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FX Volatility

Options have value

- We explore one of the profound macro mysteries of the past year: why is G10 FX vol so low, despite sharp shifts in the macro outlook and manifold risks? In the process, we develop a framework for assessing fundamental – not relative – value in FX volatility.
- We find value in G10 FX options in most pairs – especially EURUSD, USDCAD and NZDUSD – albeit not sufficient to motivate pure long volatility strategies without a strong view on the likelihood of volatility transitioning to a 'high' state.
- For clients with clear directional views in FX, however, we think the current value in FX volatility recommends expression via options rather than spot or forwards.
- For volatility specialists, we provide clear estimates, by currency, of where 'deep value' exists, the likely upside to long-vol positions conditional on remaining in a 'low-vol' environment or switching to a 'high-vol' state, or unconditionally.
- We find the determinants of a volatility 'regime' – low or high – are: 1) dispersion in expected returns to capital across economies; and 2) investor conviction on market themes. The former has been dampened by the compression of global interest rates towards their lower bound, while the latter has been held in check by skittishness induced by the plethora of risks and by divergent macro narratives.
- Although our parsimonious forecasting model suggests a falling probability of transitioning to a higher volatility regime, inclusion of other variables and our subjective judgement based on our broader analysis suggest conditions are building for a breakout of G10 FX ranges and a switch to a high-vol regime.

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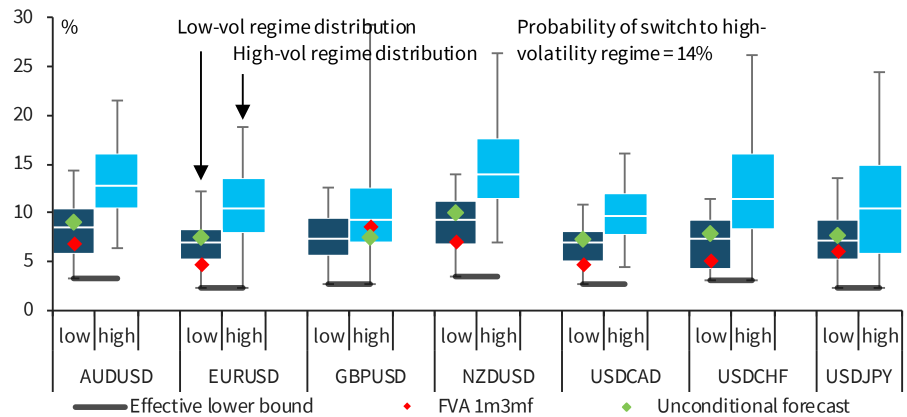
FIGURE 1

Lower than low. Most vols look cheap, even in the low vol regime



Each box represents model implied volatility distribution: bottom of the box - the 10th percentile, top of the box - the 90th percentile, white line in the middle – median. Whiskers represent minimum and maximum value.

Source: Barclays Research

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Executive summary

We explore one of the year's great macro mysteries: why hasn't FX volatility reacted to rising global risks?

One of the great macro mysteries of the past year has been the sustained low level of G10 FX volatility despite a sharp deterioration in the global economic outlook, copious geopolitical risks, manifest and potential, and a more recent pickup in volatility in other asset classes. We explore here the sources of currency volatility and in the process develop a framework for assessing fundamental (rather than relative) value in FX options.

Our exploration provides a framework that helps define 'deep value' in FX options…

We begin by demonstrating, via a conceptual model, that FX volatility does have an 'effective lower bound' (ELB) akin to 'deep value' in assets with tangible value. Using a sophisticated decomposition of high-frequency realised volatility, we establish the specific ELB for several G10 currencies. Our decomposition also highlights an important difference with the last extended period of low FX volatility in 2014 that helps to explain the causes of the current spate. Slightly higher realised vol in the recent period results from high-frequency 'jumps' in reaction to news or data; but the 'normal' or 'continuous' portion of FX volatility generally is lower now than in 2014. This suggests skittish markets that are nervous about manifold risks, but lack conviction on market direction.

…and the potential upside for volatility in either a 'high-vol' world or a continuance of the current 'low-vol' regime

To further identify the sources of FX volatility we note its clear demarcation into extended periods, or 'regimes', of high and low volatility. We develop a 'regime-switching' model that allows for simple macro variables to cause switches from one regime to the other. We identify two highly intuitive drivers of high- and low-volatility states: the degree of dispersion in returns to capital across economies (proxied by interest rate differentials); and markets' conviction regarding macro themes. Our model allows us to define the potential upside in FX volatility, by currency, either conditional on remaining in a low- (or high-) volatility regime, or unconditionally, using the derived probability of a switch in regimes.

These pieces allow us to assess fundamental value in FX options where we find decent value across G10 currencies

Fundamental value in options, by currency, is thus bounded by the ELB-defined 'deep value' and our regime contingent or unconditional estimates of upside. Despite the recent tick higher in vols on central bank policy adjustments and geopolitical events, we find value in G10 options across most currencies; EURUSD, USDCAD and NZDUSD are clear standouts. As illustrated in Figure 1, 3-month forward implied volatilities in most currency pairs are below the median value of even the 'low-vol' regime, albeit far enough above our estimate of the ELB to reduce the risk/reward favourability of pure long-volatility strategies unless one has a strong view on the likelihood of transitioning to the high-vol regime. However, our estimates, by currency, of 'deep value' and the distribution of volatility in the low-vol regime provide clear guidance for volatility specialists as to where vol could be a 'buy'. For clients who have clear directional FX views, we do believe there is sufficient value in vol at present levels to suggest expression via options as preferable to spot or forward expression.

Our analysis also reinforces our expectations for G10 FX ranges to break in the coming year

Finally, while our parsimonious forecasting model does suggest the probability of switching to the high volatility regime currently is falling, incorporating other lagged variables and our subjective judgement based on our analysis suggests that the conditions for ranges in G10 FX to break and volatility to transition to its higher state are building.

The mystery of low G10 FX volatility

With so many global risks, potential and manifest, and so great a shift in the economic outlook in the past year, why is volatility so low?

G10 FX volatility, though off its recent lows, has been stuck in a rut for a year despite seemingly abundant global risks – both potential and manifest – and sharp changes in the global backdrop. As we noted over a year ago in *Vol is a beast with two tails*, the world is awash with an expanding set of geopolitical and economic tail risks. And, indeed, since then, trade wars, Middle East escalation and a no-deal Brexit have shifted from tail risk to realisation or base case (see *When giants collide: A re-escalation*, 13 May 2019; and *No-deal unevenly priced*, 20 August 2019). While tail risks are more related to low-delta option value and the convexity of the volatility smile, their occurrence should have an effect on realised and at-the-money (ATM) vols. More to the point, the significant shift in the global outlook from mid-2018 to the present and the accompanying aggressive rally in global rates normally would presage greater exchange rate movement than the muted ranges that have instead resulted in the past year (compare for instance *Global Outlook: The US, and the rest*, 27 September 2018 with *Global Outlook: Monetary tide keeps markets afloat*, 27 June 2019). Even some of the conditions that we highlighted as helping to restrain FX vol – eg, low cross-asset vol and risk premia – have disappeared in recent months, particularly rates vol and the relentless demand for safety even at the cost of negative interest rates, but without a meaningful pick-up in FX volatility (*Writings on the vol: Don't call it a comeback*, 28 May 2019).

More fundamentally, what are the downside and upside risks to volatility and how long before it picks up?

This perplexing situation provokes three questions regarding opportunities and risks in both FX volatility markets and FX spot. The first question is: *how low can volatility go?* Two alternative ways of expressing this question are: *does the concept of 'deep value' exist in volatility? Or, how much can a long-volatility position lose?* The second question is the dual of the first: *what is the expected value, or potential gain, from a long volatility position?* And finally: *what will cause volatility in FX markets to resume, and how long do I have to wait?*

We provide an analytical framework that identifies 'deep value' and opportunities in G10 FX, explains the stickiness of range trades and reinforces our view that we are edging towards breakout

We provide an analytical framework to answer these questions and conclude that one can call current levels of FX volatility in several G10 pairs, particularly at the 3m tenor, relatively cheap, even if they no longer represent deep value. Further, with appropriate caveats, we conclude that the conditions for a breakout are mounting. Using this framework, we provide estimates of potential upside and downside to long-volatility positions in G10 FX, which currencies offer the best opportunities and a measure of expected time until breakout to a higher volatility regime. But our findings have bearing beyond volatility traders: they inform our views on the direction and timing of FX spot trends breaking out. Despite calling for a G10 range trade last year, we have been surprised by its stickiness into Q3 19 (see *FX & EM Macro Strategy Forecast Update*, 25 September 2018; and *FX & EM Macro Strategy Forecast Update*, 14 March 2019). Our analysis here helps to explain that stickiness but reinforces our view that the range may be loosening.

Is there 'deep value' in volatility?

We posit that FX volatility does have an 'Effective Lower Bound' (ELB), analogous to 'deep value' in assets with intrinsic value

After a long slog lower (and lower) in both realised and implied volatility, the most frequent question we receive from clients considering vol positions is: how much lower can FX volatility go? The experience of 2014 demonstrates that it can go lower, but our fundamental analysis suggests that we are close to what we will call the 'Effective Lower Bound' (ELB) that should represent the volatility analogue of 'deep value' in assets with intrinsic value. To illustrate that the ELB must exist and motivate our empirical analysis, we present a simple conceptual model of FX vol. We then use a sophisticated decomposition of high-frequency realised vol to estimate the ELB, by currency, and finally use that decomposition to show why the current situation is unlike 2014 and that exploitable differences exist across currencies.

A simple model of volatility

A simple conceptual model of sources of FX volatility illustrates why the ELB must exist…

Price volatility results from instantaneous imbalances between buyers and sellers in markets that necessitate a change in price to clear the difference between quantity demanded and supplied. The frequency of such transactions, the size of those instantaneous imbalances, and dealers' willingness to provide interim liquidity determine the size and frequency of resultant price changes that define its volatility. Those factors are themselves functions of the number of market participants, liquidity, positioning, and changes in the information set that change fundamental demand for the financial asset or currency. FX is more complicated than other financial prices as it is a *relative* price that not only matches fundamental cross-country demand for assets (and is itself a financial asset), but also clears commercial transactions between economies. Yet, for our purposes in estimating the ELB, we can simplify FX volatility into two components of demand and supply in currencies:

FX price volatility = Volatility from Commercial transactions +

+ Volatility from active cross-border financial investment[1]

…as FX always will have a minimum level of commercial transactions even when fundamental investment flows go to zero

This simple demarcation of FX volatility into its commercial and financial components – or baseline transactional and fundamental discretionary sources – provides a logical framework for empirical estimation of the ELB. We posit that the greatest sources of price volatility come from shifts in cross-border demand for financial assets associated with changes in view on fundamental sources of returns to capital across economies (see *FX Focus: Exit Doldrums enter hurricanes*, 3 September 2015). Large cross-border asset allocation shifts lead to trending moves it FX, while rapid fluctuations in views on growth, inflation, monetary policy, and risk can cause greater short-run volatility. When changes in fundamental views are few, or when global investors' lack of conviction (as we explain below) may be behind the current lack of volatility, the second component in the equation above falls toward zero, leaving only volatility from commercial transactions.

The minimum level of commercial transactions should provide 'white noise' FX volatility…

The volatility of commercial transactions – in which we would include passive financial investment – is unlikely to be trending, and for more liquid currencies like most of G10, likely to resemble white noise.[2] These flows should lack trend because, even for current account debtors (creditors), prevailing exchange rates – without a fundamental change in investors' views on relative risk-adjusted returns to capital – should be offset by equal financial account inflows (outflows), ie, passive savings flows. The volatility of these flows should resemble white noise as the appearance of both buyers and sellers of FX should be random and associated only with seasonality – that likely is offset by algorithmic trading – and the pace of international commerce.

…that can be estimated as through a decomposition of high-frequency FX volatility into 'continuous' and 'jump' volatility

This framework suggests a path to estimate the ELB based on a decomposition of high-frequency price volatility. If active financial investment is responsible for most trending, day-to-day, and announcement (data release, news) volatility, and then most of the remaining higher-frequency intra-day (high-frequency) volatility will represent the 'noise' of commercial transactions and passive saving flows. By decomposing high-frequency volatility, we can exclude high-frequency 'jumps' related to news and data and isolate the continuous portion that will represent both commercial and the trending portion of active financial flows.

[1] For ease of exposition, we ignore potential covariance terms as they do not affect our analysis. In the case where fundamental active management transactions go to zero, their covariances with other terms also go to zero.
[2] Note: FDI and mergers and acquisitions flows from commercial accounts would represent fundamental investment based on expected returns to capital in this framework, hence would not be represented within 'commercial' sources of volatility.

The lower tail of continuous 'white noise' volatility then likely represents a reasonable estimate of the ELB

We can then estimate the ELB as the lower tail of the distribution of continuous volatility under the assumption that active financial transactions largely have disappeared from the market at that level of volatility – due either to stable views on relative risk-adjusted returns or low conviction – and that commercial transactions have reduced to their bare minimum level. Any remaining 'white noise' volatility represents the effective lower bound (ELB). This measure of the ELB, estimated separately for each currency to account for differing levels of activity and liquidity, should represent the floor below which FX volatility cannot fall.

The 'Effective Lower Bound' (ELB): defining 'deep value' in volatility

We estimate daily annualised rates of 5min realised volatility...

We estimate daily rates of high-frequency realised volatility as the square root of the sum of squared five-minute spot return for a currency.[3] We annualise this measure to make it comparable with realised volatility at lower frequencies and with implied volatility quotations. Our estimates for high-frequency realised volatility are presented, by currency, in Figure 21 through Figure 27 in the Appendix.

Decomposing volatility at a high frequency: continuous and jumps

…and apply a statistical filter to it to decompose daily volatility into 'jump' – discontinuous non-normal moves – and 'continuous' components

We then use a statistical filter, detailed in the Appendix, to decompose high-frequency realised volatility into two parts: 'continuous' volatility, that portion represented by 'small', normally-distributed changes in exchange rates; and 'jump' volatility, the portion that represents 'large', discontinuous moves in exchange rates. Continuous volatility thus measures the trending and 'white noise' components of volatility, while jump volatility – which is not normally distributed – represents discontinuities associated with new information revealed to markets through data releases or news reports that instantaneously change perceived risks or expected returns to capital, or liquidity gaps in markets. Figure 21 through Figure 27 in the Appendix plot alongside total realised volatility our measure of continuous volatility for each currency; the apparent difference between the two is jump volatility.

White noise can't jump

Segmenting out jump volatility leaves only the regular, continuous sources of transactional volatility…

By decomposing high-frequency realised volatility into its continuous and jump components, we can now estimate the effective lower bound of FX volatility by currency. By definition, volatility cannot fall below zero. But the reality is that it will always be a strictly positive number as there always are – for open capital account economies of significant size – commercial and investment transactions occurring. Reduced to minimum necessary commercial transactions, these should result in an underlying 'white noise' level of volatility that will vary by currency liquidity and economy size. Segmenting out jump volatility related to news or liquidity gaps leaves only the continuous, regular cross-border transactions: continuous volatility in our decomposition. However, recall that continuous vol is *not* strictly commercial volatility in our conceptual model; it also represents trending financial transactions. Furthermore, commercial activity waxes and wanes, both in a predictable seasonal fashion and day to day.

…where we focus on the lower tail of residual volatility, specifically the 2nd percentile of continuous volatility as our estimate of the ELB

By focusing on the lowest tail of daily continuous volatility, however, we should exclude lower-frequency trending financial volatility and heavy commercial activity. This should represent the volatility associated with the minimum necessary level of transactions in each currency and as such demark the ELB. For our analysis, we define the 2nd percentile of the historical distribution of continuous volatility as the ELB. We believe this is a reasonable estimate as, empirically, we never observe *total* realised volatility – which includes the jump component – falling below this level, even though by definition 2% of all days have the continuous portion of volatility falling below that level. Hence, we believe our ELB estimate provides a fair assessment of where 'deep value' – fundamental, or intrinsic value – in FX volatility lies.

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[3] This high-frequency measure of volatility is also known as 'integrated volatility'Academic research indicates that sampling financial data at 5-minutes frequency offers the most robust measure of realised volatility, see Liu et al. (2015)

But Antipodeans can

Our decomposition of high-frequency volatility reveals interesting differences through time and across currencies

Figure 3 summarises recent averages of continuous and jump volatility for several G10 FX pairs (vs. USD), and compares those with their long-run averages, the average during the last period of ultra-low volatility, March-September 2014, and our estimate of the ELB. The historical and cross-currency comparisons reveal some notable observations:

i) Although *total* realised volatility now is *higher* than during 2014, the level of *continuous volatility is lower* across most G10 FX.

ii) The difference with 2014 in total realised volatility is that the jump component generally is higher in the current period.

iii) Our estimate of the ELB lies below average continuous volatility in both the 2014 and current periods of depressed volatility, and varies by currency as we expected: lower in the most liquid, internationalised currencies of the G4, somewhat higher in the currencies of smaller economies like the Antipodeans and CHF.

iv) Differences in continuous and jump volatility are notable across currencies:

   a. In contrast to other G10, USDCAD and USDCHF jump volatility is lower now than in 2014, resulting in lower total realised volatility, whereas jump volatility is significantly higher in the antipodean currencies.

   b. The EUR and GBP are the only currencies with higher levels of continuous volatility than in 2014. In the former case, we suspect this reflects rising market concern over the EA economy now versus receding worries in 2014; while we believe Brexit uncertainty has had a persistent effect on GBP's volatility.

Lower continuous and higher jump volatility than 2014 is a possible clue to causes

We view (i) and (ii) as particularly important to explaining why volatility is so low, despite myriad risks, a point that we will return to below. But to understand how it may be related we first explore cross-currency differences in the behaviour of jump volatility.

We can characterise jump volatility by its size and its intensity (frequency)

As noted, jump volatility is the volatility component associated with discontinuous market moves, for example market reactions to incoming data/events. Jump vol is, by construction, the non-normally distributed portion of total volatility, which makes it difficult to model econometrically or to forecast. Yet, we can quantify jumps by *size* and *intensity* (frequency) to analyse differences across time and currencies (see Appendix for details). Figure 28 through Figure 34 present both jump intensity and size for the G10 currencies we examine.

Jump intensities do not have a clear time series pattern – other than being uniformly low in 2014 – but vary notably by currency

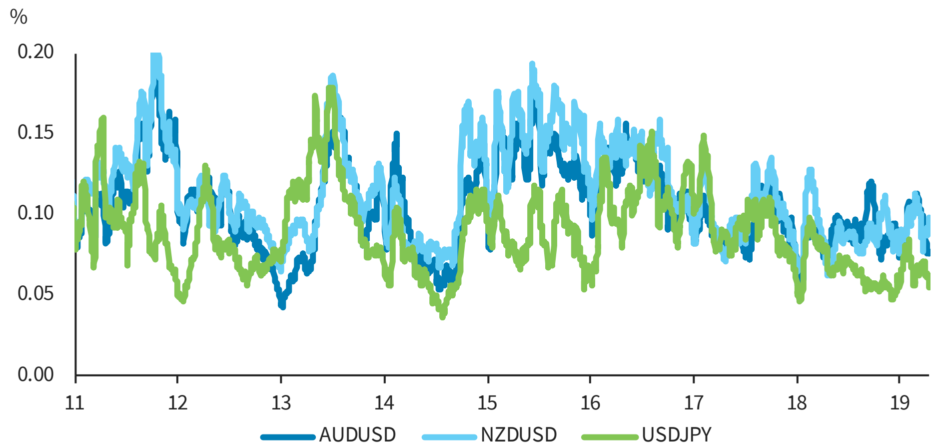
Jump intensities vary through time, but not in a clearly systematic fashion. There is some degree of autocorrelation of jump intensity, but they are relatively stable through time across currencies, though the average intensity is notably higher in CAD, CHF and GBP. The one common time-series pattern apparent in every currency (Figure 28 through Figure 34), is the depressed rate of jumps in early 2014, the last period of ultralow volatility, which accords with our earlier finding that the key difference between then and now is the lower level of jump volatility.

But jump sizes in AUD, NZD and JPY co-move with the level of continuous volatility in a pattern that suggests news affecting risk tolerance may be an important driver

There are more marked differences in jump size, both across currencies and through time. AUDUSD, NZDUSD and USDJPY are particular standouts in this regard, exhibiting *both* the largest absolute jump sizes and correlation between jump size and respective level of continuous volatility. Figure 2 illustrates the high degree of co-movement between these three currencies' jumps. Given market convention that the former two currencies represent 'risk' within the G10 group and the latter currency pair 'safety', the high correlation of jumps in these currencies suggests that news affecting risk tolerance likely is an important driver of jump volatility, a point that we will return to in explaining the difference between the current low-vol period and 2014. Jump intensities for other currencies have larger variation through time, but exhibit less obvious relationships with the level of continuous volatility (Figure 3 and Figure 28 through Figure 34). The systematic differences in jump volatility apparent in some currencies will play a role in our forecasts for volatility below.

FIGURE 2

Average jump size



Source: Barclays Research

FIGURE 3

Descriptive statistics of jump volatilities

	Estimation sample (2011-2019)			Apr-Sep 2014			Jan 2019-today		
	Jump intensity	Avg. jump size	Avg. jump size correlation with continuous vol	Jump intensity	Avg. jump size	Avg. jump size correlation with continuous vol	Jump intensity	Avg. jump size	Avg. jump size correlation with continuous vol
AUDUSD	9.4	0.1	0.4	10.2	0.1	0.2	9.4	0.1	0.3
EURUSD	14.6	0.07	0.39	12.1	0.04	-0.07	14.0	0.05	0.40
GBPUSD	17.2	0.05	0.41	19.4	0.03	0.66	16.63	0.03	0.40
NZDUSD	10.2	0.11	0.48	11.8	0.08	0.19	10.2	0.09	0.48
USDCAD	16.1	0.05	0.33	15.3	0.02	0.04	14.9	0.04	0.43
USDCHF	16.1	0.06	0.54	11.4	0.02	0.31	16.0	0.05	0.50
USDJPY	10.4	0.09	0.50	8.5	0.06	0.32	10.7	0.07	0.54

Source: Barclays Research

Two trends in jump size are apparent: high, likely Brexit-driven GBP jumps, and a trend lower through time in most other currencies

While there is not a clear systematic relationship between jump size and other volatility metrics in other G10 currencies that we examine, there are two notable trends. First, is the elevation of jump sizes in GBP since 2016, which we believe likely is related to sustained Brexit uncertainty and may reflect the withdrawal of segments of market participants that lower overall sterling liquidity. The second trend, visible in all the currencies studied with the exceptions of GBP and to a lesser extent, CAD, is the notable trend lower in jump size through time. In CHF, EUR and JPY the trend is apparent over the entire sample since 2011; in AUD and NZD the trend is visible since 2016 (and in CAD, perhaps, in the last year). The source of the apparent trend lower in jump size is beyond our scope here, but may indicate improving liquidity in G10 FX markets, at least for 'normal' daily transactions. We make just two analytical points about the trend: it explains in part the overall trend lower in realised volatility; but it also serves to highlight how aberrant H1 2014's depression in jump intensity and size across currencies was relative to a generally high level at the time.

Still jump vol is the 'lesser' of the two components; factors driving continuous vol are more important

Yet, jump volatility is only a small portion of overall realised volatility; developments in continuous volatility are far more important to the overall level. We now examine what factors may drive the level of continuous volatility across currencies as they help us to forecast the potential upside to volatility.

Hunting high and low: volatility regimes

We focus next on how high vol may rise and when, by investigating its drivers

A measure of the ELB gives us a sense of 'deep value' in FX volatility and how low it can go; but to understand how much volatility may rise – ie, how much long-vol positions can gain – and importantly, *when*, we need a framework to understand what drives the overall level of volatility through time. We first note that realised volatility's time variation exhibits a pattern of high and low periods, or regimes. We then show those are mostly a function of the continuous portion of volatility, and finally provide a model to explain what drives regimes of continuous volatility, enabling us to forecast volatility in the next section.

Apparent volatility regimes

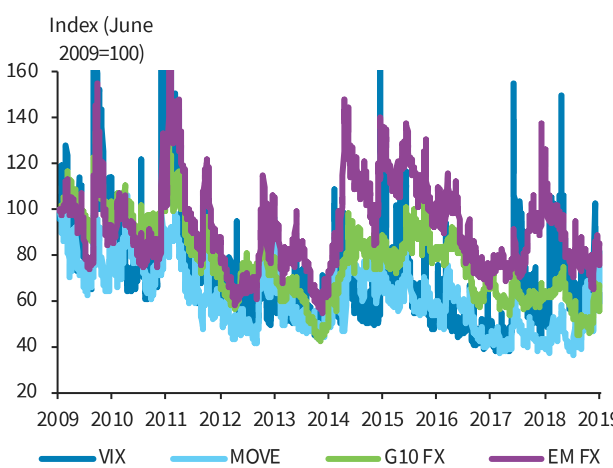
Volatility 'regimes' are clearly apparent across asset classes and within FX these regimes are associated with shifts in continuous volatility

Volatility 'regimes' across asset classes are clearly apparent: extended periods of high vol and low vol can be seen in measures of equity, bond, G10 FX, and EM FX volatility since 2009 (Figure 4). Volatility across asset classes remained high in the immediate aftermath of the Global Financial Crisis (GFC) before falling to relatively depressed levels in 2012-14, picking up again in the middle of the decade, and falling back to depressed levels since late 2016. Figure 5 focuses on G10 FX volatility showing both average total realised volatility since 2000, and the first principal component of continuous volatility across the currencies we study here. The volatility regimes are clear: high in the early '00s, post GFC and mid-decade; low in the late '00s, early '10s and more recently. Also clear is that this is primarily a function of changes in the level of continuous volatility. As noted previously, other than a persistent trend lower and an aberrant depression in early 2014, jump volatility does not display clear, consistent time variation across currencies to explain these cycles of volatility.

Further, FX vol across currencies is highly correlated…

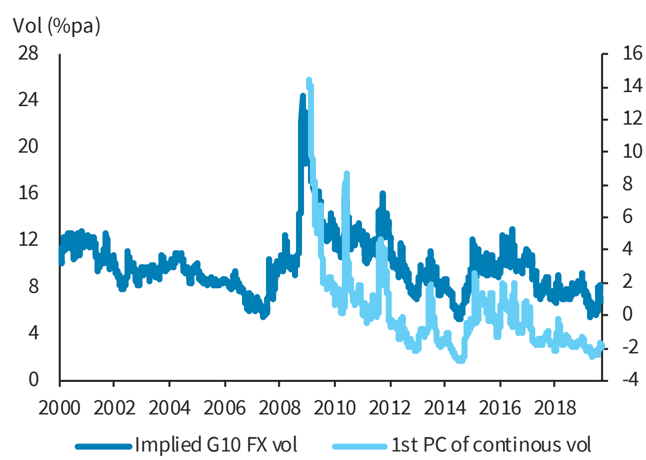
While individual currencies do exhibit some idiosyncrasies in both realised and continuous volatility, we find that most of their time variation can be explained by a common element. The first principal component of the continuous volatilities of the currencies we study here, shown in Figure 5, explains 83% of the total variation *across* these currencies. This also is apparent in the high degree of cross-correlation of continuous volatility for these currencies (Figure 6).

FIGURE 4
Normalised cross-asset 3m implied volatilities



Source: Bloomberg, Barclays Research.

FIGURE 5
Implied G10 FX volatility and 1st principal component of continuous volatility across currencies



Source: Bloomberg, Barclays Research

…suggesting common macro drivers

These findings suggest that there is likely is a common macro driver of low and high volatility regimes and that continuous volatility is an appropriate summary measure. This accords well with our earlier simplified model of sources of volatility: volatility associated with active cross-border financial (and fundamental) investments likely is driven by a macro phenomenon that will be common across FX markets, as well as other asset classes.

Macro drivers of volatility regimes

We propose and find evidence that the common drivers are returns divergence and investor conviction

We propose, and find evidence, that two related macro forces drive levels of volatility: divergence in expected returns to capital across economies and conviction of market participants' views regarding that divergence. We find the former is more statistically reliable in forecasting volatility, but the latter is important both to understand the behaviour of FX markets and to form subjective judgements about likely shifts in volatility regime.

Differences in broad returns to capital are a primary driver of currency direction in our framework, suggesting that they also play a key role in driving FX volatility

Along with lower-frequency movements in underlying currency value (ie, purchasing power parity), perceived movements in relative, risk-adjusted returns to capital are the primary drivers of currency trends and volatility under our framework (see *Three Questions: Top dollar*, 4 June 2015; and *Changeup*, 18 January 2018). As such, they are our first port of call in trying to understand the drivers of currency volatility regimes. While imperfect, especially with several economies at or flirting with the effective lower bound for interest rates, interest rate differentials are a useful proxy for broader returns to capital differences. To measure this on a multilateral basis, we plot in Figure 7 two measures of G10 interest rate dispersion, maximum less minimum and the standard deviation across G10 economies, alongside the first principal component of continuous volatility from the currencies in our study. There is an obvious and strong relationship between the levels of interest rate dispersion and level of volatility, suggesting that perceived divergence in returns to capital is a primary driver of FX volatility regimes as it leads to cross-border asset allocation shifts.

FIGURE 6
Continuous volatility correlation

	AUDUSD	NZDUSD	USDCAD	EURUSD	GBPUSD	USDCHF	USDJPY
AUDUSD	1.00	0.97	0.89	0.80	0.80	0.64	0.64
NZDUSD	0.97	1.00	0.88	0.78	0.79	0.62	0.66
USDCAD	0.89	0.88	1.00	0.78	0.78	0.62	0.62
EURUSD	0.80	0.78	0.78	1.00	0.72	0.76	0.53
GBPUSD	0.80	0.79	0.78	0.72	1.00	0.50	0.65
USDCHF	0.64	0.62	0.62	0.76	0.50	1.00	0.41
USDJPY	0.64	0.66	0.62	0.53	0.65	0.41	1.00

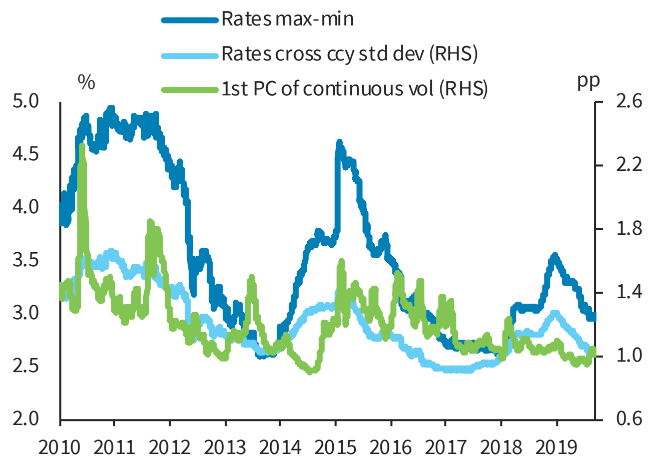
Source: Barclays Research

But in a world of incomplete information, conviction around divergence likely also plays an important role in FX vol

However, in a world of incomplete information, actual and perceived divergence in returns to capital may differ. If conviction in divergence of returns to capital differences is low, investors are unlikely to act on the divergence in their asset allocation decisions. This implies that investor conviction over relative returns to capital opportunities also may be important in determining the level of volatility.

FIGURE 7

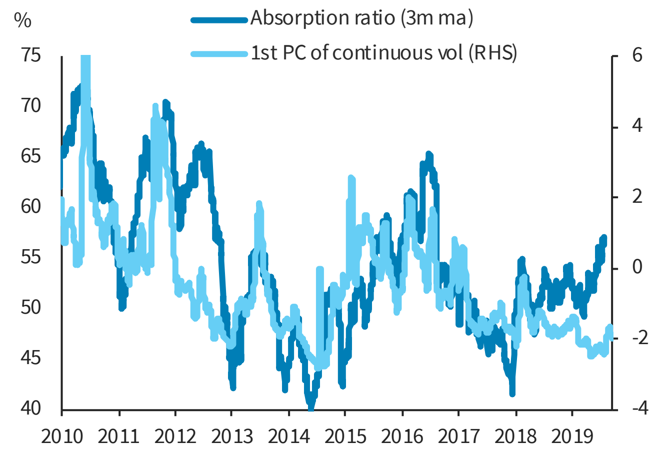
Dispersion in G10 interest rates



Source: Bloomberg, Barclays Research

FIGURE 8

1st principal component of continuous vol vs. absorption ratio



Source: Bloomberg, Barclays Research

The 'absorption ratio', a measure of co-movement of a broad range of asset prices and currencies, is a convenient measure of macro conviction

One measure of market conviction in macro trends that we have used previously is the 'absorption ratio': a measure of co-movement among a wide spectrum of global asset prices and exchange rates (see *FX Focus: Exit Doldrums enter hurricanes*).[4] If market participants have high conviction around global themes, particularly divergences in sources of returns to capital across economies or asset classes, then asset prices should display a high degree of contemporaneous co-movement. If instead, conviction in macro fundamentals is low, idiosyncratic drivers of assets and currencies will dominate price movements and correlation across prices will be low.

Both interest rates dispersion and the absorption ratio display strong concordance with FX vol

Figure 8 plots the absorption ratio versus the first principal component of continuous volatility for the currencies in our study. As with interest dispersion, there is a high degree of concordance between the two series, particularly in level, suggesting that macro conviction also is an important determinant of volatility regime.

But recently, these two series have diverged in their implications for volatility

Both expected return divergence and conviction around those expectations played unambiguous joint roles in the depressed levels of FX (and broader asset) volatility in 2014 as well as the trend lower in volatility levels after 2016, but have been more discordant and less clear in the further fall since end 2018. Interest rate dispersion picked up in 2018 – albeit it has fallen somewhat in 2019 – while the absorption ratio demonstrated persistent medium-low conviction. We see this divergence, along with elevated level of jump volatility relative to 2014, as clues to the causes of current low volatility and the likelihood of a breakout from recent currency ranges.

Modelling regime switches

We test our theory of volatility 'regimes' with a 'Markov-switching' model that endogenises these macro drivers of volatility

With two clear drivers of volatility regime identified – returns to capital dispersion and market conviction – we test our theory of continuous volatility regimes with a parsimonious econometric model that allows for two states, 'high vol' and 'low vol'. Our endogenous 'Markov-switching' model allows for time variation in macro trends to identify the duration and likelihood of a shift from a low volatility regime to a high volatility regime and vice versa. This allows us to forecast forward volatility in the next section. Full details of the model are in the Appendix.

[4] We use the first principal component from daily changes in 21 exchange rates and 17 international asset markets, including rates, credit, equities, and commodities as our measure of the absorption ratio. For more information, see 'Principal Components as a Measure of Systemic Risk,' by Mark Kritzman, Yuanzhen Li, Sebastien Page, and Roberto Rigobon, MIT Sloan Research Paper No. 4785-10, 30, June 2010.

We simplify our model for stability and to facilitate forecasting by focusing on rates dispersion as the main driver of volatility regimes

Under our starting assumption that volatility regimes are time varying and related to broader macro variables, we tested several macro variables in addition to returns to capital dispersion, proxied by interest rate dispersion, and macro conviction measured by the absorption ratio. Other candidates included measures of risk appetite, financial conditions and economic dispersion. However, we found that additional complications reduced the stability and forecasting ability of our endogenous regime switching model. Indeed, we found that while the absorption ratio has a strong contemporaneous relationship with volatility regimes, it added little forecasting power – in part because its construction has a significant backward-looking component – and hence simplified the endogenous probability function to one based solely on interest rate dispersion.

Our model confirms the intuition that returns differentials drive asset allocation flows that lift FX volatility

More precisely, we find that the higher the dispersion in rates – defined as the difference between the highest and lowest 3-month G10 interest rate at each point in time (Figure 7) – the higher the probability of staying in the high volatility regime if volatility is already in it, and similarly the higher the probability of switching to it, if vol is stuck in the low vol regime instead. This result is rather intuitive, in our view. Indeed, the persistent widening in rate differentials between the US and the rest of the world in 2015, as the Fed commenced with rate hikes, resulted in an eventual pick-up in FX volatility.

Time varying probabilities of a switch

Our model allows us to form time-varying estimates of the probability of switching from one vol regime to the other

By endogenising the likelihood of switching from a high volatility regime to a low volatility regime, or vice versa, the model provides a time-varying estimate of the switch probability that can be used in forecasting. Figure 9 reports estimated probabilities of switching from the prevailing volatility regime at any given point in time. Indisputably, FX vol was in a low regime in the first half of 2014, but the probability of switching to a higher vol regime was mounting, rising from 5% to 23%.[5] Half way through H2 2014, the volatility regime changed to the high one as rates dispersion further widened.

'Mom, are we there yet?': Estimated duration until a switch

These probabilities can be translated into a measure of expected duration of the current volatility regime

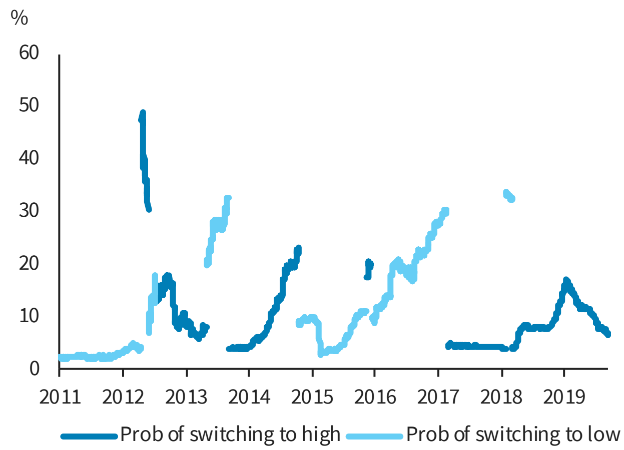
These probabilities also can be mapped to the expected duration of the current volatility regime – high or low – ie, how long before the regime is likely to switch. On an unconditional basis, we find that high volatility regimes average 230 (business) days, while low volatility regimes last about 192 days. This also means that once continuous volatility is stuck in either regime, the unconditional probability of switching is rather low. However, the *conditional* probability of a switch – conditioned on the degree of interest rate dispersion in our model – is time varying providing an estimate of the likely duration of the current volatility regime at any point in time (Figure 10).

The expected duration of the current low-vol regime shrunk as US rates diverged from the rest of the world in 2018 but has begun to rise with the rally in global rates

At present, FX markets appear to be stuck in the low volatility regime. The expected duration of staying in this regime had begun to markedly shrink last year, largely reflecting increased dispersion in G10 rates. However, the aggressive rally in global fixed income, led by US rates, is once again reducing interest rate dispersion and with it the potential for breakout from the current low volatility regime (see *FX & EM Macro Strategy: Writings on the Vol: Don't call it a comeback*, 28 May 2019). However, it is important to note that interest rates dispersion is a proxy for actual returns to capital dispersion, which we believe is the real driver of FX volatility. Growth differentials have compressed less, raising the potential that interest rates are giving a false signal, a point that we will return to in the final section.

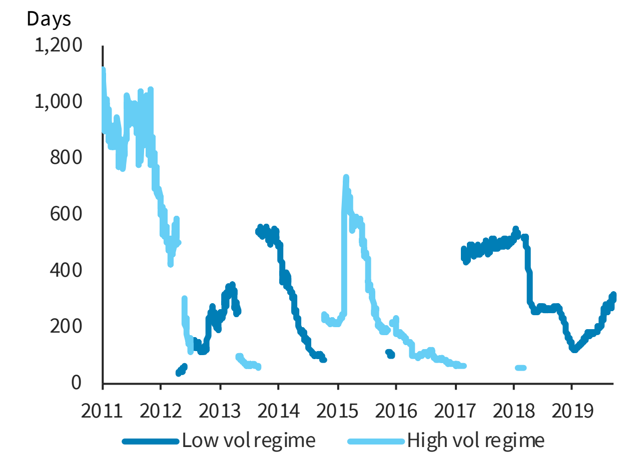
[5] Note that the probability of a switch is sensitive to the model's threshold choice, hence the change in relative conditional probability is more informative than its level. As seen in Figure 8, probability of a switch rarely exceeds 25% and never exceeds 45%.

FIGURE 9
Expected probability of switching to a different monthly volatility regime over the next month



Source: Barclays Research

FIGURE 10
Expected durations of remaining in current vol regime



Source: Barclays Research

Our model suggests still low, but higher than historical average likelihood of transition to the high-vol regime.

Figure 11 puts our model estimates in context, displaying our estimates for the likelihoods of shifting to a high volatility regime at various forward dates or within that horizon, and comparing those to historical averages. The probability of monthly volatility breaking out of the low-volatility regime remains lower than its historical average according to our model, amounting to 7%, 20% and 36%, over next one-, three- and six-months, respectively. However, some caution is necessary in interpreting these conditional probability estimates as they are sensitive to threshold specification in the model and hence better seen as ordinal rather than cardinal. Still we report for completeness and because we use these estimates in our volatility forecasts below.

Opportunities knock: where value lies in FX vol

Our model suggests that despite the recent pick-up in vol may be cheap for clients with directional views or a strong view that a shift to the high-vol state is imminent.

Armed now with estimates of ‘deep value’ in volatility, the ELB, and a model to predict how long until the continuous portion of volatility shifts to a higher regime, we can well define the risk-reward of long (or short) volatility positions. Our modelling suggests that value exists in ATMF options on most G10 FX pairs under six months, especially so in EURUSD and USDCAD, albeit not necessarily compelling enough to warrant non-directional long volatility positions unless one has a strong view on the likelihood of a break to the higher-volatility regime. But for clients with directional views on spot, the value we find in current implied volatilities suggests expression via options may be preferable to forwards or spot.

FIGURE 11
Volatility regime probabilities

	Probability of realised volatility being in 'high' regime in exactly X months		Probability of realised volatility being in 'high' regime within X months	
	Historical average	Current probability	Historical average	Current probability
1-month	8.9%	6.3%	9.5%	7.1%
3-months	21.8%	14.3%	25.8%	19.9%
6-months	32.9%	19.7%	45.0%	35.8%

Source: Barclays Research

Downside risks to long volatility

The ELB, by definition, defines where deep value lies in FX volatility.

By definition, the ELB should define how low FX volatility can go and where deep value is. While our assumption of the second percentile of our estimate of the continuous volatility distribution of each currency may be somewhat *ad hoc*, it appears to have empirical validity: as noted previously, total realised volatility only very rarely falls below it in the currencies we study within our 2011-present sample.

FX vol's recent uplift has removed it from deep value, but still looks low in historical terms

Figure 12 gives an indication of current 'deep value' in G10 FX. Reported, by currency, are realised FX volatility in the last 30 days, our estimates for the ELB, and the current percentile and historical average of realised vol based since 2011. The recent modest step-up in volatility has lifted all currencies significantly above the ELB. But, with the exception of GBP, all currencies are below their respective historical medians, with most near or within the first quartile of values. Despite the recent uplift in rates of volatility, these numbers suggest that vol remains relatively muted across G10. However, we can further refine the potential for upside by breaking down the distribution of FX volatility across currencies into high- and low-vol regimes.

FIGURE 12

Realised and model predicted volatilities

	Realised 30-day vol*	ELB	Current percentile	Historical average realised vol
AUDUSD	6.99	3.37	0.12	11.06
EURUSD	5.88	2.37	0.17	9.02
GBPUSD	9.13	2.77	0.58	9.10
NZDUSD	7.95	3.42	0.17	12.10
USDCAD	5.33	2.78	0.11	8.55
USDCHF	6.58	3.10	0.20	9.99
USDJPY	6.89	2.37	0.33	9.52

Source: Barclays Research. *Realised volatility is calculated using data until 13 September 2019

Versus the potential for gain

Our model of volatility regimes allows us to estimate not only the likelihood of switching regimes, but the distribution of returns to vol within each regime

But how much upside is there to a long vol position (or downside to short vol positions)? Our modelling of regimes of continuous volatility allows us to estimate both the likelihood of shifting to a different volatility regime and the conditional distribution of returns within each regime; ie, what the potential upside of long volatility positions are if we remain stuck in a low-volatility regime or switch to the high-vol state. However, the continuous volatility estimates miss the contribution of jump volatility, which as we saw above varies by currency through time, sometimes systematically with the level of continuous volatility. We address that by projecting our global continuous volatility measure onto future values of *total* realised volatility for each currency pair. This means that our conditional distributions for low and high volatility regimes capture the historical proportional response of jump volatility as well.

We 'bootstrap' total realised volatility distributions under both regimes to recapture the jump component of vol…

More specifically, we use our regime switching model of continuous volatility with 'bootstrapped' total realised volatility to estimate not only the expected values of realised volatility in both the high- and low-volatility regimes, but also the complete distributions of realised volatility in each regime. The bootstrap from realised volatility distributions allows us to re-capture the jump component of volatility – and any systematic time variation in it – as well as the non-normally distributed, currency-specific characteristics of volatility in each currency, while maintaining our delineation of volatility into macro-driven low and high volatility states.

…as illustrated in Figure 13 and Figure 14 for AUDUSD and EURUSD (with other currencies in the Appendix)

Figure 13 and Figure 14 illustrate the overlapping distributions of monthly realised volatility in low- and high-volatility regimes that we estimate for AUDUSD and EURUSD under our model. We also impose our effective lower bound of vol on these distributions, which is visible as a spike on the left side of low volatility distribution. Estimated distributions for the other G10 currencies in our study are found in Figure 35 through Figure 41 in the Appendix. Note, these distributions are constant through time; it is the probability of switching from low to high (or high to low) volatility that is time varying under our model.

These estimates of the non-normal distributions of volatilities in high and low regimes allow us to better demarcate value in FX volatility as regime dependent

With these distributions and our model of regime-switch probabilities, we now can provide a range of estimates for the potential upside to long volatility positions (or, equivalently, risk to short-vol positions). Because the distributions are non-normally distributed, we focus on medians as a measure of expected value. The median of the low-volatility regime distribution represents the expected upside to realised volatility, conditional or remaining in the current low-vol regime. The median of the high-volatility distribution represents the upside, conditional on shifting to the high-volatility regime, the probability of which is estimated by our model. By weighting these estimates by the probability of a regime switch, we obtain, as well, an unconditional expected value for volatility.

Does currency vol still offer value?

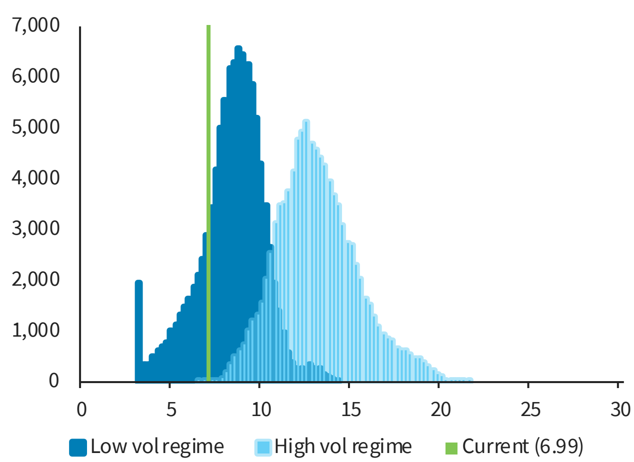
Despite the rise in volatilities off their recent lows, for all currencies except GBP realised vol remains below the median of the low-vol regime distribution

Figure 15 summarises these measures across currencies and presents a complete picture of where value lies in G10 FX volatility markets. For each currency, we present the most recent 30-day realised volatility, our estimate of the ELB, the 10th, 50th (median) and 90th percentiles of both the high- and low-volatility regime distributions, and current forward implied volatilities. It is striking that all current realised volatilities lie below median volatilities obtained from the low-vol regime, with EURUSD and USDCAD nearer their respective 10th percentiles.

Comparing with forward implied volatilities our estimates imply value still exists in G10 FX, particularly EURUSD and USDCAD

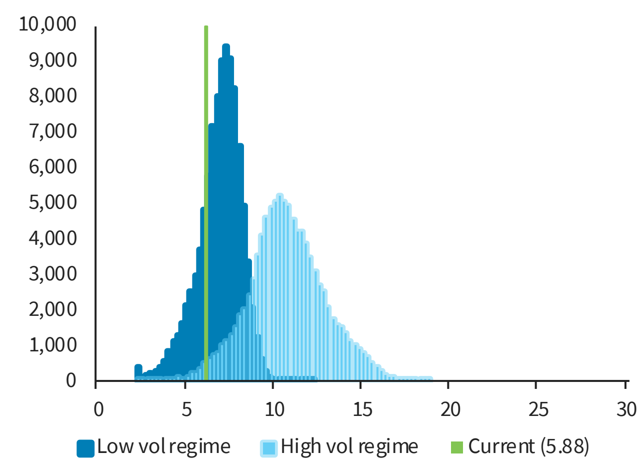
But the real measure of value is seen in comparing our estimates for likely volatility outcomes in each regime with the forward implied volatilities in the final three columns of Figure 15. With the exception of GBP, all the forward implied vols lie below the median of the low vol regime and (excluding USDJPY) below the 10th percentile of the high vol regime. In EURUSD and USDCAD 1m and 3m forward options, implied vols are nearer the 10th percentile of the *low-vol* regime and is below that in 1m3mf EURUSD options. Collectively, the picture presented by Figure 15 suggests that most G10 FX vols still offer value, albeit not the deep value that prevailed earlier this year.

FIGURE 13
AUDUSD vol regimes distributions



Source: Barclays Research

FIGURE 14
EURUSD vol regimes distributions



Source: Barclays Research

FIGURE 15

Low- and high-vol regimes distributions/median projected vols vs. market implied FVAs

			Low-volatility regime			High-volatility regime			Implied vols		
	Realised 30-day vol*	ELB	10th percentile	Median	90th percentile	10th percentile	Median	90th percentile	1m1mf	1m3mf	1m6mf
AUDUSD	6.99	3.37	5.84	8.55	10.38	10.40	12.89	16.08	7.37	6.90	7.93
EURUSD	5.88	2.37	5.18	7.03	8.27	7.93	10.56	13.53	5.56	4.83	5.92
GBPUSD	9.13	2.77	5.56	7.35	9.51	7.02	9.24	12.60	12.95	8.65	8.36
NZDUSD	7.95	3.42	6.73	9.33	11.26	11.37	14.01	17.73	7.60	7.13	8.26
USDCAD	5.33	2.78	5.00	6.89	8.15	7.82	9.77	12.00	5.55	4.78	5.94
USDCHF	6.58	3.10	4.18	7.31	9.21	8.25	11.42	16.07	5.91	5.22	6.42
USDJPY	6.89	2.37	5.25	7.22	9.25	5.84	10.50	14.95	6.50	6.01	6.73

Source: Barclays Research. *Realised volatility is calculated using data until 13 September 2019

Consolidating our estimates into a forecast for volatility using our estimated regime shift probability, we find value particularly in 3m forward options

Figure 16 consolidates our estimates for potential upside in the low- and high-volatility regimes into forecasts for forward volatilities in each currency by weighting the median volatilities in each regime with our estimates for the probability of switching regime. Recall that we estimate FX vol may switch to the high regime in one-, three- and six-months with probabilities of 6%, 14% and 20%, respectively. GBP again is exceptional in having implied volatilities above our forecasts for future volatility for one-, three- and six-month forward options. For all other currencies except the JPY six months forward, current implied volatilities are below our consolidated estimates of future volatility. Particularly at the 3m forward tenor, implied volatilities look cheap relative to our forecasts with most implied volatilities 200bp or more below our estimates.

FIGURE 16

Decomposition of realised volatility into continuous and jump volatility, and the effective lower bound of volatility

					Model predicted			Implied vols		
	Realised 30-day vol*	ELB	Median - low vol regime	Median - high vol regime	1m1mf	1m3mf	1m6mf	1m1mf	1m3mf	1m6mf
AUDUSD	6.99	3.37	8.55	12.89	8.83	9.17	9.41	7.37	6.90	7.93
EURUSD	5.88	2.37	7.03	10.56	7.25	7.53	7.72	5.56	4.83	5.92
GBPUSD	9.13	2.77	7.35	9.24	7.47	7.62	7.73	12.95	8.65	8.36
NZDUSD	7.95	3.42	9.33	14.01	9.62	10.00	10.25	7.60	7.13	8.26
USDCAD	5.33	2.78	6.89	9.77	7.07	7.30	7.46	5.55	4.78	5.94
USDCHF	6.58	3.10	7.31	11.42	7.57	7.89	8.12	5.91	5.22	6.42
USDJPY	6.89	2.37	7.22	10.50	7.43	7.69	7.87	6.50	6.01	6.73

Source: Barclays Research. *Realised volatility is calculated using data until 13 September 2019

How cheap depends on one's views on the likelihood of a vol breakout or having a directional view on FX spot

While cheap in relative terms these numbers do not make a compelling case for long-volatility strategies unless one has a strong view that a breakout to the high-vol regime is imminent. However, for clients with directional views on currencies, these calculations do suggest that expression through options may have more value than forwards or spot. We next turn to whether or not one should have a strong view on regime shift to higher volatility.

When will the ranges break?

Partial convergence of interest rates and frustratingly stubborn range trading reinforce market perceptions of sustained low vol, but we see reasons to expect a G10 vol breakout

While our estimates suggest both near- and long-term value in long G10 volatility still can be had, many market volatility investors are justly sceptical after a year in the low volatility regime has proven frustratingly costly to long-vol positions. The stubborn resistance of EURUSD, in particular, to (yet) definitively break lower despite the ECB's '*QE for ever and a day*', reinforces markets' scepticism that FX vol is on the verge of a break higher. Further, as noted, the sole macro driver of our time varying regime switch probability, interest rate dispersion, recently has declined implying a lower probability of a regime switch. However, we think that a subjective review of our findings and current market conditions suggests that a breakout in G10 volatility from recent ranges may be more likely than our parsimonious model would imply.

Revisiting sources of low volatility

The absorption ratio measure of macro conviction may help explain recent low vol and indicate the potential for a breakout

Recall that our analysis of volatility regimes focused on two key macro drivers of overall volatility level: returns to capital dispersion and macro conviction among cross-border investors. Using interest rate dispersion as a measure of the former, we noted that despite our model prediction that increasing G10 rates dispersion would lead to elevated FX volatility, after a temporary rise in volatility at the early stages of Fed tightening, FX volatility fell into a low-vol regime even as rates dispersion widened significantly in 2018. This is all the more perplexing, as we noted in the introduction, given the expanding set of macroeconomic and geopolitical risks during the same period. While we excluded the absorption ratio, measuring macro conviction, from our regime-switching model because its intrinsic lag structure inhibits its use in forecasting, its strong contemporaneous relationship with the level of volatility and persistent low level in recent years help resolve the apparent mystery and suggest a breakout in volatility may be closer than diminished rate dispersion would indicate.

Investment paralysis

FX volatility remained low in 2018 despite an acceleration in interest rate dispersion as markets questioned the US economy's ability to sustain divergence and conviction fell

We posit that while actual returns to capital dispersion did rise sharply – particularly in favour or the US – as illustrated by the rise in relative US rates, markets lacked conviction in its durability. Note that as G10 interest rates dispersion increased in 2014-15, the absorption ratio simultaneously increased and indeed followed through into 2016; yet interest rate dispersion accelerated in 2018 but our measure of macro conviction failed to rise further (see Figure 7 and Figure 8). This was consistent with commentary from the period and persistent client conversations that indicated doubts the US economy and returns could persistently deviate from the rest of the world, particularly as the USD became overvalued. Indeed, there were two distinct phases of this narrative: in 2017 expectations were that the rest of the world would converge upward to US returns to capital, while in 2018, as data began to disappoint outside the US, the narrative shifted to the US economy converging downward to the rest of the world.

Interest rate markets continuously second-guessed divergence of US rates throughout the Fed's hiking cycle and recent 'mid-cycle adjustment'

Low conviction in returns dispersion also has been apparent in interest rate markets. Throughout the Fed's persistent march higher in policy rates in 2017-18, market pricing displayed consistent doubts about how much further the Fed could tighten policy, with frontend rates uniformly below the Fed's 'dot plot' projection of future rates. As growth has weakened globally and the Fed has turned to proactive risk mitigation, rates markets have projected rapid US rates convergence as US rates have rallied far more aggressively than their global economic peers (see Figure 17).

Elevated jump volatility, particularly in AUD, NZD and JPY, amid depressed continuous vol suggest skittish markets that are highly reactive to newsflow but lack conviction on any one theme

At the same time, the rapid expansion of macroeconomic and geopolitical risks during the period diluted investor focus on specific macro themes – information overload – and accentuated investor unease over the ability of the US to sustain divergence. Both undermined market conviction. This is apparent not only in the low level of macro asset correlation illustrated by the absorption ratio, but also in the increased level of jump volatility that we observe during the current low-volatility regime relative to the 2014 period. Recall that we found this higher level of jump volatility was concentrated in correlated jumps in AUD, NZD and JPY suggesting it is associated with accentuated high-frequency changes in risk tolerance in reaction to news flow. This pattern, in conjunction with the depressed level of continuous vol and lack of market trend, is consistent with investors having a heightened sense of anxiety associated with numerous macro risks, but having low conviction over their implications.

Actual convergence? Or perceived?

A cautionary signal for relying on rates markets comes from actual growth, which has not converged as much. Despite slowing, US growth continues to significantly outpace G10 peers

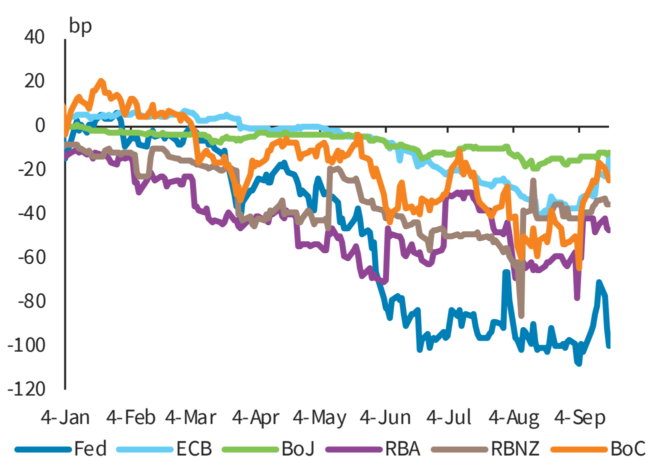
However, the convergence in economic performance has not been nearly as uniform as the projection by rates markets. The fading effects of the US tax stimulus, an 'industrial recession' in the rest of the world and trade frictions have weighed on the US manufacturing sector recently, but US domestic demand and employment growth have sustained at an above trend pace. As illustrated in Figure 18, the convergence of US growth with other advanced economies has been far less apparent than interest rate markets would imply. The US is not alone; Japanese economic activity also has remained strong amid trend weakening in China, Europe and EM. While we expect the Fed to ease policy further to offset manufacturing weakness and risks from trade and foreign economies, we project US rates to remain well above those of other G10 economies, where we forecast persistently low and falling policy rates. Further, the Fed cuts we project support a solid rebound in US growth next year, even as other parts of the global economy slow.

Our expectations for that sustained outperformance of the US are behind our expectations for USD appreciation and a likely pick-up in volatility as market conviction in convergence returns to sustained divergence

Our forecasts for sustained USD strength, particularly versus European currencies, are based in part on rising market acceptance that the US economy, and ultimately US rates, are not fully converging with the weakness apparent in the rest of the world, at least not as rapidly as rates markets would imply. As market conviction coalesces around this reality, we expect it to drive a sustained break of G10 ranges and a rebound in volatility. Forward US interest rates are at or below our expected path for actual US rate, leaving little fundamental room for rates markets to continue to absorb investors' perceptions of returns to capital convergence. If US data continue to hold up well amid sustained slowing outside of the US and manifest shocks to non-US growth, like Brexit, it will become increasingly difficult to

FIGURE 17

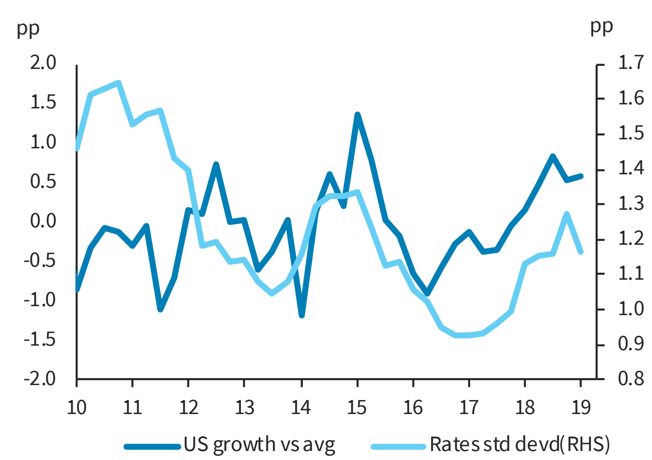
1y implied policy rate moves



Source: Barclays Live. For a live version see *here*.

FIGURE 18

Advanced economy interest rates dispersion vs difference of US and peers' average GDP growth (y/y)



Source: Bloomberg, Barclays Research

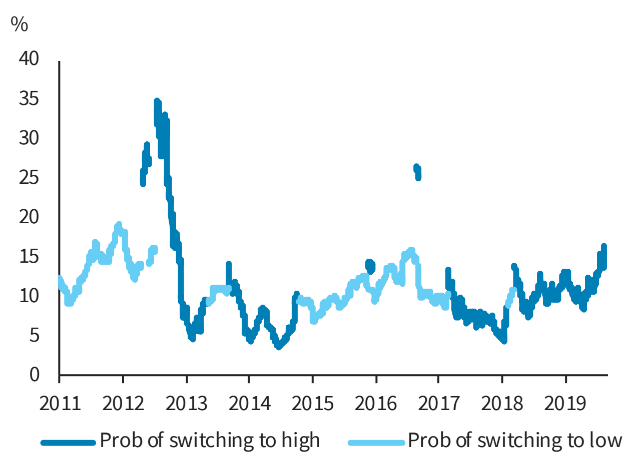
hold expectations for economic and returns to capital divergence that currently are offsetting the USD's high-carry advantage. We would expect such sustained data or a shock such as Brexit to catalyse market conviction and eventually lead to a breakout in FX volatility to its higher regime (see *No deal is a big deal*, 20 August 2019).

Incorporating the absorption ratio into our endogenous regime-switching model for FX vol highlights the risks of relying on one model specification and reinforce our subjective views

While we do not recommend these alternatives as forecasting models because of the intrinsic lag of the absorption ratio, its incorporation into our endogenous regime-switching framework illustrates the effects rising conviction have on the conditional probability of a switch to the high-vol regime. Figure 19 presents an alternative representation of the conditional probabilities of regime switch that we showed in Figure 9, but based on a model that only considers investor conviction in updating probabilities. Unlike our preferred forecasting model, it suggests the probability of a regime switch continues to rise, and indeed is higher than the conditional probability of a switch to high-vol regime that existed before that switch occurred in the 2014 low-vol regime. Figure 20 presents yet another version that incorporates both macro conviction and interest rate dispersion.[6] While the decline in interest rate dispersion has reduced the conditional probability of a regime switch to high volatility from its 2018 highs, it projects a higher likelihood than the interest rate only model. While we maintain the latter likely is a better forecasting model, we believe the alternative models in Figure 19 and Figure 20 should caution against relying solely on one specification and reinforce our subjective view that a transition to a higher volatility environment is more likely.

FIGURE 19

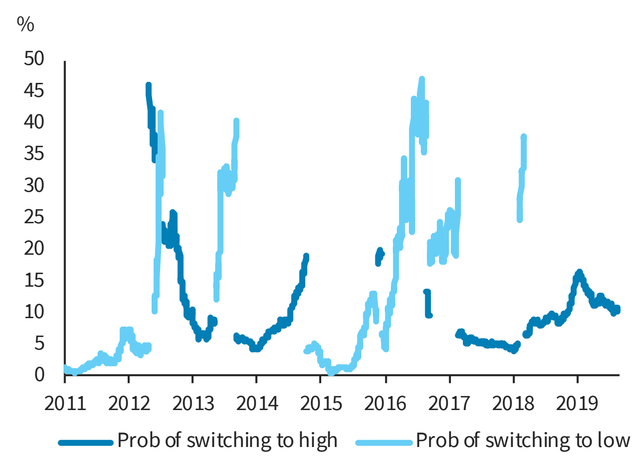
Alternative expected probability of volatility regime switch based on absorption ratio



Source: Barclays Research

FIGURE 20

Alternative expected probability of volatility regime switch based on absorption ratio and interest rates dispersion



Source: Barclays Research

6 Because these series are correlated, we include in the endogenous Markov function and orthogonalisation of the absorption ratio (relative to interest rate dispersion) rather than the unmodified absorption ratio.

Appendix

Glossary

Realised volatility	A measure of the average size of actual price changes, historically. Specifically, we annualise the square root of the daily sum of five-minute squared changes in an exchange rate.
Implied volatility	The expected future variability of exchange rate changes embedded in an FX option's price, proportional to the price of the option and quoted at an annual rate.
Forward volatility agreement (FVA)	Financial contracts similar to options but settled on the difference between *realised volatility* over a window of time in the future and the value specified in the contract.
Effective lower bound (ELB)	The lowest level to which realised volatility can theoretically fall given expectations for minimum necessary transactions in a currency pair. We estimate this as the second percentile of the historical range of *continuous volatility* for a specific currency.
Continuous volatility	The portion of total realised volatility associated with 'normal' changes in exchange rates and excluding larger moves (in either direction) that form *jump volatility*.
Jump volatility	The portion of total realised volatility associated with large, 'non-normal' changes in exchange rates and excluding smoother, more 'normal' changes (in either direction) that form *continuous volatility*.
Jump intensity	The daily frequency of 'jumps' measured in *jump volatility*.
Jump size	The daily average magnitude of 'jumps' measured in *jump volatility*.
Volatility regimes	A segmentation of *realised volatility* defined by extended periods at different average levels. In this paper we segment volatility into two regimes: high volatility and low volatility.
Absorption ratio	A measure, similar to correlation, of the co-movement of a wide spectrum of asset prices and exchange rates on a daily basis, used in this study to measure market conviction around macro themes. We assume that when there is high conviction around macro themes it drives increased correlation across asset prices and exchange rates, whereas low conviction does the opposite.
Principal component	A statistical construction that captures common variability through time across multiple underlying variables. The 'first' principal component is that which captures the maximum share of common variability. We use first principal components to measure the 'correlation' of a spectrum of asset prices as the 'absorption ratio' and to measure common sources of volatility across G10 currencies.
Unconditional expectation	A forecast or expectation for the outcome of a random variable – eg, the future level of realised volatility – without considering or conditioning on any other factors or events.
Conditional expectation	A forecast or expectation for the outcome of a random variable – eg, the future level of *realised volatility* – given something else has occurred. In this study we provide conditional expectations for the future level of realised volatility *conditional* on being in either a high- or low-volatility regime.

Computing Realised (integrated) volatility

Realised volatility is calculated using high frequency market data. Unlike, classical measures of volatility, which are backward looking, realised volatility gives a timely – daily – measure of current volatility. Technically speaking, realised volatility (Rvol) is the annualised square root of realised variance (RV): $Rvol = \sqrt{RV} * \sqrt{260}$, which, in turn, is defined as the sum of squared daily FX returns:

$$RV_t = \sum_{i=2}^{N} \left(s_{t,i} - s_{t,i-1}\right)^2,$$

where N is the number of observations in each day and $s_{t,i}$ denotes the log exchange rate in day t at time i. In our analysis we sample observations at 5-minutes frequency implying that N=288. Our daily estimates of realised volatilities for G8 currencies are shown in Figure 21 to Figure 27.

Dissecting realised volatility into continuous- and jump-volatility

In order to understand the dynamics of Rvol, we dissect RV into continuous variance (CV) and jump variance (JV), hence:

$$RV_t = CV_t + JV_t$$

CV is the part of variance that is driven by "small" changes in exchange rates, while JV is the part of variance that is driven by "large" changes in exchange rates. Fundamentally, the former refers to the variance associated with 'white-noise' economically necessary FX transactions while the latter one refers to the variance resulting from market reactions to incoming news/data/events et cetera. A time-varying threshold α_t, determines whether the change is categorised as small or large. More precisely:

$$CV_t = \sum_{i=2}^{N} \left(s_{t,i} - s_{t,i-1}\right)^2 I_{\{|s_{t,i} - s_{t,i-1}| \leq \alpha_t\}}$$

$$JV_t = \sum_{i=2}^{N} \left(s_{t,i} - s_{t,i-1}\right)^2 I_{\{|s_{t,i} - s_{t,i-1}| > \alpha_t\}}$$

where I is the indicator function taking the value of 1 if the condition in curly brackets is fulfilled and 0 otherwise (also known as the operator).

Perhaps unsurprisingly, the classification of variance into continuous and jump components is heavily affected by the selection of α_t. Due to the fact that FX return distributions exhibit heavy tails, however, a properly selected threshold should allow us to uncover the continuous part of returns that is normally distributed, conditioning on time-varying volatility.

In our selection of α_t we follow Mancini (2001), Raczko (2015) or Bollerslev and Todorov (2011) and link the time-varying threshold to the estimate of CV from the previous day:

$$\alpha_{t,i} = 3\sqrt{CV_{t-1}} \sqrt{\frac{1}{N-1}}\, TOD_i$$

where TOD_i is a time-of-a-day factor that controls for daily volatility patterns. For example, volatility will naturally, on average, be higher during hours of important data releases, like US non-farm payrolls. The TOD_i is defined as a ratio of the median quadratic change for particular time i of a day to the median quadratic change of the full sample.

The initial threshold for the first day has been set as a function of the bi-power variation measure (BPVAR) of Barndorff-Nielsen and Shephard (2004): $\alpha_{1,i} = 3\sqrt{\frac{\pi}{2}}\sqrt{BPVAR} * TOD_i$.

Our empirical analysis shows that our threshold selection is valid and all continuous exchange returns are normally distributed conditional on their time varying variance determined by CV. Figure 21 to Figure 27 depict the contribution of continuous volatility to realised volatility. We calculate this contribution as a fraction of RVol proportional to the ratio of $\frac{CV_t}{RV_t}$.

Estimating different continuous volatility regimes

Since daily continuous variance is volatile, our analysis focuses on predicting continuous variance over the coming month, denoted $CV^i_{t,t+22}$, where *i* denotes the currency pair and 22 refers to the average number of business days in a month. $CV^i_{t,t+22}$ closely co-move across currencies, indicating that changes in the level of variance is likely driven by a global factor. Consequently, we aggregate each individual $CV^i_{t,t+22}$ by extracting the first principal component from all currencies – a measure we denote as $CV_{t,t+22}$.

Our simple Markov-Switching (MS) model assumes that the future level of continuous variance is a function of a regime dependent constant $\beta_0(s_t)$ and an error term around this forecast $\epsilon_{t,t+22}$. Formulaically,

$$CV_{t,t+22} = \beta_0(s_t) + \epsilon_{t,t+22}, \qquad \epsilon_{t,t+22} \sim (0, \sigma(s_t))$$

We assume that there are two regimes for variance: high and low. In addition, high and low variance regimes are associated with high and low volatility of the model's error term. In other words, our model implies that future continuous variance can fluctuate around two levels, high and low, with the dispersion around the high level being larger than dispersion around the low level.

In addition, we do not know in which regime we will be but we provide estimates of how likely it is to end up in each of the regimes. Regime probabilities follow a Markov process, ie, probability of being in a regime depends on the previous state: $P(s_t = j | s_{t-1} = i) = p_{ij}(t)$. We also assume that these probabilities are time-varying and are a function of rates dispersion. More precisely probabilities are determined by the following logistic function:

$$p_{ij}(X_t, \delta_i) = \frac{\exp(X_t' \delta_{ij})}{\sum_{s=1}^{2} \exp(X_t' \delta_{is})}$$

where X_t is a matrix containing vector of ones and vector with rates dispersion measure, while δ denotes parameters of this transformation.

Mapping global continuous variance CV to realised volatility RVol

In the next step we map our global continuous variance (CV) measure into realised variance (RV) of each currency, which in turn can be easily mapped into realised volatility (RVol). The mapping takes the form of simple linear regression:

$$RV^i_{t,t+22} = \lambda_0 + \lambda_1 CV_{t,t+22} + \xi_{t,t+22} \qquad \xi_{t,t+22} \sim (0, \sigma_\xi)$$

where $\xi_{t,t+22}$ represents two types of errors, first is the error of mapping global continuous variance into currency specific continuous variances, and second is the error of mapping continuous variance into the total realised variance. The role of two mapping parameters is to capture currency specific relationship between jump variance and continuous variance. For example, for AUD and NZD, the jump variance is proportional to the continuous variance, while for other currencies this relation is markedly weaker.

Bootstrapping realised volatility distributions under high and low regime

We use the aforementioned model to estimate the expected average realised volatility over the next month (Rvol) under the two regimes and provide distributions around these expectations. Since our model errors exhibit non-Gaussian patterns, we use a Bootstrap technique to obtain distributions – we re-sample errors obtained from MS regression and from mapping regression. In that way we make sure that the asymmetric nature of Realised volatility distribution is preserved. We also force distributions to respect the effective lower-bound proposed in the main text, by adjusting all bootstrapped values below the effective minimum to the effective lower bound.

Characteristics of jump volatility

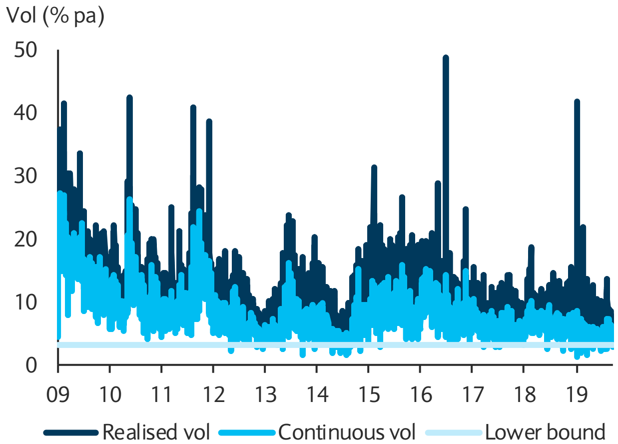
As highlighted in the text, we characterise market jumps with two measures: jump intensity and average jump size. The former is defined as the average number of jumps per day (NJ), where jumps are classified based on the indicator function described above. The latter is calculated as a root mean squared change:

$$AvgJ = \sqrt{\frac{\sum_{i=2}^{N}\left(s_{t,i} - s_{t,i-1}\right)^2 I_{\{|s_{t,i}-s_{t,i-1}|>\alpha_t\}}}{NJ}}$$

The size of jump has a truncated distribution, with many observations concentrated at the threshold level and only few values being far of the threshold. Simple arithmetic mean would not properly reflect these outliers, while our AvgJ should properly capture them.

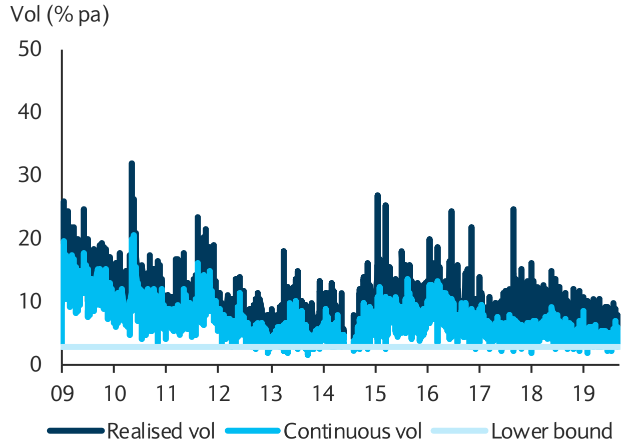
Realised and continuous volatility

FIGURE 21
AUDUSD: Realised and continuous volatility



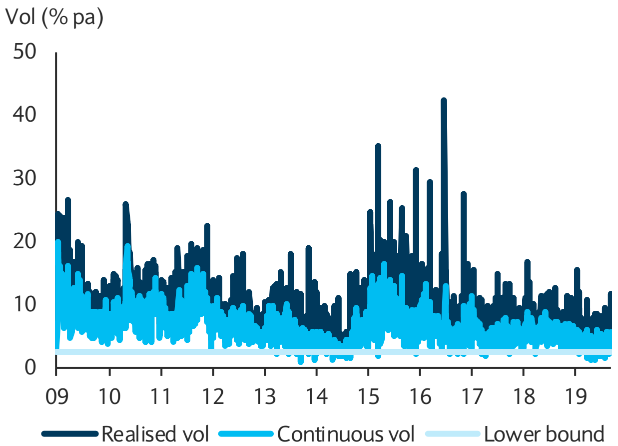
Source: Barclays Research

FIGURE 22
USDCAD: Realised and continuous volatility



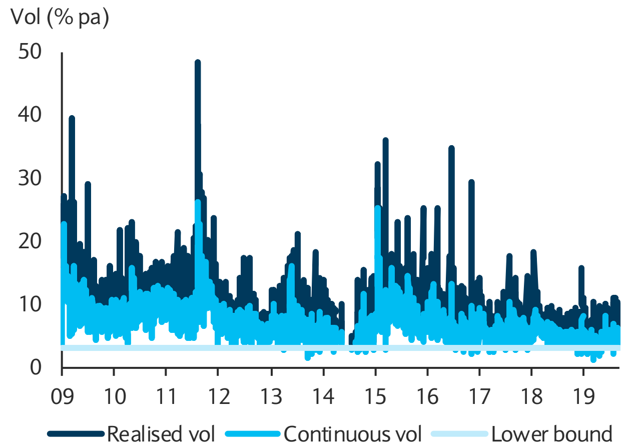
Source: Barclays Research

FIGURE 23
EURUSD: Realised and continuous volatility



Source: Barclays Research

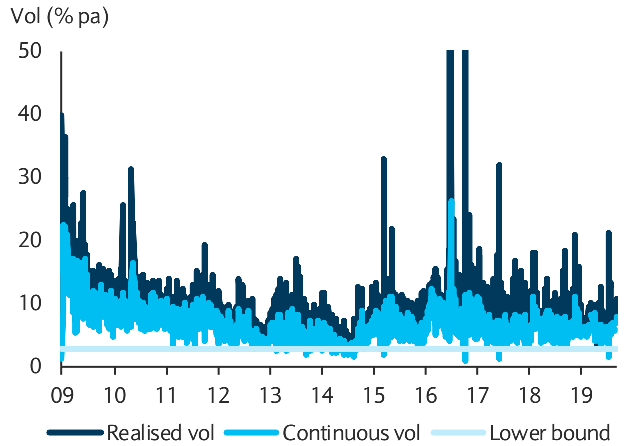
FIGURE 24
USDCHF: Realised and continuous volatility



Source: Barclays Research

FIGURE 25

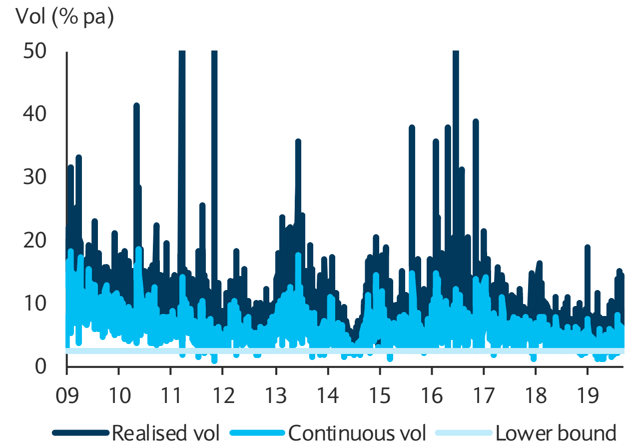
GBPUSD: Realised and continuous volatility



Source: Barclays Research

FIGURE 26

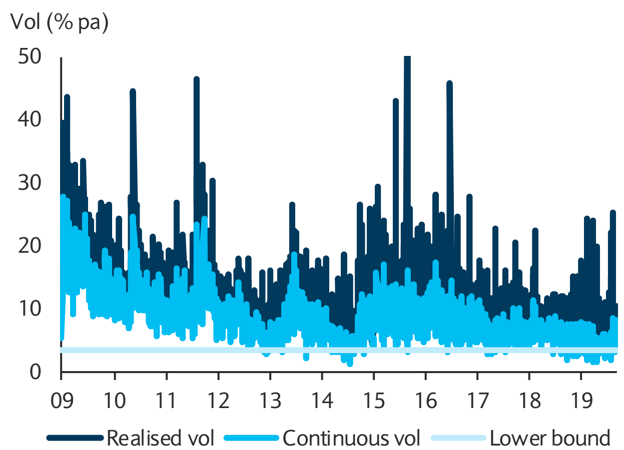
USDJPY: Realised and continuous volatility



Source: Barclays Research

FIGURE 27

NZDUSD: Realised and continuous volatility



Source: Barclays Research.

Jump intensities and average jump sizes

FIGURE 28

EURUSD: Jump intensities and average jump size

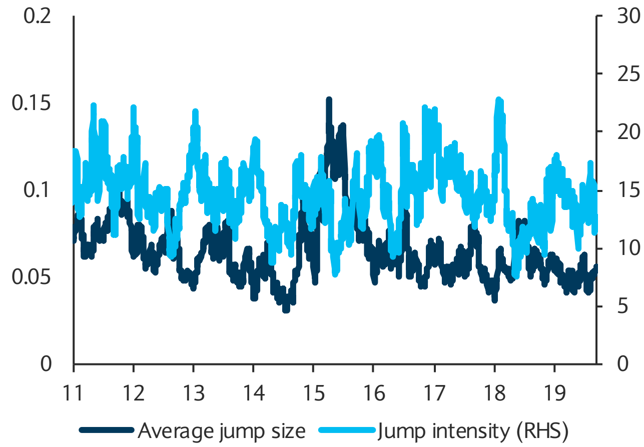


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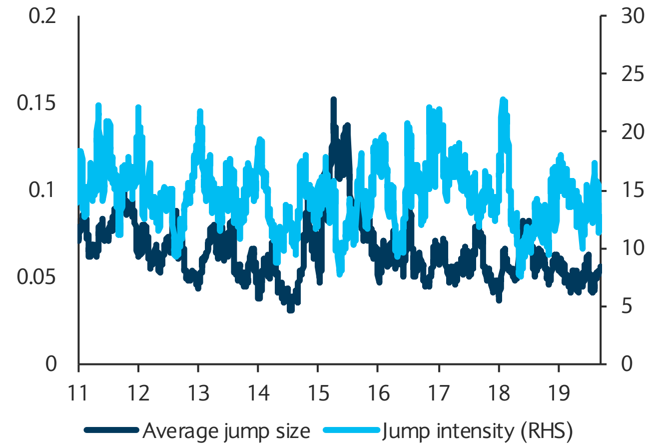
FIGURE 29

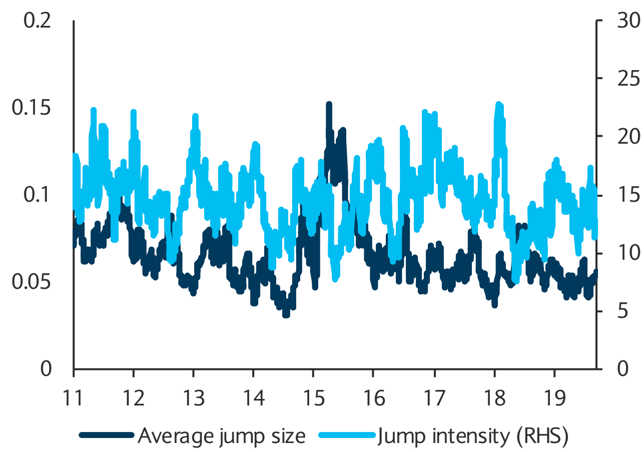
GBPUSD: Jump intensities and average jump size



Source: Barclays Research

FIGURE 30

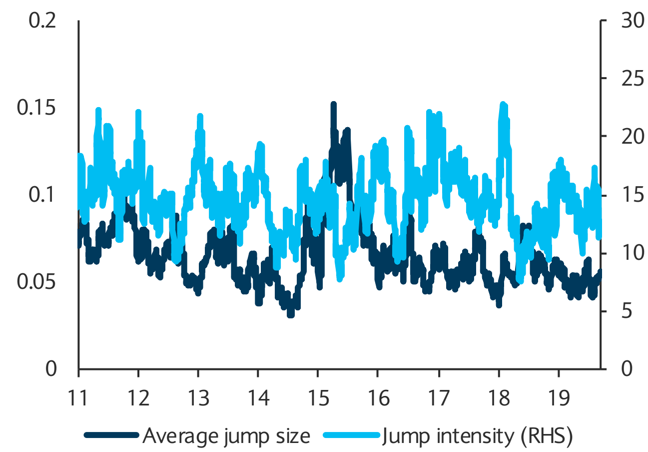
USDCHF: Jump intensities and average jump size



Source: Barclays Research

FIGURE 31

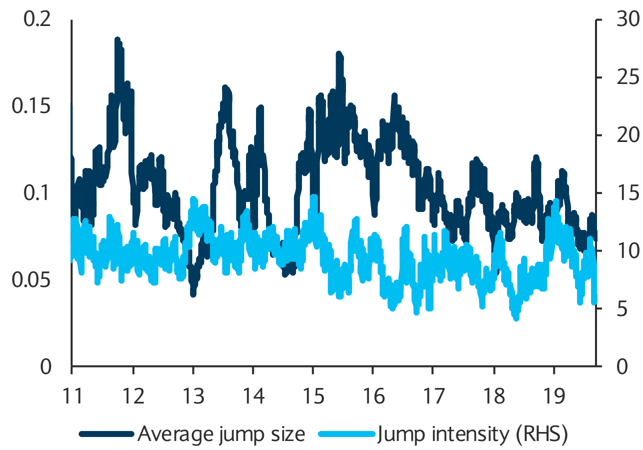
USDJPY: Jump intensities and average jump size



Source: Barclays Research

FIGURE 32

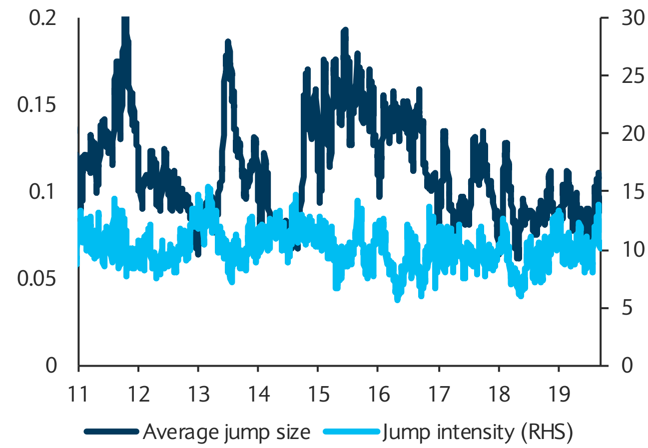
AUDUSD: Jump intensities and average jump size



Source: Barclays Research

FIGURE 33

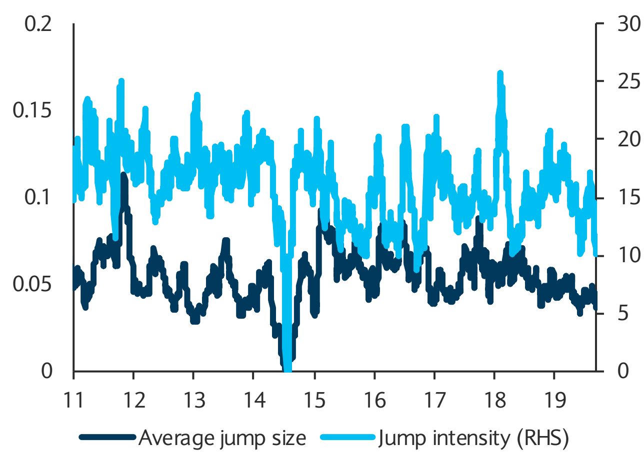
NZDUSD: Jump intensities and average jump size



Source: Barclays Research

FIGURE 34

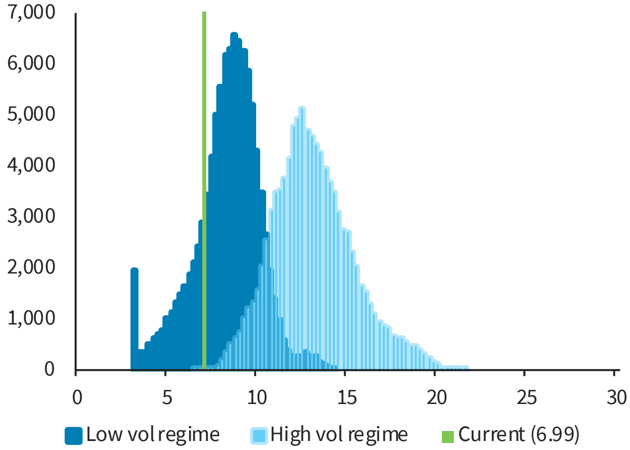
USDCAD: Jump intensities and average jump size



Source: Barclays Research

FIGURE 35

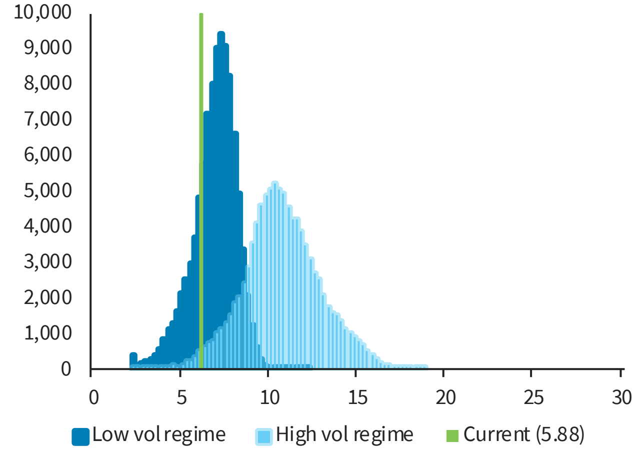
AUDUSD vol regimes distributions



Source: Barclays Research

FIGURE 36

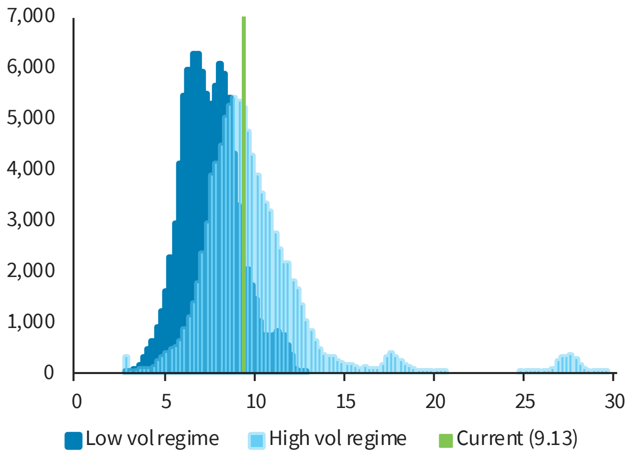
EURUSD vol regimes distributions



Source: Barclays Research

FIGURE 37

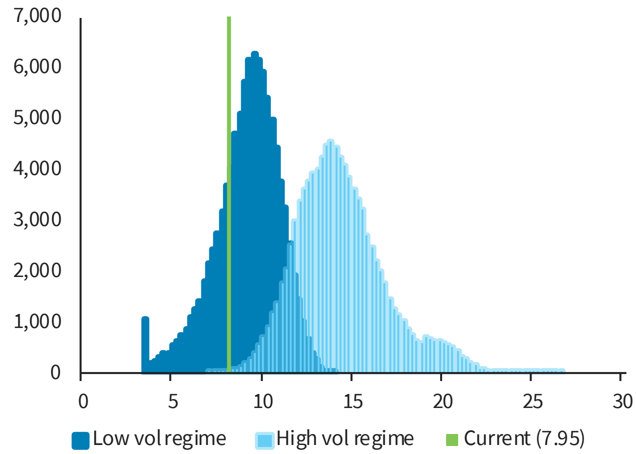
GBPUSD vol regimes distributions



Source: Barclays Research

FIGURE 38

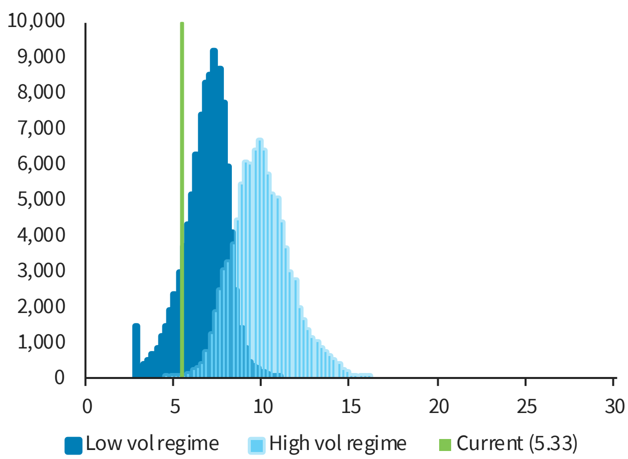
NZDUSD vol regimes distributions



Source: Barclays Research

FIGURE 39

USDCAD vol regimes distributions



Source: Barclays Research

FIGURE 40

USDCHF vol regimes distributions

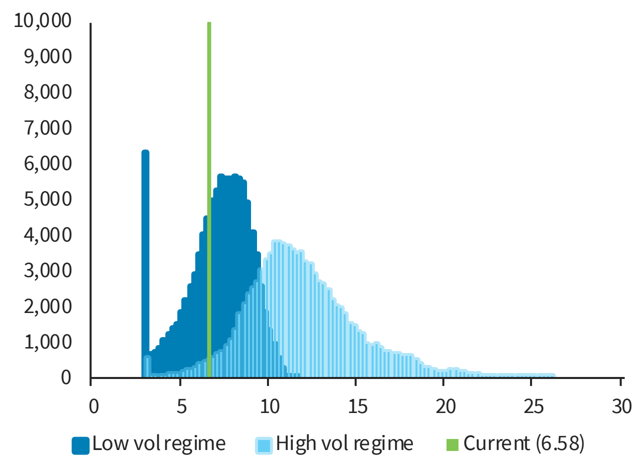


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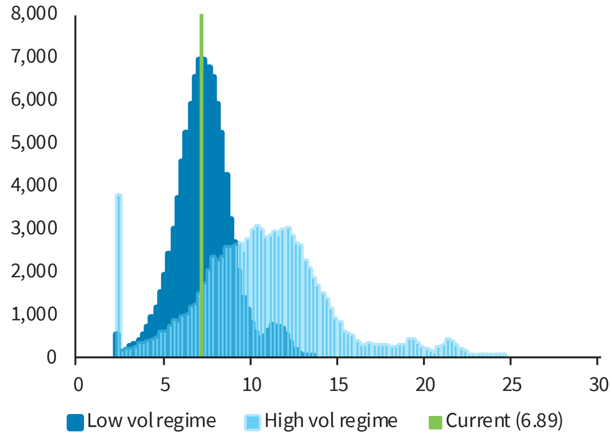
FIGURE 41

USDJPY vol regimes distributions



Source: Barclays Research

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