

A look ahead at options pricing and volatility

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Academics on sabbatical leave are usually ‘taking stock’ of their previous research, thinking about writing a book or starting new projects. I have chosen a rather indirect path to enlightenment: to spend my sabbatical in a hedge fund trading options and forecasting volatility. Hopefully, this request of the Editor-in-Chief of Quantitative Finance for writing a ‘general article on volatility’ will be an opportunity to reflect a bit on the interrelation of option pricing theory and quantitative trading strategies as I see them today.

First, the usual disclaimer: a state-of-the-art survey paper on volatility trading is impossible to write, at least for me. There is simply too much material. For this reason, I will limit this paper to a few topics that I am familiar with, namely where pricing theory and trading interact.

We are at a turning point in pricing theory. On the theoretical side of things, the input of mathematicians and physicists on the field has been tremendous. Confluent hypergeometric functions, integro-differential equations, multi-factor models — just to mention a few examples — have been applied to pricing options and many papers have been published in quantitative finance journals such as this one. If a researcher even *thinks* about a probability distribution as an alternative to the Black–Scholes model, chances are that this distribution has already been tested (usually by a graduate student or a Wall Street quant), a paper has been written and it has been put to work somewhere.

So, is option-pricing theory dead? I believe that the answer is ‘no’, but that we need to broaden our horizons.

First point: until now, option-pricing theory has worked almost exclusively on improving the ‘pricing kernel’. It has not considered other very important elements that go into the price of an option. I am referring to the effects of news about the underlying asset that will be released during the lifetime of the option at known dates. To generate profitable trades, option traders have to reconcile stylized facts about the move-

ment of the underlying asset and the history of implied volatilities with the current price of an option and determine whether it is fairly valued. This judgment will necessarily take into account the fact that there are earnings announcements, releases of macro-economic statistics, ex-dividend dates, takeover proceedings and court judgments, the results of clinical trials (in the case of biotechnology and pharmaceutical stocks) or other idiosyncratic news that will be released over the life of the option. Option pricing theory has proposed very little in terms of handling these very real issues. For theorists, this is a controversial point: the efficient markets dogma assures us that all news is ‘priced in’ so we need not worry. But is this really the case? I don’t think so. The impact of a theory improved in this direction would be great.

Second point: very recent structural developments in options markets may lead to exciting new trading techniques and improved the way in which we view and price listed options *in aggregate*. This major development is the advent of electronic trading of equity options as a primary way of trading in the U.S. markets (‘Direct Market Access’). To some extent, parallel developments are taking place in Europe. Electronic access allows traders to view the market as composed of multiple exchanges — each with its bid-ask spread and depth — and to trade options on several underlying assets across different markets systematically. This leads naturally to portfolio trading of options. An option pricing theory that can handle in a practical way multiple underlying stocks has yet to emerge.

News is coming your way — but are you ready?

Prior to joining the research department of a bulge-bracket investment bank, I had an interview with its head trader for U.S. interest rate options. The interview went

more or less like this: after glancing over my resume, he said: 'Obviously you have written a lot of papers. Fine. So let me ask you this: In two weeks, there is a Federal Reserve monetary policy meeting and an announcement will be made. Your model for short-term interest-rate options says that implied volatility should be 13%. One-month options are trading at 10.5%–11%. What do you do?' I was puzzled. Clearly, I expected a question about some intricate point in options theory where I would dazzle him with my encyclopaedic knowledge. But the gentleman didn't oblige. I proceeded to have a small panic moment and mumbled something (I think) like 'You revise the assumptions of the model and do some more statistics?'. Smirk across the table. I thought hard but could not come up with anything else. The trader looks at his watch impatiently and said 'I have to step out and will return shortly'. Left alone in the room for what seemed like a long time, I wondered what the correct answer to this strange question should be. The trader finally returned and asked me if I found the answer; I replied that that I didn't know. He looked at me straight in the eye and said: '*the answer is YOU BUY THE MARKET!*' The meeting ended shortly thereafter.

I began to realize that derivatives pricing models are viewed — at least by some people — as more than 'risk-management tools' or ways to price exotic options in terms of plain vanillas. Pricing models allow you to investigate the relation between your prior assumptions on price moves and the 'market forecast' or 'market consensus' — through the lens of implied volatility — and thus to create an assessment of value. The Fed announcement date should perhaps be taken into account because uncertainty should increase volatility, all other things equal. Aha.

Later, my own experience trading equity volatility confirmed this point of view. Implied volatility *does* increase for options if there is impending news on the underlying asset. Also, this effect is more pronounced for equities than for other assets like interest rates, due to the fact that the valuation of companies is more idiosyncratic in nature than that of rates or commodities. Let me review a few situations that tend to 'distort' implied volatility.

Most large companies in the U.S. and Europe report earnings regularly to investors. These announcements are made at dates that are known and recorded in the financial news services and certain websites. Since the stock price can move by a significant amount after the announcement, this should be reflected in the implied volatility and — we wish! — in a good option-pricing model. The most straightforward way to do this is to consider that the announcement will give rise to extra randomness in the stock price. This randomness will result in an implied volatility that rises until the announcement date and then drops back to its 'normal' level.

Things that complicate this in practice are that (1) the normal volatility level may not be so easy to estimate; (2) sometimes the implied volatility does not drop immediately after the earnings release; (3) companies have a tendency to *pre-announce* earnings and some option market participants may know about the pre-announcement whereas others may not; (4) there are stocks that act like 'bellwether stocks' for the economy or their sector. Their earnings announcement may affect the broader sector. For example, Intel Corp. is currently the bellwether semiconductor stock. It tends to act like a leading indicator to the market, since a drop in computer demand or an increase generally signals something about the overall economic activity, on the one hand, but also will affect specifically other semiconductor and computer-related companies. The same can be said in the Internet sector about Yahoo, Ebay and Amazon. Question: should there be an increase in implied volatility for options on stocks that are strongly correlated with such bellwether stocks around earnings dates for the latter?

Takeovers and mergers also affect volatility. In market parlance, we say that a company is 'in a deal'. Generally a large capitalization company, with lower volatility, buys one with higher volatility and smaller market capitalization. Prior to the actual deal, the volatility of the target company will exhibit strange effects. If the deal is in cash, at a specified price (say \$20 per share), all calls with strikes below 20 dollars will trade at a high implied volatility, whereas all options with strikes above the takeover price will trade at nearly zero volatility. Volatilities for long expiries should be very low. The reason is that all optionality on that stock disappears after the deal. Pricing options with a naïve model for volatility (based on historical realized or implied volatility) which ignores this can result in big errors.

A slightly different effect holds for mergers in which one company uses shares to buy the other. In this case, the volatility of the target company should converge to the volatility of the buyer company. Once again, traders may be lured into purchasing options on the target company at what appears to be a low premium, but in reality is not. Pricing options around mergers is the counterpart in 'volatility-land' of risk arbitrage, which consists of trading stocks based on the probabilities that two companies will merge. In 2004, a hostile takeover of PeopleSoft by Oracle Corp. affected the implied volatility of PeopleSoft throughout the year, although after several months there is no certainty that the buyout will take place, with periodic announcements by the PeopleSoft board and tender offers by Oracle. Traders in PeopleSoft options know that the buyout is an important (if not *the* most important) determinant of the option premium. Examples like this abound.

I should also mention the importance of announcements of results of clinical trials in the valuation of

options on biotechnology and pharmaceutical stocks. These are times of great breakthroughs in medical therapy and — we should also add — disappointments with promising therapies that didn't quite work. Biotechnology companies often sink or swim based on the success of drugs in their trials pipeline. In the U.S. and Europe, regulators have implemented a very strict protocol for clinical trials. Key dates around which drugs are approved or rejected are published in advance and known to traders. Biotechnology stocks can make large moves around announcement dates and the option implied volatility expresses this view. Once again, this is something that is difficult to model well and that nevertheless affects the dynamics of option prices.

In summary, dates in which impending news is to be released play an important role in practical option valuation. How should we model this? Sometimes people tell me that this is too hard and that there is just too much news to consider. I remain sceptical, preferring to think that most of the stream of news affecting a company can be represented as a diffusion process, but that there are special dates that add a discrete aspect to the valuation. Perhaps, these should be modelled with price jumps. In any case, I don't think that this program has been carried out to reflect the subtleties of the question.

Electronic markets, cross-asset and cross-market trading

US options markets

Currently, U.S. listed option markets comprise six separate exchanges: the Chicago Board of Trade (CBOE), the American Stock Exchange (AMEX), the Philadelphia Stock Exchange (PHLX), the Pacific Coast Exchange (PCOE), the International Securities Exchange (ISE) and the Boston Options Exchange (BOX). The latter two exchanges are 100% electronic, i.e. there is no 'floor' or physical location where humans trade options. A central computer matches all orders. The ISE is currently volume leader in some of the major products, such as the options on the Nasdaq-100 Trust (QQQQ). The remaining exchanges also have electronic access, with slight differences as to how orders are handled in each case. These 'hybrid' execution systems still rely on humans to run the order book and to provide liquidity, continuing the 30+-year-old system of specialist/market-makers. In the mixed execution system, the specialist can see the order, try to trade on his price or leave the order in the book. A very important feature of the American system is the *cross-listing* of options on the same underlying stock in different exchanges. Options on Microsoft Corporation trade on all six exchanges and traders can observe in real time the bid-ask prices and depths for all six markets in real time. Cross-listing prevents markets from crossing each other: the bid-offer

prices must be 'nested', i.e. there cannot exist arbitrage opportunities by trading the same option in different exchanges. The Options Clearing Corporation (OCC) is the authority governing these exchanges. Current regulations are such that all trades must be effectuated in one of the six exchanges and cleared through OCC member firms. In this way, customers are guaranteed prices, which are arbitrage-free across exchanges. Also high-frequency price information is available throughout the trading day. End-of-day prices also are more stable once products are cross-listed. Of course, this is very good for investors, who benefit from improved prices through competition!

From the professionals' perspective, it would be an understatement to say that this high-technology price environment has challenged the way business is carried out. Decimalization, electronic trading and the current cross-listed structure have radically increased price-discovery, hence competition, hence diminished spreads that constitute the natural profit source of specialists and market-makers. As with any evolutionary system, traders have had to adapt and deal with more informed customers (hedge-funds, institutional investors, portfolio managers). How does this state of affairs impact option-pricing models? I will give a natural answer to this question, but first let's discuss the picture on the other side of the Atlantic, where things are different.

European markets

Since Europe was not monetarily or politically unified 20 years ago, the situation of financial markets is very different than in the U.S. Originally, there were separate stock and derivatives markets for different countries. Starting approximately 15 years ago, markets started to consolidate. Futures and options markets are highly electronic in Europe, where screen-based trading has been in place for many years. The differences with U.S. markets are substantial, however.

The Dutch (AEX), English (LIFFE), French (MONEP), Italian (MIB) and Spanish (IBEX) equity derivatives markets have unified under an umbrella clearing organization called Euronext. This market does not include the German (Xetra) and Swiss (SMI) derivatives markets, which are consolidated under the name Eurex. Swiss and German equity derivatives are cross-listed and trades can clear through Eurex. To my knowledge, only a few products such as Eurostoxx futures and options are cross-listed between Euronext and Eurex. So, to begin with, there are two separate liquidity pools.

Another important characteristic of Europe is the way in which the over-the-counter (OTC), or 'upstairs' market interacts with the exchanges. In the U.S., all option trades must take place in one of the six exchanges. This means that if bank A and bank B wish to trade 10 000 Disney options (a large trade) this trade must be

executed in the exchange in a 'competitive bid' process in which all participants can bid for the options. In practice, market regulations allow for traders to obtain indications of interest in the upstairs markets, but nevertheless all trades are cleared in the market. In Europe there is no obligation to clear OTC trades in the exchanges immediately. Large block trades are often done upstairs and cleared hours later in Euronext or Eurex. Thus, banks concentrate the liquidity for trading equity options in Europe.

This has consequences for modelling. In fact one of the main problems that one faces with quantitative options trading in Europe has to do with the reliability of historical data acquisition. At this time, quantitative traders must deal with historical options data that may not reflect the actual prices at which trades took place, since these could have been OTC and were recorded much later. Thus, the lack of a central regulatory body, like the U.S. Options Clearing Corporation, makes it more difficult to obtain a complete historical record of trades. This naturally makes the market more 'incomplete' than the U.S. market. I believe that statistical filtering and estimation methods to generate reliable data for trades on Eurozone equity derivatives would be very useful to develop volatility trading strategies. With the exception of Liffe options, where Euronext has generated a historical database of implied volatility surfaces, this work remains largely to be done.

It's the correlation, stupid!

Setting aside the opacity that still exists in Europe regarding trading options on stocks, the advent of electronic direct market access gives rise to a completely different approach to option valuation.

First, easy electronic access to multiple exchanges allows traders to check whether an option is well-priced, not only with respect to its past realized and implied volatilities, but also with respect to other options in a 'peer group'. The peer group can be the common industry sector, or a set of stocks that share exposure to a common 'risk factor' (à la Sharpe), or to other methods. Options on ETFs (Exchange Traded Funds) are also available to analyze sector volatility. These developments will undoubtedly have a deep impact on option theory, since we are now squarely in the realm of trading portfolios of options, and the relative-value trading of volatilities.

My Wall Street and European friends involved in option market-making in electronic exchanges tell me that it is not a simple business. An electronic market-maker in the ISE must post markets for hundreds of options on hundreds of names. Aside from needing a very good software to post markets in real time, market-makers need be careful about traders that can understand the relative values of different volatilities and build trades that link options across different stocks.

One way to express this problem in more mathematical terms is to understand how the implied volatility surfaces of stocks should move in relation to each other. In classical option theory, the volatility surface is an object obtained by integrating the prices of traded options within a consistent pricing kernel. The rationale behind this is that the information contained in different strikes and expirations completes the market and helps us price 'exotics' (always the exotics!). In the framework that I am proposing, we are at even a higher level: we are in a world with multiple underlying assets, each of which has its own volatility surface. All the surfaces are evolving at the same time and interact. I believe that, since the stocks are correlated, one volatility surface carries information about another. Thus, for instance a large change in the volatility surface of a 'bellwether' stock may impact the surfaces of other stocks. Modelling the joint evolution of these surfaces is the ultimate goal, which matches the current multi-asset, multi-market trading framework in which we exist right now.

Finally, there is a choice in terms of which exchange to use for multiply-listed options. Clearly, if we look for immediacy in execution and tight markets, some of the US markets like the ISE are a destination of choice. But the ISE is not necessarily always the best destination. Furthermore, the possibility to improve wider markets allows traders equipped with good models to generate profits by hedging in different markets and with different stocks.

In conclusion, I believe that the quantitative finance community has made great strides in option valuation when it comes to understanding pricing kernels and their relation to implied volatility surfaces, at the single stock level. However strongly I believe that improvements can be made in terms of discrete-event management. Finally, the 'new new' frontier seems to lie in how to integrate this knowledge into managing a portfolio of options across different assets and to construct profitable and diversified positions. This is undoubtedly one of the important research directions for the next few years.