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The evolving dynamics of the Australian SPI 200 implied volatility surface

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ABSTRACT

This paper is concerned with the evolutionary behaviour of implied volatility patterns, which identifies vega uncertainty. Using a principal component analysis (PCA), we compare reported results in US and European markets with our findings here for Australian markets. In this way, we seek to establish the degree to which prior findings have “universality” as opposed to being strictly the outcome of a particular market at a particular time. In a broad sense, we are able to reproduce prior findings. But there are differences. Prior studies find that prevailing shocks impact primarily uniformly across options independently of moneyness (a “parallel shift”) with a second effect (a “Z-shaped twist”) that impacts differentially in relation to the option’s degree of moneyness. We find that the “parallel shift” can be interpreted as applying primarily to in-the-money (ITM) options and the Z-shaped twist to out-of-the-money (OTM) options. As a result, the overall effects are interpreted in relation to a volatility smile.

1. Introduction

In recent years, considerable interest has focused on the behaviour of the implied volatilities of option contracts derived from inverting the Black-Scholes (1973) model. The empirical evidence shows that for options on the same underlying at the same point in time, implied volatilities vary across both different strike prices and different times-to-maturity. In addition, implied volatilities also vary, in a stochastic way, across different points in time for a given option, suggesting that implied volatilities can be viewed as a two-dimensional surface which evolves over time (Skiadopoulos et al., 1999). Thus, even when at a particular moment in time an index option is priced so as to accommodate the option’s implied volatility, the option’s “vega” risk is exposed as the changing dynamics of the implied volatility surface with respect to moneyness (in- or out-of-the-money) and time-to-maturity expose

For this reason, the time-evolution of implied volatility has stimulated study aimed at inducing a degree of structure on the processes that underpin the phenomenon. Such quantification is of direct interest to practitioners trading in options. Not only do changes in implied volatility serve as convenient shorthand for changes in prices for traders, but, increasingly, market participants are also interested in trading volatility directly. From a theoretical standpoint, the reduction of changing implied volatilities as a function of moneyness and time-to-maturity to identified trends provides the framework within

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which theoretical comprehension can be developed.[1] Thus there is a need to confirm reported findings in the context of alternative option types and market settings so that they can be accorded a degree of "universality", or alternatively be interpreted as having a restricted application for a particular class of options over a particular period.

Due to the fact that volatility of volatility follows a stationary autoregressive progress in time, a principal components analysis (PCA) offers an appropriate technique for analysis of the dynamics of implied volatility. The technique allows for the time-series of daily changes in implied volatility as a function of moneyness to be constructed in terms of a limited number of combinations (dimensions) of the moneyness designations.[2] Skiadopoulos et al. (1999) use PCA to study the dynamics of the S&P 500 implied volatility surface by investigating the number and shape of shocks that move the implied volatility smiles and surfaces. Fengler et al. (2003) have followed the Skiadopoulos et al. (1999) study with a PCA for the implied volatility surface along maturity slices for DAX options.

More recent developments – so as to be able to cross-reference findings with prior findings – have remained restricted to pre-global financial crisis (GFC) data. Thus, a more recent study by Bernales and Guidolin (2014) – which uses data for S&P 500 options prior to end 2006 – explores how the time-variation of stock option volatility surfaces might be expected to evolve as an outcome of the learning behaviour of agents in option markets. They determine best forecasts by incorporating information from the dynamics in the option volatility surfaces. In this paper – so as to be able to cross-reference our findings with prior findings – we have adhered to the same restriction before venturing as to how the GFC has altered relationships either for the period of crisis or indeed more permanently. Bernales and Guidolin (2015) – again for S&P 500 options – show how that learning leads to time-varying beliefs and generates predictability patterns across option contracts with different strike prices and maturities. As an outcome, the implied movements in the implied volatility surface can be made to resemble those observed empirically. Carra and Wu (2016) develop an option pricing framework that is developed from how institutional investors actually manage options positions. Their framework commences with the near-term dynamics of the implied volatility surface, from which no-arbitrage constraints are derived. When the framework is applied to the S&P 500 index (1997–2015), they show that, as for option implied volatilities, realized and expected volatilities can be constructed across option contracts, and find that the extracted risk premium significantly predicts future stock returns.

The present study focuses on the implied volatility surface dynamics of Australian ASX SPI 200 options prior to the GFC. For this period, Skiadopoulos et al. (1999) and Fengler et al. (2003) report that prevailing shocks impact primarily uniformly across options independently of moneyness (a "parallel shift") with a second effect (a "Z-shaped twist") that impacts differentially in relation to the option's degree of moneyness. Here, we report important differences. Significantly, we find that the evolvement of implied volatility for at-the-money (ATM) options exhibits a high degree of independence from both in-the-money (ITM) and out-of-the-money (OTM) options, and that the first and second principal components of the PCA can may be interpreted as separating the behaviour of the ITM and OTM classes. Our explanation of the observed phenomena is therefore able to identify the Z-shaped twist at the interface between in-the-money and out-of-the – money options as signifying that these two classes of options represent two different "types of assets." This finding provides a foundation for an interpretation of the option volatility smile as the outcome of different expectations and preferences across these two classes of options.

2. Data and methodology

In line with Skiadopoulos et al. (1999), we record daily differences of implied volatilities across different levels of moneyness and different ranges of days to expiry (expiry buckets). The motivation is that, notwithstanding the Black-Scholes (1973) model, we know that, empirically, the option's implied volatility is a function of both attributes. We capture change in average daily implied volatility for levels of moneyness – which we define as the level of the index divided by the exercise level for the option (S/K) – underlying market price divided by the partitioned on increments of 0.1 from 0.55 to 2.1 (16 subgroups), with the range of days to expiration categorised in there expiry buckets: 0–21 days, 21–186 days, and 186–552 days. The three expiry buckets are analysed separately over each of the six years 2001–2006. The ASX SPI 200 implied volatility surface for a total of 721,300 data points over the period 2001–2006 is plotted as a function of moneyness and time to maturity in Fig. 1.

For each time-to-expiry bucket, the intention is to determine how implied volatility evolves as a function of a restricted number of "components" of moneyness. Specifically, PCA allows us to take the matrix $CAIV_{t,k}$ of the changes in daily average implied volatility for each trading day of the year ($t = 1$, T) at each level of moneyness ($k = 1$, K) and reconstruct the matrix in terms of a "principal" number of "components" of the contributions from the moneyness levels. Thus, a PCA allows us to construct constituents vectors y_n:

$$y_n = \sum_{k=1}^{K} CAIV_{t,k} c_{k,n} \tag{1}$$

[1] For example, recent studies have found predictable dynamics in the implied volatility surfaces such as can be attributed to general equilibrium models (Chalamandaris and Tsekrekos (2010).

[2] See studies, for example, by Hsieh (1993) and Hafner and Wallmeier (2001).