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Economic Watch

US

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Economic Analysis

US

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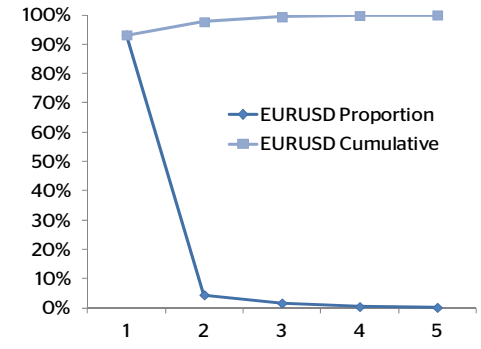
Common Factors in FX Volatility Term Structures

- **Our principal component model suggests that one factor explains 93% of EURUSD and USDJPY volatility**
- **The data suggests the level shift factor has increased in importance**
- **The model predictions demonstrate some anomalies in the term structure**

Implied volatilities for major exchange rates are generated from applying the Black Scholes formula to options prices. Volatility is implied in this sense because the method generates a figure for volatility that satisfies the observed price of a particular option when inserted into the formula. As such, the implied volatility may diverge from the actual volatility. With the addition of options of different maturities, this method allows the calculation of the term structure of volatility. Market convention is to relate the implied volatilities of at-the-money (ATM) options, since this tie down one possible axis of variability in the options. What is left is a representation of foreign exchange option volatility into the future. Naturally, some of these options are more liquid than others. For those that are liquid, a long time series of daily implied volatility exists for exchange rates from one month to one year forward.

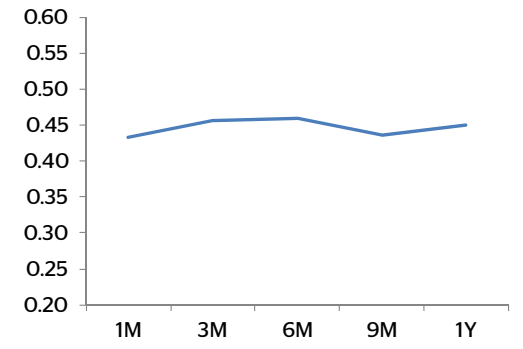
We can extract some informative metrics about trends in foreign exchange implied volatility from this data using principal component analysis (PCA). PCA allows us to extract a signal from an unobservable factor that explains the variation in the data. For the daily data that is available from 1999 to present, we aggregated the information into weekly averages. After visually inspecting the data, Dickey-Fuller tests augmented with generalized least squares (GLS) determined the presence of unit roots and thus log differences were fed into the PCA regressions. By applying PCA to EURUSD and USDJPY ATM implied volatility from one month to one year we find that one principle component explains 93% of the data for each exchange rate. In both cases, a Kaiser-Meyer-Olin measure of sampling adequacy exhibit that the data is meritorious for PCA. Visual inspections of the eigenvalues from the PCA regression confirm that we should retain only one principal component. Furthermore, we also examine the factor loadings of our first component and they are strongly reminiscent of a level parameter found in other studies. As such, the first component can be considered a level shift parameter that moves with the exchange rate volatility.

Chart 1
Proportion Explained by Components



Source: BBVA Research

Chart 2
EURUSD Factor Loadings of First Component

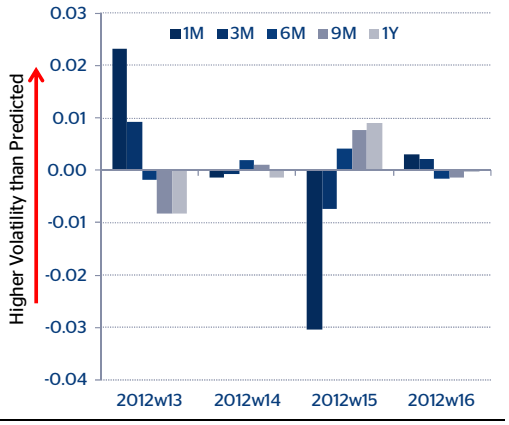


Source: Bureau of Labor Statistics and BBVA Research

As a robustness check, we also performed the regressions over different samples of the data. Interestingly, restricting the sample to the end of 2007 and 2008 shows a slightly increased explanatory power of the second factor for both EURUSD and USDJPY. The level shift parameter remains dominant and never falls below 89% explanatory power. The loadings implied from the second component are reminiscent of a slope shift parameter, with negative loadings for the short end and positive loadings for the long end of the term structure, as one would expect under normal conditions. Although we still consider the first component as stable over time, the data shows that conditions in EURUSD and USDJPY have tended to increase further the influence of shifts in the level of volatility.

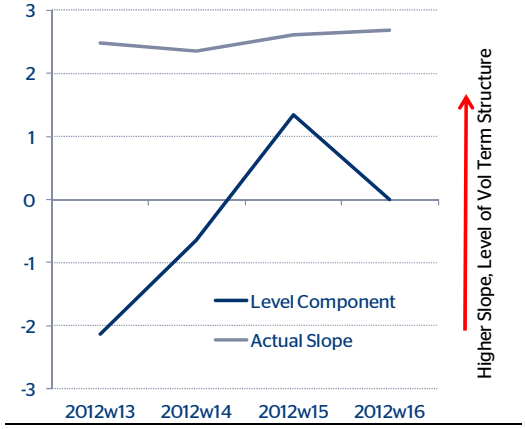
Now that we are armed with a model that explains most of the variation in the implied volatility term structure, we can examine deviations from the model's predictions to find anomalies in the movement of the term structure. For example, if certain parts of the term structure change more (less) than suggested by historical variation, we can say that volatility in this part of the term structure is overvalued (undervalued). Opportunities for arbitrage do not appear to last more than a few weeks in the term structure of implied volatility. To accompany the analysis, we can also show the slope of the term structure, which is the spread between the one-month and one-year implied volatility. This spread also exhibits a skewed distribution, illustrating some arbitrage opportunities when this spread becomes extreme.

Chart 3
EURUSD ATM Volatility Model by PCA



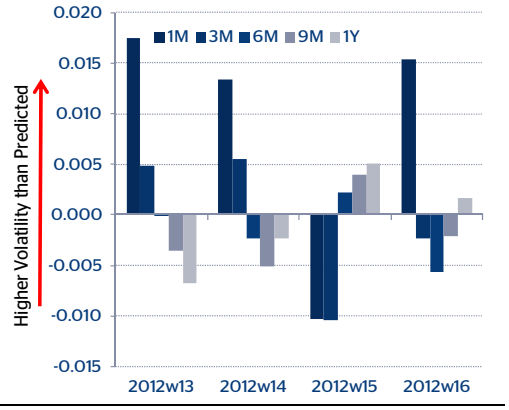
Source: BBVA Research

Chart 4
EURUSD Volatility Term Structure and Slope



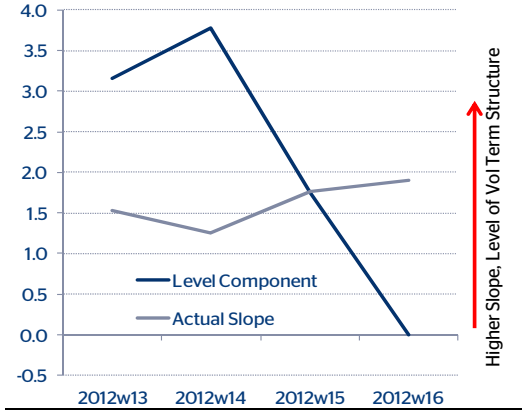
Source: BBVA Research

Chart 5
USDJPY ATM Volatility Model by PCA



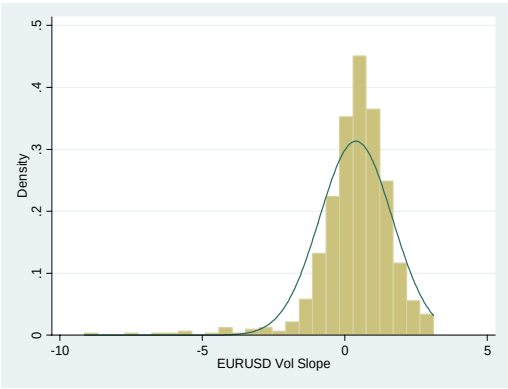
Source: BBVA Research

Chart 6
USDJPY Volatility Term Structure and Slope



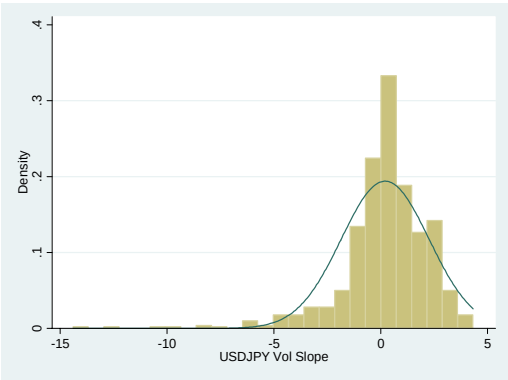
Source: BBVA Research

Chart 7
EURUSD Kernel Density Estimate v Normal



Source: Bureau of Labor Statistics and BBVA Research

Chart 8
USDJPY Kernel Density Estimate v Normal



Source: BBVA Research

Bottom line: Finding Statistical Regularities in FX Volatility Term Structures

Fitting the implied volatility of exchange rates to a principal components model suggests that one component explains most of the variation in the data. Moreover, this component has gained strength since the crisis began, meaning level shifts are somewhat more important than the effect of the slope in recent years. This may be the result of higher exchange rate volatility following the collapse of Lehman Brothers and/or effective and persistent central bank intervention. For example, intervention announcements from the Bank of Japan may be more influential in the post-crisis era than in the years leading up to the crisis. Overall, our model is a guide to potential statistical regularities in the implied volatility term structure. Departures from these regularities, while short-lived, offer a better filter for the information stemming from the implied volatility term structure.