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Joint modeling of call and put implied volatility

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Abstract

This paper exploits the fact that implied volatilities calculated from identical call and put options have often been empirically found to differ, although they should be equal in theory. We propose a new bivariate mixture multiplicative error model and show that it is a good fit to Nikkei 225 index call and put option implied volatility (IV). A good model fit requires two mixture components in the model, allowing for different mean equations and error distributions for calmer and more volatile days. Forecast evaluation indicates that, in addition to jointly modeling the time series of call and put IV, cross effects should be added to the model: put-side implied volatility helps forecast call-side IV, and vice versa. Impulse response functions show that the IV derived from put options recovers faster from shocks, and the effect of shocks lasts for up to six weeks.

Keywords: Implied volatility; Option markets; Volatility forecasting; MEM models; Impulse responses

1. Introduction

In theory, the implied volatilities derived from a call option and a put option with the same underlying asset, strike price, and expiration date should be equal — both reflect the market's expectation of the volatility of the returns of the underlying asset during the remaining life of the two options. However, empirical research suggests that when call and put implied volatilities (IV) are backed out of option prices using an option pricing formula, they often deviate from each other.

The reason behind the inequality of put and call implied volatilities may lie in the different demand structure for calls and puts. There is an inherent demand for put options that does not exist for similar calls, as institutional investors buy puts regularly for purposes of portfolio insurance. There are often no market participants looking to sell the same options to offset this demand, meaning that prices may need to be bid up high enough for market makers to be willing to become counterparties to the deals. With no market imperfections such as transaction costs or other frictions present, option prices should always

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be determined by no-arbitrage conditions, making the implied volatilities of identical call and put options the same. However, in real-world markets the presence of imperfections may allow option prices to depart from no-arbitrage bounds if there is, for example, an imbalance between supply and demand in the market. References to existing literature and more details on this topic are provided in Section 2.

Despite the fact that call and put-side implied volatilities differ, they must be tightly linked to one another at all times — after all, they both represent the same market expectation, and the driving forces behind their values are common. Therefore, it can be argued that there is potential value added in jointly modeling time series of implied volatilities, one derived from call option prices and the other from put option prices. Further, the interactions between the two variables can be studied with cross effects, i.e., allowing call IV to depend on lagged values of put IV, and vice versa.

The modeling of IV provides a valuable addition to the extensive body of literature on volatility modeling. IV is truly a forward-looking measure: implied volatility is the market's expectation of the volatility in the returns of an option's underlying asset during the remaining life of the option in question. Examples of the IV modeling literature include Ahoniemi (2008), who finds that there is some predictability in the direction of change of the VIX Volatility Index, an index of the IV of S&P 500 index options. Dennis, Mayhew, and Stivers (2006) find that daily innovations in the VIX Volatility Index contain very reliable incremental information about the future volatility of the S&P 100 index.[1] Other studies that attempt to forecast IV or to utilize the information contained in IV to trade in option markets include Harvey and Whaley (1992), Noh, Engle, and Kane (1994), and Poon and Pope (2000). Reliable forecasts of implied volatility can benefit option traders, and many other market participants as well: all investors with risk management concerns could also benefit from accurate forecasts of future volatility.

The implied volatility data used in this study are calculated separately from call and put options on the Japanese Nikkei 225 index. Separate time series for call and put-side IV offer a natural application for the bivariate multiplicative model presented below. In their analysis of implied volatilities of options on the S&P 500 index, the FTSE 100 index, and the Nikkei 225 index, Mo and Wu (2007) find that US and UK implied volatilities are more correlated with each other than with Japanese implied volatilities, indicating that the Japanese market exhibits more country-specific movements. Therefore, it is interesting to analyze the Japanese option market and its implied volatility in this context, as investors may be presented with possibilities in the Japanese index option market that are not available elsewhere. Mo and Wu (2007) also report that the implied volatility skew is flatter in Japan than in the US or UK markets. They conclude that in Japan, the risk premium for global return risks is smaller than in the other two countries. The developments in the Japanese stock market during the late 1990s in particular are very different from Western markets, with prices declining persistently in Japan. This characteristic also makes the Japanese market unique. Mo and Wu (2007) observe that out-of-the-money calls have relatively higher IVs in Japan, as investors there expect a recovery after many years of economic downturn. Investors in Japan seem to price more heavily against volatility increases than against market crashes.

In this paper, we introduce a new bivariate multiplicative error model (MEM). MEM models have gained ground in recent years due to the increasing interest in modeling non-negative time series in financial market research.[2] The use of MEM models does not require logarithms to be taken of the data, allowing for the direct modeling of variables such as the duration between trades, the bid-ask spread, volume, and volatility. Recent papers that successfully employ multiplicative error modeling in volatility applications include Engle and Gallo (2006), Lanne (2006, 2007), Brunetti and Lildholdt (2007), and Ahoniemi (2007). Lanne (2006) finds that the gamma distribution is well suited for the multiplicative modeling of the realized volatility of two exchange rate series; and Ahoniemi (2007), using the same data

[1] The data set used by Dennis et al. (2006) ends at the end of 1995, when options on the S&P 100 index were used to calculate the value of the VIX. The Chicago Board Options Exchange has since switched to S&P 500 options.

[2] A special case of multiplicative error models is the autoregressive conditional duration (ACD) model, for which an abundant body of literature has emerged over the past ten years.