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Misreaction or misspecification? A re-examination of volatility anomalies

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ABSTRACT

Existing research examines the impact of volatility shocks on the relative pricing of long-term vs. short-term options and documents patterns of "short-horizon underreaction" and "long-horizon overreaction" in the options market. These studies, however, rely on implied volatilities derived from specific option-pricing models and are thus subject to model specification errors. In this paper, we show that these anomalous patterns are the result of model misspecification as opposed to market misreaction. We provide evidence that these patterns are consistent with, in both direction and magnitude, inherent biases in the misspecified models. We also apply a model-free approach to re-examine the anomalous patterns and find no evidence of market misreaction.

1. Introduction

Option implied volatility reflects investors' expectations of future volatility over the remaining life of the option. As new information arrives, investors revise their expectations of future volatility leading to changes in implied volatility. If investors formulate their expectations rationally, the level of and change in implied volatility should fully incorporate the set of information accumulated to date and newly arrived information. Previous empirical research (e.g., Stein, 1989; Poteshman, 2001) examines the impact of volatility shocks on the relative pricing of long-term vs. short-term options and documents certain anomalous patterns. This is interpreted as market misreaction to volatility shocks. These studies, however, rely on implied volatilities derived from specific option-pricing models and are thus subject to model specification errors. In this paper, we argue that these anomalies are the result of model misspecification as opposed to market misreaction. We provide evidence that these patterns are consistent with both the direction and magnitude of pricing biases inherent in the specific models assumed by previous studies. We also implement a model-free approach to re-examine the anomalous patterns and find no evidence of market misreaction.

Parallel to the literature on stock market anomalies, previous empirical studies document misreaction to volatility shocks in the options market. For example, Stein (1989) derives volatility term structure relations under the assumption of a mean-reverting, AR(1)-type stochastic volatility model and empirically tests the theoretical relationship using Black and Scholes (1973, B-S) implied volatilities from the S&P 100 (OEX) index options during the period from December 1983 to September 1987. He finds that the estimated slope coefficient of the volatility term structure is significantly higher than predicted and the forecast error for future volatility is negatively correlated with the short-term volatility. These results are interpreted as evidence that long-term volatility overreacts to changes in short-term volatility. In a subsequent study, Poteshman (2001) performs further tests on options market misreaction by examining implied volatilities from the S&P 500 (SPX) index options during the period from June 1988 to August 1997. In addition to using data from a different options market and time period, he also performs new tests of market misreaction by fitting Heston's (1993) stochastic volatility model (the Heston model, hereafter) to option prices. He then extracts instantaneous volatilities from the fitted model using both full sample and subsets of short-term and long-term options. Comparing instantaneous volatilities extracted from short-term and long-term options, he examines how volatility shocks are projected over the long horizon relative to the short horizon. His findings support Stein's (1989) overreaction hypothesis and a new pattern of market underreaction at short horizons. He concludes that these mixed patterns of

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"*long-horizon overreaction*" and "*short-horizon underreaction*" are consistent with investors who have established prior beliefs and are initially slow to recognize/react to volatility shocks and yet are prone to overreact once they do recognize the volatility shocks.[1]

Evidence on volatility anomalies is mixed, however. The findings may vary depending on model specification and choice of option markets and sample periods. For example, Campa and Chang (1995) empirically examine volatility term structure under the Hull and White (1987) stochastic volatility model using daily currency option prices from December 1, 1989 to August 31, 1992. They find little evidence that long-term volatility overreacts to innovations in short-term volatility. Heynen et al. (1994) examine volatility term structure under three alternative model specifications – mean-reverting, GARCH, and EGARCH volatility models. Their mean-reverting model is essentially the same AR(1) model assumed by Stein (1989). They empirically test the derived term structure relations using equity and equity index options and find that the results vary substantially across model specifications. Although overreaction cannot be rejected under either the mean-reverting model or the GARCH model, it is rejected under the EGARCH model. In other words, model specification is critical and market misreaction may or may not be rejected depending on the assumed volatility model.

The mixed findings on market misreaction is not entirely unexpected. All previous studies have relied on implied volatilities calculated using specific option-pricing models such as the B-S model or the Heston model. Their findings are based on joint tests of the expectations hypothesis and the assumed option-pricing model and are thus subject to model specification errors. Empirical studies such as Bates (1996, 2000, 2006), Bakshi et al. (1997, 2000), Andersen et al. (2002), Pan (2002), Carr and Wu (2003), Chernov et al. (2003) and Eraker et al. (2003) provide evidence of severe misspecification in the B-S model and commonly used stochastic volatility models. Although specification errors can potentially have significant effects on tests of market misreaction (e.g., Heynen et al., 1994), the existing literature has not addressed the issue of how model misspecification may lead to conflicting findings on market misreaction.

In this paper, we examine the impact of misspecified models on tests of market misreaction and provide an explanation for the conflicting findings in previous studies. In particular, we focus on specification errors of the B-S model and the Heston model since most previous studies perform misreaction tests using implied volatilities based on these two models. We show that both models impose specific structures on the relationship between implied volatilities of long-term and short-term options. Such model-specific relations have direct implications for misreaction tests. We provide both theoretical arguments and Monte Carlo analysis to demonstrate that the patterns of long-horizon overreaction and short-horizon underreaction are consistent with the direction and magnitude of model specification errors inherent in these models. Even in the absence of any market misreaction, these model-specific relations may lead to the false identification of anomalous patterns in implied volatility.

More importantly, we adopt a model-free approach and perform new tests of market misreaction. In contrast to previous studies, we do not make any specific assumptions about the underlying asset price process or make use of any option-pricing models. We thus avoid the problems arising from joint tests of the null hypothesis and the assumed model in previous studies. The key ingredient of our approach is the use of model-free implied volatility[2] that is extracted directly from market prices of options across strike prices. In addition, the model-free implied volatility is also informationally more efficient than the B-S implied volatility (e.g., Jiang and Tian, 2005). Empirical tests using the model-free implied volatility are thus also more efficient than corresponding tests using the B-S implied volatility.[3]

Using SPX options data from June 1, 1988 to December 31, 2007, we perform model-free tests of market misreaction as well as their model-based counterparts. By performing both model-based and model-free versions of the same test, it is possible to disentangle the effect of model misspecification and misreaction. Replicating Stein's model-based test, we find a similar negative relationship between the forecast error of future volatility and the short-term volatility. This is consistent with Stein's finding of long-term volatility overreacting to changes in short-term volatility. In contrast, the model-free version of the same test provides no evidence of any negative (or positive) relationship, rejecting the overreaction hypothesis. Removing model specification problems associated with previous studies, all evidence of market misreaction disappears.

Combining results from both model-free and model-based tests, it is clear that the model-based tests can erroneously reject the null hypothesis when model-free tests do not. This finding casts doubt on the validity of volatility anomalies identified in previous studies. When a model-based test finds evidence of negative correlation, it does not necessarily indicate market misreaction. Model-free tests should be performed as well to corroborate the findings. One must be cautious when drawing conclusions from the results of model-based tests.

The rest of the paper is organized as follows. Section 2 provides a review of the relevant literature on options market misreaction and motivates the present study. In Section 3, we examine the impact of model specification errors on the misreaction tests in previous studies. Model-free tests of market misreaction are described and implemented in Section 4. The final section concludes.

2. Model-based tests and volatility anomalies

Parallel to the literature on stock market anomalies, previous empirical studies have identified certain patterns of market misreaction in the options market. These studies (e.g., Stein, 1989; Poteshman, 2001) investigate market misreaction by measuring how the level and change in implied volatilities react to volatility shocks. In particular, they focus on volatility term structure relations and examine whether long-term implied volatility misreacts to changes in short-term implied volatility. Collectively, they find

[1] Both "long-horizon overreaction" and "short-horizon underreaction" describe how volatility shocks have different impact on short-term vs. long-term options. The mechanisms used to detect them are different however. While the former is detected by examining whether the volatility forecast error (or unexpected change in volatility) is predictable by the short-term volatility, the latter is detected by investigating whether long-term and short-term volatilities react consistently to volatility shock (or unexpected change in volatility). Note also that the terms "short-horizon" and "long-horizon" refer to option maturities and are used interchangeably with "short-term" and "long-term" in the existing literature. We continue to use these terms following previous research.

[2] The concept of model-free implied variance/volatility arose from the development of variance swaps and appeared in as early as Dupire (1994) and Neuberger (1994). It is further developed and refined by Carr and Madan (1998), Demeterfi et al. (1999), Britten-Jones and Neuberger (2000), Jiang and Tian (2005) and Carr and Wu (2009).

[3] Our model-free approach is in the spirit of previous empirical research on arbitrage-free relationships in the options market. These studies include Chance (1987), Kamara and Miller (1995), Aït-Sahalia and Lo (1998) and Ackert and Tian (2001) (on put–call parity violations by the SPX options), Diz and Finucane (1993), Finucane (1997) and Poteshman and Serbin (2003) (on irrational early exercise of the OEX and equity options), and Bondarenko (2003) (on violations of statistical arbitrage by the SPX options).