(Almost) Everything You Wanted To Know About FX Volatility Smile (Part I)—Intro to the FX Market

Harel Jacobson · Follow

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The options space is a fascinating world in which sophisticated calculus, probability theory, and other quantitative disciplines come together to help us solve one simple question: "what is the fair value of product X on some underlying asset, given few input parameters?"

Clearly, we know how to answer that question today using our go-to options' pricing models. While there are many reasons to criticize the well-known Black-Scholes options pricing model, It does a good job of mapping a collection of inputs to one output — an option's price (and its derivatives, aka, the Greeks).

The main criticism of the Black-Scholes model is its "flat volatility" assumption, which assumes volatility (the one input that is not observed directly in the market, yet it's the most important one) is flat across all strikes and maturities. Nearly 50 years after the original publication, we know that the volatility dynamic is anything but flat (the original paper was published in June 1973, if you fancy quant finance trivia).

Soon after Black-Scholes published their paper, practitioners and researchers started raising questions with regard to the "flat volatility" assumption, especially given the fact that it was observed that some underlying assets like equities had a tendency to exhibit higher variance when they declined than when they moved higher. Financial markets referred to this phenomenon as the "leverage effect," which meant that a move lower in stock price increased the relative debt and created more volatility (and vice versa when stock price moved higher). On October 19th, 1987, we got the ultimate proof of that phenomenon when the US equity market fell sharply (The Dow Jones Industrial Average fell that day a little over 20%).

As most long-term investors are inherently "long" equity in their portfolios (either directly or indirectly, via their pension plans), it makes perfect sense to buy protection against adverse moves (or, in other words, pay a risk premium for owning portfolio protection). Hence, the volatility skew, where OTM puts exhibit higher implied volatility than OTM calls with the same distance from the ATM, captures that phenomenon.

While it is clear why markets like equities/bonds/commodities exhibit a volatility skew, in the FX market, things get a bit more complicated (for various reasons), and if it's not enough that the FX market trades almost exclusively in the inter-bank market (OTC). Things get even more complicated when we introduce exotic structures and examine their effect on the underlying spot/vol dynamic.

In this write-up, we will take a tour into the wild jungle of FX derivatives space to understand the hows and whys of the FX implied smile dynamic.

A Beginner's Guide to the FX Market Players

Before we dive deep into the nitty-gritty of the FX volatility dynamic, we should understand who the main players are in the market and what's their utility function/objective, as the relations between the different players shape the dynamic we observe on the volatility surface.

Generally, we can distinguish between three main players in the market:

1. **Interbank Dealers/ Market-Makers (sell-side)** — The interbank dealers (and non-bank dealers) act as the liquidity provider to the buy-side (end-users) and risk underwriters. They are intended to warehouse the risk buy-side players looking to buy/sell. The market-maker (MM) dynamically hedges its book in an attempt to keep its risk (greeks) inventories "under-check" (avoiding large directional greeks exposure). The vast majority of the MMs' profit comes from the bid-ask spread and the ability to own high-order greeks (convexity) at a cheap cost.

2. **Hedgers (Real-Money/Corporates)** — Corporates/Real-Money players use the FX derivatives market to hedge their cashflows and cross-asset funding risk. For the most part, they are insensitive to the price of volatility. That is, when they need to hedge exposure, they will not determine whether to hedge or not based on the price of volatility. They are active both in the vanilla space (using vanilla strategies like risk-reversal, calendar spreads, and call/put spreads) and exotic derivatives space. Due to the varying nature of the cashflow timing/duration, they trade across the term structure (expiry dates), and in some cases, they will trade options out to 10–20yrs. Needless to say, the supply/demand created by the hedgers' community is the main driver of the volatility surface dynamic in normal markets, as they constantly need to re-hedge (or unwind) their exposures.

3. **Speculators (CTAs, Macro, Vol/RV Managers)** — The speculative community is probably the most diverse type of player. Unlike hedgers, speculators are opportunistic players which would trade only when opportunities present themselves (or when they have a concise view of which they could trade upon). Within the speculator community, we can find both CTA/Trend-Following/Macro players that are highly directional in their view and exposure (preferably with positive rates carry) and Vol/Relative Value managers that take advantage of mispricing of volatility, either on the implied surface level or relative to the realized underlying spot dynamic (aka, volatility risk-premium). If we think about it, Vol/RV managers act as a secondary underwriters of risk in the market and help MM take risk off their books.

Now that we mapped the market by players, let’s understand how their flows impact the volatility surface…

Generally speaking, the existence of implied volatility skew indicates that the "market" (i.e., end-users) is willing to pay a higher premium for owning out-of-the-money (OTM) options on one side of the at-the-money (ATM) strike over the other. For example, in equity index options, put options trade at a premium to the equivalent distance calls options because end-users, for the most part, want to hedge their wealth and therefore buy put options to protect their portfolios. In FX, however, this is not as straightforward as in other markets. As FX exposure depends on cashflows (and their direction) in two currencies, importers and exporters have opposite risks (importers hedge against a depreciation of the local currency against a foreign, while exporters hedge against an appreciation of the local currency).

In theory, all else being equal, if the only players in the market were hedgers (corporates) and dealers, the implied skew should have been determined by the current account between two countries (so calls for the currency of a country with a trade surplus should trade in premium to puts). However, in practice, this is hardly the case. If we look at Emerging-Market countries like China, which has a significant trade surplus with the US, the implied skew is "call dominated" (meaning OTM calls trade over OTM put, or in other words, the Risk-Reversal is positive). This positive RR (risk-reversal) contradicts the idea that corporates (hedgers) impact the shape of the skew (otherwise, there should be more demand for hedges against the local currency's strength). Obviously, more driving forces shape the implied volatility smile, and this is where things start to get very interesting…

Currency speculators are, by far, the most diverse in their flows and positions. While macro funds and CTAs mostly follow a macroeconomic narrative/trend (and tend to express their views using FX/Rates derivatives) and are mostly driven by interest rates differential (i.e., carry), multi-managers use FX as part of their overall portfolios (to use correlation benefits to hedge other parts of their trading books). These groups are less "vol sensitive" and generally use FX derivatives (mostly options and options structures) to express their macro views or hedge their core carry strategies. As a result, their flows, in most cases, create a demand/supply of certain strikes/maturities (and impact the volatility premium for these strikes/tenors). Lastly, RV/Vol managers, in their attempt to engage in "volatility arbitrage," act as a secondary risk underwriters.

On the other side of each trade, we will normally find either a bank dealer (for example, Citi/JP Morgan) or a non-bank market-maker (Optiver, Susquehanna). Unlike listed markets, where the vast majority of the flow goes through the exchanges (and options chains), in the FX market, most of the trades are made OTC (over-the-counter). There is a listed futures market for USD-crosses on CME (for futures and options), but this market represents a fraction of the "true" volume that is traded in the FX market.

The fact that end-users face a single counterpart (that could be a bank, broker, or non-bank dealer) means that the price the end-user will get is subject to which counterparts they have credit lines with, their counterparts' inventories, and risk limits. The more credit lines an end user has with different counterparts, the tighter/more competitive price they will see.

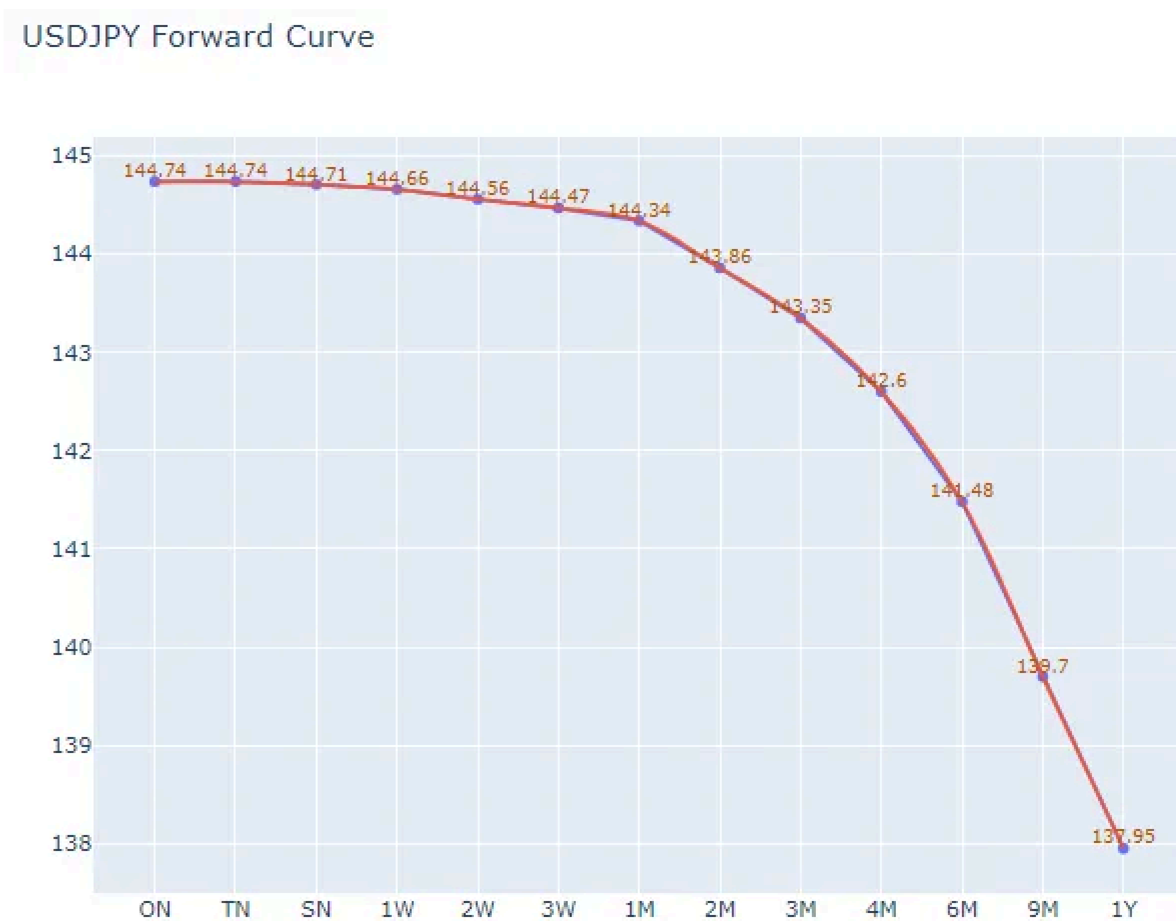
A Soft Introduction to FX Volatility Smile

Now that we understand the market landscape and the different players, let's dip our toes into the ocean that's volatility modeling and understand how the FX implied volatility is modeled.

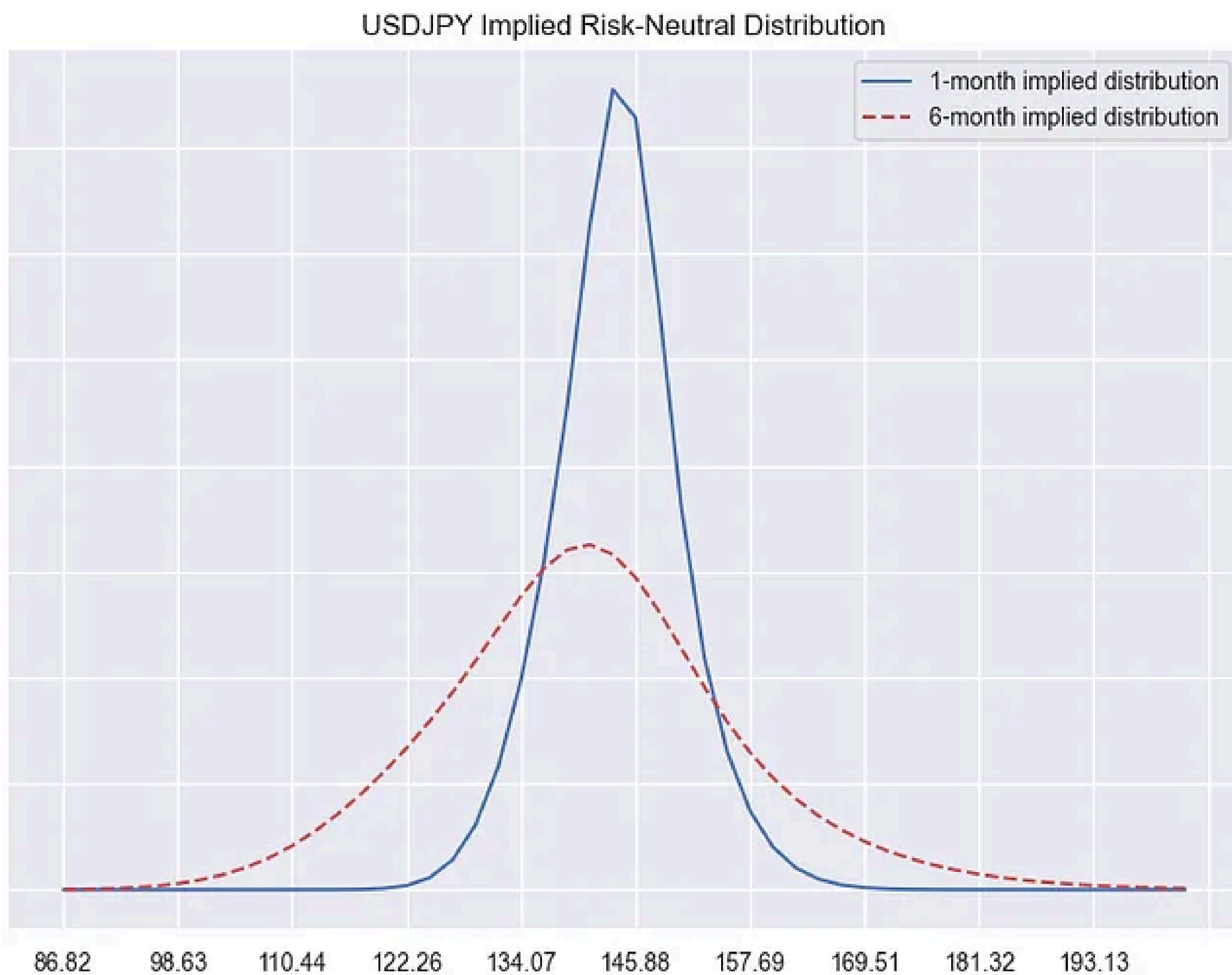
Generally speaking, the FX options market is significantly different than other options markets due to market-specific quoting conventions. Unlike the equity market, where "floating" (generic) strikes are quoted as %-

Moneyness (away from the ATM strike), in FX, "floating" strikes are quoted in delta terms (meaning that the fixed/numerical strike will be solved from the "delta strike").

If that's too confusing, let's think about the following example: we want to compare two OTM USDJPY call options with different maturities: 1-month and 6-month. Given that the USD yield curve is upward sloping (meaning that the market implies a path of increasing US rates), the USDJPY forward rate will be different between 1-month and 6-month. If we look at the USDJPY forward curve, it will look like this:



Our 1-month ATM-forward strike will be 144.34, while the 6-month ATM-forward strike will be 141.48, so if we were to compare two 5% OTM calls options, we needed first to ask ourselves whether the distance is measured relative to spot (144.70) or forward, and we also need to account for the fact that the difference in maturities (i.e., a 6-month option has far greater time-value than a 1-month option) affect the risk that both options have (whether that a delta or vega risk). Plotting both risk-neutral distributions (i.e., the distribution of outcomes derived from the implied vol surface) shows the difference between the two:



As we can see, comparing strikes of different maturities (even for the same underlying asset) is not as intuitive as one might think (pretty much like comparing apples to oranges). Moreover, the unique OTC nature of the FX market means that strikes are not bounded by options chains (hence strikes are not fixed by maturities and intervals), and most volatility practitioners (whether those are market-makers or buy-side traders) trade options to hedge their greeks (rather than have interest in particular strike), it makes more sense to quote strike moneyness in delta terms. For example, if we want to buy a USDJPY 1-month 25-delta call option, the "fixed" strike will be ~147.80 (with the spot price at 144.70), but if we want to buy the equivalent delta-moneyness option (i.e., 25-delta call) in a 6-month option the "fixed" strike will be, all of a sudden, 150. How can that be?

A short refresher of what "delta" represents. The option's delta represents the sensitivity of the option's value to a small change in the underlying asset, and from a probability point of view, it represents the likelihood of the option being in the money at maturity. The longer our option's lifetime, the greater the time value and the wider the distribution (hence, why the 6-month 25-delta call fixed strike is about 1.5% higher than the same delta-strike of 1-

step in understanding FX volatility surface modeling…

FX Volatility Surface Modeling 101

Volatility modeling in the FX space is clearly a deep and mathematically intense topic, so I will try to make it as simple and intuitive as possible (as much as you can make such a topic intuitive).

Generally speaking, dealers/market markers will quote clients any combination of strikes and maturities they will ask for, but there are specific strikes/maturities that are liquidly traded (quoted) in the market. These strikes/tenors are usually called "liquid pillars". When we ask our friendly dealer (let's call them Goldman Stanely) for a "vol run" of our currency pair of choice, this is what we will usually get:

	ATM	25D RR	25D BF	10D RR	10D BF
Exp	Bid / Ask	Bid / Ask	Bid / Ask	Bid / Ask	Bid / Ask
1D	32.050 / 41.250	-5.275 / -1.575	-0.237 / 1.563	-12.6... / 0.050	-1.187 / 5.113
1W	23.950 / 26.550	-3.700 / -3.200	0.475 / 0.875	-8.625 / -3.725	0.875 / 3.075
1M	19.950 / 20.800	-3.975 / -3.575	0.412 / 0.812	-7.550 / -5.950	1.925 / 2.725
3M	17.900 / 18.800	-4.250 / -3.650	0.175 / 0.875	-9.100 / -5.300	1.525 / 3.425
6M	16.200 / 17.000	-4.050 / -3.650	0.225 / 0.825	-7.975 / -6.375	2.075 / 2.875
9M	15.450 / 16.100	-4.150 / -3.750	0.212 / 0.812	-7.500 / -6.000	2.037 / 2.838
1Y	14.900 / 15.600	-4.100 / -3.700	0.262 / 0.762	-7.925 / -6.325	2.037 / 2.838
2Y	15.050 / 15.700	-4.225 / -3.425	0.288 / 0.788	-8.500 / -5.400	1.863 / 3.363

(*we can also see that indicative pricing on their eFX trading platform, but we like some personal attention by our sales coverage).

Now you are probably saying, "we know what ATM vol means, but what the hell is 25/10D RR (Risk Reversal)/BF (Butterfly), and why are they quoted/why do we need them???"

Luckily, after having spent years in the business, I feel eligible to answer that question, so here it goes...

There are generally five liquidly traded strikes for most maturities: ATM vol, 25-delta call/put, and 10-delta call/put. Wait... but the vol run we just saw had only ATM/RR/BF quotes, so how come we get five liquid points???

This is when we need to deploy some basic math (I promise to keep it super basic)

Let's define RR(Δ) in the following way:

$$Call\left(K_c, \sigma(K_c)\right) - Put\left(K_p, \sigma\left(K_p\right)\right)$$

And BF(**Δ**) in the following way:

$$\frac{1}{2}\left(Call\big(K_c, \sigma(K_c)\big) + Put\left(K_p, \sigma\big(K_p\big)\right)\right) - ATM(K_0)$$

Now I sense some of you are scratching their heads and mumbling, “but he said he will keep it simple. This looks awfully complicated”, So let’s take a deep breath and simplify them easily…

Starting with RR- this equation is simply the difference between the implied vol of the Δ-call and Δ-put (if we are looking at 25-delta RR, it is going to be vol(25-delta call) — vol(25-delta put)

Next, we have the BF equation, which is simply the average of the Δ call/put vol — ATM vol.

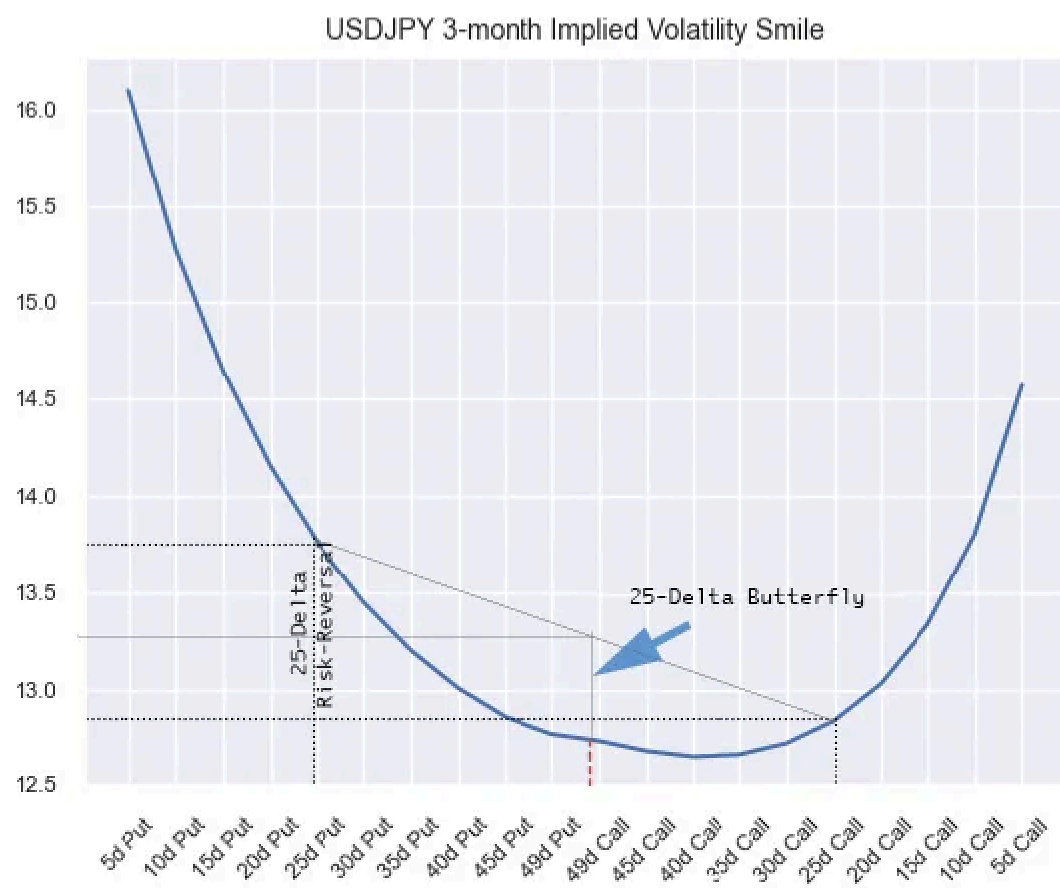
(*both equations are represented in terms of options prices, but being that we construct the volatility smile, we can simply use the implied volatilities).

So now we have two equations (RR and BF) with two unknowns: vol(**Δ**-Call) and vol (Δ-Put), which we can easily solve using substitution. At the end of the process, we get the following equations:

$$\sigma(\Delta_{call}) = \sigma_{atm} + BF(\Delta) + \frac{RR(\Delta)}{2}$$

$$\sigma(\Delta_{put}) = \sigma_{atm} + BF(\Delta) - \frac{RR(\Delta)}{2}$$

Given that we are being contributed (in most cases) 25-delta and 10-delta RR/BF, we end up with 10-delta call/put, 25-delta call/put, and ATM. If we want to interpolate between the volatility points we found, we can either use interpolation methods (like a quadratic spline) or a volatility surface model like Vanna-Volga (the standard go-to volatility surface model in FX). If we visually represent the above process, we will get something similar to the below volatility smile (where the y-axis will represent the implied volatility level, and the x-axis will represent the strike price)



To summarize, so far, we've learned the basics of implied volatility (and strike quoting convention) in the FX options market, and we've learned how to derive the “main strikes” of a volatility smile, which is the first step of understanding the FX derivatives market.

In Part II of the trilogy, we will dig deeper into the whys and hows of implied volatility modeling (ask answer why it’s conventional to quote RR/BF as opposed to other strategies…), as well as understand how the market microstructure (and options flows) impact the implied volatility dynamic.

Stay Tuned…

Harel.

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Written by Harel Jacobson

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Global Volatility Trading. Python addict. Bloomberg Junkie. Amateur Boxer and boxing coach (RSB cert.)!No investment advice!

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Rajarshiguha
about 2 years ago (edited)

Hi Harel, thanks for the great piece. I had an observation and wanted to be sure my understanding was correct:

You write that "If we look at Emerging-Market countries like China, which has a significant trade surplus with the US, the implied skew is......

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Eric Dai
over 1 year ago

Currently working on an FX desk in London and really appreciate your work here at explaining things! Helps a lot! Thank you!!

Reply

GreenTea_Pasta
about 2 years ago

Hey, just wanted to understand more on this part below.

If we think about it, Vol/RV managers act as a secondary underwriter of risk in the market and help MM take risk off their books.

Could someone enlighten me pls?

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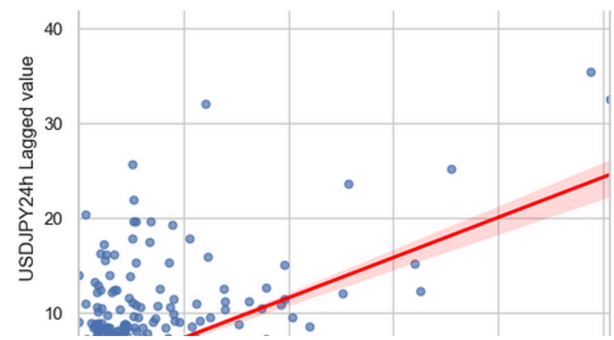

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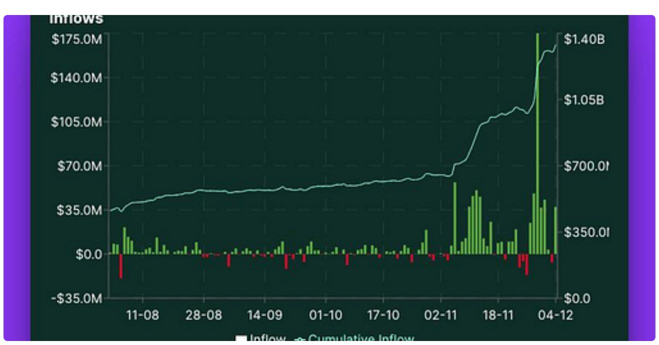

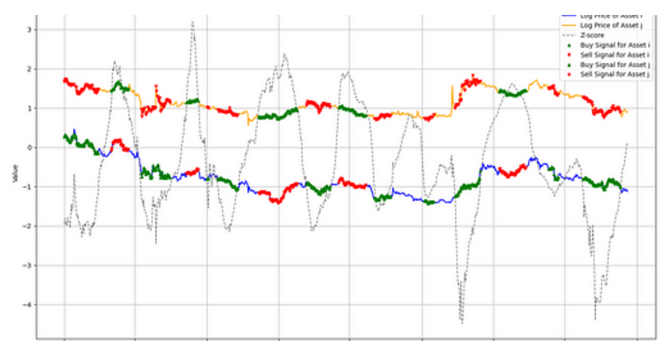

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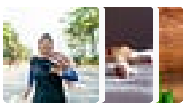

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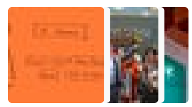

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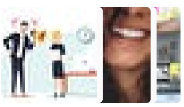

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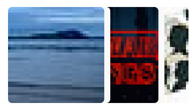

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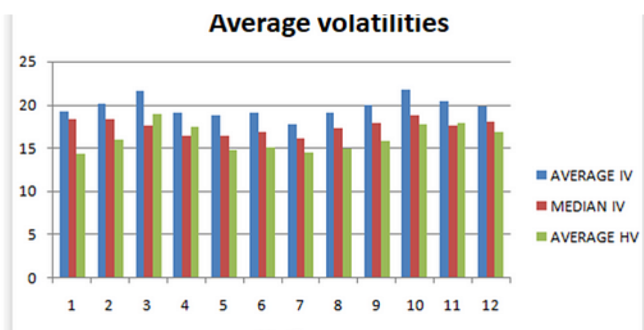

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