greeks: Sensitivities of Prices of Financial Options and Implied Volatilities

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Summary

The greeks R package leverages the Black-Scholes model and more general jump diffusion models to compute sensitivities of financial option prices for European, geometric and arithmetic Asian, as well as American options, with various payoff functions (for a treatment see Hull (2022), and Angus (1999) for the case of geometric Asian options). The Black-Scholes model is the standard approach for modelling stock prices, while jump diffusion models aim to offer a more realistic representation of market movements, see Kou (2002). Furthermore, methods to compute implied volatilities are provided for a wide range of option types and custom payoff functions. Classical formulas are implemented for European options in the Black-Scholes model, as is presented in Hull (2022). In the case of Asian options, Malliavin Monte Carlo Greeks are implemented, see Hudde & Rüschendorf (2023), or Lyuu et al. (2019). For American options, the Binomial Tree method is implemented, as is presented in Hull (2022). greeks includes a Shiny app to interactively plot the results.

Statement of need

The accurate pricing of financial options and the computation of the Greeks, i.e., the sensitivities of option prices with respect to the input parameters, is of great theoretical and practical interest in finance. For instance, the Greek Δ (Delta) measures how the price of an option changes with a minor change in the underlying asset's price, while Γ (Gamma) measures how Δ itself changes as the price of the underlying shifts. Both Greeks are important for hedging an option. Several software packages exist, but a comprehensive framework including both exotic options and an interactive visualization tool is still missing.

For example, a widely known program to compute Greeks is the Excel add-in DerivaGem which accompanies Options, Futures and other Derivatives (Hull, 2022). DerivaGem computes option prices, Greeks and implied volatilities and displays them interactively. The model selection is restrained to the Black-Scholes and the Binomial Tree models. The framework Quantlib (Ametrano & Ballabio, 2003), which is ported to R via RQuantLib (Eddelbuettel et al., 2023), provides option prices and Greeks for American options in the Binomial Tree model, and for European and geometric Asian options in the Black-Scholes model. Yet, arithmetic Asian options are not considered.

Further packages on CRAN include derivmkts (McDonald, 2022) and OptionPricing (Dingeç & Hörmann, 2022). derivmkts only computes Greeks for Binomial and European options. OptionPricing implements very efficient algorithms for arithmetic Asian call options, but not for put options, and only the Greeks Δ and Γ.

greeks is the most comprehensive R package for the computation of Greeks, i.e., the only one for European, American, and geometric as well as arithmetic Asian Greeks. In addition, Asian Greeks with digital payoff functions and second-order Greeks are computed. Also, it is the only

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R package for the computation of Greeks in jump diffusion models.

greeks has been applied to investigate the performance of Monte Carlo Greeks for jump diffusion models from Hudde & Rüschendorf (2023). Furthermore, greeks can be used in (under-)graduate courses in financial mathematics to provide a better understanding of option prices and Greeks by interactive visualizations. greeks is also suited for financial risk management purposes.

How to run the Shiny app

The interactive Shiny app is started with greeks::Greeks_UI():
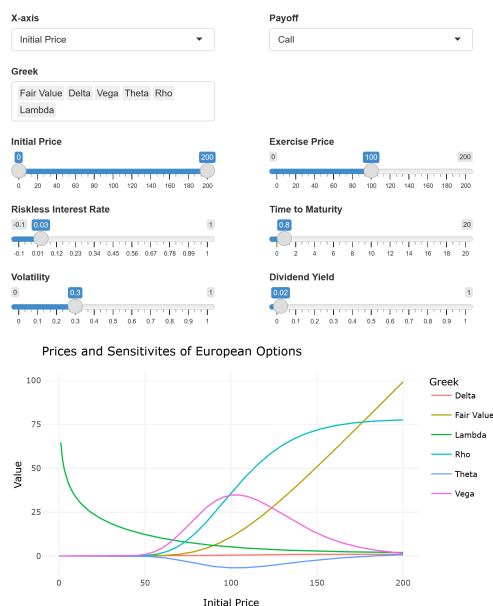
This works for European options, American options, geometric Asian options, as well as Asian options. Due to the computational complexity required by the jump diffusion model, making it impractical for interactive exploration, the Shiny app only supports the much quicker-to-compute Black-Scholes model. For the same reason, the set of Greeks is limited depending on the option type. On the y-axis, the option value and the value of the Greeks are displayed. For the x-axis, several parameters like initial_price or time_to_maturity are possible choices for visualization.

Acknowledgements

I would like thank the Editor Charlotte Soneson and the reviewers Oskar Laverny and Ba Hung for their continuous support in improving the package and the paper.

References

Ametrano, F., & Ballabio, L. (2003). *QuantLib - a free/open-source library for quantitative finance*. http://quantlib.org/

Angus, J. E. (1999). A note on pricing Asian derivatives with continuous geometric averaging. *Journal of Futures Markets*, *19(7)*, 845–858. https://doi.org/10.1002/(SICI)1096-9934(199910)19:7%3C845::AID-FUT6%3E3.0.CO;2-D

Dingeç, K., & Hörmann, W. (2022). *OptionPricing: Option pricing with efficient simulation algorithms*. https://cran.r-project.org/web/packages/OptionPricing/

Eddelbuettel, D., Nguyen, K., & Leitch, T. (2023). *RQuantLib: R interface to the 'QuantLib' library*. https://cran.r-project.org/web/packages/RQuantLib/

Hudde, A., & Rüschendorf, L. (2023). European and Asian Greeks for exponential Lévy processes. *Methodology and Computing in Applied Probability*, *25 (39)*. https://doi.org/10.1007/s11009-023-10014-5

Hull, J. C. (2022). *Options, futures, and other derivatives* (11th Edition). Pearson.

Kou, S. G. (2002). A jump-diffusion model for option pricing. *Management Science*, *48(8)*. https://doi.org/10.1287/mnsc.48.8.1086.166

Lyuu, Y.-D., Teng, H.-W., Tseng, Y.-T., & Wang, S.-X. (2019). A systematic and efficient simulation scheme for the Greeks of financial derivatives. *Quantitative Finance*, *19*(7), 1199–1219. https://doi.org/10.1080/14697688.2018.1562196

McDonald, R. (2022). *Derivmkts: Functions and R code to accompany derivatives markets*. https://cran.r-project.org/web/packages/derivmkts/