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A superconvergent partial differential equation approach to price variance swaps under regime switching models

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Abstract

We present a superconvergent finite difference algorithm to price discretely sampled variance swaps. We consider the Black–Scholes model, the Merton's jump-diffusion model, stochastic volatility models that use constant-elasticity of variance for the instantaneous variance and corresponding regime switching models. PDE approach provides a universal and efficient framework for pricing under these models. To obtain extremely accurate results, we solve PDEs whose associated terminal conditions can be represented as second-order polynomials based on the two popular definitions of realised variance and for which the spatial derivatives greater than second-order are all zero. We then apply second-order finite difference discretisations in space with an exponential time integration. We also derive analytical solutions under the Merton's model and some regime switching models to validate our superconvergent results.

Keywords: variance swaps, finite difference, exponential time integration, Merton's jump-diffusion model, stochastic volatility model, regime switching models
2010 MSC: 35G61, 91B25, 65M06

1. Introduction

The most popular volatility derivative that exists in financial markets is the variance swap. Replicated by a portfolio of vanilla options [1, 2], the contract has a zero upfront premium with payoff

$$V_T = L\left(\sigma_R^2 - K\right),$$

at maturity T, where L is the notional amount per volatility squared. At initiation of the contract,

$$V_0 = \mathbb{E}\left[\exp\left(-\int_0^T r\,dt\right) L\left(\sigma_R^2 - K\right)\right],$$

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