News

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Thinking about Building a Volatility Surface? Think Again

At first glance, constructing a volatility surface looks like a straightforward exercise – identify options that trade on the assets or securities of interest, obtain prices for those options across strikes and expirations, and compute implied vols from those prices. *Voila*. But that description only scratches the surface (pardon the pun)

– a closer look reveals there is a great deal more to consider. In fact, constructing a thoughtful, reliable volatility surface (and updating it every day), may be one of the more challenging, painstaking aspects of maintaining a robust risk management system.

In this article, we summarize the process and validation procedures TS Imagine uses to construct implied volatility surfaces for equity, equity index and commodity options. This multi-step process includes choices of option models and price snaps, chain reconciliation, volatility calculation, and smoothing. We provide a high-level description of these issues and include some technical details for those clients who are interested.

In addition to the standard Black Scholes model used to price European options, the following models, available in TS Imagine, are commonly used in the industry:

Finite difference – Discretizes the continuous approach to solving differential equations, approximating them with difference equations and using finite differences to calculate the derivatives.

Baroni-Adesi and Whaley – To price American options, this model separately computes the European option value, then estimates the early exercise premium using a quadratic equation.

Full Binomial / Discrete Yield Binomial – Binomial trees model the evolution of underlying option variables over time. While computationally more intensive than Black Scholes, this approach can be more accurate, especially for long-dated options on securities with dividend payouts, which can be treated as discrete yields.

Which Option Models?

The first step is to choose the option models to use when calculating implied volatility from a given price. Different models produce different answers from the same inputs, so it is important to select the model that is best suited for each instrument. TS Imagine uses a Finite Difference model for American options and the Black Scholes model for European options. Other models, specifically Baroni-Adesi and Whaley, and Full Binomial and Discrete Yield Binomial models, are also available so that clients can customize their vol surfaces using the model(s) of their choice.

Price? Which Price?

Once you have chosen the option model to use, calculating the implied volatility of the option is a mathematical exercise – but what price do you use? Many (perhaps most) options markets are rather illiquid. Should one use the last traded price? That may sound appealing since it reflects an actual transaction, but the last trade could have occurred many hours or even days prior to the close of the market for the underlying. Our preference is to use the Settlement Price from the Exchange, but if none is available it is reasonable to use the bid, mid or ask price as of the close. However, that requires another decision; using one or the other will produce different answers. We use the mid price, as a compromise to “minimize” the difference.

Of course, when constructing a volatility surface it is important that the prices used be as timely and current as possible, but not all prices are available at the same time. The market for the underlying and the market where the options are traded might close at different times. TS Imagine has checks in place to make sure both the underlyings and option prices are available and are “snapped” at the same time. Of course, there are time zone differences to consider also. To cover markets globally, we maintain three regions, East, West and GMT. If data for the East region is complete, that vol surface is refreshed without waiting for markets in the other regions to close. If a portfolio has a mix of securities that cut across time zones, it may be appropriate to wait until all of the volatility curves and surfaces are refreshed for a given day, but that may not be optimal; running reports earlier on some portion of the portfolio may be preferable.

Price Filtering

After deciding which option models and prices to use, and establishing processes to capture prices that are consistent between the options and the underlying consistently, can we declare victory and publish the vol surface? Not yet. It is critical to establish reasonableness checks and filter out prices that fail to meet those

criteria. For example, if a series of option prices are not monotonically increasing or decreasing across maturities or strikes, the resulting volatility surface won't make sense and could suggest there is a risk-free arbitrage opportunity that does not truly exist. Similarly, mixing option prices from different days will produce a bad curve for a given underlying. This may not be obvious to the end-user by visual inspection, but it communicates bad information and there must be a process in place to prevent that from happening.

TS Imagine performs the following filters on all equity and commodity options to decide whether or not they will be included in modeling the volatility surface.

- **Eliminate all options for which prices have not been snapped over the last five business days.** To establish our filtering criteria, we individually examined over 30 exchanges representing over 3-4 million option contracts to determine the quality of the theoretical, evaluated prices each exchange would send in the absence of a traded price. Excluding all illiquid option prices is not the best decision, as it would eliminate useful info. For example, while the EUREX option market is illiquid, if the option is not traded on a given day the exchange can still send a useful settlement price. In cases where the exchange does not provide a Settlement price, such as in the U.S., we generally use the mid price.
- **Eliminate in the money options.** This means the volatility surface focuses on the time value of the options, rather than on any intrinsic value. The rule seems simple enough, but again there is more to it than meets the eye. How does one determine the at-the-money strike? If that line is drawn in the wrong place, the result is a different (and probably bad) volatility surface. At TS Imagine, we use listed futures prices to decide where to draw an at-the-money line, relying on contracts that are expiring on or close to the date the option expires to make the determination (note that the choice of bid/ask/mid also matters in this decision). In cases where there are no usable prices for out-of-the-money options, or the maturity date of the longest futures contract is shorter than the furthest option expiry date so that we cannot use the futures market to determine the at-the-money strike, we can price a synthetic forward contract for that strike level, or for a maturity date corresponding to that option expiry and use put-call parity to compute prices.If there are no futures contracts on the underlying, the point at which put options become more expensive than call options can indicate the region of the ATM strike, and we can use put-call parity to determine a precise ATM line. This approach can have a tremendous impact on the integrity of the volatility surface. Since there are no futures on individual stocks, although using dividend forecasts is an acceptable method of projecting forward prices under some conditions, we believe a better approach is to use dividend futures when such a market exists. For stocks that do not pay dividends, using put-call parity to imply forward prices is preferable.
- **Eliminate options where prices are not increasing or decreasing monotonically.** For each expiry, we sort puts and calls by strike and find the longest non-decreasing/non-increasing price sub-sequence. We select strikes from the longest sub-sequence and discard the rest.
- **Eliminate options where the bid/ask spread is too high.** For each expiry, we calculate the mean and standard deviation of the spread and eliminate options with spreads greater than four standard deviations higher than the mean. This weeds out bad prices that can creep in for various reasons.
- **Use only those options that should be included in a given vol surface.** For example, options on the same underlying that have the same expiry dates but different expiry frequencies (e.g., monthly versus quarterly) have different degrees of liquidity and therefore different prices. TS Imagine gives clients the flexibility to use weekly vol surfaces to price weekly options, and so on. We also have a separate futures options curve for contracts such as the S&P 500, rather than simply using the spot S&P 500 index option curve.
- **Check for zeroes** – If settlement price is used, eliminate those with a price of zero; if the mid price is used, eliminate contracts with a bid and/or ask equal to zero.
- **Remove options that have been identified as illiquid from selected exchanges** *(we have filtering criteria in place for each exchange that can be easily modified to apply exceptions as needed).*

After completing the above steps, we check the remaining strikes for a given expiry. If the number of remaining strikes is below 20% of the median number of strikes on the curve, we exclude that expiry from the volatility surface.
Note that all of these filtering decisions were made in consultation with our clients.

Liquidity Checks

Lastly, we check for liquidity. We consider an option to be illiquid if one of the following conditions is met:

- The option has not been traded for last five business days.
- The option has no volume or open interest and the Last Trade date (according to Refinitiv) is N/A.

Some exchanges calculate theoretical settlement prices for illiquid options. In such cases, if the theoretical price improves the volatility surface, that contract or exchange can be excluded from the above checks. Further, in some markets (such as the U.S. equity options market), bid and ask prices are good enough to create a volatility surface even though the options may not be very liquid, so those exchanges can be excluded from the above checks as well. Whether a given underlying or exchange should be excluded from these price check criteria requires judgment. TS Imagine's Data Team investigates and decides these exceptions on a case-by-case basis.

TS Imagine also uses implied volatility surfaces to extract at-the-money volatilities for constant maturity instruments and stores these values in our historical price database. We use these time series as inputs for VaR and historical simulations to measure volatility risk.

Every trader, portfolio or risk manager who deals with derivatives must have confidence in the way implied volatilities are calculated in constructing a volatility surface. In addition to providing a better understanding of the complexities and nuances of constructing volatility surfaces, we hope this explanation has provided a high level of confidence in TS Imagine's processes in this arena. Contact us for more information about how we construct volatility surfaces.

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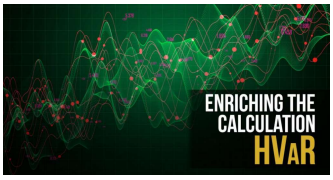

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HVaR, By Dr Lance Smith, Chief Strategy Officer, TS Imagine Historical VaR (HVaR) has become a standard measure of risk in which a current portfolio is subjected to the market conditions of a prior day and the resulting P&L is recorded. Read entire article here.

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Limitations of HVaR: When the Future No Longer Looks Like...

HVaR assumes that present market dynamics are captured in the historical record – what should we do when the world changes? Since Russia's invasion of Ukraine, commodity markets have entered new trading patterns and Lance Smith, TS Imagine Chief Strategy Officer explains some of the tools that can be used to help HVaR without disturbing other risk factors.

APRIL 12, 2022