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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

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## 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

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

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

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

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