Package ‘greeks’

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Title Sensitivities of Prices of Financial Options and Implied Volatilities

Version 1.4.4

Description Methods to calculate sensitivities of financial option prices for European, geometric and arithmetic Asian, and American options, with various payoff functions in the Black Scholes model, and in more general jump diffusion models. A shiny app to interactively plot the results is included. 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, J. C. (2017), Options, Futures, and Other Derivatives.
In the case of Asian options, Malliavin Monte Carlo Greeks are implemented, see Hudde, A. & Rüschendorf, L. (2023). European and Asian Greeks for exponential Lévy processes. <doi:10.1007/s11009-023-10014-5>. For American options, the Binomial Tree Method is implemented, as is presented in Hull, J. C. (2017).

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BugReports `https://github.com/ahudde/greeks/issues`

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Contents

`Binomial_American_Greeks`

Computes the Greeks of an American call- or put-option with the Binomial options pricing model

---

Description

In contract to European Options, American options can be executed at any time until the expiration date. For more details on the definition of Greeks in general see Greeks. This functions computes Greeks of American put- and call options in the binomial option pricing model (see (Hull, 2022)).

Usage

```
Binomial_American_Greeks(
  initial_price = 100,
  exercise_price = 100,
  r = 0,
  time_to_maturity = 1,
  volatility = 0.3,
  dividend_yield = 0,
  payoff = "call",
  greek = c("fair_value", "delta", "vega", "theta", "rho", "epsilon", "gamma"),
  steps = 1000,
  eps = 1/1e+05
)
```

Arguments

`initial_price` • initial price of the underlying asset.

`exercise_price` • strike price of the option.

`r` • risk-free interest rate.

time_to_maturity
- time to maturity.

volatility
- volatility of the underlying asset.

dividend_yield
- dividend yield.

payoff
- the payoff function, a string in ("call", "put").

greek
- the Greek to be calculated.

steps
- the number of integration steps.

eps
- the step size for the finite difference method to calculate theta, vega, rho and epsilon

Value

Named vector containing the values of the Greeks specified in the parameter `greek`.

References

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

See Also

Greeks_UI for an interactive visualization

Examples

```
Binomial_American_Greeks(initial_price = 100, exercise_price = 100,
r = 0, time_to_maturity = 1, volatility = 0.3, dividend_yield = 0,
payoff = "call", greek = c("fair_value", "delta", "vega", "theta", "rho",
"epsilon", "gamma"), steps = 20)
```

BS_European_Greeks — *Computes the Greeks of a European call- or put-option, or of digital options in the Black Scholes model.*

Description

For details on the definition of Greeks see Greeks.

Usage

```
BS_European_Greeks(
  initial_price = 100,
  exercise_price = 100,
  r = 0,
  time_to_maturity = 1,
  volatility = 0.3,
  dividend_yield = 0,
```

```
  payoff = "call",
  greek = c("fair_value", "delta", "vega", "theta", "rho", "epsilon", "lambda", "gamma",
    "vanna", "charm", "vomma", "veta", "speed")
)
```

Arguments

- `initial_price` • initial price of the underlying asset
- `exercise_price` • strike price of the option
- `r` • risk-free interest rate
- `time_to_maturity` • time to maturity in years
- `volatility` • volatility of the underlying asset
- `dividend_yield` • dividend yield
- `payoff` • in c("call", "put", "cash_or_nothing_call", "cash_or_nothing_put", "asset_or_nothing_call", "asset_or_nothing_put")
- `greek` • Greeks to be calculated in c("fair_value", "delta", "vega", "theta", "rho", "epsilon", "lambda", "gamma", "vanna", "charm", "vomma", "veta", "vera", "speed", "zomma", "color", "ultima")

Value

Named vector containing the values of the Greeks specified in the parameter `greek`.

See Also

Malliavin_European_Greeks for the Monte Carlo implementation

Greeks_UI for an interactive visualization

Examples

```
BS_European_Greeks(initial_price = 120, exercise_price = 100,
r = 0.02, time_to_maturity = 4.5, dividend_yield = 0.015, volatility = 0.22,
greek = c("fair_value", "delta", "gamma"), payoff = "put")
```

BS_Geometric_Asian_Greeks

Computes the Greeks of a Geometric Asian Option with classical Call- and Put-Payoff in the Black Scholes model

---

Description

For the definition of geometric Asian options see Malliavin_Geometric_Asian_Greeks. BS_Geometric_Asian_Greeks offers a fast and exaction computation of Geometric Asian Greeks.

Usage

```
BS_Geometric_Asian_Greeks(
  initial_price = 100,
  exercise_price = 100,
  r = 0,
  time_to_maturity = 1,
  volatility = 0.3,
  dividend_yield = 0,
  payoff = "call",
  greek = c("fair_value", "delta", "rho", "vega", "theta", "gamma")
)
```

Arguments

- `initial_price`
  - initial price of the underlying asset, can also be a vector
- `exercise_price`
  - strike price of the option
- `r`
  - risk-free interest rate
- `time_to_maturity`
  - time to maturity in years
- `volatility`
  - volatility of the underlying asset
- `dividend_yield`
  - dividend yield
- `payoff`
  - the payoff function, either a string in ("call", "put")
- `greek`
  - the Greeks to be calculated in c("fair_value", "delta", "vega", "theta", "rho", "gamma", "vomma")

Value

Named vector containing the values of the Greeks specified in the parameter `greek`.

See Also

Malliavin_Geometric_Asian_Greeks for the Monte Carlo implementation which provides digital and custom payoff functions and also works for the jump diffusion model

Greeks_UI for an interactive visualization

Examples

```
BS_Geometric_Asian_Greeks(initial_price = 110, exercise_price = 100,
r = 0.02, time_to_maturity = 4.5, dividend_yield = 0.015, volatility = 0.22,
greek = c("fair_value", "delta", "rho", "vega", "theta", "gamma"),
payoff = "put")
```

BS_Implied_Volatility *Computes the implied volatility for European put- and call options in the Black Scholes model via Halley's method.*

Description

For the definition of *implied volatility* see Implied_Volatility. BS_Implied_Volatility offers a very fast implementation for European put- and call options applying Halley's method (see en.wikipedia.org/wiki/Halley%27s_method).

Usage

```
BS_Implied_Volatility(
  option_price,
  initial_price = 100,
  exercise_price = 100,
  r = 0,
  time_to_maturity = 1,
  dividend_yield = 0,
  payoff = "call",
  start_volatility = 0.3,
  precision = 1e-09
)
```

Arguments

`option_price`	• current price of the option
`initial_price`	• initial price of the underlying asset.
`exercise_price`	• strike price of the option.
`r`	• risk-free interest rate.
`time_to_maturity`	• time to maturity.
`dividend_yield`	• dividend yield.
`payoff`	• the payoff function, a string in ("call", "put").
`start_volatility`	• the volatility value to start the approximation
`precision`	• precision of the result

Value

Named vector containing the values of the Greeks specified in the parameter `greek`.

See Also

Implied_Volatility for American and Asian options, and for digital payoff functions

Examples

```
BS_Implied_Volatility(option_price = 27, initial_price = 100,
exercise_price = 100, r = 0.03, time_to_maturity = 5, dividend_yield = 0.015,
payoff = "call")
```

BS_Malliavin_Asian_Greeks

Computes the Greeks of an Asian option with the Malliavin Monte Carlo Method in the Black Scholes model

---

Description

For a description of Asian Greeks see Malliavin_Asian_Greeks. BS_Malliavin_Asian_Greeks offers a fast implementation in the Black Scholes model.

Usage

```
BS_Malliavin_Asian_Greeks(
  initial_price = 100,
  exercise_price = 100,
  r = 0,
  time_to_maturity = 1,
  volatility = 0.3,
  dividend_yield = 0,
  payoff = "call",
  greek = c("fair_value", "delta", "vega", "rho"),
  steps = round(time_to_maturity * 252),
  paths = 1000,
  seed = 1
)
```

Arguments

`initial_price`	• initial price of the underlying asset, can also be a vector
`exercise_price`	• strike price of the option, can also be a vector
`r`	• risk-free interest rate
`time_to_maturity`	• time to maturity in years
`volatility`	• volatility of the underlying asset
`dividend_yield`	• dividend yield
`payoff`	• the payoff function, either a string in ("call", "put"), or a function
`greek`	• Greeks to be calculated in c("fair_value", "delta", "rho", "vega")
`steps`	• the number of integration steps
`paths`	• the number of simulated paths
`seed`	• the seed of the random number generator

Value

Named vector containing the values of the Greeks specified in the parameter `greek`.

See Also

Malliavin_Asian_Greeks for a greater set of Greeks and also in the jump diffusion model

Greeks_UI for an interactive visualization

Examples

```
BS_Malliavin_Asian_Greeks(initial_price = 110, exercise_price = 100,
r = 0.02, time_to_maturity = 4.5, dividend_yield = 0.015, volatility = 0.22,
greek = c("fair_value", "delta", "rho"), payoff = "put")
```

`Greeks` *Computes the Greeks of various options in the Black Scholes model or both in the Black Scholes model or a Jump Diffusion model in the case of Asian Options, or in the Binomial options pricing model*

Description

Greeks are derivatives of the option value with respect to underlying parameters. For instance, the Greek $\Delta = \frac{\partial \text{fair\_value}}{\partial \text{initial\_price}}$ (Delta) measures how the price of an option changes with a minor change in the underlying asset's price, while $\Gamma = \frac{\partial \text{fair\_value}}{\partial \text{initial\_price}}$ (Gamma) measures how Δ itself changes as the price of the underlying asset shifts. Greeks can be computed for different types of options: For

- **European Greeks** see also BS_European_Greeks and Malliavin_European_Greeks
- **American Greeks** see also Binomial_American_Greeks
- **Asian Greeks** see also BS_Malliavin_Asian_Greeks and Malliavin_Asian_Greeks
- **Geometric Asian Greeks** see also BS_Geometric_Asian_Greeks and Malliavin_Asian_Greeks

The Greeks are defined as the following partial derivatives of the option value:

- `Delta` = $\Delta = \frac{\partial \text{fair\_value}}{\partial \text{initial\_price}}$, the derivative with respect to the price of the underlying asset
- `Vega` = $\mathcal{V} = \frac{\partial \text{fair\_value}}{\partial \text{volatility}}$, the derivative with respect to the volatility
- `Theta` = $\Theta = -\frac{\partial \text{fair\_value}}{\partial \text{time\_to\_maturity}}$, the negative derivative with respect to the time until expiration of the option
- `rho` = $\rho = \frac{\partial \text{fair\_value}}{\partial r}$, the derivative with respect to the risk-free interest rate
- `Epsilon` = $\epsilon = \frac{\partial \text{fair\_value}}{\partial \text{time\_to\_maturity}}$, the derivative with respect to the dividend yield of the underlying asset
- `Lambda` = $\lambda = \Delta \times \frac{\text{initial\_price}}{\text{exercise\_price}}$
- `Gamma` = $\Gamma = \frac{\partial^2 \text{fair\_value}}{\partial \text{initial\_price}^2}$, the second derivative with respect to the price of the underlying asset

- `Vanna` = $\frac{\partial\Delta}{\partial\text{volatility}} = \frac{\partial^2\text{fair\_value}}{\partial\text{intial\_price}\,\partial\text{volatility}}$, the derivative of Δ with respect to the volatility
- `Vomma` = $\frac{\partial^2\text{fair\_value}}{\partial\text{volatility}^2}$, the second derivative with respect to the volatility
- `Veta` = $\frac{\partial\mathcal{V}}{\partial r} = \frac{\partial^2\text{fair\_value}}{\partial\text{volatility}\,\partial\text{time\_to\_maturity}}$, the derivative of $\mathcal{V}$ with respect to the time until expiration of the option
- `Vera` = $\frac{\partial^2\text{fair\_value}}{\partial\text{volatiliy}\,\partial\text{r}}$, the derivative of $\mathcal{V}$ with respect to the risk-free interest rate
- `Speed` = $\frac{\partial\Gamma}{\partial\text{initial\_price}} = \frac{\partial^3\text{fair\_value}}{\partial\text{initial\_price}^3}$, the third derivative of the option value with respect to the price of the underlying asset
- `Zomma` = $\frac{\Gamma}{\text{volatility}} = \frac{\partial^3\text{fair\_value}}{\partial\text{volatility}^3}$, the derivative of Gamma with respect to the volatility
- `Color` = $\frac{\partial\Gamma}{\partial\text{r}} = \frac{\partial^3\text{fair\_value}}{\partial\text{initial\_price}^2\partial\text{r}}$, the derivative of Gamma with respect to the risk-free interest rate
- `Ultima` = $\frac{\partial\text{Vomma}}{\partial\text{volatility}} = \frac{\partial^3\text{fair\_value}}{\partial\text{volatility}^3}$, the third derivative with respect to the volatility

Greeks computes Greeks for the following option types:

- **European put- and call options**, which give to option holder the right but not the obligation to sell (resp. buy) the underlying asset for a specific price at a specific date. If K is the exercise price, and S_T the value of the underlying asset at time-to-maturity T, a European options pay off the following amount at expiration:
  - $\max\{K - S_T, 0\}$ for a **put-option**
  - $\max\{S_T - K, 0\}$ for a **call-option**
- **American put- and call options** are like European options, but allow the holder to exercise at any time until expiration
- **European cash-or-nothing put- and call options** provide the holder with a fixed amount of cash, if the value of the underlying asset is below (resp. above) a certain strike price
- **European asset-or-nothing put- and call options** are similar to cash-or-nothing options, but provide the holder with one share of the asset.
- **Asian put- and call options** have a similar payoff to European put- and call options but differ from European options in that they are path dependent. Not the price S_T of the underlying asset at time-to-maturity T is evaluated, but the arithmetic average $\frac{1}{T}\int_0^T S_t dt$. We get the payoffs
  - $\max\{K - \frac{1}{T}\int_0^T S_t dt, 0\}$ for an Asian **put-option**
  - $\max\{\frac{1}{T}\int_0^T S_t dt - K, 0\}$ for an Asian **call-option**
- **Geometric Asian options** differ from Asian options in that the geometric average $\exp\left(\frac{1}{T}\int_0^T \ln S_t dt\right)$ is evaluated.

For reference see Hull (2022) or

en.wikipedia.org/wiki/Greeks_(finance).

Usage

```
Greeks(
  initial_price,
  exercise_price,
  r,
  time_to_maturity,
  volatility,
  dividend_yield = 0,
  model = "Black_Scholes",
  option_type = "European",
  payoff = "call",
  greek = c("fair_value", "delta", "vega", "theta", "rho", "gamma"),
  antithetic = TRUE,
  ...
)
```

Arguments

`initial_price`	• initial price of the underlying asset
`exercise_price`	• strike price of the option
`r`	• risk-free interest rate
`time_to_maturity`	• time to maturity in years
`volatility`	• volatility of the underlying asset
`dividend_yield`	• dividend yield
`model`	• the model to be chosen in ("black_scholes", "jump_diffusion")
`option_type`	in c("European", "American", "Asian", "Geometric Asian", "Digital", "Binomial) - the type of option to be considered
`payoff`	• in c("call", "put", "cash_or_nothing_call", "cash_or_nothing_put", "asset_or_nothing_call", "asset_or_nothing_put")
`greek`	• Greeks to be calculated in c("fair_value", "delta", "vega", "theta", "rho", "epsilon", "lambda", "gamma", "vanna", "charm", "vomma", "veta", "vera", "speed", "zomma", "color", "ultima")
`antithetic`	• if TRUE, antithetic random numbers will be chosen to decrease variance
`...`	• ... Other arguments passed on to methods

Value

Named vector containing the values of the Greeks specified in the parameter `greek`.

References

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

en.wikipedia.org/wiki/Greeks_(finance)

See Also

BS_European_Greeks for option_type = "European"

Binomial_American_Greeks for option_type = "American"

BS_Geometric_Asian_Greeks for option_type = = "Geometric Asian" and model = "black_scholes"

BS_Malliavin_Asian_Greeks for option_type = = "Asian" and model = "black_scholes" and greek in c("fair_value", "delta", "rho", "vega")

Malliavin_Asian_Greeks for more general cases of Asian Greeks

Greeks_UI for an interactive visualization

Examples

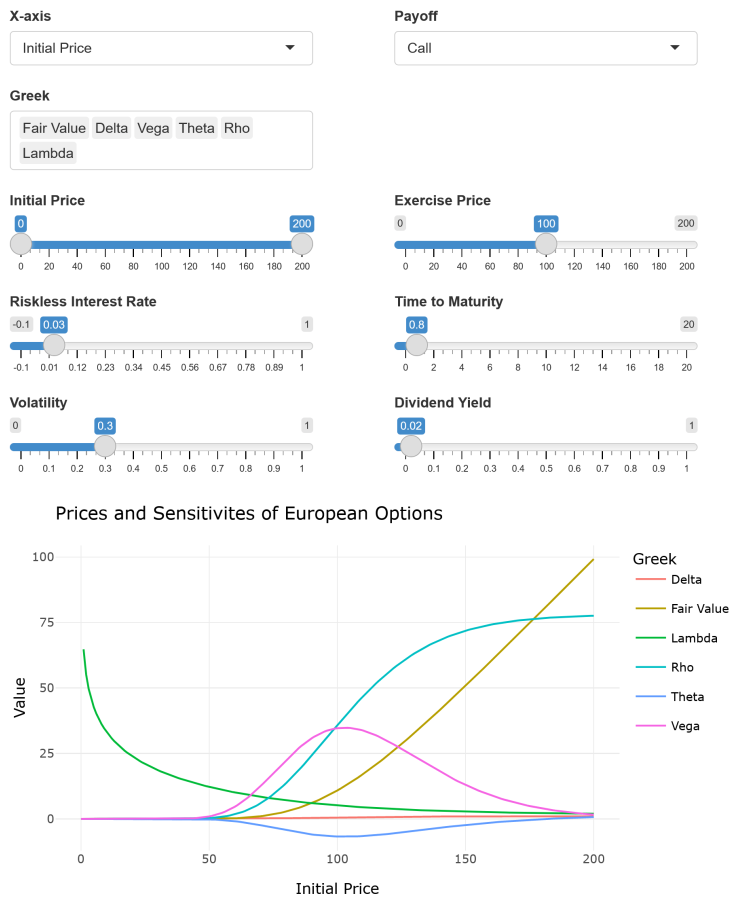
```
Greeks(initial_price = 100, exercise_price = 120, r = 0.01,
time_to_maturity = 5, volatility = 0.30, payoff = "call")

Greeks(initial_price = 100, exercise_price = 100, r = -0.005,
time_to_maturity = 1, volatility = 0.30, payoff = "put",
option_type = "American")
```

Greeks_UI *Opens a shiny app to interactively visualize option prices and Greeks.*

Description

Opens a shiny app to interactively visualize option prices and Greeks. This works for European Options (see BS_European_Greeks), American Options (see Binomial_American_Greeks), Geometric Asian Options (see BS_Geometric_Asian_Greeks), as well as Asian options (see BS_Malliavin_Asian_Greeks). For performance reasons, just the Black-Scholes model is possible, and for some cases, the set of Greeks is limited. On the y-Axis, the option value resp. the value of the greeks are displayed, for the x-axis, several parameters like `initial_price` or `time_to_maturity` are possible.



Usage

```
Greeks_UI()
```

`Implied_Volatility` *Computes the implied volatility for various options via Newton's method*

Description

If the value of an option, and other (model)parameters like the risk-free interest rate, the time-to-maturity, and the dividend yield are known, the assumed volatility of the underlying asset, the *implied volatility* can be inferred. See Hull (2022).

Usage

```
Implied_Volatility(
  option_price,
```

```
  initial_price = 100,
  exercise_price = 100,
  r = 0,
  time_to_maturity = 1,
  dividend_yield = 0,
  model = "Black_Scholes",
  option_type = "European",
  payoff = "call",
  start_volatility = 0.3,
  precision = 1e-06,
  max_iter = 30
)
```

Arguments

`option_price`
- current price of the option

`initial_price`
- initial price of the underlying asset

`exercise_price`
- strike price of the option

`r`
- risk-free interest rate

`time_to_maturity`
- time to maturity in years

`dividend_yield`
- dividend yield

`model`
- the model to be chosen

`option_type` in c("European", "American", "Geometric Asian", "Asian", "Digital") - the type of option to be considered

`payoff`
- in c("call", "put")

`start_volatility` initial guess

`precision` precision of the computation

`max_iter` maximal number of iterations of the approximation

Value

Named vector containing the values of the Greeks specified in the parameter `greek`.

References

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

See Also

BS_Implied_Volatility for the special case option_type = "European" and payoff in c("call", "put")

Examples

```
Implied_Volatility(15, r = 0.05, option_type = "Asian",
payoff = "call")
```

`Malliavin_Asian_Greeks` *Computes the Greeks of an Asian option with the Malliavin Monte Carlo Method in the Black Scholes model, or for Asian options, also in a Jump Diffusion model*

Description

Asian options are path-dependent. If S_t is the price of the underlying asset at time t, the execution of an Asian option depends on the average price of option, $\frac{1}{T}\int_0^T S_t dt$, where T is the time-to-maturity of the option. For more details on the definition of Greeks in general see Greeks.

For a description of Malliavin Monte Carlo Methods for Greeks see for example (Hudde & Rüschendorf, 2023).

Usage

```
Malliavin_Asian_Greeks(
  initial_price = 100,
  exercise_price = 100,
  r = 0,
  time_to_maturity = 1,
  volatility = 0.3,
  dividend_yield = 0,
  payoff = "call",
  greek = c("fair_value", "delta", "rho", "vega", "theta", "gamma"),
  model = "black_scholes",
  lambda = 0.2,
  alpha = 0.3,
  jump_distribution = function(n) stats::rt(n, df = 3),
  steps = round(time_to_maturity * 252),
  paths = 10000,
  seed = 1,
  antithetic = FALSE
)
```

Arguments

`initial_price`
- initial price of the underlying asset, can also be a vector

`exercise_price`
- strike price of the option, can also be a vector

`r`
- risk-free interest rate

`time_to_maturity`
- time to maturity in years

`volatility`
- volatility of the underlying asset

`dividend_yield`
- dividend yield

`payoff`	• the payoff function, either a string in ("call", "put", "digital_call", "digital_put"), or a function
`greek`	• the Greek to be calculated
`model`	• the model to be chosen in ("black_scholes", "jump_diffusion")
`lambda`	• the lambda of the Poisson process in the jump-diffusion model
`alpha`	• the alpha in the jump-diffusion model influences the jump size
`jump_distribution`	• the distribution of the jumps, choose a function which generates random numbers with the desired distribution
`steps`	• the number of integration steps
`paths`	• the number of simulated paths
`seed`	• the seed of the random number generator
`antithetic`	• if TRUE, antithetic random numbers will be chosen to decrease variance

Value

Named vector containing the values of the Greeks specified in the parameter `greek`.

References

Hudde, A., & Rüschendorf, L. (2023). European and Asian Greeks for Exponential Lévy Processes. Methodol Comput Appl Probab, 25 (39). doi:10.1007/s11009023100145

See Also

BS_Malliavin_Asian_Greeks for a faster computation, but only in the Black Scholes model and with a smaller set of Greeks

Examples

```
Malliavin_Asian_Greeks(initial_price = 110, exercise_price = 100,
r = 0.02, time_to_maturity = 4.5, dividend_yield = 0.015, volatility = 0.22,
greek = c("fair_value", "delta", "rho"), payoff = "put")
```

Malliavin_European_Greeks

Computes the Greeks of a European option with the Malliavin Monte Carlo Method in the Black Scholes model

---

Description

For details on the definition of Greeks see Greeks. For a description of Malliavin Monte Carlo Methods for Greeks see for example (Hudde & Rüschendorf, 2023).

Usage

```
Malliavin_European_Greeks(
  initial_price = 100,
  exercise_price = 100,
  r = 0,
  time_to_maturity = 1,
  volatility = 0.3,
  payoff = "call",
  greek = c("fair_value", "delta", "vega", "theta", "rho", "gamma"),
  model = "Black Scholes",
  paths = 10000,
  seed = 1,
  antithetic = FALSE
)
```

Arguments

`initial_price`
- initial price of the underlying asset

`exercise_price`
- strike price of the option

`r`
- risk-free interest rate

`time_to_maturity`
- time to maturity in years

`volatility`
- volatility of the underlying asset

`payoff`
- the payoff function, either a string in ("call", "put", "cash_or_nothing_call", "cash_or_nothing_call", "asset_or_nothing_call", "asset_or_nothing_put"), or a function

`greek`
- the Greeks to be calculated in ("fair_value", "delta", "vega", "theta", "rho", "gamma")

`model`
- the model to be chosen

`paths`
- the number of simulated paths

`seed`
- the seed of the random number generator

`antithetic`
- if TRUE, antithetic random numbers will be chosen to decrease variance

Value

Named vector containing the values of the Greeks specified in the parameter `greek`

References

Hudde, A., & Rüschendorf, L. (2023). European and Asian Greeks for Exponential Lévy Processes. Methodol Comput Appl Probab, 25 (39). doi:10.1007/s11009023100145

See Also

BS_European_Greeks for the exact and fast implementation for call-, put- and digital payoff functions

Examples

```
Malliavin_European_Greeks(initial_price = 110,
exercise_price = 100, r = 0.02, time_to_maturity = 4.5,
volatility = 0.22, greek = c("fair_value", "delta", "rho"), payoff = "put")
```

Malliavin_Geometric_Asian_Greeks

Computes the Greeks of a geometric Asian option with the Malliavin Monte Carlo Method in the Black Scholes- or Jump diffusion model

---

Description

In contrast to Asian options (see Malliavin_Asian_Greeks), geometric Asian options evaluate the geometric average $\exp\left(\frac{1}{T}\int_0^T \ln S_t dt\right)$, where S_t is the price of the underlying asset at time t and T is the time-to-maturity of the option (see en.wikipedia.org/wiki/Asian_option#European_Asian_call_and_put_options_with_geometric_averaging). For more details on the definition of Greeks see Greeks, and for a description of the Malliavin Monte Carlo Method for Greeks see for example (Hudde & Rüschendorf, 2023).

Usage

```
Malliavin_Geometric_Asian_Greeks(
  initial_price = 100,
  exercise_price = 100,
  r = 0,
  time_to_maturity = 1,
  volatility = 0.3,
  dividend_yield = 0,
  payoff = "call",
  greek = c("fair_value", "delta", "rho", "vega", "theta", "gamma"),
  model = "black_scholes",
  lambda = 0.2,
  alpha = 0.3,
  jump_distribution = function(n) stats::rt(n, df = 3),
  steps = round(time_to_maturity * 252),
  paths = 10000,
  seed = 1,
  antithetic = FALSE
)
```

Arguments

`initial_price`	• initial price of the underlying asset, can also be a vector
`exercise_price`	• strike price of the option, can also be a vector
`r`	• risk-free interest rate

`time_to_maturity`
- time to maturity in years

`volatility`
- volatility of the underlying asset

`dividend_yield`
- dividend yield

`payoff`
- the payoff function, either a string in ("call", "put", "digital_call", "digital_put"), or a function

`greek`
- the Greek to be calculated

`model`
- the model to be chosen in ("black_scholes", "jump_diffusion")

`lambda`
- the lambda of the Poisson process in the jump-diffusion model

`alpha`
- the alpha in the jump-diffusion model influences the jump size

`jump_distribution`
- the distribution of the jumps, choose a function which generates random numbers with the desired distribution

`steps`
- the number of integration steps

`paths`
- the number of simulated paths

`seed`
- the seed of the random number generator

`antithetic`
- if TRUE, antithetic random numbers will be chosen to decrease variance

Value

Named vector containing the values of the Greeks specified in the parameter `greek`.

References

Hudde, A., & Rüschendorf, L. (2023). European and Asian Greeks for Exponential Lévy Processes. Methodol Comput Appl Probab, 25 (39). doi:10.1007/s11009023100145

See Also

BS_Geometric_Asian_Greeks for exact and fast computation in the Black Scholes model and for put- and call payoff functions

Examples

```
Malliavin_Asian_Greeks(initial_price = 110, exercise_price = 100,
r = 0.02, time_to_maturity = 4.5, dividend_yield = 0.015, volatility = 0.22,
greek = c("fair_value", "delta", "rho"), payoff = "put")
```

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