The Impact of Market Conditions on the Performance of Different Option Pricing Models

Master Thesis

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Executive summary

This thesis discusses the performance of different option pricing models during turbulent market periods extending (1) from September 2nd, 1997 through December 30th, 1997, (2) from July 17th, 2001 through November 16th, 2001, (3) from January 3rd, 2007 through May 2nd, 2007, and (4) from August 11th, 2008 through December 12th, 2008. It focuses on the jump-diffusion model of Merton (1973), the stochastic volatility model of Heston (1993), and the stochastic volatility/jump-diffusion model of Bates (1996).

The growing complexity of financial markets and the longing for increasingly complex mathematical models to account for the need of providing efficient pricing and hedging of derivative securities created some substantial challenge in the field of quantitative finance.

Fractal scaling laws initially introduced by Mandelbrot (1963) are used in this thesis to develop a simple method that allows modeling the evolution of the CBOE volatility index (VIX). Confirmed by algorithms which are based on mementa, we identify seven extreme events of which four are used to define the sample periods for the empirical analysis of the option pricing models.

In consideration of the empirical findings that option pricing models suffer from misspecification, this thesis discusses a new approach which is exclusively based on extremely long-term options. This *time to maturity approach* takes the special features of the „term structure' of implied volatility surfaces into account, as it is proven empirically that the smile effect almost disappears for long-term options. This study shows – with the ultimate aim of extracting relevant information content from option prices to examine how theses derivative securities behaved in different market periods – that the *time to maturity approach* reduces the error functional significantly, especially for long-term options.

The calibration of option pricing models to obtain implied parameters which fit the observed market prices results in an optimization problem on non-linear surfaces. The probability that we may end up in a local optimum when applying traditional optimization techniques (like linear or quadratic optimization routines) requires more complex optimization techniques. An evolutionary algorithm, which allows approximating the global optimum stochastically, is used in this thesis to implement different option pricing models.

Applying several restarts of the optimization run indicates evidence that the numerical techniques provide quite stable results. In general, however, implied parameters of the tested option pricing models do not convert to the „true' solution, inducing important biases. The variance and the mean jump size parameter of the jump-diffusion model of Merton seem to be an exception, as they remain quite stable during several restarted optimization runs.

To sum up, the ability to incorporate the volatility surface measured by the in-sample fit and to model its evolution measured by the out-of-sample performance depends strongly on the market condition. Additionally, the out-of-sample mean absolute percentage error (MAPE) is found to be an efficient measure of market sentiment as it exhibit a remarkably stability over several optimization routines on the same data set.