	10.6%	8.2%	7.7%	8.5%	7.1%	9.0%	7.8%	5.8%	2.9%	4.3%	3.4%	2.7%	4.6%	6.0%	6.8%	6.5%	6.0%	7.2%	6.7%	7.5%
GBPUSD	7.6%	7.1%	7.3%	5.7%	7.7%	6.6%	6.3%	9.6%	10.2%	6.7%	4.8%	3.6%	5.8%	4.8%	3.7%	5.5%	3.9%	5.6%	4.2%	6.4%	5.4%	13.3%
NZDUSD	2.1%	2.5%	3.9%	2.8%	2.1%	1.9%	2.1%	2.5%	3.2%	3.0%	2.8%	3.4%	3.3%	2.9%	2.9%	3.2%	2.9%	2.2%	2.1%	2.2%	2.1%	2.1%
USDTRY	4.0%	2.2%	3.1%	2.4%	2.3%	2.5%	2.5%	2.1%	2.1%	1.6%	1.6%	1.8%	2.6%	1.8%	1.6%	1.7%	2.4%	2.7%	1.7%	3.0%	2.6%	2.4%
USDZAR	2.7%	2.1%	4.0%	1.8%	1.9%	1.8%	1.2%	1.3%	1.2%	1.1%	1.6%	1.4%	1.2%	1.2%	0.8%	1.3%	1.8%	1.1%	1.1%	1.2%	1.7%	2.2%
USDSGD	1.6%	1.5%	1.4%	1.7%	1.5%	2.5%	2.9%	2.3%	2.0%	2.0%	3.3%	6.1%	3.4%	4.3%	2.1%	2.3%	1.8%	1.8%	2.3%	5.4%	2.5%	3.1%
USDSEK	0.9%	0.8%	0.9%	1.1%	1.4%	0.6%	0.4%	0.5%	0.7%	0.5%	0.6%	0.5%	0.7%	0.5%	0.6%	0.7%	1.2%	0.8%	1.0%	1.8%	1.1%	1.1%
USDNOK	1.4%	0.7%	0.7%	0.8%	0.7%	0.4%	0.5%	0.5%	0.6%	0.6%	0.6%	0.4%	0.6%	0.9%	0.7%	0.6%	0.7%	0.6%	1.3%	1.2%	1.1%	1.0%

Colors show relative spikes in activity vs. its own history, sorted by 2018Q1 volumes.
Source: BofA Merrill Lynch Global Research, DTCC

Decoupling hedging vs speculation

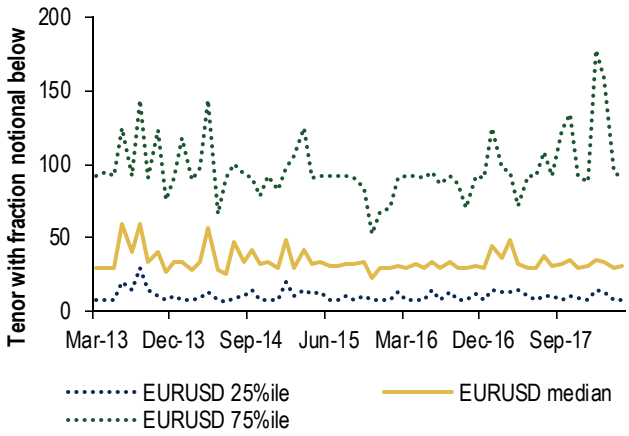
The SDR database also offers important information on hedging and speculative flows. By slicing recorded trades by tenor and computing average daily volume over time, the change of volume over shorter-term tenor relative to longer-term tenor suggests the market's relative demands of speculation over hedging. In our view, flows over 6 months tend to reflect portfolio hedging, while flows under 1 month tend to capture event positioning.

Chart 33: EURUSD vanilla options flows by tenor (ADV, mm)



Source: BofA Merrill Lynch Global Research, DTCC

Chart 34: Half of EURUSD flow has tenor between 8d and 91d



Source: BofA Merrill Lynch Global Research, DTCC

Dividing EURUSD notional flows by tenor

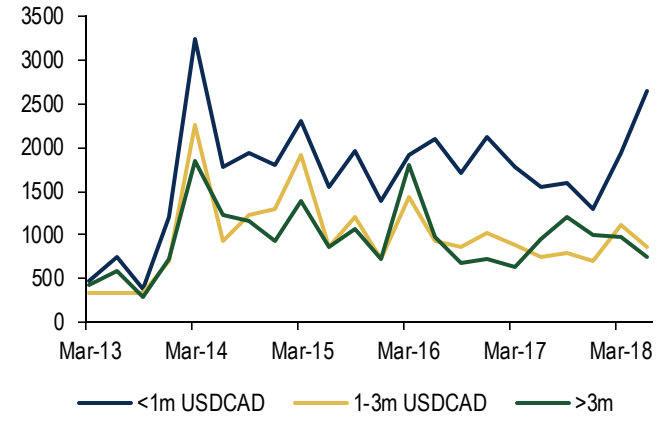
The average daily volume of EURUSD spiked across all tenors during 2015Q1. This pattern has repeated over time (2015Q4, 2016Q4, 2018Q1). The most recent equity market selloff in February 2018 showed increasing option volumes across all tenors (Chart 33). The average daily volume has since normalized as equity market turbulence started to fade by 2018Q2.

By computing the monthly distribution of average daily volume, we found that half of the EURUSD vanilla volumes are executed with tenors between 1 week and 3 months. The 1st quarter of flows takes place with tenors below 8days. Next, the 2nd quarter has tenors between 8d and 31 days. The 3rd quarter has maturity between 31d and 91d (Chart 34) and the final quarter has tenor above 91d. The recent equity market selloff has resulted in a spike in EURUSD's 75th tenor percentile for January, indicating more longer-tenor flows (at that time 4th quarter of notional flows had tenor over 177 days).

Rising short-term flows in CAD and GBP

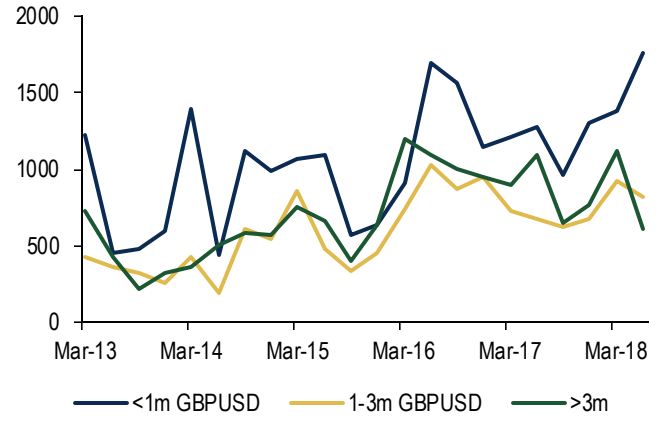
By contrast, volume has been increasing for short tenor USDCAD options in recent months. In our view, the market is trading NAFTA as a more short-term risk and the volume traded for options over 3 months subsequently decreased (Chart 35). The same pattern appears in GBPUSD as the market focuses on short-term risk. Average daily volumes of less than 1 month options exceed historical highs during Brexit in 2016Q2 (Chart 36). Subsequently, volume decreased for longer-term options.

Chart 35: USDCAD vanilla options flows by tenor (ADV, mm)



Source: BofA Merrill Lynch Global Research, DTCC

Chart 36: GBPUSD vanilla options flows by tenor (ADV, mm)



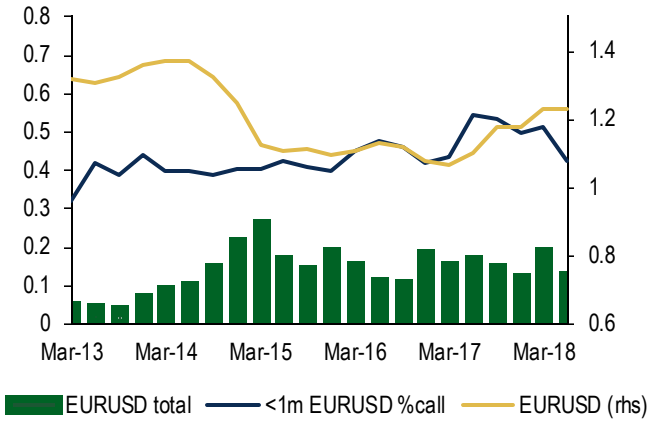
Source: BofA Merrill Lynch Global Research, DTCC

Preview of spot using fraction of puts and calls

The relative demand for puts and calls offers insights of subsequent spot movement. This new database effectively permits the creation of option volume and put-call ratio indicators for FX markets. The put-call ratio is likely to be a useful addition to the positioning toolkit.

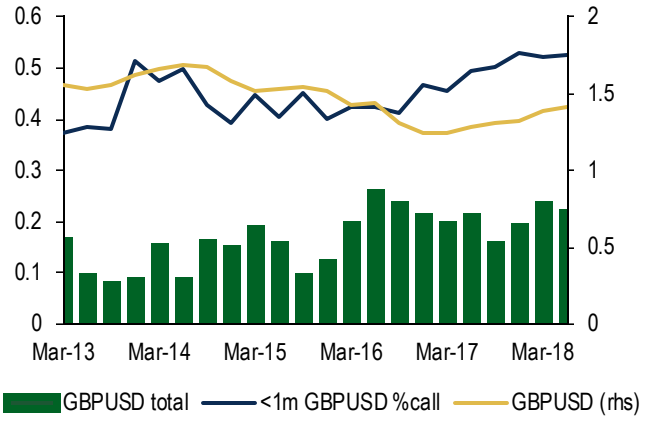
The SDR flow in short-term <1m EUR/USD options leaned more for puts on sustained volumes (Chart 37). In our view, this is a negative signal for the EUR/USD as the options market expects the dollar upside. SDR data was relatively one-sided for GBPUSD, favoring GBP upside. The flow in short-term <1m GBP/USD options leaned more toward calls, saw interest in GBP/USD topside (Chart 38). In our view, the options market is turning more constructive on Brexit transition (The game theory of a UK-EU transition deal and FX implications).

Chart 37: Options flows in <1m EURUSD vanilla calls



Source: BofA Merrill Lynch Global Research, DTCC

Chart 38: Options flows in <1m GBPUSD vanilla calls



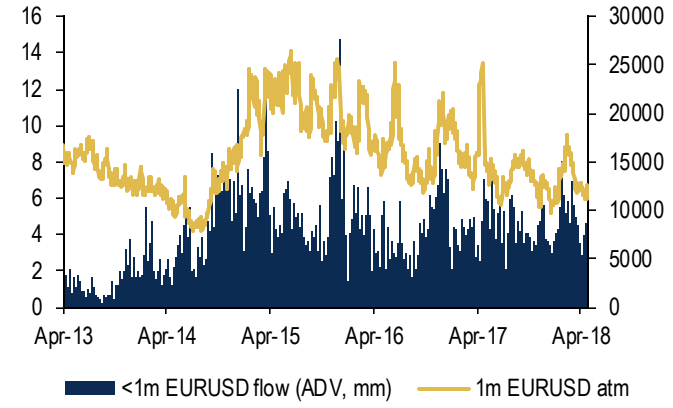
Source: BofA Merrill Lynch Global Research, DTCC

Understanding the volatility regime through volumes

Volume is also an important factor to gauge volatility. Our previous analysis shows a 20-40% correlation between daily FX options volumes and FX volatility. While SDR does not indicate if the trade was buy or sell initiated, we believe most directional information is captured by buy orders looking to gain leverage as compared to spot trades. For the most part, only specialist investors have appetite to sell volatility outright.

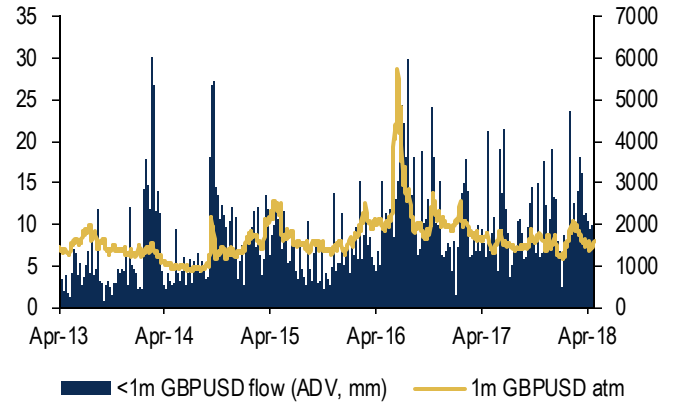
Like spot flows, larger option flows tend to support rising FX volatility. EURUSD volatility spikes when option volumes rise (Chart 39). The lack of EUR catalysts in Q1 suppressed trading in EURUSD options and kept EUR volatility in check. GBPUSD volatility also tracks closely with option flow (Chart 40). Unexpected events such as Brexit caused a sudden rise in volatility and a spike in volume, followed by a calm-down in trading activity and lower volatility.

Chart 39: EURUSD volume and volatility



Source: BofA Merrill Lynch Global Research, DTCC

Chart 40: GBPUSD volume and volatility



Source: BofA Merrill Lynch Global Research, DTCC

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