

# **FinancePy 0.33**

Dominic O’Kane

December 9, 2023



# Contents

<b>1</b>	<b>Introduction to FinancePy</b>	<b>3</b>
<b>2</b>	<b>financepy.utils</b>	<b>7</b>
2.1	amount . . . . .	9
2.2	calendar . . . . .	10
2.3	currency . . . . .	17
2.4	date . . . . .	18
2.5	day_count . . . . .	30
2.6	distribution . . . . .	32
2.7	error . . . . .	33
2.8	frequency . . . . .	35
2.9	global_types . . . . .	36
2.10	global_vars . . . . .	38
2.11	helpers . . . . .	39
2.12	latex . . . . .	45
2.13	math . . . . .	46
2.14	polyfit . . . . .	54
2.15	schedule . . . . .	56
2.16	singleton . . . . .	59
2.17	solver_ld . . . . .	60
2.18	solver_cg . . . . .	63
2.19	solver_nm . . . . .	68
2.20	stats . . . . .	70
2.21	__init__ . . . . .	72
<b>3</b>	<b>financepy.market.curves</b>	<b>73</b>
3.1	discount_curve . . . . .	75
3.2	discount_curve_flat . . . . .	80
3.3	discount_curve_ns . . . . .	82
3.4	discount_curve_nss . . . . .	84
3.5	discount_curve_poly . . . . .	86
3.6	discount_curve_pwf . . . . .	88
3.7	discount_curve_pwl . . . . .	90
3.8	discount_curve_zeros . . . . .	92
3.9	interpolator . . . . .	94
3.10	__init__ . . . . .	97

<b>4</b>	<b>financepy.market.volatility</b>	<b>99</b>
4.1	equity_vol_curve . . . . .	100
4.2	equity_vol_surface . . . . .	101
4.3	fx_vol_surface . . . . .	106
4.4	fx_vol_surface_plus . . . . .	112
4.5	ibor_cap_vol_curve . . . . .	120
4.6	ibor_cap_vol_curve_fn . . . . .	122
4.7	swaption_vol_surface . . . . .	123
4.8	__init__ . . . . .	127
<b>5</b>	<b>financepy.products.equity</b>	<b>129</b>
5.1	equity_american_option . . . . .	131
5.2	equity_asian_option . . . . .	133
5.3	equity_barrier_option . . . . .	140
5.4	equity_basket_option . . . . .	143
5.5	equity_binomial_tree . . . . .	146
5.6	equity_chooser_option . . . . .	149
5.7	equity_cliquet_option . . . . .	152
5.8	equity_compound_option . . . . .	154
5.9	equity_digital_option . . . . .	158
5.10	equity_fixed_lookback_option . . . . .	160
5.11	equity_float_lookback_option . . . . .	162
5.12	equity_forward . . . . .	164
5.13	equity_index_option . . . . .	166
5.14	equity_model_types . . . . .	169
5.15	equity_one_touch_option . . . . .	170
5.16	equity_option . . . . .	173
5.17	equity_rainbow_option . . . . .	176
5.18	equity_swap . . . . .	180
5.19	equity_swap_leg . . . . .	183
5.20	equity_vanilla_option . . . . .	186
5.21	equity_variance_swap . . . . .	194
5.22	__init__ . . . . .	197
<b>6</b>	<b>financepy.products.credit</b>	<b>199</b>
6.1	cds . . . . .	200
6.2	cds_basket . . . . .	208
6.3	cds_curve . . . . .	211
6.4	cds_index_option . . . . .	214
6.5	cds_index_portfolio . . . . .	218
6.6	cds_option . . . . .	223
6.7	cds_tranche . . . . .	225
6.8	__init__ . . . . .	227
<b>7</b>	<b>financepy.products.bonds</b>	<b>229</b>
7.1	bond . . . . .	231
7.2	bond_annuity . . . . .	242

7.3	bond_callable . . . . .	245
7.4	bond_convertible . . . . .	247
7.5	bond_frn . . . . .	252
7.6	bond_future . . . . .	259
7.7	bond_market . . . . .	262
7.8	bond_mortgage . . . . .	264
7.9	bond_option . . . . .	266
7.10	bond_portfolio . . . . .	268
7.11	bond_zero . . . . .	273
7.12	yield_curve . . . . .	282
7.13	yield_curve_model . . . . .	284
7.14	zero_curve . . . . .	288
7.15	__init__ . . . . .	291
<b>8</b>	<b>financepy.products.rates</b>	<b>293</b>
8.1	bermudan_swaption . . . . .	296
8.2	callable_swap . . . . .	298
8.3	dual_curve . . . . .	299
8.4	ibor_basis_swap . . . . .	302
8.5	ibor_cap_floor . . . . .	305
8.6	ibor_conventions . . . . .	308
8.7	ibor_deposit . . . . .	309
8.8	ibor_fra . . . . .	311
8.9	ibor_future . . . . .	314
8.10	ibor_lmm_products . . . . .	316
8.11	ibor_single_curve . . . . .	320
8.12	ibor_swap . . . . .	324
8.13	ibor_swaption . . . . .	328
8.14	ois . . . . .	331
8.15	ois_basis_swap . . . . .	335
8.16	ois_curve . . . . .	338
8.17	swap_fixed_leg . . . . .	342
8.18	swap_float_leg . . . . .	345
8.19	__init__ . . . . .	348
<b>9</b>	<b>financepy.products.fx</b>	<b>349</b>
9.1	fx_barrier_option . . . . .	350
9.2	fx_digital_option . . . . .	353
9.3	fx_double_digital_option . . . . .	355
9.4	fx_fixed_lookback_option . . . . .	357
9.5	fx_float_lookback_option . . . . .	359
9.6	fx_forward . . . . .	361
9.7	fx_mkt_conventions . . . . .	363
9.8	fx_one_touch_option . . . . .	364
9.9	fx_option . . . . .	367
9.10	fx_rainbow_option . . . . .	369

9.11	fx_vanilla_option . . . . .	373
9.12	fx_variance_swap . . . . .	379
9.13	__init__ . . . . .	382
<b>10</b>	<b>financepy.models</b>	<b>383</b>
10.1	bachelier . . . . .	385
10.2	bdt_tree . . . . .	386
10.3	bk_tree . . . . .	392
10.4	black . . . . .	399
10.5	black_scholes . . . . .	406
10.6	black_scholes_analytic . . . . .	408
10.7	black_scholes_mc . . . . .	414
10.8	black_scholes_mc_tests . . . . .	417
10.9	black_shifted . . . . .	419
10.10	bond_analytics . . . . .	420
10.11	cir_mc . . . . .	421
10.12	equity_barrier_models . . . . .	424
10.13	equity_crr_tree . . . . .	425
10.14	equity_lsmc . . . . .	427
10.15	finite_difference . . . . .	428
10.16	finite_difference_PSOR . . . . .	432
10.17	gauss_copula . . . . .	434
10.18	gauss_copula_lhp . . . . .	435
10.19	gauss_copula_lhplus . . . . .	438
10.20	gauss_copula_onefactor . . . . .	440
10.21	gbm_process_simulator . . . . .	444
10.22	heston . . . . .	447
10.23	hw_tree . . . . .	453
10.24	imm_mc . . . . .	462
10.25	loss_dbn_builder . . . . .	468
10.26	merton_firm . . . . .	469
10.27	merton_firm_mkt . . . . .	472
10.28	model . . . . .	474
10.29	option_implied_dbn . . . . .	475
10.30	process_simulator . . . . .	476
10.31	rates_ho_lee . . . . .	480
10.32	sabr . . . . .	482
10.33	sabr_shifted . . . . .	486
10.34	sobol . . . . .	490
10.35	student_t_copula . . . . .	491
10.36	vasicek_mc . . . . .	492
10.37	volatility_fns . . . . .	495
10.38	__init__ . . . . .	500



# Chapter 1

## Introduction to FinancePy

### Latest News and Versions

1. 33 released

- Tidied up key rate code - Fixed unit tests for pytest - Fixed vectorisation of barrier options - Various pep8 fixes

1. 32 released

- Fixed bug in Bond OAS and ASW

1. 31 released

Schedule - Corrected bug in schedule generation - Corrected bug in CDS protection leg integral

Many Bond Classes have been amended - Changed FULL price to DIRTY price in functions UPDATE YOUR CODE PLEASE. APOLS for inconvenience. - Removed face amount from bond class - how much you buy is not intrinsic to a bond - Made number of ex-dividend days a member of bond class - Added adjustment for ex-dividend dates to yield calculations - Revised accrued and principal functions to take face amount as input - Updated document

1. 30 released

- Added PrettyPrint to required dependencies

1. 22 Nov 22

Version 0.260 has been released and pushed to PyPI - Create Date from python datetime - Zero coupon bond class - Fixed bug in bond payment date

1. 31-Aug-2022

Version 0.240 has just been released and pushed to PyPI with changes - Negative terms in date class - Recovery rates do not default to standard value for CDS curves



## DISCLAIMER

This software is distributed FREE AND WITHOUT ANY WARRANTY.

Report any bugs or suggestions here as an issue.

## CONTRIBUTORS WANTED !

If you have a knowledge of Quantitative Finance and a reasonable knowledge of Python, then please consider contributing to this project. There are small tasks and big tasks to be done. Just look in the list of Issues and you may find something you can do. Before you begin, please comment in the issue thread in case someone else may be working on that issue. Or you can contact me directly at dominic.okane at edhec.edu.

If you are a user and require some additional functionality, then please add it as an issue.

## Quick Start Guide

FinancePy can be installed from pip using the following command:

`'pip install financepy'`

To upgrade an existing installation type:

`'pip install --upgrade financepy'`

I have encountered problems using Anaconda3-2020.07 due to some Numba and LLVM Lite problems. However, Anaconda3-2020.02 works.

## *Using FinancePy in a Jupyter Notebook*

Once financepy has been installed, it is easy to get started.

Just download the project and examine the set of Jupyter Notebooks in the notebook folder.

A pdf manual describing all the functions can be found in the project directory.

## Overview

FinancePy is a python-based library that is currently in beta version. It covers the following functionality:

- Valuation and risk models for a wide range of equity, FX, interest rate and credit derivatives.

Although it is written entirely in Python, it can achieve speeds comparable to C++ by using Numba. As a result the user has both the ability to examine the underlying code and the ability to perform pricing and risk at speeds which compare to a library written in C++.

The target audience for this library includes:

- Students of finance and students of python
- Academics teaching finance or conducting research into finance
- Traders wishing to price or risk-manage a derivative.
- Quantitative analysts seeking to price or reverse engineer a price.
- Risk managers wishing to replicate and understand price sensitivity.

- Portfolio managers wishing to check prices or calculate risk measures.
- Fund managers wanting to value a portfolio or examine a trading strategy.

Users should have a good, but not advanced, understanding of Python. In terms of Python, the style of the library has been determined subject to the following criteria:

1. To make the code as simple as possible so that those with a basic Python fluency can understand and check the code.
2. To keep all the code in Python so users can look through the code to the lowest level.
3. To offset the performance impact of (2) by leveraging Numba to make the code as fast as possible without resorting to Cython.
4. To make the design product-based rather than model-based so someone wanting to price a specific product can easily find that without having to worry too much about the model “just use the default” unless they want to. For most products, a Monte-Carlo implementation has been provided both as a reference for testing and as a way to better understand how the product functions in terms of payments, their timings and conditions.
5. To make the library as complete as possible so a user can find all their required finance-related functionality in one place. This is better for the user as they only have to learn one interface.
6. To avoid complex designs. Limited inheritance unless it allows for significant code reuse. Some code duplication is OK, at least temporarily.
7. To have good documentation and easy-to-follow examples.
8. To make it easy for interested parties to contribute.

In many cases the valuations should be close to if not identical to those produced by financial systems such as Bloomberg. However for some products, larger value differences may arise due to differences in date generation and interpolation schemes. Over time it is hoped to reduce the size of such differences.

Important Note:

- IF YOU HAVE ANY PRICING OR RISK EXAMPLES YOU WOULD LIKE REPLICATED, SEND SCREENSHOTS OF ALL THE UNDERLYING DATA, MODEL DETAILS AND VALUATION.
- IF THERE IS A PRODUCT YOU WOULD LIKE TO HAVE ADDED, SEND ME THE REQUEST.
- IF THERE IS FUNCTIONALITY YOU WOULD LIKE ADDED, SEND ME A REQUEST.

## ***The Library Design***

The underlying Python library is split into a number of major modules:

- Utils - These are utility functions used to assist you with modelling a security. These include dates (Date), calendars, schedule generation, some finance-related mathematics functions and some helper functions.

- Market - These are modules that capture the market information used to value a security. These include interest rate and credit curves, volatility surfaces and prices.
- Models - These are the low-level models used to value derivative securities ranging from Black-Scholes to complex stochastic volatility models.
- Products - These are the actual securities and range from Government bonds to Bermudan swaptions.

Any product valuation is the result of the following data design:

- `*VALUATION** = **PRODUCT** + **MODEL** + **MARKET**`

The interface to each product has a `value()` function that will take a model and market to produce a price.

## **Author**

Dominic O’Kane. I am a Professor of Finance at the EDHEC Business School in Nice, France. I have 12 years of industry experience and over 15 years of academic experience.

Contact me at [dominic.okane@edhec.edu](mailto:dominic.okane@edhec.edu).

## **Dependencies**

FinancePy depends on Numpy, Numba, Scipy and basic python libraries such as `os`, `sys` and `datetime`.

## **Changelog**

See the changelog for a detailed history of changes.

## **Contributions**

Contributions are very welcome. There are a number of requirements:

- The code should be Pep8 compliant.
- Comments are required for every class and function, and they should be a clear description.
- At least one broad test case and a set of unit tests must be provided for every function.
- Avoid very pythonic constructions. For example a loop is as good as a list comprehension. And with numba it can be faster. Readability is the priority.

## **License**

GPL-3.0 License - See the license file in this folder for details.

## Chapter 2

# financepy.utils

### Introduction

This is a collection of modules used across a wide range of FinancePy functions. Examples include date generation, special mathematical functions and useful helper functions for performing some repeated action

- Date is a class for handling dates in a financial setting. Special functions are included for computing IMM dates and CDS dates and moving dates forward by tenors.
- Calendar is a class for determining which dates are not business dates in a specific region or country.
- DayCount is a class for determining accrued interest in bonds and also accrual factors in ISDA swap-like contracts.
- Error is a class which handles errors in the calculations done within FinancePy
- `annual_frequency` takes in a `annual_frequency` type and then returns the number of payments per year
- `global_vars` holds the value of constants used across the whole of FinancePy
- `helper_functions` is a set of helpful functions that can be used in a number of places
- `math` is a set of mathematical functions specific to finance which have been optimised for speed using Numba
- `FinSobol` is the implementation of Sobol quasi-random number generator. It has been speeded up using Numba.
- `FinRateConverter` converts rates for one compounding `annual_frequency` to rates for a different `annual_frequency`
- `FinSchedule` generates a sequence of cashflow payment dates in accordance with financial market standards
- `FinStatistics` calculates a number of statistical variables such as mean, standard deviation and variance
- `FinTestCases` is the code that underlies the test case framework used across FinancePy

***FinDayCount***

The year fraction function can take up to 3 dates, D1, D2 and D3 and a annual\_frequency in specific cases. The current day count methods are listed below.

- THIRTY 360 BOND - 30E/360 ISDA 2006 4.16f, German, Eurobond(ISDA 2000)
- THIRTY E 360 - ISDA 2006 4.16(g) 30/360 ISMA, ICMA
- THIRTY E 360 ISDA - ISDA 2006 4.16(h)
- THIRTY E PLUS 360 - A month has 30 days. It rolls D2 to next month if D2 = 31
- ACT ACT ISDA - Splits accrued period into leap and non-leap year portions.
- ACT ACT ICMA - Used for US Treasury notes and bonds. Takes 3 dates and a annual\_frequency.
- ACT 365 F - Denominator is always Fixed at 365, even in a leap year
- ACT 360 - Day difference divided by 360 - always
- ACT 365L - the 29 Feb is counted if it is in the date range

## 2.1 amount

### ***Class: Amount***

#### **Amount**

*Create Amount object.*

```
Amount(notional: float = ONE_MILLION,
       currency_type: CurrencyTypes = CurrencyTypes.NONE):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
notional	float	-	ONE_MILLION
currency_type	CurrencyTypes	-	CurrencyTypes.NONE

#### **`--repr--`**

*Print out the details of the schedule and the actual dates. This can be used for providing transparency on schedule calculations.*

```
__repr__():
```

The function arguments are described in the following table.

#### **amount**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
amount():
```

The function arguments are described in the following table.

#### **`_print`**

*Print out the details of the schedule and the actual dates. This can be used for providing transparency on schedule calculations.*

```
_print():
```

The function arguments are described in the following table.

## 2.2 calendar

### ***Enumerated Type: BusDayAdjustTypes***

This enumerated type has the following values:

- NONE
- FOLLOWING
- MODIFIED\_FOLLOWING
- PRECEDING
- MODIFIED\_PRECEDING

### ***Enumerated Type: CalendarTypes***

This enumerated type has the following values:

- NONE
- WEEKEND
- AUSTRALIA
- CANADA
- FRANCE
- GERMANY
- ITALY
- JAPAN
- NEW\_ZEALAND
- NORWAY
- SWEDEN
- SWITZERLAND
- TARGET
- UNITED\_STATES
- UNITED\_KINGDOM

### ***Enumerated Type: DateGenRuleTypes***

This enumerated type has the following values:

- FORWARD
- BACKWARD

### ***Class: Calendar***

Class to manage designation of payment dates as holidays according to a regional or country-specific calendar convention specified by the user. It also supplies an adjustment method which takes in an adjustment convention and then applies that to any date that falls on a holiday in the specified calendar.

## Calendar

*Create a calendar based on a specified calendar type.*

```
Calendar(cal_type: CalendarTypes):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
cal_type	CalendarTypes	-	-

## adjust

*Adjust a payment date if it falls on a holiday according to the specified business day convention.*

```
adjust(dt: Date,
       bd_type: BusDayAdjustTypes):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	Date	-	-
bd_type	BusDayAdjustTypes	-	-

## add\_business\_days

*Returns a new date that is numDays business days after Date. All holidays in the chosen calendar are assumed not business days.*

```
add_business_days(start_dt: Date,
                  numDays: int):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
start_dt	Date	-	-
numDays	int	-	-

## is\_business\_day

*Determines if a date is a business day according to the specified calendar. If it is it returns True, otherwise False.*

```
is_business_day(dt: Date):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	Date	-	-



## is\_holiday

*Determines if a date is a Holiday according to the specified calendar. Weekends are not holidays unless the holiday falls on a weekend date.*

```
is_holiday(dt: Date):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	Date	-	-

## holiday\_weekend

*Weekends by themselves are a holiday.*

```
holiday_weekend(dt: Date):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	Date	-	-

## holiday\_australia

*Only bank holidays. Weekends by themselves are not a holiday.*

```
holiday_australia(dt: Date):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	Date	-	-

## holiday\_united\_kingdom

*Only bank holidays. Weekends by themselves are not a holiday.*

```
holiday_united_kingdom(dt):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	-	-	-

**holiday\_france**

*Only bank holidays. Weekends by themselves are not a holiday.*

```
holiday_france(dt) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	-	-	-

**holiday\_sweden**

*Only bank holidays. Weekends by themselves are not a holiday.*

```
holiday_sweden(dt) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	-	-	-

**holiday\_germany**

*Only bank holidays. Weekends by themselves are not a holiday.*

```
holiday_germany(dt) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	-	-	-

**holiday\_switzerland**

*Only bank holidays. Weekends by themselves are not a holiday.*

```
holiday_switzerland(dt) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	-	-	-

## holiday\_japan

*Only bank holidays. Weekends by themselves are not a holiday.*

```
holiday_japan(dt):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	-	-	-

## holiday\_new\_zealand

*Only bank holidays. Weekends by themselves are not a holiday.*

```
holiday_new_zealand(dt):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	-	-	-

## holiday\_norway

*Only bank holidays. Weekends by themselves are not a holiday.*

```
holiday_norway(dt):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	-	-	-

## holiday\_united\_states

*Only bank holidays. Weekends by themselves are not a holiday. This is a generic US calendar that contains the superset of holidays for bond markets, NYSE, and public holidays. For each of these and other categories there will be some variations.*

```
holiday_united_states(dt):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	-	-	-

**holiday\_canada**

*Only bank holidays. Weekends by themselves are not a holiday.*

```
holiday_canada(dt) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	-	-	-

**holiday\_italy**

*Only bank holidays. Weekends by themselves are not a holiday.*

```
holiday_italy(dt) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	-	-	-

**holiday\_target**

*Only bank holidays. Weekends by themselves are not a holiday.*

```
holiday_target(dt) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	-	-	-

**holiday\_none**

*No day is a holiday.*

```
holiday_none(dt) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	-	-	-

**get\_holiday\_list**

*generates a list of holidays in a specific year for the specified calendar. Useful for diagnostics.*

```
get_holiday_list(year: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
year	float	-	-

**easter\_monday**

*Get the day in a given year that is Easter Monday. This is not easy to compute so we rely on a pre-calculated array.*

```
easter_monday(year: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
year	float	-	-

**\_\_str\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__str__():
```

The function arguments are described in the following table.

**\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

## 2.3 currency

### ***Enumerated Type: CurrencyTypes***

This enumerated type has the following values:

- USD
- EUR
- GBP
- CHF
- CAD
- AUD
- NZD
- DKK
- SEK
- HKD
- NONE

## 2.4 date

### **Enumerated Type: DateFormatTypes**

This enumerated type has the following values:

- BLOOMBERG
- US\_SHORT
- US\_MEDIUM
- US\_LONG
- US\_LONGEST
- UK\_SHORT
- UK\_MEDIUM
- UK\_LONG
- UK\_LONGEST
- DATETIME

### **Class: Date()**

A date class to manage dates that is simple to use and includes a number of useful date functions used frequently in Finance.

### **Date**

*Create a date given a day of month, month and year. The arguments must be in the order of day (of month), month number and then the year. The year must be a 4-digit number greater than or equal to 1900. The user can also supply an hour, minute and second for intraday work. Example Input: start\_dt = Date(1, 1, 2018)*

```
Date(d, m, y, hh=0, mm=0, ss=0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
d	-	-	-
m	-	-	-
y	-	-	-
hh	-	-	0
mm	-	-	0
ss	-	-	0

### **d**

*Get day of month as integer*

```
d():
```

The function arguments are described in the following table.

**m***Get month of year as integer*`m() :`

The function arguments are described in the following table.

**y***Get year as integer*`y() :`

The function arguments are described in the following table.

**excel\_dt***get this date in form of Excel date i.e. as an integer*`excel_dt() :`

The function arguments are described in the following table.

**weekday***get day of week as integer*`weekday() :`

The function arguments are described in the following table.

**from\_string***Create a Date from a date and format string. Example Input: start\_dt = Date('1-1-2018', '*`from_string(cls, date_string, formatString):`

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
cls	-	-	-
date_string	-	-	-
formatString	-	-	-



## from\_date

Create a Date from a python datetime.date object or from a Numpy datetime64 object. Example Input: `start_dt = Date.from_dt(datetime.date(2022, 11, 8))`

```
from_date(cls, date: [datetime.date, np.datetime64]):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
cls	-	-	-
date	[datetime.date,np.datetime64]	-	-

## \_refresh

Update internal representation of date as number of days since the 1st Jan 1900. This is same as Excel convention.

```
_refresh():
```

The function arguments are described in the following table.

## --gt--

PLEASE ADD A FUNCTION DESCRIPTION

```
__gt__(other):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
other	-	-	-

## --lt--

PLEASE ADD A FUNCTION DESCRIPTION

```
__lt__(other):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
other	-	-	-

**--ge--***PLEASE ADD A FUNCTION DESCRIPTION*`__ge__(other):`

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
other	-	-	-

**--le--***PLEASE ADD A FUNCTION DESCRIPTION*`__le__(other):`

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
other	-	-	-

**--sub--***PLEASE ADD A FUNCTION DESCRIPTION*`__sub__(other):`

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
other	-	-	-

**--rsub--***PLEASE ADD A FUNCTION DESCRIPTION*`__rsub__(other):`

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
other	-	-	-

**--eq--***PLEASE ADD A FUNCTION DESCRIPTION*`--eq__(other) :`

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
other	-	-	-

**is\_weekend***returns True if the date falls on a weekend.*`is_weekend() :`

The function arguments are described in the following table.

**is\_eom***returns True if this date falls on a month end.*`is_eom() :`

The function arguments are described in the following table.

**eom***returns last date of month of this date.*`eom() :`

The function arguments are described in the following table.

**add\_hours***Returns a new date that is h hours after the Date.*`add_hours(hours) :`

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
hours	-	-	-

## add\_days

Returns a new date that is `num_days` after the Date. I also make it possible to go backwards a number of days.

```
add_days(num_days: int = 1):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
num_days	int	-	1

## add\_weekdays

Returns a new date that is `num_days` working days after Date. Note that only weekends are taken into account. Other Holidays are not. If you want to include regional holidays then use `add_business_days` from the `FinCalendar` class.

```
add_weekdays(num_days: int):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
num_days	int	-	-

## add\_months

Returns a new date that is `mm` months after the Date. If `mm` is an integer or float you get back a single date. If `mm` is a vector you get back a vector of dates.

```
add_months(mm: (list, int)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
mm	list or int	-	-

## add\_years

Returns a new date that is `yy` years after the Date. If `yy` is an integer or float you get back a single date. If `yy` is a list you get back a vector of dates.

```
add_years(yy: (np.ndarray, float)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
yy	np.ndarray or float	-	-

## next\_cds\_date

Returns a CDS date that is mm months after the Date. If no argument is supplied then the next CDS date after today is returned.

```
next_cds_date(mm: int = 0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
mm	int	-	0

## third\_wednesday\_of\_month

For a specific month and year this returns the day number of the 3rd Wednesday by scanning through dates in the third week.

```
third_wednesday_of_month(m: int, # Month number
                          y: int): # Year number
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
m	int	Month number	-
y	int	Year number	-

## next\_imm\_date

This function returns the next IMM date after the current date This is a 3rd Wednesday of Jun, March, Sep or December. For an IMM contract the IMM date is the First Delivery Date of the futures contract.

```
next_imm_date():
```

The function arguments are described in the following table.

## add\_tenor

Return the date following the Date by a period given by the tenor which is a string consisting of a number and a letter, the letter being d, w, m, y for day, week, month or year. This is case independent. For example 10Y means 10 years while 120m also means 10 years. The date is NOT weekend or holiday calendar adjusted. This must be done AFTERWARDS.

```
add_tenor(tenor: (list, str)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
tenor	list or str	-	-

**datetime***Returns a datetime of the date*`datetime() :`

The function arguments are described in the following table.

**str***returns a formatted string of the date*`str(format) :`

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
format	-	-	-

**\_\_repr\_\_***returns a formatted string of the date*`__repr__() :`

The function arguments are described in the following table.

**\_print***prints formatted string of the date.*`_print() :`

The function arguments are described in the following table.

**set\_date\_format***Function that sets the global date format type.*`set_date_format(format_type) :`

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
format_type	-	-	-

## is\_leap\_year

*Test whether year y is a leap year - if so return True, else False*

```
is_leap_year(y: int):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
y	int	-	-

## parse\_dt

*PLEASE ADD A FUNCTION DESCRIPTION*

```
parse_dt(date_str, date_format):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
date_str	-	-	-
date_format	-	-	-

## calculate\_list

*Calculate list of dates so that we can do quick lookup to get the number of dates since 1 Jan 1900 (inclusive) BUT TAKING INTO ACCOUNT THE FACT THAT EXCEL MISTAKENLY CALLS 1900 A LEAP YEAR. For us, agreement with Excel is more important than this leap year error and in any case, we will not usually be calculating day differences with start dates before 28 Feb 1900. Note that Excel inherited this "BUG" from LOTUS 1-2-3.*

```
calculate_list():
```

The function arguments are described in the following table.

## date\_index

*PLEASE ADD A FUNCTION DESCRIPTION*

```
date_index(d, m, y):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
d	-	-	-
m	-	-	-
y	-	-	-

## date\_from\_index

*Reverse mapping from index to date. Take care with numba as it can do weird rounding on the integer. Seems OK now.*

```
date_from_index(idx):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
idx	-	-	-

## weekday

*PLEASE ADD A FUNCTION DESCRIPTION*

```
weekday(day_count):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
day_count	-	-	-

## vectorisation\_helper

*PLEASE ADD A FUNCTION DESCRIPTION*

```
vectorisation_helper(func):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
func	-	-	-

## daily\_working\_day\_schedule

*Returns a list of working dates between start\_dt and end\_dt. This function should be replaced by dateRange once add\_tenor allows for working days.*

```
daily_working_day_schedule(self,
                           start_dt: Date,
                           end_dt: Date):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
self	-	-	-
start_dt	Date	-	-
end_dt	Date	-	-



## datediff

*Calculate the number of days between two Findates.*

```
datediff(d1: Date,
         d2: Date):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
d1	Date	-	-
d2	Date	-	-

## from\_datetime

*Construct a Date from a datetime as this is often needed if we receive inputs from other Python objects such as Pandas dataframes.*

```
from_datetime(dt: Date):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	Date	-	-

## days\_in\_month

*Get the number of days in the month (1-12) of a given year y.*

```
days_in_month(m, y):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
m	-	-	-
y	-	-	-

## date\_range

*Returns a list of dates between start\_dt (inclusive) and end\_dt (inclusive). The tenor represents the distance between two consecutive dates and is set to daily by default.*

```
date_range(start_dt: Date,
           end_dt: Date,
           tenor: str = "1D"):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
start_dt	Date	-	-
end_dt	Date	-	-
tenor	str	-	"1D"

**test\_type**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
test_type() :
```

The function arguments are described in the following table.

## 2.5 day\_count

### **Enumerated Type: DayCountTypes**

This enumerated type has the following values:

- ZERO
- THIRTY\_360\_BOND
- THIRTY\_E\_360
- THIRTY\_E\_360\_ISDA
- THIRTY\_E\_PLUS\_360
- ACT\_ACT\_ISDA
- ACT\_ACT\_ICMA
- ACT\_365F
- ACT\_360
- ACT\_365L
- SIMPLE

### **Class: DayCount**

Calculate the fractional day count between two dates according to a specified day count convention.

## DayCount

Create Day Count convention by passing in the Day Count Type.

```
DayCount(dccType: DayCountTypes):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dccType	DayCountTypes	-	-

## year\_frac

*This method performs two functions: 1) It calculates the year fraction between dates dt1 and dt2 using the specified day count convention which is useful for calculating year fractions for Libor products whose flows are day count adjusted. In this case we will set dt3 to be None 2) This function is also for calculating bond accrued where dt1 is the last coupon date, dt2 is the settlement date of the bond and date dt3 must be set to the next coupon date. You will also need to provide a coupon frequency for some conventions. Note that if the date is intra-day, i.e. hh,mm and ss do not equal zero then that is used in the calculation of the year frac. This avoids discontinuities for short-dated intraday products. It should not affect normal dates for which hh=mm=ss=0. This seems like a useful source: <https://www.eclipsesoftware.biz/DayCountConventions.html> Wikipedia also has a decent survey of the conventions [https://en.wikipedia.org/wiki/Day\\_count\\_convention](https://en.wikipedia.org/wiki/Day_count_convention) and <http://data.cbonds.info/files/cbondscalculator.pdf>*

```
year_frac(dt1: Date, # Start of coupon period
          dt2: Date, # Settlement (for bonds) or period end(swaps)
          dt3: Date = None, # End of coupon period for accrued
```

```
freq_type: FrequencyTypes = FrequencyTypes.ANNUAL,
isTerminationDate: bool = False): # Is dt2 a term date
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt1	Date	Start of coupon period	-
dt2	Date	Settlement (for bonds) or period end(swaps)	-
dt3	Date	End of coupon period for accrued	None
freq_type	FrequencyTypes	-	FrequencyTypes.ANNUAL
isTerminationDate	bool	Is dt2 a term date	False

### **\_\_repr\_\_**

*Returns the calendar type as a string.*

```
__repr__():
```

The function arguments are described in the following table.

### **is\_last\_day\_of\_feb**

*Returns True if we are on the last day of February*

```
is_last_day_of_feb(dt: Date):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	Date	-	-

## 2.6 distribution

### ***Class: FinDistribution()***

#### **FinDistribution**

*Initialise FinDistribution with x values and associated vector of density times dx values.*

```
FinDistribution(x, y):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	-	-	-
y	-	-	-

#### **sum**

*This should equal 1.0 for the entire distribution.*

```
sum():
```

The function arguments are described in the following table.

## 2.7 error

### **Class: *FinError(Exception)***

Simple error class specific to FinPy. Need to decide how to handle FinancePy errors. Work in progress.

### **FinError**

Create *FinError* object by passing a message string.

```
FinError(message: str):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
message	str	-	-

### **\_print**

PLEASE ADD A FUNCTION DESCRIPTION

```
_print():
```

The function arguments are described in the following table.

### **hide\_traceback**

Avoid long error message

```
_hide_traceback(exc_tuple=None, filename=None, tb_offset=None,
                 exception_only=False, running_compiled_code=False):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
exc_tuple	-	-	None
filename	-	-	None
tb_offset	-	-	None
exception_only	-	-	False
running_compiled_code	-	-	False

### **func\_name**

Get error message

```
func_name():
```

The function arguments are described in the following table.

**suppress\_traceback***Avoid long error message*

```
suppress_traceback() :
```

The function arguments are described in the following table.

## 2.8 frequency

### ***Enumerated Type: FrequencyTypes***

This enumerated type has the following values:

- ZERO
- SIMPLE
- ANNUAL
- SEMI\_ANNUAL
- TRI\_ANNUAL
- QUARTERLY
- MONTHLY
- CONTINUOUS

### **annual\_frequency**

*This is a function that takes in a Frequency Type and returns a float value for the number of times a year a payment occurs.*

```
annual_frequency(freq_type: FrequencyTypes):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
freq_type	FrequencyTypes	-	-



## 2.9 global\_types

### ***Enumerated Type: FinLongShort***

This enumerated type has the following values:

- LONG
- SHORT

### ***Enumerated Type: OptionTypes***

This enumerated type has the following values:

- EUROPEAN\_CALL
- EUROPEAN\_PUT
- AMERICAN\_CALL
- AMERICAN\_PUT
- DIGITAL\_CALL
- DIGITAL\_PUT
- ASIAN\_CALL
- ASIAN\_PUT
- COMPOUND\_CALL
- COMPOUND\_PUT

### ***Enumerated Type: EquityBarrierTypes***

This enumerated type has the following values:

- DOWN\_AND\_OUT\_CALL
- DOWN\_AND\_IN\_CALL
- UP\_AND\_OUT\_CALL
- UP\_AND\_IN\_CALL
- UP\_AND\_OUT\_PUT
- UP\_AND\_IN\_PUT
- DOWN\_AND\_OUT\_PUT
- DOWN\_AND\_IN\_PUT

### ***Enumerated Type: FinCapFloorTypes***

This enumerated type has the following values:

- CAP
- FLOOR

### ***Enumerated Type: SwapTypes***

This enumerated type has the following values:

- PAY
- RECEIVE

***Enumerated Type: ReturnTypes***

This enumerated type has the following values:

- TOTAL\_RETURN
- PRICE\_RETURN

***Enumerated Type: FinExerciseTypes***

This enumerated type has the following values:

- EUROPEAN
- BERMUDAN
- AMERICAN

***Enumerated Type: FinSolverTypes***

This enumerated type has the following values:

- CONJUGATE\_GRADIENT
- NELDER\_MEAD
- NELDER\_MEAD\_NUMBA

***Enumerated Type: TouchOptionTypes***

This enumerated type has the following values:

- DOWN\_AND\_IN\_CASH\_AT\_HIT
- UP\_AND\_IN\_CASH\_AT\_HIT
- DOWN\_AND\_IN\_CASH\_AT\_EXPIRY
- UP\_AND\_IN\_CASH\_AT\_EXPIRY
- DOWN\_AND\_OUT\_CASH\_OR\_NOTHING
- UP\_AND\_OUT\_CASH\_OR\_NOTHING
- DOWN\_AND\_IN\_ASSET\_AT\_HIT
- UP\_AND\_IN\_ASSET\_AT\_HIT
- DOWN\_AND\_IN\_ASSET\_AT\_EXPIRY
- UP\_AND\_IN\_ASSET\_AT\_EXPIRY
- DOWN\_AND\_OUT\_ASSET\_OR\_NOTHING
- UP\_AND\_OUT\_ASSET\_OR\_NOTHING

## 2.10 global\_vars

## 2.11 helpers

### **`_func_name`**

*Extract calling function name - using a protected method is not that advisable but calling `inspect.stack` is so slow it must be avoided.*

```
_func_name():
```

The function arguments are described in the following table.

### **`grid_index`**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
grid_index(t, grid_times):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t	-	-	-
grid_times	-	-	-

### **`beta_vector_to_corr_matrix`**

*Convert a one-factor vector of factor weights to a square correlation matrix.*

```
beta_vector_to_corr_matrix(betas):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
betas	-	-	-

### **`pv01_times`**

*Calculate a bond style pv01 by calculating remaining coupon times for a bond with  $t$  years to maturity and a coupon frequency of  $f$ . The order of the list is reverse time order - it starts with the last coupon date and ends with the first coupon date.*

```
pv01_times(t: float,
           f: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t	float	-	-
f	float	-	-

## times\_from\_dates

If a single date is passed in then return the year from valuation date but if a whole vector of dates is passed in then convert to a vector of times from the valuation date. The output is always a numpy vector of times which has only one element if the input is only one date.

```
times_from_dates(dt: (Date, list),
                 value_dt: Date,
                 day_count_type: DayCountTypes = None):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	Date or list	-	-
value_dt	Date	-	-
day_count_type	DayCountTypes	-	None

## check\_vector\_differences

Compare two vectors elementwise to see if they are more different than tolerance.

```
check_vector_differences(x: np.ndarray,
                        y: np.ndarray,
                        tol: float = 1e-6):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	np.ndarray	-	-
y	np.ndarray	-	-
tol	float	-	1e-6

## check\_date

Check that input *d* is a Date.

```
check_date(d: Date):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
d	Date	-	-

## dump

PLEASE ADD A FUNCTION DESCRIPTION

```
dump(obj):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
obj	-	-	-

## print\_tree

*Function that prints a binomial or trinomial tree to screen for the purpose of debugging.*

```
print_tree(array: np.ndarray,
           depth: int = None):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
array	np.ndarray	-	-
depth	int	-	None

## input\_time

*Validates a time input in relation to a curve. If it is a float then it returns a float as long as it is positive. If it is a Date then it converts it to a float. If it is a Numpy array then it returns the array as long as it is all positive.*

```
input_time(dt: Date,
           curve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	Date	-	-
curve	-	-	-

## listdiff

*Calculate a vector of differences between two equal sized vectors.*

```
listdiff(a: np.ndarray,
         b: np.ndarray):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
a	np.ndarray	-	-
b	np.ndarray	-	-

## dotproduct

*Fast calculation of dot product using Numba.*

```
dotproduct(xVector: np.ndarray,
           yVector: np.ndarray):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
xVector	np.ndarray	-	-
yVector	np.ndarray	-	-

## frange

*fast range function that takes start value, stop value and step.*

```
frange(start: int,
       stop: int,
       step: int):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
start	int	-	-
stop	int	-	-
step	int	-	-

## normalise\_weights

*Normalise a vector of weights so that they sum up to 1.0.*

```
normalise_weights(wt_vector: np.ndarray):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
wt_vector	np.ndarray	-	-

## label\_to\_string

*Format label/value pairs for a unified formatting.*

```
label_to_string(label: str,
                value: (float, str),
                separator: str = "\\n",
                list_format: bool = False):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
label	str	-	-
value	float or str	-	-
separator n"	str	-	"
list_format	bool	-	False

## table\_to\_string

*Format a 2D array into a table-like string.*

```
table_to_string(header: str,
                value_table,
                float_precision="10.7f"):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
header	str	-	-
value_table	-	-	-
float_precision	-	-	"10.7f"

## format\_table

*Format a 2D array into a table-like string. Similar to "table\_to\_string", but using a wrapper around PrettyTable to get a nice formatting.*

```
format_table(header: (list, tuple),
             rows: (list, tuple)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
header	list or tuple	-	-
rows	list or tuple	-	-

## to\_usable\_type

*Convert a type such that it can be used with 'isinstance'*

```
to_usable_type(t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t	-	-	-



## uniform\_to\_default\_time

*Fast mapping of a uniform random variable to a default time given a survival probability curve.*

```
uniform_to_default_time(u, t, v):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
u	-	-	-
t	-	-	-
v	-	-	-

## accrued\_tree

*Fast calculation of accrued interest using an Actual/Actual type of convention. This does not calculate according to other conventions.*

```
accrued_tree(grid_times: np.ndarray,
             grid_flows: np.ndarray,
             face: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
grid_times	np.ndarray	-	-
grid_flows	np.ndarray	-	-
face	float	-	-

## check\_argument\_types

*Check that all values passed into a function are of the same type as the function annotations. If a value has not been annotated, it will not be checked.*

```
check_argument_types(func, values):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
func	-	-	-
values	-	-	-

## 2.12 latex

### convertToLatexTable

*PLEASE ADD A FUNCTION DESCRIPTION*

```
convertToLatexTable(txt, sep="_", header_list=[]):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
txt	-	-	-
sep	-	-	” ”
header_list	-	-	[]

## 2.13 math

### accrued\_interpolator

*Fast calculation of accrued interest using an Actual/Actual type of convention. This does not calculate according to other conventions.*

```
accrued_interpolator(t_set: float, # Settlement time in years
                    cpn_times: np.ndarray,
                    cpn_amounts: np.ndarray):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t_set	float	Settlement time in years	-
cpn_times	np.ndarray	-	-
cpn_amounts	np.ndarray	-	-

### is\_leap\_year

*Test whether year y is a leap year - if so return True, else False*

```
is_leap_year(y: int):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
y	int	-	-

### scale

*Scale all of the elements of an array by the same amount factor.*

```
scale(x: np.ndarray,
      factor: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	np.ndarray	-	-
factor	float	-	-

### test\_monotonicity

*Check that an array of doubles is monotonic and strictly increasing.*

```
test_monotonicity(x: np.ndarray):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	np.ndarray	-	-

## test\_range

*Check that all of the values of an array fall between a lower and upper bound.*

```
test_range(x: np.ndarray,
           lower: float,
           upper: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	np.ndarray	-	-
lower	float	-	-
upper	float	-	-

## maximum

*Determine the array in which each element is the maximum of the corresponding element in two equally length arrays a and b.*

```
maximum(a: np.ndarray,
        b: np.ndarray):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
a	np.ndarray	-	-
b	np.ndarray	-	-

## maxaxis

*Perform a search for the vector of maximum values over an axis of a 2D Numpy Array*

```
maxaxis(s: np.ndarray):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	np.ndarray	-	-

## minaxis

*Perform a search for the vector of minimum values over an axis of a 2D Numpy Array*

```
minaxis(s: np.ndarray):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	np.ndarray	-	-

## covar

*Calculate the Covariance of two arrays of numbers. TODO: check that this works well for Numpy Arrays and add NUMBA function signature to code. Do test of timings against Numpy.*

```
covar(a: np.ndarray,
      b: np.ndarray):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
a	np.ndarray	-	-
b	np.ndarray	-	-

## pair\_gcd

*Determine the Greatest Common Divisor of two integers using Euclid's algorithm. TODO - compare this with math.gcd(a,b) for speed. Also examine to see if I should not be declaring inputs as integers for NUMBA.*

```
pair_gcd(v1: float,
         v2: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
v1	float	-	-
v2	float	-	-

## nprime

*Calculate the first derivative of the Cumulative Normal CDF which is simply the PDF of the Normal Distribution*

```
nprime(x: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	float	-	-

## heaviside

*Calculate the Heaviside function for x*

```
heaviside(x: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	float	-	-

## frange

*Calculate a range of values from start in steps of size step. Ends as soon as the value equals or exceeds stop.*

```
frange(start: int,
       stop: int,
       step: int):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
start	int	-	-
stop	int	-	-
step	int	-	-

## normpdf

*Calculate the probability density function for a Gaussian (Normal) function at value x*

```
normpdf(x: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	float	-	-

## N

*Fast Normal CDF function based on Hull OFAODS 4th Edition Page 252. This function is accurate to 6 decimal places.*

```
N(x):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	-	-	-

## n\_vect

*PLEASE ADD A FUNCTION DESCRIPTION*

```
n_vect(x):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	-	-	-

## n\_prime\_vect

*PLEASE ADD A FUNCTION DESCRIPTION*

```
n_prime_vect(x):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	-	-	-

## normcdf\_integrate

*Calculation of Normal Distribution CDF by simple integration which can become exact in the limit of the number of steps tending towards infinity. This function is used for checking as it is slow since the number of integration steps is currently hardcoded to 10,000.*

```
normcdf_integrate(x: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	float	-	-

## normcdf\_slow

*Calculation of Normal Distribution CDF accurate to 1d-15. This method is faster than integration but slower than other approximations. Reference: J.L. Schonfelder, Math Comp 32(1978), pp 1232-1240.*

```
normcdf_slow(z: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
z	float	-	-

## phi3

*Bivariate Normal CDF function to upper limits \$b1\$ and \$b2\$ which uses integration to perform the inner-most integral. This may need further refinement to ensure it is optimal as the current range of integration is from -7 and the integration steps are  $dx = 0.001$ . This may be excessive.*

```
phi3(b1: float,
     b2: float,
     b3: float,
     r12: float,
     r13: float,
     r23: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
b1	float	-	-
b2	float	-	-
b3	float	-	-
r12	float	-	-
r13	float	-	-
r23	float	-	-

## norminvcdf

*This algorithm computes the inverse Normal CDF and is based on the algorithm found at (<http://home.online.no/~pjacklam/notes/invnorm/>) which is by John Herrero (3-Jan-03)*

```
norminvcdf(p):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
p	-	-	-

## M

PLEASE ADD A FUNCTION DESCRIPTION

```
M(a, b, c):
```

The function arguments are described in the following table.



Argument Name	Type	Description	Default Value
a	-	-	-
b	-	-	-
c	-	-	-

## phi2

*Drezner and Wesolowsky implementation of bi-variate normal*

```
phi2(h1, hk, r):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
h1	-	-	-
hk	-	-	-
r	-	-	-

## cholesky

*Numba-compliant wrapper around Numpy cholesky function.*

```
cholesky(rho):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
rho	-	-	-

## corr\_matrix\_generator

*Utility function to generate a full rank  $n \times n$  correlation matrix with a flat correlation structure and value rho.*

```
corr_matrix_generator(rho, n):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
rho	-	-	-
n	-	-	-

## npv

*Function to calculate the npv given irr and cashflow. It can be used to do root search in IRR. times\_cfs is a list of tuples. The tuple is in the form of (years from first date, cashflow)*

```
npv(irr: float, times_cfs: list):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
irr	float	-	-
times_cfs	list	-	-

## band\_matrix\_multiplication

PLEASE ADD A FUNCTION DESCRIPTION

```
band_matrix_multiplication(A, m1, m2, b):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
A	-	-	-
m1	-	-	-
m2	-	-	-
b	-	-	-

## solve\_tridiagonal\_matrix

Solve  $A u = r$  for vector  $u$  when  $A$  is tridiagonal The matrix  $A$  is split into vectors  $a$ ,  $b$ , and  $c$  contain the three non-zero elements of each row of  $A$ , in order. i.e. the vector  $b$  is the main diagonal of  $A$ , with  $a$  and  $c$  the elements either side of the main diagonal. Note that  $a[0]$  and  $c[-1]$  are not used, and so can be any value.

```
solve_tridiagonal_matrix(A, r):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
A	-	-	-
r	-	-	-

## transpose\_tridiagonal\_matrix

PLEASE ADD A FUNCTION DESCRIPTION

```
transpose_tridiagonal_matrix(A):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
A	-	-	-

## 2.14 polyfit

### `_coeff_mat`

PLEASE ADD A FUNCTION DESCRIPTION

```
_coeff_mat(x, deg):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	-	-	-
deg	-	-	-

### `_fit_x`

PLEASE ADD A FUNCTION DESCRIPTION

```
_fit_x(a, b):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
a	-	-	-
b	-	-	-

### `fit_poly`

PLEASE ADD A FUNCTION DESCRIPTION

```
fit_poly(x, y, deg):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	-	-	-
y	-	-	-
deg	-	-	-

### `eval_polynomial`

Compute polynomial  $P(x)$  where  $P$  is a vector of coefficients, highest order coefficient at  $P[0]$ . Uses Horner's Method.

```
eval_polynomial(P, x):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
P	-	-	-
x	-	-	-

## 2.15 schedule

### **Class: Schedule**

A schedule is a set of dates generated according to ISDA standard rules which starts on the next date after the effective date and runs up to a termination date. Dates are adjusted to a provided calendar. The zeroth element is the previous coupon date (PCD) and the first element is the Next Coupon Date (NCD). We reference ISDA 2006.

### **Schedule**

*Create Schedule object which calculates a sequence of dates following the ISDA convention for fixed income products, mainly swaps. If the date gen rule type is FORWARD we get the unadjusted dates by stepping forward from the effective date in steps of months determined by the period tenor - i.e. the number of months between payments. We stop before we go past the termination date. If the date gen rule type is BACKWARD we get the unadjusted dates by stepping backward from the termination date in steps of months determined by the period tenor - i.e. the number of months between payments. We stop before we go past the effective date. - If the EOM flag is false, and the start date is on the 31st then the the unadjusted dates will fall on the 30 if a 30 is a previous date. - If the EOM flag is false and the start date is 28 Feb then all unadjusted dates will fall on the 28th. - If the EOM flag is false and the start date is 28 Feb then all unadjusted dates will fall on their respective EOM. We then adjust all of the flow dates if they fall on a weekend or holiday according to the calendar specified. These dates are adjusted in accordance with the business date adjustment. The effective date is never adjusted as it is not a payment date. The termination date is not automatically business day adjusted in a swap - assuming it is a holiday date. This must be explicitly stated in the trade confirm. However, it is adjusted in a CDS contract as standard. Inputs first\_dt and next\_to\_last\_dt are for managing long payment stubs at the start and end of the swap but \*have not yet been implemented\*. All stubs are currently short, either at the start or end of swap.*

```
Schedule(effective_dt: Date, # Also known as the start date
         # This is UNADJUSTED (set flag to adjust it)
         termination_dt: Date,
         freq_type: FrequencyTypes = FrequencyTypes.ANNUAL,
         cal_type: CalendarTypes = CalendarTypes.WEEKEND,
         bd_type: BusDayAdjustTypes = BusDayAdjustTypes.FOLLOWING,
         dg_type: DateGenRuleTypes = DateGenRuleTypes.BACKWARD,
         adjust_termination_dt: bool = True, # Default is to adjust
         end_of_month: bool = False, # All flow dates are EOM if True
         first_dt=None, # First coupon date
         next_to_last_dt=None): # Penultimate coupon date
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
effective_dt	Date	Also known as the start date	-
termination_dt	Date	-	-
freq_type	FrequencyTypes	-	FrequencyTypes.ANNUAL
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.FOLLOWING
dg_type	DateGenRuleTypes	-	DateGenRuleTypes.BACKWARD
adjust_termination_dt	bool	Default is to adjust	True
end_of_month	bool	All flow dates are EOM if True	False
first_dt	-	First coupon date	None
next_to_last_dt	-	Penultimate coupon date	None

## schedule\_dts

Returns a list of the schedule of Dates.

```
schedule_dts() :
```

The function arguments are described in the following table.

## \_generate

Generate schedule of dates according to specified date generation rules and also adjust these dates for holidays according to the specified business day convention and the specified calendar.

```
_generate() :
```

The function arguments are described in the following table.

## \_\_repr\_\_

Print out the details of the schedule and the actual dates. This can be used for providing transparency on schedule calculations.

```
__repr__() :
```

The function arguments are described in the following table.

## \_print

Print out the details of the schedule and the actual dates. This can be used for providing transparency on schedule calculations.

```
_print() :
```

The function arguments are described in the following table.

## 2.16 singleton

### ***Class: Singleton(type)***

Singleton type which is used to ensure there is only one instance across the whole project.

#### ***\_\_call\_\_***

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__call__(cls, *args, **kwargs):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
cls	-	-	-
*args	-	-	-
**kwargs	-	-	-



## 2.17 solver\_1d

### results

*r*Select from a tuple of(*root*, *funcalls*, *iterations*, *flag*)

```
_results(r):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
<i>r</i>	-	-	-

### **newton\_secant**

*Find a zero from the secant method using the jitted version of Scipy's secant method. Note that 'func' must be jitted via Numba. Parameters ——— func : callable and jitted The function whose zero is wanted. It must be a function of a single variable of the form f(x,a,b,c...), where a,b,c... are extra arguments that can be passed in the 'args' parameter. x0 : float An initial estimate of the zero that should be somewhere near the actual zero. args : tuple, optional(default=()) Extra arguments to be used in the function call. tol : float, optional(default=1.48e-8) The allowable error of the zero value. maxiter : int, optional(default=50) Maximum number of iterations. disp : bool, optional(default=True) If True, raise a RuntimeError if the algorithm didn't converge. Returns ——— results : namedtuple A namedtuple containing the following items: :: root - Estimated location where function is zero. function\_calls - Number of times the function was called. iterations - Number of iterations needed to find the root. converged - True if the routine converged*

```
newton_secant(func, x0, args=(), tol=1.48e-8, maxiter=50, disp=True):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
<i>func</i>	-	-	-
<i>x0</i>	-	-	-
<i>args</i>	-	-	()
<i>tol</i>	-	-	1.48e-8
<i>maxiter</i>	-	-	50
<i>disp</i>	-	-	True

### **newton**

PLEASE ADD A FUNCTION DESCRIPTION

```
newton(func, x0, fprime=None, args=None, tol=1.48e-8, maxiter=50,
        fprime2=None, x1=None, rtol=0.0, full_output=False, disp=False):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
func	-	-	-
x0	-	-	-
fprime	-	-	None
args	-	-	None
tol	-	-	1.48e-8
maxiter	-	-	50
fprime2	-	-	None
x1	-	-	None
rtol	-	-	0.0
full_output	-	-	False
disp	-	-	False

## brent\_max

*PLEASE ADD A FUNCTION DESCRIPTION*

```
brent_max(func, a, b, args, xtol=1e-5, maxiter=500):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
func	-	-	-
a	-	-	-
b	-	-	-
args	-	-	-
xtol	-	-	1e-5
maxiter	-	-	500

## bisection

*Bisection algorithm. You need to supply root brackets x1 and x2.*

```
bisection(func, x1, x2, args, xtol=1e-6, maxIter=100):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
func	-	-	-
x1	-	-	-
x2	-	-	-
args	-	-	-
xtol	-	-	1e-6
maxIter	-	-	100

## minimize\_wolfe\_powel

*Minimize a differentiable multivariate function. Parameters ———* *f* : function to minimize. The function must return the value of the function (float) and a numpy array of partial derivatives of shape (D,) with respect to X, where D is the dimensionality of the function. *X* : numpy array - Shape : (D, 1) initial guess. *length* : int The length of the run. If positive, length gives the maximum number of line searches, if negative its absolute value gives the maximum number of function evaluations. *args* : tuple Tuple of parameters to be passed to the function *f*. *reduction* : float The expected reduction in the function value in the first linesearch (if None, defaults to 1.0) *verbose* : bool If True - prints the progress of minimize. (default is True) *concise* : bool If True - returns concise convergence info, only the minimum function value (necessary when optimizing a large number of parameters) (default is False) *Return* ——— *Xs* : numpy array - Shape : (D, 1) The found solution. *convergence* : numpy array - Shape : (i, D+1) Convergence information. The first column is the function values returned by the function being minimized. The next D columns are the guesses of X during the minimization process. If *concise* = True, convergence information is only the minimum function value. This is necessary only when optimizing a large number of parameters. *i* : int Number of line searches or function evaluations depending on which was selected. The function returns when either its length is up, or if no further progress can be made (ie, we are at a (local) minimum, or so close that due to numerical problems, we cannot get any closer) Copyright (C) 2001 - 2006 by Carl Edward Rasmussen (2006-09-08). Converted to python by David Lines (2019-23-08)

```
minimize_wolfe_powel(f, X, length, fargs=(), reduction=None,
                    verbose=False, concise=False):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
f	-	-	-
X	-	-	-
length	-	-	-
fargs	-	-	()
reduction	-	-	None
verbose	-	-	False
concise	-	-	False

## 2.18 solver\_cg

### **Class: OptimizeResult(dict)**

Represents the optimization result. Attributes ——— x : ndarray The solution of the optimization. success : bool Whether or not the optimizer exited successfully. status : int Termination status of the optimizer. Its value depends on the underlying solver. Refer to ‘message’ for details. message : str Description of the cause of the termination. fun, jac, hess: ndarray Values of objective function, its Jacobian and its Hessian (if available). The Hessians may be approximations, see the documentation of the function in question. hess\_inv : object Inverse of the objective functions Hessian; may be an approximation. Not available for all solvers. The type of this attribute may be either np.ndarray or scipy.sparse.linalg.LinearOperator. nfev, njev, nhev : int Number of evaluations of the objective functions and of its Jacobian and Hessian. nit : int Number of iterations performed by the optimizer. maxcv : float The maximum constraint violation. Notes — There may be additional attributes not listed above depending of the specific solver. Since this class is essentially a subclass of dict with attribute accessors, one can see which attributes are available using the ‘keys()’ method.

#### **\_\_getattr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__getattr__(name):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
name	-	-	-

#### **\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

#### **\_\_dir\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__dir__():
```

The function arguments are described in the following table.

## **polak\_ribiere\_powell\_step**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
polak_ribiere_powell_step(alpha, gfkpl=None):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
alpha	-	-	-
gfkpl	-	-	None

## descent\_condition

*PLEASE ADD A FUNCTION DESCRIPTION*

```
descent_condition(alpha, xkpl, fp1, gfkpl):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
alpha	-	-	-
xkpl	-	-	-
fp1	-	-	-
gfkpl	-	-	-

## fmin\_cg

*PLEASE ADD A FUNCTION DESCRIPTION*

```
fmin_cg(f, x0, fprime=None, fargs=(), gtol=1e-5, norm=Inf, epsilon=_epsilon,
        maxiter=None, full_output=0, disp=1, retall=0, callback=None):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
f	-	-	-
x0	-	-	-
fprime	-	-	None
fargs	-	-	()
gtol	-	-	1e-5
norm	-	-	Inf
epsilon	-	-	_epsilon
maxiter	-	-	None
full_output	-	-	0
disp	-	-	1
retall	-	-	0
callback	-	-	None

**`_check_unknown_options`***PLEASE ADD A FUNCTION DESCRIPTION*

```
_check_unknown_options(unknown_options):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
unknown_options	-	-	-

**`_prepare_scalar_function`**

*Creates a `ScalarFunction` object for use with scalar minimizers (BFGS/LBFGSB/SLSQP/TNC/CG/etc). Parameters ——— `fun` : callable The objective function to be minimized. “`fun(x, *args)` -> float” where “`x`” is an 1-D array with shape `(n,)` and “`args`” is a tuple of the fixed parameters needed to completely specify the function. `x0` : ndarray, shape `(n,)` Initial guess. Array of real elements of size `(n,)`, where ‘`n`’ is the number of independent variables. `jac` : callable, ‘2-point’, ‘3-point’, ‘cs’, None, optional Method for computing the gradient vector. If it is a callable, it should be a function that returns the gradient vector: “`jac(x, *args)` -> array\_like, shape `(n,)`” If one of ‘2-point’, ‘3-point’, ‘cs’ is selected then the gradient is calculated with a relative step for finite differences. If ‘None’, then two-point finite differences with an absolute step is used. `args` : tuple, optional Extra arguments passed to the objective function and its derivatives (‘`fun`’, ‘`jac`’ functions). `bounds` : sequence, optional Bounds on variables. ‘new-style’ bounds are required. `eps` : float or ndarray If ‘`jac` is None’ the absolute step size used for numerical approximation of the jacobian via forward differences. `finite_diff_rel_step` : None or array\_like, optional If ‘`jac` in [‘2-point’, ‘3-point’, ‘cs’]’ the relative step size to use for numerical approximation of the jacobian. The absolute step size is computed as “`h = rel_step * sign(x0) * max(1, abs(x0))`”, possibly adjusted to fit into the bounds. For “`method=‘3-point’`” the sign of ‘`h`’ is ignored. If None (default) then step is selected automatically. `hess` : callable, ‘2-point’, ‘3-point’, ‘cs’, None Computes the Hessian matrix. If it is callable, it should return the Hessian matrix: “`hess(x, *args)` -> LinearOperator, spmatrix, array, `(n, n)`” Alternatively, the keywords ‘2-point’, ‘3-point’, ‘cs’ select a finite difference scheme for numerical estimation. Whenever the gradient is estimated via finite-differences, the Hessian cannot be estimated with options ‘2-point’, ‘3-point’, ‘cs’ and needs to be estimated using one of the quasi-Newton strategies. Returns ——— `sf` : `ScalarFunction`*

```
_prepare_scalar_function(fun, x0, jac=None, args=(), bounds=None,
                        epsilon=None, finite_diff_rel_step=None,
                        hess=None):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
fun	-	-	-
x0	-	-	-
jac	-	-	None
args	-	-	()
bounds	-	-	None
epsilon	-	-	None
finite_diff_rel_step	-	-	None
hess	-	-	None

## vecnorm

PLEASE ADD A FUNCTION DESCRIPTION

```
vecnorm(x, ord=2):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	-	-	-
ord	-	-	2

## \_line\_search\_wolfe12

Same as `line_search_wolfe1`, but fall back to `line_search_wolfe2` if suitable step length is not found, and raise an exception if a suitable step length is not found. Raises — `_LineSearchError` If no suitable step size is found

```
_line_search_wolfe12(f, fprime, xk, pk, gfk, old_fval, old_old_fval,
                    **kwargs):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
f	-	-	-
fprime	-	-	-
xk	-	-	-
pk	-	-	-
gfk	-	-	-
old_fval	-	-	-
old_old_fval	-	-	-
**kwargs	-	-	-

## \_minimize\_cg

Minimization of scalar function of one or more variables using the conjugate gradient algorithm. Options — `disp` : bool Set to True to print convergence messages. `maxiter` : int Maximum number of iterations

to perform. *gtol* : float Gradient norm must be less than 'gtol' before successful termination. *norm* : float Order of norm (Inf is max, -Inf is min). *eps* : float or ndarray If 'jac is None' the absolute step size used for numerical approximation of the jacobian via forward differences. *return\_all* : bool, optional Set to True to return a list of the best solution at each of the iterations. *finite\_diff\_rel\_step* : None or array\_like, optional If 'jac in ['2-point', '3-point', 'cs']' the relative step size to use for numerical approximation of the jacobian. The absolute step size is computed as " $h = \text{rel\_step} * \text{sign}(x_0) * \max(1, \text{abs}(x_0))$ ", possibly adjusted to fit into the bounds. For "method='3-point'" the sign of 'h' is ignored. If None (default) then step is selected automatically.

```
_minimize_cg(fun, x0, args=(), jac=None, callback=None,
             gtol=1e-5, norm=Inf, eps=_epsilon, maxiter=None,
             disp=False, return_all=False, finite_diff_rel_step=None,
             **unknown_options):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
fun	-	-	-
x0	-	-	-
args	-	-	()
jac	-	-	None
callback	-	-	None
gtol	-	-	1e-5
norm	-	-	Inf
eps	-	-	_epsilon
maxiter	-	-	None
disp	-	-	False
return_all	-	-	False
finite_diff_rel_step	-	-	None
**unknown_options	-	-	-



## 2.19 solver\_nm

### nelder\_mead

PLEASE ADD A FUNCTION DESCRIPTION

```
nelder_mead(fun, x0, bounds=np.array([[ ], [ ]]).T, args=(), tol_f=1e-10,
            tol_x=1e-10, max_iter=1000, roh=1., chi=2., v=0.5, sigma=0.5):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
fun	-	-	-
x0	-	-	-
bounds	-	-	np.array([[ ], [ ]]).T
args	-	-	()
tol_f	-	-	1e-10
tol_x	-	-	1e-10
max_iter	-	-	1000
roh	-	-	1.
chi	-	-	2.
v	-	-	0.5
sigma	-	-	0.5

### \_initialize\_simplex

Generates an initial simplex for the Nelder-Mead method. JIT-compiled in 'nopython' mode using Numba. Parameters ——— x0 : ndarray(float, ndim=1) Initial guess. Array of real elements of size (n,), where 'n' is the number of independent variables. bounds: ndarray(float, ndim=2) Sequence of (min, max) pairs for each element in x0. Returns ——— vertices : ndarray(float, ndim=2) Initial simplex with shape (n+1, n).

```
_initialize_simplex(x0, bounds):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x0	-	-	-
bounds	-	-	-

### \_check\_params

Checks whether the parameters for the Nelder-Mead algorithm are valid. JIT-compiled in 'nopython' mode using Numba. Parameters ——— rho : scalar(float) Reflection parameter. Must be strictly greater than 0. chi : scalar(float) Expansion parameter. Must be strictly greater than max(1, roh). v : scalar(float) Contraction parameter. Must be strictly between 0 and 1. sigma : scalar(float) Shrinkage parameter. Must be strictly between 0 and 1. bounds: ndarray(float, ndim=2) Sequence of (min, max) pairs for each element in x. n : scalar(int) Number of independent variables.

```
_check_params(rho, chi, v, sigma, bounds, n):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
rho	-	-	-
chi	-	-	-
v	-	-	-
sigma	-	-	-
bounds	-	-	-
n	-	-	-

### **`_check_bounds`**

*Checks whether 'x' is within 'bounds'. JIT-compiled in 'nopython' mode using Numba. Parameters ———*  
*— x : ndarray(float, ndim=1) 1-D array with shape (n,) of independent variables. bounds: ndarray(float, ndim=2) Sequence of (min, max) pairs for each element in x. Returns ——— bool 'True' if 'x' is within 'bounds', 'False' otherwise.*

```
_check_bounds(x, bounds):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	-	-	-
bounds	-	-	-

## 2.20 stats

### mean

*Calculate the arithmetic mean of a vector of numbers  $x$ .*

```
mean(x: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
$x$	float	-	-

### stdev

*Calculate the standard deviation of a vector of numbers  $x$ .*

```
stdev(x: ndarray):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
$x$	ndarray	-	-

### stderr

*Calculate the standard error estimate of a vector of numbers  $x$ .*

```
stderr(x: ndarray):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
$x$	ndarray	-	-

### var

*Calculate the variance of a vector of numbers  $x$ .*

```
var(x: ndarray):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
$x$	ndarray	-	-

## moment

*Calculate the  $m$ -th moment of a vector of numbers  $x$ .*

```
moment(x: ndarray,  
       m: int):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	ndarray	-	-
m	int	-	-

## correlation

*Calculate the correlation between two series  $x1$  and  $x2$ .*

```
correlation(x1: ndarray,  
            x2: ndarray):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x1	ndarray	-	-
x2	ndarray	-	-

## 2.21 `__init__`

## Chapter 3

# financepy.market.curves

### Discount Curves

These modules create a family of discount curve types related to the term structures of interest rates. Discount curves that can be used to present value a future cash flow. These differ from best fits curves in that they exactly refit the prices of bonds or CDS. The different discount curves are created by calibrating to different instruments. They also differ in terms of the term structure shapes they can have. Different shapes have different impacts in terms of locality on risk management performed using these different curves. There is often a trade-off between smoothness and locality. These are curves which supply a discount factor that can be used to present-value future payments.

#### ***DiscountCurve***

This is a curve made from a Numpy array of times and discount factor values that represents a discount curve. It also requires a specific interpolation scheme. A function is also provided to return a survival probability so that this class can also be used to handle term structures of survival probabilities. Other curves inherit from this in order to share common functionality.

#### ***DiscountCurveFlat***

This is a class that takes in a single flat rate.

#### ***DiscountCurveNS***

Implementation of the Nelson-Siegel curve parametrisation.

#### ***DiscountCurveNSS***

Implementation of the Nelson-Siegel-Svensson curve parametrisation.

#### ***DiscountCurveZeros***

This is a discount curve that is made from a vector of times and zero rates.

## ***Interpolate***

This module contains the interpolation function used throughout the discount curves when a discount factor needs to be interpolated. There are three interpolation methods:

1. **PIECEWISE LINEAR** - This assumes that a discount factor at a time between two other known discount factors is obtained by linear interpolation. This approach does not guarantee any smoothness but is local. It does not guarantee positive forwards (assuming positive zero rates).
2. **PIECEWISE LOG LINEAR** - This assumes that the log of the discount factor is interpolated linearly. The log of a discount factor to time  $T$  is  $T \times R(T)$  where  $R(T)$  is the zero rate. So this is not linear interpolation of  $R(T)$  but of  $T \times R(T)$ .
3. **FLAT FORWARDS** - This interpolation assumes that the forward rate is constant between discount factor points. It is not smooth but is highly local and also ensures positive forward rates if the zero rates are positive.

## 3.1 discount\_curve

### **Class: DiscountCurve**

class DiscountCurve:

### **DiscountCurve**

Create the discount curve from a vector of times and discount factors with an anchor date and specify an interpolation scheme. As we are explicitly linking dates and discount factors, we do not need to specify any compounding convention or day count calculation since discount factors are pure prices. We do however need to specify a convention for interpolating the discount factors in time.

```
DiscountCurve(value_dt: Date,
              df_dts: list,
              df_values: np.ndarray,
              interp_type: InterpTypes = InterpTypes.FLAT_FWD_RATES):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
df_dts	list	-	-
df_values	np.ndarray	-	-
interp_type	InterpTypes	-	InterpTypes.FLAT_FWD_RATES

### **\_zero\_to\_df**

Convert a zero with a specified compounding frequency and day count convention to a discount factor for a single maturity date or a list of dates. The day count is used to calculate the elapsed year fraction.

```
_zero_to_df(value_dt: Date, # TODO: why is value_date not used ?
            rates: (float, np.ndarray),
            times: (float, np.ndarray),
            freq_type: FrequencyTypes,
            dc_type: DayCountTypes):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	TODO: why is value_date not used ?	-
rates	float or np.ndarray	-	-
times	float or np.ndarray	-	-
freq_type	FrequencyTypes	-	-
dc_type	DayCountTypes	-	-



## **`_df_to_zero`**

Given a dates this first generates the discount factors. It then converts the discount factors to a zero rate with a chosen compounding frequency which may be continuous, simple, or compounded at a specific frequency which are all choices of `FrequencyTypes`. Returns a list of discount factor.

```
_df_to_zero(dfs: (float, np.ndarray),
            maturity_dts: (Date, list),
            freq_type: FrequencyTypes,
            dc_type: DayCountTypes):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dfs	float or np.ndarray	-	-
maturity_dts	Date or list	-	-
freq_type	FrequencyTypes	-	-
dc_type	DayCountTypes	-	-

## **`zero_rate`**

Calculation of zero rates with specified frequency. This function can return a vector of zero rates given a vector of dates so must use Numpy functions. Default frequency is a continuously compounded rate.

```
zero_rate(dts: (list, Date),
           freq_type: FrequencyTypes = FrequencyTypes.CONTINUOUS,
           dc_type: DayCountTypes = DayCountTypes.ACT_360):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dts	list or Date	-	-
freq_type	FrequencyTypes	-	FrequencyTypes.CONTINUOUS
dc_type	DayCountTypes	-	DayCountTypes.ACT_360

## **`cc_rate`**

Calculation of zero rates with continuous compounding. This function can return a vector of cc rates given a vector of dates so must use Numpy functions.

```
cc_rate(dts: (list, Date),
         dc_type: DayCountTypes = DayCountTypes.SIMPLE):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dts	list or Date	-	-
dc_type	DayCountTypes	-	DayCountTypes.SIMPLE

## swap\_rate

Calculate the swap rate to maturity date. This is the rate paid by a swap that has a price of par today. This is the same as a Libor swap rate except that we do not do any business day adjustments.

```
swap_rate(effective_dt: Date,
          maturity_dt: (list, Date),
          freq_type=FrequencyTypes.ANNUAL,
          dc_type: DayCountTypes = DayCountTypes.THIRTY_E_360):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
effective_dt	Date	-	-
maturity_dt	list or Date	-	-
freq_type	-	-	FrequencyTypes.ANNUAL
dc_type	DayCountTypes	-	DayCountTypes.THIRTY_E_360

## df

Function to calculate a discount factor from a date or a vector of dates. The day count determines how dates get converted to years. I allow this to default to ACT\_ACT\_ISDA unless specified.

```
df(dt: (list, Date),
   day_count=DayCountTypes.ACT_ACT_ISDA):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	list or Date	-	-
day_count	-	-	DayCountTypes.ACT_ACT_ISDA

## \_df

Hidden function to calculate a discount factor from a time or a vector of times. Discourage usage in favour of passing in dates.

```
_df(t: (float, np.ndarray)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t	float or np.ndarray	-	-

## survival\_prob

This returns a survival probability to a specified date based on the assumption that the continuously compounded rate is a default hazard rate in which case the survival probability is directly analogous to a discount factor.

```
survival_prob(dt: Date):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	Date	-	-

## fwd

*Calculate the continuously compounded forward rate at the forward Date provided. This is done by perturbing the time by one day only and measuring the change in the log of the discount factor divided by the time increment dt. I am assuming continuous compounding over the one date.*

```
fwd(dts: Date):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dts	Date	-	-

## fwd

*Calculate the continuously compounded forward rate at the forward time provided. This is done by perturbing the time by a small amount and measuring the change in the log of the discount factor divided by the time increment dt.*

```
_fwd(times: (np.ndarray, float)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
times	np.ndarray or float	-	-

## bump

*Adjust the continuously compounded forward rates by a perturbation upward equal to the bump size and return a curve object with this bumped curve. This is used for interest rate risk.*

```
bump(bump_size: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
bump_size	float	-	-

**fwd\_rate**

Calculate the forward rate between two forward dates according to the specified day count convention. This defaults to Actual 360. The first date is specified and the second is given as a date or as a tenor which is added to the first date.

```
fwd_rate(start_dt: (list, Date),
         date_or_tenor: (Date, str),
         dc_type: DayCountTypes = DayCountTypes.ACT_360):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
start_dt	list or Date	-	-
date_or_tenor	Date or str	-	-
dc_type	DayCountTypes	-	DayCountTypes.ACT_360

**\_\_repr\_\_**

PLEASE ADD A FUNCTION DESCRIPTION

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

Simple print function for backward compatibility.

```
_print():
```

The function arguments are described in the following table.

## 3.2 discount\_curve\_flat

### **Class: *DiscountCurveFlat(DiscountCurve)***

A very simple discount curve based on a single zero rate with its own specified compounding method. Hence, the curve is assumed to be flat. It is used for quick and dirty analysis and when limited information is available. It inherits several methods from `FinDiscountCurve`.

### **DiscountCurveFlat**

*Create a discount curve which is flat. This is very useful for quick testing and simply requires a curve date a rate and a compound frequency. As we have entered a rate, a corresponding day count convention must be used to specify how time periods are to be measured. As the curve is flat, no interpolation scheme is required.*

```
DiscountCurveFlat(value_dt: Date,
                  flat_rate: (float, np.ndarray),
                  freq_type: FrequencyTypes = FrequencyTypes.CONTINUOUS,
                  dc_type: DayCountTypes = DayCountTypes.ACT_ACT_ISDA):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
flat_rate	float or np.ndarray	-	-
freq_type	FrequencyTypes	-	FrequencyTypes.CONTINUOUS
dc_type	DayCountTypes	-	DayCountTypes.ACT_ACT_ISDA

### **bump**

*Create a new `FinDiscountCurveFlat` object with the entire curve bumped up by the bumpsize. All other parameters are preserved.*

```
bump(bump_size: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
bump_size	float	-	-

### **df**

*Return discount factors given a single or vector of dts. The discount factor depends on the rate and this in turn depends on its compounding frequency, and it defaults to continuous compounding. It also depends on the day count convention. This was set in the construction of the curve to be `ACT_ACT_ISDA`.*

```
df(dts: (Date, list)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dts	Date or list	-	-

**`__repr__`**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**`_print`**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

### 3.3 discount\_curve\_ns

#### **Class: DiscountCurveNS(DiscountCurve)**

Implementation of Nelson-Siegel parametrisation of a discount curve. The internal rate is a continuously compounded rate but you can calculate alternative frequencies by providing a corresponding compounding frequency. A day count convention is needed to ensure that dates are converted to the correct time in years. The class inherits methods from FinDiscountCurve.

#### **DiscountCurveNS**

*Creation of a FinDiscountCurveNS object. Parameters are provided individually for beta\_0, beta\_1, beta\_2 and tau. The zero rates produced by this parametrisation have an implicit compounding convention that defaults to continuous but which can be overridden.*

```
DiscountCurveNS(value_dt: Date,
                 beta_0: float,
                 beta_1: float,
                 beta_2: float,
                 tau: float,
                 freq_type: FrequencyTypes = FrequencyTypes.CONTINUOUS,
                 dc_type: DayCountTypes = DayCountTypes.ACT_ACT_ISDA):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
beta_0	float	-	-
beta_1	float	-	-
beta_2	float	-	-
tau	float	-	-
freq_type	FrequencyTypes	-	FrequencyTypes.CONTINUOUS
dc_type	DayCountTypes	-	DayCountTypes.ACT_ACT_ISDA

#### **zero\_rate**

*Calculation of zero rates with specified frequency according to NS parametrisation. This method overrides that in FinDiscountCurve. The parametrisation is not strictly in terms of continuously compounded zero rates, this function allows other compounding and day counts. This function returns a single or vector of zero rates given a vector of dates so must use Numpy functions. The default frequency is a continuously compounded rate and ACT ACT day counting.*

```
zero_rate(dates: (list, Date),
          freq_type: FrequencyTypes = FrequencyTypes.CONTINUOUS,
          dc_type: DayCountTypes = DayCountTypes.ACT_360):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dates	list or Date	-	-
freq_type	FrequencyTypes	-	FrequencyTypes.CONTINUOUS
dc_type	DayCountTypes	-	DayCountTypes.ACT_360

### **`_zero_rate`**

*Zero rate for Nelson-Siegel curve parametrisation. This means that the  $t$  vector must use the curve day count.*

```
_zero_rate(times: (float, np.ndarray)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
times	float or np.ndarray	-	-

### **`df`**

*Return discount factors given a single or vector of dates. The discount factor depends on the rate and this in turn depends on its compounding frequency and it defaults to continuous compounding. It also depends on the day count convention. This was set in the construction of the curve to be ACT\_ACT\_ISDA.*

```
df(dates: (Date, list)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dates	Date or list	-	-

### **`__repr__`**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

### **`_print`**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.



### 3.4 discount\_curve\_nss

#### **Class: *DiscountCurveNSS(DiscountCurve)***

Implementation of Nelson-Siegel-Svensson parametrisation of the zero rate curve. The zero rate is assumed to be continuously compounded. This can be changed when calling for zero rates. A day count convention is needed to ensure that dates are converted to the correct time in years. The class inherits methods from `FinDiscountCurve`.

#### **DiscountCurveNSS**

Create a `FinDiscountCurveNSS` object by passing in curve valuation date plus the 4 different beta values and the 2 tau values. The zero rates produced by this parametrisation have an implicit compounding convention that defaults to continuous but can be overridden.

```
DiscountCurveNSS(value_dt: Date,
                  beta_0: float,
                  beta_1: float,
                  beta_2: float,
                  beta_3: float,
                  tau_1: float,
                  tau_2: float,
                  freq_type: FrequencyTypes = FrequencyTypes.CONTINUOUS,
                  day_count_type: DayCountTypes = DayCountTypes.ACT_ACT_ISDA):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
beta_0	float	-	-
beta_1	float	-	-
beta_2	float	-	-
beta_3	float	-	-
tau_1	float	-	-
tau_2	float	-	-
freq_type	FrequencyTypes	-	FrequencyTypes.CONTINUOUS
day_count_type	DayCountTypes	-	DayCountTypes.ACT_ACT_ISDA

#### **zero\_rate**

Calculation of zero rates with specified frequency according to NSS parametrisation. This method overrides that in `FinDiscountCurve`. The NSS parametrisation is no strictly terms of continuously compounded zero rates, this function allows other compounding and day counts. This function returns a single or vector of zero rates given a vector of dates so must use Numpy functions. The default frequency is a continuously compounded rate and ACT ACT day counting.

```
zero_rate(dates: (list, Date),
          freq_type: FrequencyTypes = FrequencyTypes.CONTINUOUS,
          dc_type: DayCountTypes = DayCountTypes.ACT_360):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dates	list or Date	-	-
freq_type	FrequencyTypes	-	FrequencyTypes.CONTINUOUS
dc_type	DayCountTypes	-	DayCountTypes.ACT_360

### **`_zero_rate`**

*Calculation of zero rates given a single time or a numpy vector of times. This function can return a single zero rate or a vector of zero rates. The compounding frequency must be provided.*

```
_zero_rate(times: (float, np.ndarray)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
times	float or np.ndarray	-	-

### **`df`**

*Return discount factors given a single or vector of dates. The discount factor depends on the rate and this in turn depends on its compounding frequency and it defaults to continuous compounding. It also depends on the day count convention. This was set in the construction of the curve to be ACT ACT ISDA.*

```
df(dates: (Date, list)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dates	Date or list	-	-

### **`__repr__`**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

### **`_print`**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

### 3.5 discount\_curve\_poly

#### **Class: DiscountCurvePoly(DiscountCurve)**

Zero Rate Curve of a specified frequency parametrised using a cubic polynomial. The zero rate is assumed to be continuously compounded but this can be amended by providing a frequency when extracting zero rates. We also need to specify a Day count convention for time calculations. The class inherits all of the methods from FinDiscountCurve.

#### **DiscountCurvePoly**

*Create zero rate curve parametrised using a cubic curve from coefficients and specifying a compounding frequency type and day count convention.*

```
DiscountCurvePoly(value_dt: Date,
                  coefficients: (list, np.ndarray),
                  freq_type: FrequencyTypes = FrequencyTypes.CONTINUOUS,
                  dc_type: DayCountTypes = DayCountTypes.ACT_ACT_ISDA):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
coefficients	list or np.ndarray	-	-
freq_type	FrequencyTypes	-	FrequencyTypes.CONTINUOUS
dc_type	DayCountTypes	-	DayCountTypes.ACT_ACT_ISDA

#### **zero\_rate**

*Calculation of zero rates with specified frequency according to polynomial parametrisation. This method overrides FinDiscountCurve. The parametrisation is not strictly in terms of continuously compounded zero rates, this function allows other compounding and day counts. This function returns a single or vector of zero rates given a vector of dates so must use Numpy functions. The default frequency is a continuously compounded rate and ACT ACT day counting.*

```
zero_rate(dts: (list, Date),
          freq_type: FrequencyTypes = FrequencyTypes.CONTINUOUS,
          dc_type: DayCountTypes = DayCountTypes.ACT_360):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dts	list or Date	-	-
freq_type	FrequencyTypes	-	FrequencyTypes.CONTINUOUS
dc_type	DayCountTypes	-	DayCountTypes.ACT_360

**`_zero_rate`**

*Calculate the zero rate to maturity date but with times as inputs. This function is used internally and should be discouraged for external use. The compounding frequency defaults to that specified in the constructor of the curve object. Which may be annual to continuous.*

```
_zero_rate(times: (float, np.ndarray)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
times	float or np.ndarray	-	-

**`df`**

*Calculate the fwd rate to maturity date but with times as inputs. This function is used internally and should be discouraged for external use. The compounding frequency defaults to that specified in the constructor of the curve object.*

```
df(dates: (list, Date)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dates	list or Date	-	-

**`__repr__`**

*Display internal parameters of curve.*

```
__repr__():
```

The function arguments are described in the following table.

**`_print`**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

### 3.6 discount\_curve\_pwf

#### **Class: DiscountCurvePWF(DiscountCurve)**

Curve is made up of a series of zero rates sections with each having a piecewise flat zero rate. The default compounding assumption is continuous. The class inherits methods from FinDiscountCurve.

#### **DiscountCurvePWF**

*Creates a discount curve using a vector of times and zero rates that assumes that the zero rates are piecewise flat.*

```
DiscountCurvePWF(value_dt: Date,
                  zero_dts: list,
                  zero_rates: (list, np.ndarray),
                  freq_type: FrequencyTypes = FrequencyTypes.CONTINUOUS,
                  day_count_type: DayCountTypes = DayCountTypes.ACT_ACT_ISDA):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
zero_dts	list	-	-
zero_rates	list or np.ndarray	-	-
freq_type	FrequencyTypes	-	FrequencyTypes.CONTINUOUS
day_count_type	DayCountTypes	-	DayCountTypes.ACT_ACT_ISDA

#### **\_zero\_rate**

*The piecewise flat zero rate is selected and returned.*

```
_zero_rate(times: (float, np.ndarray, list)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
times	float or np.ndarray,list	-	-

#### **\_fwd**

*Calculate the continuously compounded forward rate at the forward time provided. This is done by perturbing the time by a small amount and measuring the change in the log of the discount factor divided by the time increment dt.*

```
_fwd(times: (np.ndarray, list)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
times	np.ndarray or list	-	-

**df**

*Return discount factors given a single or vector of dates. The discount factor depends on the rate and this in turn depends on its compounding frequency and it defaults to continuous compounding. It also depends on the day count convention. This was set in the construction of the curve to be ACT\_ACT\_ISDA.*

```
df(dates: (Date, list)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dates	Date or list	-	-

**\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

### 3.7 discount\_curve\_pwl

#### **Class: DiscountCurvePWL(DiscountCurve)**

Curve is made up of a series of sections assumed to each have a piece-wise linear zero rate. The zero rate has a specified frequency which defaults to continuous. This curve inherits all of the extra methods from FinDiscountCurve.

#### **DiscountCurvePWL**

*Curve is defined by a vector of increasing times and zero rates.*

```
DiscountCurvePWL(value_dt: Date,
                  zero_dts: (Date, list),
                  zero_rates: (list, np.ndarray),
                  freq_type: FrequencyTypes = FrequencyTypes.CONTINUOUS,
                  dc_type: DayCountTypes = DayCountTypes.ACT_ACT_ISDA):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
zero_dts	Date or list	-	-
zero_rates	list or np.ndarray	-	-
freq_type	FrequencyTypes	-	FrequencyTypes.CONTINUOUS
dc_type	DayCountTypes	-	DayCountTypes.ACT_ACT_ISDA

#### **\_zero\_rate**

*Calculate the piecewise linear zero rate. This is taken from the initial inputs. A simple linear interpolation scheme is used. If the user supplies a frequency type then a conversion is done.*

```
_zero_rate(times: (list, np.ndarray)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
times	list or np.ndarray	-	-

#### **df**

*Return discount factors given a single or vector of dates. The discount factor depends on the rate and this in turn depends on its compounding frequency and it defaults to continuous compounding. It also depends on the day count convention. This was set in the construction of the curve to be ACT\_ACT\_ISDA.*

```
df(dates: (Date, list)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dates	Date or list	-	-

**\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.



### 3.8 discount\_curve\_zeros

#### **Class: DiscountCurveZeros(DiscountCurve)**

This is a curve calculated from a set of dates and zero rates. As we have rates as inputs, we need to specify the corresponding compounding frequency. Also to go from rates and dates to discount factors we need to compute the year fraction correctly and for this we require a day count convention. Finally, we need to interpolate the zero rate for the times between the zero rates given and for this we must specify an interpolation convention. The class inherits methods from FinDiscountCurve.

#### **DiscountCurveZeros**

*Create the discount curve from a vector of dates and zero rates factors. The first date is the curve anchor. Then a vector of zero dates and then another same-length vector of rates. The rate is to the corresponding date. We must specify the compounding frequency of the zero rates and also a day count convention for calculating times which we must do to calculate discount factors. Finally we specify the interpolation scheme for off-grid dates.*

```
DiscountCurveZeros(value_dt: Date,
                   zero_dts: list,
                   zero_rates: (list, np.ndarray),
                   freq_type: FrequencyTypes = FrequencyTypes.ANNUAL,
                   dc_type: DayCountTypes = DayCountTypes.ACT_ACT_ISDA,
                   interp_type: InterpTypes = InterpTypes.FLAT_FWD_RATES):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
zero_dts	list	-	-
zero_rates	list or np.ndarray	-	-
freq_type	FrequencyTypes	-	FrequencyTypes.ANNUAL
dc_type	DayCountTypes	-	DayCountTypes.ACT_ACT_ISDA
interp_type	InterpTypes	-	InterpTypes.FLAT_FWD_RATES

#### **\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

#### **\_print**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

## 3.9 interpolator

### *Enumerated Type: InterpTypes*

This enumerated type has the following values:

- FLAT\_FWD\_RATES
- LINEAR\_FWD\_RATES
- LINEAR\_ZERO\_RATES
- FINCUBIC\_ZERO\_RATES
- NATCUBIC\_LOG\_DISCOUNT
- NATCUBIC\_ZERO\_RATES
- PCHIP\_ZERO\_RATES
- PCHIP\_LOG\_DISCOUNT

### *Class: Interpolator()*

class Interpolator():

### **Interpolator**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
Interpolator(interpolator_type: InterpTypes):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
interpolator_type	InterpTypes	-	-

### **fit**

*# Second derivatives at left is zero and first derivative at # right is clamped to zero.*

```
fit(times: np.ndarray,
    dfs: np.ndarray):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
times	np.ndarray	-	-
dfs	np.ndarray	-	-

### **interpolate**

*Interpolation of discount factors at time  $x$  given discount factors at times provided using one of the methods in the enum InterpTypes. The value of  $x$  can be an array so that the function is vectorised.*

```
interpolate(t: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t	float	-	-

## interpolate

*Fast interpolation of discount factors at time  $x$  given discount factors at times provided using one of the methods in the enum `InterpTypes`. The value of  $x$  can be an array so that the function is vectorised.*

```
interpolate(t: (float, np.ndarray), # time or array of times
            times: np.ndarray, # Vector of times on grid
            dfs: np.ndarray, # Vector of discount factors
            method: int): # Interpolation method which is value of enum
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t	float or np.ndarray	time or array of times	-
times	np.ndarray	Vector of times on grid	-
dfs	np.ndarray	Vector of discount factors	-
method	int	Interpolation method which is value of enum	-

## \_uinterpolate

*Return the interpolated value of  $y$  given  $x$  and a vector of  $x$  and  $y$ . The values of  $x$  must be monotonic and increasing. The different schemes for interpolation are linear in  $y$  (as a function of  $x$ ), linear in  $\log(y)$  and piecewise flat in the continuously compounded forward  $y$  rate.*

```
_uinterpolate(t, times, dfs, method):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t	-	-	-
times	-	-	-
dfs	-	-	-
method	-	-	-

## \_vinterpolate

*Return the interpolated values of  $y$  given  $x$  and a vector of  $x$  and  $y$ . The values of  $x$  must be monotonic and increasing. The different schemes for interpolation are linear in  $y$  (as a function of  $x$ ), linear in  $\log(y)$  and piecewise flat in the continuously compounded forward  $y$  rate.*

```
_vinterpolate(xValues,
              xvector,
              dfs,
              method):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
xValues	-	-	-
xvector	-	-	-
dfs	-	-	-
method	-	-	-

## 3.10 `__init__`



## Chapter 4

# financepy.market.volatility

### Market Volatility

These modules create a family of curve types related to the market volatility. There are three types of class:

1. Term structures of volatility i.e. volatility as a function of option expiry date.
2. Volatility curves which are smile/skews so store volatility as a function of option strike.
3. Volatility surfaces which hold volatility as a function of option expiry date AND option strike.

The classes are as follows:

#### ***equity\_vol\_surface***

Constructs an equity volatility surface that fits to a grid of market volatilities at a set of strikes and expiry dates. It implements the SVI parametric form for fitting and interpolating volatilities. It also provides plotting of the volatility curve and surfaces.

#### ***FinFXVolSurface***

FX volatility as a function of option expiry and strike. This class constructs the surface from the ATM volatility plus a choice of 10 and 25 delta strangles and risk reversals or both. This is done for multiple expiry dates. A number of curve fitting choices are possible including polynomial in delta and SABR.

#### ***FinlborCapFloorVol***

Libor cap/floor volatility as a function of option expiry (cap/floor start date). Takes in cap (flat) volatility and bootstraps the caplet volatility. This is assumed to be piecewise flat.

#### ***FinlborCapFloorVolFn***

Parametric function for storing the cap and caplet volatilities based on form proposed by Rebonato.



## 4.1 equity\_vol\_curve

### **Class: *EquityVolCurve()***

Class to manage a smile or skew in volatility at a single maturity horizon. It fits the volatility using a polynomial. Includes analytics to extract the implied pdf of the underlying at maturity. THIS NEEDS TO BE SUBSTITUTED WITH FINEQUITYVOLSURFACE.

### **EquityVolCurve**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
EquityVolCurve(curve_dt,
               expiry_dt,
               strikes,
               volatilities,
               polynomial=3):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
curve_dt	-	-	-
expiry_dt	-	-	-
strikes	-	-	-
volatilities	-	-	-
polynomial	-	-	3

### **volatility**

*Return the volatility for a strike using a given polynomial interpolation.*

```
volatility(strike):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
strike	-	-	-

### **calculate\_pdf**

*calculate the probability density function of the underlying using the volatility smile or skew curve following the approach set out in Breedon and Litzenberger.*

```
calculate_pdf():
```

The function arguments are described in the following table.

## 4.2 equity\_vol\_surface

### **Class: EquityVolSurface**

Class to perform a calibration of a chosen parametrised surface to the prices of equity options at different strikes and expiry tenors. There is a choice of volatility function from cubic in delta to full SABR and SSVI. Check out VolFuncTypes. Visualising the volatility curve is useful. Also, there is no guarantee that the implied pdf will be positive.

### EquityVolSurface

Create the EquitySurface object by passing in market vol data for a list of strikes and expiry dates.

```
EquityVolSurface(value_dt: Date,
                 stock_price: float,
                 discount_curve: DiscountCurve,
                 dividend_curve: DiscountCurve,
                 expiry_dts: (list),
                 strikes: (list, np.ndarray),
                 volatility_grid: (list, np.ndarray),
                 volatility_function_type: VolFuncTypes = VolFuncTypes.CLARK,
                 finSolverType: FinSolverTypes = FinSolverTypes.NELDER_MEAD):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
expiry_dts	list or (list	-	-
strikes	list or np.ndarray	-	-
volatility_grid	list or np.ndarray	-	-
volatility_function_type	VolFuncTypes	-	VolFuncTypes.CLARK
finSolverType	FinSolverTypes	-	NELDER_MEAD

### vol\_from\_strike\_dt

Interpolates the Black-Scholes volatility from the volatility surface given call option strike and expiry date. Linear interpolation is done in variance space. The smile strikes at bracketed dates are determined by determining the strike that reproduces the provided delta value. This uses the calibration delta convention, but it can be overridden by a provided delta convention. The resulting volatilities are then determined for each bracketing expiry time and linear interpolation is done in variance space and then converted back to a lognormal volatility.

```
vol_from_strike_dt(K, expiry_dt):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
K	-	-	-
expiry_dt	-	-	-

## vol\_from\_delta\_dt

*Interpolates the Black-Scholes volatility from the volatility surface given a call option delta and expiry date. Linear interpolation is done in variance space. The smile strikes at bracketed dates are determined by determining the strike that reproduces the provided delta value. This uses the calibration delta convention, but it can be overridden by a provided delta convention. The resulting volatilities are then determined for each bracketing expiry time and linear interpolation is done in variance space and then converted back to a lognormal volatility.*

```
vol_from_delta_dt(call_delta, expiry_dt, delta_method=None):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
call_delta	-	-	-
expiry_dt	-	-	-
delta_method	-	-	None

## \_build\_vol\_surface

*Main function to construct the vol surface.*

```
_build_vol_surface(finSolverType=FinSolverTypes.NELDER_MEAD):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
finSolverType	-	-	NELDER_MEAD

## check\_calibration

*Compare calibrated vol surface with market and output a report which sets out the quality of fit to the ATM and 10 and 25 delta market strangles and risk reversals.*

```
check_calibration(verbose: bool, tol: float = 1e-6):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
verbose	bool	-	-
tol	float	-	1e-6

**implied\_dbns**

*Calculate the pdf for each tenor horizon. Returns a list of FinDistribution objects, one for each tenor horizon.*

```
implied_dbns(lowS, highS, num_intervals):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
lowS	-	-	-
highS	-	-	-
num_intervals	-	-	-

**plot\_vol\_curves**

*Generates a plot of each of the vol discount implied by the market and fitted.*

```
plot_vol_curves():
```

The function arguments are described in the following table.

**\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

*Print a list of the unadjusted coupon payment dates used in analytic calculations for the bond.*

```
_print():
```

The function arguments are described in the following table.

**\_obj**

*Return a value that is minimised when the ATM, MS and RR vols have been best fitted using the parametric volatility curve represented by params and specified by the vol\_type\_value. We fit at one time slice only.*

```
_obj(params, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
params	-	-	-
*args	-	-	-

## **`_solve_to_horizon`**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_solve_to_horizon(s, t, r, q,
                  strikes,
                  time_index,
                  volatility_grid,
                  vol_type_value,
                  x_inits,
                  finSolverType):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
t	-	-	-
r	-	-	-
q	-	-	-
strikes	-	-	-
time_index	-	-	-
volatility_grid	-	-	-
vol_type_value	-	-	-
x_inits	-	-	-
finSolverType	-	-	-

## **vol function**

*Return the volatility for a strike using a given polynomial interpolation following Section 3.9 of Iain Clark book.*

```
vol_function(vol_function_type_value, params, f, k, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
vol_function_type_value	-	-	-
params	-	-	-
f	-	-	-
k	-	-	-
t	-	-	-

**\_delta\_fit***PLEASE ADD A FUNCTION DESCRIPTION*

```
_delta_fit(k, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
k	-	-	-
*args	-	-	-

**\_solver\_for\_smile\_strike**

*Solve for the strike that sets the delta of the option equal to the target value of delta allowing the volatility to be a function of the strike.*

```
_solver_for_smile_strike(s, t, r, q,
                        option_type_value,
                        volatilityTypeValue,
                        delta_target,
                        initial_guess,
                        parameters):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
t	-	-	-
r	-	-	-
q	-	-	-
option_type_value	-	-	-
volatilityTypeValue	-	-	-
delta_target	-	-	-
initial_guess	-	-	-
parameters	-	-	-

## 4.3 fx\_vol\_surface

### **Class: FXVolSurface()**

Class to perform a calibration of a chosen parametrised surface to the prices of FX options at different strikes and expiry tenors. The calibration inputs are the ATM and 25 Delta volatilities given in terms of the market strangle and risk reversals. There is a choice of volatility function ranging from polynomial in delta to a limited version of SABR.

### **FXVolSurface**

*Create the FinFXVolSurface object by passing in market vol data for ATM and 25 Delta Market Strangles and Risk Reversals.*

```
FXVolSurface(value_dt: Date,
             spot_fx_rate: float,
             currency_pair: str,
             notional_currency: str,
             dom_discount_curve: DiscountCurve,
             for_discount_curve: DiscountCurve,
             tenors: (list),
             atm_vols: (list, np.ndarray),
             mktStrangle25DeltaVols: (list, np.ndarray),
             riskReversal25DeltaVols: (list, np.ndarray),
             atmMethod: FinFXATMMethod = FinFXATMMethod.FWD_DELTA_NEUTRAL,
             delta_method: FinFXDeltaMethod = FinFXDeltaMethod.SPOT_DELTA,
             volatility_function_type: VolFuncTypes = VolFuncTypes.CLARK):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
spot_fx_rate	float	-	-
currency_pair	str	-	-
notional_currency	str	-	-
dom_discount_curve	DiscountCurve	-	-
for_discount_curve	DiscountCurve	-	-
tenors	list or (list	-	-
atm_vols	list or np.ndarray	-	-
mktStrangle25DeltaVols	list or np.ndarray	-	-
riskReversal25DeltaVols	list or np.ndarray	-	-
atmMethod	FinFXATMMethod	-	FWD_DELTA_NEUTRAL
delta_method	FinFXDeltaMethod	-	SPOT_DELTA
volatility_function_type	VolFuncTypes	-	VolFuncTypes.CLARK

### **volatility**

*Interpolate the Black-Scholes volatility from the volatility surface given the option strike and expiry date. Linear interpolation is done in variance  $x$  time.*

```
volatility(K, expiry_dt):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
K	-	-	-
expiry_dt	-	-	-

## build\_vol\_surface

*PLEASE ADD A FUNCTION DESCRIPTION*

```
build_vol_surface():
```

The function arguments are described in the following table.

## solver\_for\_smile\_strike

*Solve for the strike that sets the delta of the option equal to the target value of delta allowing the volatility to be a function of the strike.*

```
solver_for_smile_strike(option_type_value,
                        delta_target,
                        tenor_index,
                        initialValue):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
option_type_value	-	-	-
delta_target	-	-	-
tenor_index	-	-	-
initialValue	-	-	-

## check\_calibration

*PLEASE ADD A FUNCTION DESCRIPTION*

```
check_calibration(verbose: bool, tol: float = 1e-6):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
verbose	bool	-	-
tol	float	-	1e-6



## implied\_dbns

Calculate the pdf for each tenor horizon. Returns a list of *FinDistribution* objects, one for each tenor horizon.

```
implied_dbns(low_fx, high_fx, num_intervals):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
low_fx	-	-	-
high_fx	-	-	-
num_intervals	-	-	-

## plot\_vol\_curves

PLEASE ADD A FUNCTION DESCRIPTION

```
plot_vol_curves():
```

The function arguments are described in the following table.

## \_\_repr\_\_

PLEASE ADD A FUNCTION DESCRIPTION

```
__repr__():
```

The function arguments are described in the following table.

## \_print

Print a list of the unadjusted coupon payment dates used in analytic calculations for the bond.

```
_print():
```

The function arguments are described in the following table.

## g

PLEASE ADD A FUNCTION DESCRIPTION

```
g(K, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
K	-	-	-
*args	-	-	-

### obj\_fast

*Return a function that is minimised when the ATM, MS and RR vols have been best fitted using the parametric volatility curve represented by cvec*

```
obj_fast(params, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
params	-	-	-
*args	-	-	-

### solve\_to\_horizon\_fast

*PLEASE ADD A FUNCTION DESCRIPTION*

```
solve_to_horizon_fast(s, t,
                      rd, rf,
                      K_ATM, atm_vol,
                      ms_25d_vol, rr_25d_vol,
                      delta_method_value, vol_type_value,
                      xopt):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
t	-	-	-
rd	-	-	-
rf	-	-	-
K_ATM	-	-	-
atm_vol	-	-	-
ms_25d_vol	-	-	-
rr_25d_vol	-	-	-
delta_method_value	-	-	-
vol_type_value	-	-	-
xopt	-	-	-

### vol\_function

*Return the volatility for a strike using a given polynomial interpolation following Section 3.9 of Iain Clark book.*

```
vol_function(vol_function_type_value, params, f, k, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
vol_function_type_value	-	-	-
params	-	-	-
f	-	-	-
k	-	-	-
t	-	-	-

## delta\_fit

*PLEASE ADD A FUNCTION DESCRIPTION*

```
delta_fit(K, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
K	-	-	-
*args	-	-	-

## solver\_for\_smile\_strike\_fast

*Solve for the strike that sets the delta of the option equal to the target value of delta allowing the volatility to be a function of the strike.*

```
solver_for_smile_strike_fast(s, t, rd, rf,
                             option_type_value,
                             volatilityTypeValue,
                             delta_target,
                             delta_method_value,
                             initial_guess,
                             parameters):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
t	-	-	-
rd	-	-	-
rf	-	-	-
option_type_value	-	-	-
volatilityTypeValue	-	-	-
delta_target	-	-	-
delta_method_value	-	-	-
initial_guess	-	-	-
parameters	-	-	-

### solve\_for\_strike

*This function determines the implied strike of an FX option given a delta and the other option details. It uses a one-dimensional Newton root search algorithm to determine the strike that matches an input volatility.*

```
solve_for_strike(spot_fx_rate,
                 tdel, rd, rf,
                 option_type_value,
                 delta_target,
                 delta_method_value,
                 volatility):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
spot_fx_rate	-	-	-
tdel	-	-	-
rd	-	-	-
rf	-	-	-
option_type_value	-	-	-
delta_target	-	-	-
delta_method_value	-	-	-
volatility	-	-	-

## 4.4 fx\_vol\_surface\_plus

### ***Class: FXVolSurfacePlus()***

Class to perform a calibration of a chosen parametrised surface to the prices of FX options at different strikes and expiry tenors. The calibration inputs are the ATM and 25 and 10 Delta volatilities in terms of the market strangle and risk reversals. There is a choice of volatility function from cubic in delta to full SABR. Check out VolFuncTypes. Parameter alpha [0,1] is used to interpolate between fitting only 25D when alpha=0 to fitting only 10D when alpha=1.0. Alpha=0.5 assigns equal weights. A vol function with more parameters will give a better fit. Of course. But it might also overfit. Visualising the volatility curve is useful. Also, there is no guarantee that the implied pdf will be positive.

### **FXVolSurfacePlus**

*Create the FinFXVolSurfacePlus object by passing in market vol data for ATM, 25 Delta and 10 Delta strikes. The alpha weight shifts the fitting between 25D and 10D. Alpha = 0.0 is 100% 25D, Alpha = 1.0 is 100% 10D.*

```
FXVolSurfacePlus(value_dt: Date,
                  spot_fx_rate: float,
                  currency_pair: str,
                  notional_currency: str,
                  dom_discount_curve: DiscountCurve,
                  for_discount_curve: DiscountCurve,
                  tenors: (list),
                  atm_vols: (list, np.ndarray),
                  mktStrangle25DeltaVols: (list, np.ndarray),
                  riskReversal25DeltaVols: (list, np.ndarray),
                  mktStrangle10DeltaVols: (list, np.ndarray),
                  riskReversal10DeltaVols: (list, np.ndarray),
                  alpha: float,
                  atmMethod: FinFXATMMMethod = FinFXATMMethod.FWD_DELTA_NEUTRAL,
                  delta_method: FinFXDeltaMethod = FinFXDeltaMethod.SPOT_DELTA,
                  volatility_function_type: VolFuncTypes = VolFuncTypes.CLARK,
                  finSolverType: FinSolverTypes = FinSolverTypes.NELDER_MEAD,
                  tol: float = 1e-8):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
spot_fx_rate	float	-	-
currency_pair	str	-	-
notional_currency	str	-	-
dom_discount_curve	DiscountCurve	-	-
for_discount_curve	DiscountCurve	-	-
tenors	list or (list	-	-
atm_vols	list or np.ndarray	-	-
mktStrangle25DeltaVols	list or np.ndarray	-	-
riskReversal25DeltaVols	list or np.ndarray	-	-
mktStrangle10DeltaVols	list or np.ndarray	-	-
riskReversal10DeltaVols	list or np.ndarray	-	-
alpha	float	-	-
atmMethod	FinFXATMMMethod	-	FWD_DELTA_NEUTRAL
delta_method	FinFXDeltaMethod	-	SPOT_DELTA
volatility_function_type	VolFuncTypes	-	VolFuncTypes.CLARK
finSolverType	FinSolverTypes	-	NELDER_MEAD
tol	float	-	1e-8

### vol from strike\_dt

*Interpolates the Black-Scholes volatility from the volatility surface given call option strike and expiry date. Linear interpolation is done in variance space. The smile strikes at bracketed dates are determined by determining the strike that reproduces the provided delta value. This uses the calibration delta convention, but it can be overridden by a provided delta convention. The resulting volatilities are then determined for each bracketing expiry time and linear interpolation is done in variance space and then converted back to a lognormal volatility.*

```
vol_from_strike_dt(K, expiry_dt):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
K	-	-	-
expiry_dt	-	-	-

### delta\_to\_strike

*Interpolates the strike at a delta and expiry date. Linear time to expiry interpolation is used in strike.*

```
delta_to_strike(call_delta, expiry_dt, delta_method):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
call_delta	-	-	-
expiry_dt	-	-	-
delta_method	-	-	-

## vol\_from\_delta\_dt

*Interpolates the Black-Scholes volatility from the volatility surface given a call option delta and expiry date. Linear interpolation is done in variance space. The smile strikes at bracketed dates are determined by determining the strike that reproduces the provided delta value. This uses the calibration delta convention, but it can be overridden by a provided delta convention. The resulting volatilities are then determined for each bracketing expiry time and linear interpolation is done in variance space and then converted back to a lognormal volatility.*

```
vol_from_delta_dt(call_delta,
                  expiry_dt,
                  delta_method=None):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
call_delta	-	-	-
expiry_dt	-	-	-
delta_method	-	-	None

## \_build\_vol\_surface

*Main function to construct the vol surface.*

```
_build_vol_surface(finSolverType=FinSolverTypes.NELDER_MEAD,
                  tol=1e-8):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
finSolverType	-	-	NELDER_MEAD
tol	-	-	1e-8

## check\_calibration

*Compare calibrated vol surface with market and output a report which sets out the quality of fit to the ATM and 10 and 25 delta market strangles and risk reversals.*

```
check_calibration(verbose: bool, tol: float = 1e-6):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
verbose	bool	-	-
tol	float	-	1e-6

## implied\_dbns

*Calculate the pdf for each tenor horizon. Returns a list of FinDistribution objects, one for each tenor horizon.*

```
implied_dbns(lowFX, highFX, num_intervals):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
lowFX	-	-	-
highFX	-	-	-
num_intervals	-	-	-

## plot\_vol\_curves

*Generates a plot of each of the vol discount implied by the market and fitted.*

```
plot_vol_curves():
```

The function arguments are described in the following table.

## \_\_repr\_\_

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

## \_print

*Print a list of the unadjusted coupon payment dates used in analytic calculations for the bond.*

```
_print():
```

The function arguments are described in the following table.

## -g

*PLEASE ADD A FUNCTION DESCRIPTION*



```
_g(K, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
K	-	-	-
*args	-	-	-

## **`_interpolate_gap`**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_interpolate_gap(k, strikes, gaps):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
k	-	-	-
strikes	-	-	-
gaps	-	-	-

## **`_obj`**

*Return a function that is minimised when the ATM, MS and RR vols have been best fitted using the parametric volatility curve represented by params and specified by the vol\_type\_value*

```
_obj(params, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
params	-	-	-
*args	-	-	-

## **`_obj_gap`**

*Return a function that is minimised when the ATM, MS and RR vols have been best fitted using the parametric volatility curve represented by params and specified by the vol\_type\_value*

```
_obj_gap(gaps, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
gaps	-	-	-
*args	-	-	-

**\_solve\_to\_horizon***PLEASE ADD A FUNCTION DESCRIPTION*

```

_solve_to_horizon(s, t, rd, rf,
                  K_ATM, atm_vol,
                  ms_25d_vol, rr_25d_vol,
                  ms_10d_vol, rr_10d_vol,
                  delta_method_value, vol_type_value,
                  alpha,
                  x_inits,
                  ginitis,
                  finSolverType,
                  tol):

```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
t	-	-	-
rd	-	-	-
rf	-	-	-
K_ATM	-	-	-
atm_vol	-	-	-
ms_25d_vol	-	-	-
rr_25d_vol	-	-	-
ms_10d_vol	-	-	-
rr_10d_vol	-	-	-
delta_method_value	-	-	-
vol_type_value	-	-	-
alpha	-	-	-
x_inits	-	-	-
ginitis	-	-	-
finSolverType	-	-	-
tol	-	-	-

**vol\_function**

*Return the volatility for a strike using a given polynomial interpolation following Section 3.9 of Iain Clark book.*

```

vol_function(vol_function_type_value, params, strikes, gaps, f, k, t):

```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
vol_function_type_value	-	-	-
params	-	-	-
strikes	-	-	-
gaps	-	-	-
f	-	-	-
k	-	-	-
t	-	-	-

## **\_delta\_fit**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_delta_fit(k, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
k	-	-	-
*args	-	-	-

## **\_solver\_for\_smile\_strike**

*Solve for the strike that sets the delta of the option equal to the target value of delta allowing the volatility to be a function of the strike.*

```
_solver_for_smile_strike(s, t, rd, rf,
                        option_type_value,
                        volatilityTypeValue,
                        delta_target,
                        delta_method_value,
                        initial_guess,
                        parameters,
                        strikes,
                        gaps):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
t	-	-	-
rd	-	-	-
rf	-	-	-
option_type_value	-	-	-
volatilityTypeValue	-	-	-
delta_target	-	-	-
delta_method_value	-	-	-
initial_guess	-	-	-
parameters	-	-	-
strikes	-	-	-
gaps	-	-	-

## solve\_for\_strike

*This function determines the implied strike of an FX option given a delta and the other option details. It uses a one-dimensional Newton root search algorithm to determine the strike that matches an input volatility.*

```
solve_for_strike(spot_fx_rate,
                 tdel, rd, rf,
                 option_type_value,
                 delta_target,
                 delta_method_value,
                 volatility):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
spot_fx_rate	-	-	-
tdel	-	-	-
rd	-	-	-
rf	-	-	-
option_type_value	-	-	-
delta_target	-	-	-
delta_method_value	-	-	-
volatility	-	-	-

## 4.5 ibor\_cap\_vol\_curve

### **Class: *IborCapVolCurve()***

Class to manage a term structure of cap (flat) volatilities and to do the conversion to caplet (spot) volatilities. This does not manage a strike dependency, only a term structure. The cap and caplet volatilities are keyed off the cap and caplet maturity dates. However this volatility only applies to the evolution of the Ibor rate out to the caplet start dates. Note also that this class also handles floor vols.

### **IborCapVolCurve**

*Create a cap/floor volatility curve given a curve date, a list of cap maturity dates and a vector of cap volatilities. To avoid confusion first date of the capDates must be equal to the curve date and first cap volatility for this date must equal zero. The internal times are calculated according to the provided day count convention. Note cap and floor volatilities are the same for the same strike and tenor, I just refer to cap volatilities in the code for code simplicity.*

```
IborCapVolCurve(curve_dt, # Valuation date for cap volatility
                cap_maturity_dts, # curve date + maturity dates for caps
                cap_sigmas, # Flat cap volatility for cap maturity dates
                dc_type):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
curve_dt	-	Valuation date for cap volatility	-
cap_maturity_dts	-	curve date + maturity dates for caps	-
cap_sigmas	-	Flat cap volatility for cap maturity dates	-
dc_type	-	-	-

### **generate\_caplet\_vols**

*Bootstrap caplet volatilities from cap volatilities using similar notation to Hull's book (page 32.11). The first volatility in the vector of caplet vols is zero.*

```
generate_caplet_vols():
```

The function arguments are described in the following table.

### **caplet\_vol**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
caplet_vol(dt):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	-	-	-

### cap\_vol

*Return the cap flat volatility for a specific cap maturity date for the last caplet/floorlet in the cap/floor. The volatility interpolation is piecewise flat.*

```
cap_vol(dt) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	-	-	-

### \_\_repr\_\_

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__() :
```

The function arguments are described in the following table.

## 4.6 ibor\_cap\_vol\_curve\_fn

### **Class: *IborCapVolCurveFn()***

Class to manage a term structure of caplet volatilities using the parametric form suggested by Rebonato (1999).

### **IborCapVolCurveFn**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
IborCapVolCurveFn (curve_dt,
                    a,
                    b,
                    c,
                    d) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
curve_dt	-	-	-
a	-	-	-
b	-	-	-
c	-	-	-
d	-	-	-

### **cap\_floorlet\_vol**

*Return the caplet volatility.*

```
cap_floorlet_vol (dt) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	-	-	-

## 4.7 swaption\_vol\_surface

### **Class: SwaptionVolSurface()**

Class to perform a calibration of a chosen parametrised surface to the prices of swaptions at different expiry dates and swap tenors. There is a choice of volatility function from cubic in delta to full SABR and SSVI. Check out VolFuncTypes. Visualising the volatility curve is useful. Also, there is no guarantee that the implied pdf will be positive.

### SwaptionVolSurface

Create the *FinSwaptionVolSurface* object by passing in market vol data for a list of strikes and expiry dates.

```
SwaptionVolSurface(value_dt: Date,
                   expiry_dts: (list),
                   fwd_swap_rates: (list, np.ndarray),
                   strike_grid: (np.ndarray),
                   volatility_grid: (np.ndarray),
                   volatility_function_type: VolFuncTypes = VolFuncTypes.SABR,
                   finSolverType: FinSolverTypes = FinSolverTypes.NELDER_MEAD):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
expiry_dts	list or (list	-	-
fwd_swap_rates	list or np.ndarray	-	-
strike_grid	np.ndarray or (np.ndarray	-	-
volatility_grid	np.ndarray or (np.ndarray	-	-
volatility_function_type	VolFuncTypes	-	VolFuncTypes.SABR
finSolverType	FinSolverTypes	-	NELDER_MEAD

### vol\_from\_strike\_dt

Interpolates the Black-Scholes volatility from the volatility surface given call option strike and expiry date. Linear interpolation is done in variance space. The smile strikes at bracketed dates are determined by determining the strike that reproduces the provided delta value. This uses the calibration delta convention, but it can be overridden by a provided delta convention. The resulting volatilities are then determined for each bracketing expiry time and linear interpolation is done in variance space and then converted back to a lognormal volatility.

```
vol_from_strike_dt(K, expiry_dt):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
K	-	-	-
expiry_dt	-	-	-



**\_build\_vol\_surface**

*Main function to construct the vol surface.*

```
_build_vol_surface(finSolverType=FinSolverTypes.NELDER_MEAD):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
finSolverType	-	-	NELDER_MEAD

**check\_calibration**

*Compare calibrated vol surface with market and output a report which sets out the quality of fit to the ATM and 10 and 25 delta market strangles and risk reversals.*

```
check_calibration(verbose: bool, tol: float = 1e-6):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
verbose	bool	-	-
tol	float	-	1e-6

**plot\_vol\_curves**

*Generates a plot of each of the vol discount implied by the market and fitted.*

```
plot_vol_curves():
```

The function arguments are described in the following table.

**\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

*Print a list of the unadjusted coupon payment dates used in analytic calculations for the bond.*

```
_print():
```

The function arguments are described in the following table.

**\_obj**

*Return a value that is minimised when the ATM, MS and RR vols have been best fitted using the parametric volatility curve represented by params and specified by the vol\_type\_value at a single time slice only.*

```
_obj(params, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
params	-	-	-
*args	-	-	-

**\_solve\_to\_horizon**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_solve_to_horizon(t, f,
                  strikes_grid,
                  time_index,
                  volatility_grid,
                  vol_type_value,
                  x_inits,
                  finSolverType):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t	-	-	-
f	-	-	-
strikes_grid	-	-	-
time_index	-	-	-
volatility_grid	-	-	-
vol_type_value	-	-	-
x_inits	-	-	-
finSolverType	-	-	-

**vol function**

*Return the volatility for a strike using a given polynomial interpolation following Section 3.9 of Iain Clark book.*

```
vol_function(vol_function_type_value, params, f, k, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
vol_function_type_value	-	-	-
params	-	-	-
f	-	-	-
k	-	-	-
t	-	-	-

## 4.8 `__init__`



## Chapter 5

# financepy.products.equity

### Equity Products

This folder contains a set of Equity-related products. It includes:

#### ***EquityVanillaOption***

Handles simple European-style call and put options on a dividend paying stock with analytical and monte-carlo valuations.

#### ***EquityAmericanOption***

Handles America-style call and put options on a dividend paying stock with tree-based valuations.

#### ***EquityAsianOption***

Handles call and put options where the payoff is determined by the average-stock price over some period before expiry.

#### ***EquityBasketOption***

Handles call and put options on a basket of assets, with an analytical and Monte-Carlo valuation according to Black-Scholes model.

#### ***EquityCompoundOption***

Handles options to choose to enter into a call or put option. Has an analytical valuation model for European style options and a tree model if either or both options are American style exercise.

#### ***EquityDigitalOption***

Handles European-style options to receive cash or nothing, or to receive the asset or nothing. Has an analytical valuation model for European style options.

***EquityFixedLookbackOption***

Handles European-style options to receive the positive difference between the strike and the minimum (put) or maximum (call) of the stock price over the option life.

***EquityFloatLookbackOption***

Handles an equity option in which the strike of the option is not fixed but is set at expiry to equal the minimum stock price in the case of a call or the maximum stock price in the case of a put. In other words the buyer of the call gets to buy the asset at the lowest price over the period before expiry while the buyer of the put gets to sell the asset at the highest price before expiry. """

***EquityBarrierOption***

Handles an option which either knocks-in or knocks-out if a specified barrier is crossed from above or below, resulting in owning or not owning a call or a put option. There are eight variations which are all valued.

***EquityRainbowOption***

TBD

***EquityVarianceSwap***

TBD

Products that have not yet been implemented include:

- Power Options
- Ratchet Options
- Forward Start Options
- Log Options

## 5.1 equity\_american\_option

### **Class: *EquityAmericanOption(EquityOption)***

Class for American (and European) style options on simple vanilla calls and puts - a tree valuation model is used that can handle both.

### **EquityAmericanOption**

*Class for American style options on simple vanilla calls and puts. Specify the expiry date, strike price, whether the option is a call or put and the number of options.*

```
EquityAmericanOption(expiry_dt: Date,
                      strike_price: float,
                      option_type: OptionTypes,
                      num_options: float = 1.0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
expiry_dt	Date	-	-
strike_price	float	-	-
option_type	OptionTypes	-	-
num_options	float	-	1.0

### **value**

*Valuation of an American option using a CRR tree to take into account the value of early exercise.*

```
value(value_dt: Date,
      stock_price: (np.ndarray, float),
      discount_curve: DiscountCurve,
      dividend_curve: DiscountCurve,
      model: Model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	np.ndarray or float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	Model	-	-

### **\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```



The function arguments are described in the following table.

### **`_print`**

*Simple print function for backward compatibility.*

```
_print() :
```

The function arguments are described in the following table.

## 5.2 equity\_asian\_option

### **Enumerated Type: AsianOptionValuationMethods**

This enumerated type has the following values:

- GEOMETRIC
- TURNBULL\_WAKEMAN
- CURRAN

### **Class: EquityAsianOption**

Class for an Equity Asian Option. This is an option with a final payoff linked to the averaging of the stock price over some specified period before the option expires. The valuation is done for both an arithmetic and a geometric average but the former can only be done either using an analytical approximation of the arithmetic average distribution or by using Monte-Carlo simulation.

### **EquityAsianOption**

Create an *EquityAsian* option object which takes a start date for the averaging, an expiry date, a strike price, an option type and a number of observations.

```
EquityAsianOption(start_averaging_dt: Date,
                  expiry_dt: Date,
                  strike_price: float,
                  option_type: OptionTypes,
                  num_obs: int = 100):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
start_averaging_dt	Date	-	-
expiry_dt	Date	-	-
strike_price	float	-	-
option_type	OptionTypes	-	-
num_obs	int	-	100

### **value**

Calculate the value of an Asian option using one of the specified analytical approximations for an average rate option. These are the three enumerated values in the enum *AsianOptionValuationMethods*. The choices of approximation are (i) *GEOMETRIC* - the average is a geometric one as in paper by Kenna and Worst (1990), (ii) *TURNBULL\_WAKEMAN* - this is a value based on an edgeworth expansion of the moments of the arithmetic average, and (iii) *CURRAN* - another approximative approach by Curran based on conditioning on the geometric mean price. Just choose the corresponding enumerated value to switch between these different approaches. Note that the accrued average is only required if the value date is inside the averaging period for the option.

```
value(value_dt: Date,
```

```

stock_price: float,
discount_curve: DiscountCurve,
dividend_curve: DiscountCurve,
model,
method: AsianOptionValuationMethods,
accrued_average: float = None):

```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	-	-	-
method	AsianOptionValuationMethods	-	-
accrued_average	float	-	None

### **`_value_geometric`**

*This option valuation is based on paper by Kemna and Vorst 1990. It calculates the Geometric Asian option price which is a lower bound on the Arithmetic option price. This should not be used as a valuation model for the Arithmetic Average option but can be used as a control variate for other approaches.*

```

_value_geometric(value_dt, stock_price, discount_curve,
                 dividend_curve, model, accrued_average):

```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
stock_price	-	-	-
discount_curve	-	-	-
dividend_curve	-	-	-
model	-	-	-
accrued_average	-	-	-

### **`_value_curran`**

*Valuation of an Asian option using the result by Vorst.*

```

_value_curran(value_dt, stock_price, discount_curve,
              dividend_curve, model, accrued_average):

```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
stock_price	-	-	-
discount_curve	-	-	-
dividend_curve	-	-	-
model	-	-	-
accrued_average	-	-	-

### **`_value_turnbull_wakeman`**

*Asian option valuation based on paper by Turnbull and Wakeman 1991 which uses the edgeworth expansion to find the first two moments of the arithmetic average.*

```
_value_turnbull_wakeman(value_dt, stock_price, discount_curve,
                        dividend_curve, model, accrued_average):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
stock_price	-	-	-
discount_curve	-	-	-
dividend_curve	-	-	-
model	-	-	-
accrued_average	-	-	-

### **`_value_mc`**

*Monte Carlo valuation of the Asian Average option using standard Monte Carlo code enhanced by Numba. I have discontinued the use of this as it is both slow and has limited variance reduction.*

```
_value_mc(value_dt: Date,
          stock_price: float,
          discount_curve: DiscountCurve,
          dividend_curve: DiscountCurve,
          model,
          num_paths: int,
          seed: int,
          accrued_average: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	-	-	-
num_paths	int	-	-
seed	int	-	-
accrued_average	float	-	-

### **`_value_mc_fast`**

*Monte Carlo valuation of the Asian Average option. This method uses a lot of Numpy vectorisation. It is also helped by Numba.*

```
_value_mc_fast(value_dt,
               stock_price,
               discount_curve,
               dividend_curve, # Yield
               model,          # Model
               num_paths,      # Numpaths integer
               seed,
               accrued_average):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
stock_price	-	-	-
discount_curve	-	-	-
dividend_curve	-	Yield	-
model	-	Model	-
num_paths	-	Numpaths integer	-
seed	-	-	-
accrued_average	-	-	-

### **`value_mc`**

*Monte Carlo valuation of the Asian Average option using a control variate method that improves accuracy and reduces the variance of the price. This uses Numpy and Numba. This is the standard MC pricer.*

```
value_mc(value_dt: Date,
          stock_price: float,
          discount_curve: DiscountCurve,
          dividend_curve: DiscountCurve,
          model,
          num_paths: int,
          seed: int,
          accrued_average: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	-	-	-
num_paths	int	-	-
seed	int	-	-
accrued_average	float	-	-

### **\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

### **\_print**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

### **\_value\_mc\_numba**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_value_mc_numba(t0,
                 t,
                 tau,
                 K,
                 n,
                 option_type,
                 stock_price,
                 interest_rate,
                 dividend_yield,
                 volatility,
                 num_paths,
                 seed,
                 accrued_average):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t0	-	-	-
t	-	-	-
tau	-	-	-
K	-	-	-
n	-	-	-
option_type	-	-	-
stock_price	-	-	-
interest_rate	-	-	-
dividend_yield	-	-	-
volatility	-	-	-
num_paths	-	-	-
seed	-	-	-
accrued_average	-	-	-

### **`_value_mc_fast_numba`**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_value_mc_fast_numba(t0: float,
                     t: float,
                     tau: float,
                     K: float,
                     n: int,
                     option_type: int,
                     stock_price: float,
                     interest_rate: float,
                     dividend_yield: float,
                     volatility: float,
                     num_paths: int,
                     seed: int,
                     accrued_average: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t0	float	-	-
t	float	-	-
tau	float	-	-
K	float	-	-
n	int	-	-
option_type	int	-	-
stock_price	float	-	-
interest_rate	float	-	-
dividend_yield	float	-	-
volatility	float	-	-
num_paths	int	-	-
seed	int	-	-
accrued_average	float	-	-

**`_value_mc_fast_cv_numba`***PLEASE ADD A FUNCTION DESCRIPTION*

```
_value_mc_fast_cv_numba(t0, t, tau, K, n, option_type, stock_price,
                        interest_rate, dividend_yield, volatility, num_paths,
                        seed, accrued_average, v_g_exact):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t0	-	-	-
t	-	-	-
tau	-	-	-
K	-	-	-
n	-	-	-
option_type	-	-	-
stock_price	-	-	-
interest_rate	-	-	-
dividend_yield	-	-	-
volatility	-	-	-
num_paths	-	-	-
seed	-	-	-
accrued_average	-	-	-
v_g_exact	-	-	-



## 5.3 equity\_barrier\_option

### **Class: EquityBarrierOption(EquityOption)**

Class to hold details of an Equity Barrier Option. It also calculates the option price using Black Scholes for 8 different variants on the Barrier structure in enum EquityBarrierTypes.

### **EquityBarrierOption**

*Create the EquityBarrierOption by specifying the expiry date, strike price, option type, barrier level, the number of observations per year and the notional.*

```
EquityBarrierOption(expiry_dt: Date,
                    strike_price: float,
                    option_type: EquityBarrierTypes,
                    barrier_level: float,
                    num_obs_per_year: (int, float) = 252,
                    notional: float = 1.0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
expiry_dt	Date	-	-
strike_price	float	-	-
option_type	EquityBarrierTypes	-	-
barrier_level	float	-	-
num_obs_per_year	int or float	-	252
notional	float	-	1.0

### **value**

*This prices an Equity Barrier option using the formulae given in the paper by Clewlow, Llanos and Strickland December 1994 which can be found at <https://warwick.ac.uk/fac/soc/wbs/subjects/finance/research/wpaperseries/1994/94-54.pdf>*

```
value(value_dt: Date,
      stock_price: (float, np.ndarray),
      discount_curve: DiscountCurve,
      dividend_curve: DiscountCurve,
      model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float or np.ndarray	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	-	-	-

**value\_mc**

*A Monte-Carlo based valuation of the barrier option which simulates the evolution of the stock price of at a specified number of annual observation times until expiry to examine if the barrier has been crossed and the corresponding value of the final payoff, if any. It assumes a GBM model for the stock price.*

```
value_mc(t: float,
         k,
         option_type: int,
         b,
         notional,
         s: float,
         r: float,
         process_type,
         model_params,
         num_ann_obs: int = 252,
         num_paths: int = 10000,
         seed: int = 4242):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t	float	-	-
k	-	-	-
option_type	int	-	-
b	-	-	-
notional	-	-	-
s	float	-	-
r	float	-	-
process_type	-	-	-
model_params	-	-	-
num_ann_obs	int	-	252
num_paths	int	-	10000
seed	int	-	4242

**\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

## 5.4 equity\_basket\_option

### **Class: EquityBasketOption**

A EquityBasketOption is a contract to buy a put or a call option on an equally weighted portfolio of different stocks, each with its own price, volatility and dividend yield. An analytical and monte-carlo pricing model have been implemented for a European style option.

### **EquityBasketOption**

*Define the EquityBasket option by specifying its expiry date, its strike price, whether it is a put or call, and the number of underlying stocks in the basket.*

```
EquityBasketOption(expiry_dt: Date,
                    strike_price: float,
                    option_type: OptionTypes,
                    num_assets: int):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
expiry_dt	Date	-	-
strike_price	float	-	-
option_type	OptionTypes	-	-
num_assets	int	-	-

### **\_validate**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_validate(stock_prices,
          dividend_yields,
          volatilities,
          correlations):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
stock_prices	-	-	-
dividend_yields	-	-	-
volatilities	-	-	-
correlations	-	-	-

### **value**

*Basket valuation using a moment matching method to approximate the effective variance of the underlying basket value. This approach is able to handle a full rank correlation structure between the individual assets.*

```
value(value_dt: Date,
      stock_prices: np.ndarray,
      discount_curve: DiscountCurve,
      dividend_curves: (list),
      volatilities: np.ndarray,
      correlations: np.ndarray):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_prices	np.ndarray	-	-
discount_curve	DiscountCurve	-	-
dividend_curves	list or (list	-	-
volatilities	np.ndarray	-	-
correlations	np.ndarray	-	-

## value\_mc

*Valuation of the EquityBasketOption using a Monte-Carlo simulation of stock prices assuming a GBM distribution. Cholesky decomposition is used to handle a full rank correlation structure between the individual assets. The num\_paths and seed are pre-set to default values but can be overwritten.*

```
value_mc(value_dt: Date,
         stock_prices: np.ndarray,
         discount_curve: DiscountCurve,
         dividend_curves: (list),
         volatilities: np.ndarray,
         corr_matrix: np.ndarray,
         num_paths: int = 10000,
         seed: int = 4242):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_prices	np.ndarray	-	-
discount_curve	DiscountCurve	-	-
dividend_curves	list or (list	-	-
volatilities	np.ndarray	-	-
corr_matrix	np.ndarray	-	-
num_paths	int	-	10000
seed	int	-	4242

## \_\_repr\_\_

PLEASE ADD A FUNCTION DESCRIPTION

```
__repr__():
```

The function arguments are described in the following table.

### **`_print`**

*Simple print function for backward compatibility.*

```
_print() :
```

The function arguments are described in the following table.

## 5.5 equity\_binomial\_tree

### ***Enumerated Type: EquityTreePayoffTypes***

This enumerated type has the following values:

- FWD\_CONTRACT
- VANILLA\_OPTION
- DIGITAL\_OPTION
- POWER\_CONTRACT
- POWER\_OPTION
- LOG\_CONTRACT
- LOG\_OPTION

### ***Enumerated Type: EquityTreeExerciseTypes***

This enumerated type has the following values:

- EUROPEAN
- AMERICAN

### ***Class: EquityBinomialTree()***

class EquityBinomialTree():

### **EquityBinomialTree**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
EquityBinomialTree() :
```

The function arguments are described in the following table.

### **value**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
value(stock_price,
      discount_curve,
      dividend_curve,
      volatility,
      num_steps,
      value_dt,
      payoff,
      expiry_dt,
      payoff_type,
      exercise_type,
      payoff_params) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
stock_price	-	-	-
discount_curve	-	-	-
dividend_curve	-	-	-
volatility	-	-	-
num_steps	-	-	-
value_dt	-	-	-
payoff	-	-	-
expiry_dt	-	-	-
payoff_type	-	-	-
exercise_type	-	-	-
payoff_params	-	-	-

**`_validate_payoff`***PLEASE ADD A FUNCTION DESCRIPTION*

```
_validate_payoff(payoff_type, payoff_params):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
payoff_type	-	-	-
payoff_params	-	-	-

**`_payoff_value`***PLEASE ADD A FUNCTION DESCRIPTION*

```
_payoff_value(s, payoff_type, payoff_params):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
payoff_type	-	-	-
payoff_params	-	-	-

**`_value_once`***PLEASE ADD A FUNCTION DESCRIPTION*

```
_value_once(stock_price,
            r,
            q,
            volatility,
            num_steps,
```



```
time_to_expiry,
payoff_type,
exercise_type,
payoff_params):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
stock_price	-	-	-
r	-	-	-
q	-	-	-
volatility	-	-	-
num_steps	-	-	-
time_to_expiry	-	-	-
payoff_type	-	-	-
exercise_type	-	-	-
payoff_params	-	-	-

## 5.6 equity\_chooser\_option

### **Class: EquityChooserOption(EquityOption)**

A EquityChooserOption is an option which allows the holder to either enter into a call or a put option on a later expiry date, with both strikes potentially different and both expiry dates potentially different. This is known as a complex chooser. All the option details are set at trade initiation.

### **EquityChooserOption**

*Create the EquityChooserOption by passing in the chooser date and then the put and call expiry dates as well as the corresponding put and call strike prices.*

```
EquityChooserOption(choose_dt: Date,
                    call_expiry_dt: Date,
                    put_expiry_dt: Date,
                    call_strike_price: float,
                    put_strike_price: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
choose_dt	Date	-	-
call_expiry_dt	Date	-	-
put_expiry_dt	Date	-	-
call_strike_price	float	-	-
put_strike_price	float	-	-

### **value**

*Value the complex chooser option using an approach by Rubinstein (1991). See also Haug page 129 for complex chooser options.*

```
value(value_dt: Date,
      stock_price: float,
      discount_curve: DiscountCurve,
      dividend_curve: DiscountCurve,
      model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	-	-	-

## value\_mc

*Value the complex chooser option Monte Carlo.*

```
value_mc(value_dt: Date,
         stock_price: float,
         discount_curve: DiscountCurve,
         dividend_curve: DiscountCurve,
         model,
         num_paths: int = 10000,
         seed: int = 4242):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	-	-	-
num_paths	int	-	10000
seed	int	-	4242

## \_\_repr\_\_

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

## \_print

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

## f

*Complex chooser option solve for critical stock price that makes the forward starting call and put options have the same price on the chooser date.*

```
_f(ss, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
ss	-	-	-
*args	-	-	-

## 5.7 equity\_cliquet\_option

### **Class: *EquityCliquetOption(EquityOption)***

A EquityCliquetOption is a series of options which start and stop at successive times with each subsequent option resetting its strike to be ATM at the start of its life. This is also known as a reset option.

### **EquityCliquetOption**

*Create the EquityCliquetOption by passing in the start date and the end date and whether it is a call or a put. Some additional data is needed in order to calculate the individual payments.*

```
EquityCliquetOption(start_dt: Date,
                    final_expiry_dt: Date,
                    option_type: OptionTypes,
                    freq_type: FrequencyTypes,
                    day_count_type: DayCountTypes = DayCountTypes.THIRTY_E_360,
                    cal_type: CalendarTypes = CalendarTypes.WEEKEND,
                    bd_type: BusDayAdjustTypes = BusDayAdjustTypes.FOLLOWING,
                    dg_type: DateGenRuleTypes = DateGenRuleTypes.BACKWARD):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
start_dt	Date	-	-
final_expiry_dt	Date	-	-
option_type	OptionTypes	-	-
freq_type	FrequencyTypes	-	-
day_count_type	DayCountTypes	-	DayCountTypes.THIRTY_E_360
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.FOLLOWING
dg_type	DateGenRuleTypes	-	DateGenRuleTypes.BACKWARD

### **value**

*Value the cliquet option as a sequence of options using the Black- Scholes model.*

```
value(value_dt: Date,
      stock_price: float,
      discount_curve: DiscountCurve,
      dividend_curve: DiscountCurve,
      model: Model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	Model	-	-

## **print\_payments**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
print_payments() :
```

The function arguments are described in the following table.

## **\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__() :
```

The function arguments are described in the following table.

## **\_print**

*Simple print function for backward compatibility.*

```
_print() :
```

The function arguments are described in the following table.

## 5.8 equity\_compound\_option

### **Class: *EquityCompoundOption(EquityOption)***

A *EquityCompoundOption* is a compound option which allows the holder to either buy or sell another underlying option on a first expiry date that itself expires on a second expiry date. Both strikes are set at trade initiation.

### **EquityCompoundOption**

*Create the *EquityCompoundOption* by passing in the first and second expiry dates as well as the corresponding strike prices and option types.*

```
EquityCompoundOption(cExpiryDate: Date, # Compound Option expiry date
                     cOptionType: OptionTypes, # Compound option type
                     cStrikePrice: float, # Compound option strike
                     uExpiryDate: Date, # Underlying option expiry date
                     uOptionType: OptionTypes, # Underlying option type
                     uStrikePrice: float): # Underlying option strike price
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
cExpiryDate	Date	Compound Option expiry date	-
cOptionType	OptionTypes	Compound option type	-
cStrikePrice	float	Compound option strike	-
uExpiryDate	Date	Underlying option expiry date	-
uOptionType	OptionTypes	Underlying option type	-
uStrikePrice	float	Underlying option strike price	-

### **value**

*Value the compound option using an analytical approach if it is entirely European style. Otherwise use a Tree approach to handle the early exercise. Solution by Geske (1977), Hodges and Selby (1987) and Rubinstein (1991). See also Haug page 132.*

```
value(value_dt: Date,
      stock_price: float,
      discount_curve: DiscountCurve,
      dividend_curve: DiscountCurve,
      model,
      num_steps: int = 200):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	-	-	-
num_steps	int	-	200

### **\_value\_tree**

*This function is called if the option has American features.*

```
_value_tree(value_dt,
            stock_price,
            discount_curve,
            dividend_curve,
            model,
            num_steps=200):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
stock_price	-	-	-
discount_curve	-	-	-
dividend_curve	-	-	-
model	-	-	-
num_steps	-	-	200

### **implied\_stock\_price**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_implied_stock_price(stock_price,
                    expiry_dt1,
                    expiry_dt2,
                    strike_price1,
                    strike_price2,
                    option_type2,
                    interest_rate,
                    dividend_yield,
                    model):
```

The function arguments are described in the following table.



Argument Name	Type	Description	Default Value
stock_price	-	-	-
expiry_dt1	-	-	-
expiry_dt2	-	-	-
strike_price1	-	-	-
strike_price2	-	-	-
option_type2	-	-	-
interest_rate	-	-	-
dividend_yield	-	-	-
model	-	-	-

**\_\_repr\_\_***PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**\_print***Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

**\_f***PLEASE ADD A FUNCTION DESCRIPTION*

```
_f(s0, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s0	-	-	-
*args	-	-	-

**\_value\_once***PLEASE ADD A FUNCTION DESCRIPTION*

```
_value_once(s,
            r,
            q,
```

```

volatility,
t1, t2,
option_type1, option_type2,
k1, k2,
num_steps):

```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
r	-	-	-
q	-	-	-
volatility	-	-	-
t1	-	-	-
t2	-	-	-
option_type1	-	-	-
option_type2	-	-	-
k1	-	-	-
k2	-	-	-
num_steps	-	-	-

## 5.9 equity\_digital\_option

### **Enumerated Type: *FinDigitalOptionTypes***

This enumerated type has the following values:

- CASH\_OR\_NOTHING
- ASSET\_OR\_NOTHING

### **Class: *EquityDigitalOption(EquityOption)***

A EquityDigitalOption is an option in which the buyer receives some payment if the stock price has crossed a barrier ONLY at expiry and zero otherwise. There are two types: cash-or-nothing and the asset-or-nothing option. We do not care whether the stock price has crossed the barrier today, we only care about the barrier at option expiry. For a continuously- monitored barrier, use the EquityOneTouchOption class.

### **EquityDigitalOption**

*Create the digital option by specifying the expiry date, the barrier price and the type of option which is either a EUROPEAN\_CALL or a EUROPEAN\_PUT or an AMERICAN\_CALL or AMERICAN\_PUT. There are two types of underlying - cash or nothing and asset or nothing.*

```
EquityDigitalOption(expiry_dt: Date,
                    barrier: float,
                    call_put_type: OptionTypes,
                    digital_type: FinDigitalOptionTypes):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
expiry_dt	Date	-	-
barrier	float	-	-
call_put_type	OptionTypes	-	-
digital_type	FinDigitalOptionTypes	-	-

### **value**

*Digital Option valuation using the Black-Scholes model assuming a barrier at expiry. Handles both cash-or-nothing and asset-or-nothing options.*

```
value(value_dt: Date,
      s: (float, np.ndarray),
      discount_curve: DiscountCurve,
      dividend_curve: DiscountCurve,
      model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
s	float or np.ndarray	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	-	-	-

## value\_mc

*Digital Option valuation using the Black-Scholes model and Monte Carlo simulation. Product assumes a barrier only at expiry. Monte Carlo handles both a cash-or-nothing and an asset-or-nothing option.*

```
value_mc(value_dt: Date,
         stock_price: float,
         discount_curve: DiscountCurve,
         dividend_curve: DiscountCurve,
         model,
         num_paths: int = 10000,
         seed: int = 4242):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	-	-	-
num_paths	int	-	10000
seed	int	-	4242

## \_\_repr\_\_

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

## \_print

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

## 5.10 equity\_fixed\_lookback\_option

### **Class: *EquityFixedLookbackOption(EquityOption)***

This is an equity option in which the strike of the option is fixed but the value of the stock price used to determine the payoff is the maximum in the case of a call option, and a minimum in the case of a put option.

### **EquityFixedLookbackOption**

*Create the FixedLookbackOption by specifying the expiry date, the option type and the option strike.*

```
EquityFixedLookbackOption(expiry_dt: Date,
                           option_type: OptionTypes,
                           strike_price: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
expiry_dt	Date	-	-
option_type	OptionTypes	-	-
strike_price	float	-	-

### **value**

*Valuation of the Fixed Lookback option using Black-Scholes using the formulae derived by Conze and Viswanathan (1991). One of the inputs is the minimum of maximum of the stock price since the start of the option depending on whether the option is a call or a put.*

```
value(value_dt: Date,
       stock_price: float,
       discount_curve: DiscountCurve,
       dividend_curve: DiscountCurve,
       volatility: float,
       stock_min_max: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
volatility	float	-	-
stock_min_max	float	-	-

### **value\_mc**

*Monte Carlo valuation of a fixed strike lookback option using a Black-Scholes model that assumes the stock follows a GBM process.*

```

value_mc(value_dt: Date,
         stock_price: float,
         discount_curve: DiscountCurve,
         dividend_curve: DiscountCurve,
         volatility: float,
         stock_min_max: float,
         num_paths: int = 10000,
         num_steps_per_year: int = 252,
         seed: int = 4242):

```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
volatility	float	-	-
stock_min_max	float	-	-
num_paths	int	-	10000
num_steps_per_year	int	-	252
seed	int	-	4242

### **`__repr__`**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

### **`_print`**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

## 5.11 equity\_float\_lookback\_option

### **Class: *EquityFloatLookbackOption(EquityOption)***

This is an equity option in which the strike of the option is not fixed but is set at expiry to equal the minimum stock price in the case of a call or the maximum stock price in the case of a put. In other words the buyer of the call gets to buy the asset at the lowest price over the period before expiry while the buyer of the put gets to sell the asset at the highest price before expiry.

### **EquityFloatLookbackOption**

*Create the FloatLookbackOption by specifying the expiry date and the option type. The strike is determined internally as the maximum or minimum of the stock price depending on whether it is a put or a call option.*

```
EquityFloatLookbackOption(expiry_dt: Date,
                          option_type: OptionTypes):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
expiry_dt	Date	-	-
option_type	OptionTypes	-	-

### **value**

*Valuation of the Floating Lookback option using Black-Scholes using the formulae derived by Goldman, Sosin and Gatto (1979).*

```
value(value_dt: Date,
      stock_price: float,
      discount_curve: DiscountCurve,
      dividend_curve: DiscountCurve,
      volatility: float,
      stock_min_max: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
volatility	float	-	-
stock_min_max	float	-	-

### **value\_mc**

*Monte Carlo valuation of a floating strike lookback option using a Black-Scholes model that assumes the stock follows a GBM process.*

```

value_mc(value_dt: Date,
         stock_price: float,
         discount_curve: DiscountCurve,
         dividend_curve: DiscountCurve,
         volatility: float,
         stock_min_max: float,
         num_paths: int = 10000,
         num_steps_per_year: int = 252,
         seed: int = 4242):

```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
volatility	float	-	-
stock_min_max	float	-	-
num_paths	int	-	10000
num_steps_per_year	int	-	252
seed	int	-	4242

**\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.



## 5.12 equity\_forward

**Class: *EquityForward()***

### EquityForward

*Creates a EquityForward which allows the owner to buy the stock at a price agreed today. Need to specify if LONG or SHORT.*

```
EquityForward(expiry_dt: Date,
              forward_price: float, # PRICE OF 1 UNIT OF FOREIGN IN DOM CCY
              notional: float,
              long_short: FinLongShort = FinLongShort.LONG):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
expiry_dt	Date	-	-
forward_price	float	PRICE OF 1 UNIT OF FOREIGN IN DOM CCY	-
notional	float	-	-
long_short	FinLongShort	-	LONG

### value

*Calculate the value of an equity forward contract from the stock price and discount and dividend discount.*

```
value(value_dt,
      stock_price, # Current stock price
      discount_curve,
      dividend_curve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
stock_price	-	Current stock price	-
discount_curve	-	-	-
dividend_curve	-	-	-

### forward

*Calculate the forward price of the equity forward contract.*

```
forward(value_dt,
        stock_price, # Current stock price
        discount_curve,
        dividend_curve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
stock_price	-	Current stock price	-
discount_curve	-	-	-
dividend_curve	-	-	-

**\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

## 5.13 equity\_index\_option

### ***Class: EquityIndexOption***

Class for managing plain vanilla European/American calls and puts on equity indices.

### **EquityIndexOption**

*Create the Equity Index option object by specifying the expiry date, the option strike, the option type and the number of options.*

```
EquityIndexOption(expiry_dt: Union[Date, list],
                  strike_price: Union[float, np.ndarray],
                  option_type: OptionTypes,
                  num_options: Optional[float] = 1.0,
                  ):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
expiry_dt	Date or list	-	-
strike_price	float or np.ndarray	-	-
option_type	OptionTypes	-	-
num_options	Optional[float]	-	1.0

### **value**

*Equity Index Option valuation using Black model.*

```
value(value_dt: Union[Date, list],
      forward_price: float,
      discount_curve: DiscountCurve,
      model: Model,
      ):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date or list	-	-
forward_price	float	-	-
discount_curve	DiscountCurve	-	-
model	Model	-	-

### **delta**

*Calculate delta of a European/American Index option.*

```
delta(value_dt: Date,
      forward_price: float,
```

```
discount_curve: DiscountCurve,
model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
forward_price	float	-	-
discount_curve	DiscountCurve	-	-
model	-	-	-

## gamma

*Calculate gamma of a European/American Index option.*

```
gamma(value_dt: Date,
       forward_price: float,
       discount_curve: DiscountCurve,
       model: Model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
forward_price	float	-	-
discount_curve	DiscountCurve	-	-
model	Model	-	-

## vega

*Calculate vega of a European/American Index option.*

```
vega(value_dt: Date,
      forward_price: float,
      discount_curve: DiscountCurve,
      model: Model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
forward_price	float	-	-
discount_curve	DiscountCurve	-	-
model	Model	-	-

## theta

*Calculate theta of a European/American Index option.*

```
theta(value_dt: Date,
      forward_price: float,
      discount_curve: DiscountCurve,
      model: Model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
forward_price	float	-	-
discount_curve	DiscountCurve	-	-
model	Model	-	-

## implied\_volatility

*Calculate the Black implied volatility of a European/American Index option.*

```
implied_volatility(value_dt: Date,
                  forward_price: Union[float, list, np.ndarray],
                  discount_curve: DiscountCurve,
                  model: Model,
                  price: float,
                  ):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
forward_price	float or list,np.ndarray	-	-
discount_curve	DiscountCurve	-	-
model	Model	-	-
price	float	-	-

## \_\_repr\_\_

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

## \_print

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

## 5.14 equity\_model\_types

**Class: *EquityModel***

### EquityModel

*PLEASE ADD A FUNCTION DESCRIPTION*

```
EquityModel():
```

The function arguments are described in the following table.

**Class: *EquityModelHeston(EquityModel)***

class EquityModelHeston(EquityModel):

### EquityModelHeston

*PLEASE ADD A FUNCTION DESCRIPTION*

```
EquityModelHeston(volatility, mean_reversion):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
volatility	-	-	-
mean_reversion	-	-	-

**`--repr--`**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

## 5.15 equity\_one\_touch\_option

### **Class: *EquityOneTouchOption(EquityOption)***

A EquityOneTouchOption is an option in which the buyer receives one unit of cash OR stock if the stock price touches a barrier at any time before the option expiry date and zero otherwise. The choice of cash or stock is made at trade initiation. The single barrier payoff must define whether the option pays or cancels if the barrier is touched and also when the payment is made (at hit time or option expiry). All of these variants are all members of the FinTouchOptionTypes enumerated type.

### **EquityOneTouchOption**

*Create the one touch option by defining its expiry date and the barrier level and a payment size if it is a cash*

```
EquityOneTouchOption(expiry_dt: Date,
                      option_type: TouchOptionTypes,
                      barrier_price: float,
                      payment_size: float = 1.0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
expiry_dt	Date	-	-
option_type	TouchOptionTypes	-	-
barrier_price	float	-	-
payment_size	float	-	1.0

### **value**

*Equity One-Touch Option valuation using the Black-Scholes model assuming a continuous (American) barrier from value date to expiry. Handles both cash-or-nothing and asset-or-nothing options.*

```
value(value_dt: Date,
      stock_price: (float, np.ndarray),
      discount_curve: DiscountCurve,
      dividend_curve: DiscountCurve,
      model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float or np.ndarray	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	-	-	-

**value\_mc**

*Touch Option valuation using the Black-Scholes model and Monte Carlo simulation. Accuracy is not great when compared to the analytical result as we only observe the barrier a finite number of times. The convergence is slow.*

```
value_mc(value_dt: Date,
         stock_price: float,
         discount_curve: DiscountCurve,
         dividend_curve: DiscountCurve,
         model,
         num_paths: int = 10000,
         num_steps_per_year: int = 252,
         seed: int = 4242):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	-	-	-
num_paths	int	-	10000
num_steps_per_year	int	-	252
seed	int	-	4242

**\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

**\_barrier\_pay\_one\_at\_hit\_pv\_down**

*Pay \$1 if the stock crosses the barrier H from above. PV payment.*



```
_barrier_pay_one_at_hit_pv_down(s, H, r, dt):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
H	-	-	-
r	-	-	-
dt	-	-	-

### **`_barrier_pay_one_at_hit_pv_up`**

*Pay \$1 if the stock crosses the barrier H from below. PV payment.*

```
_barrier_pay_one_at_hit_pv_up(s, H, r, dt):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
H	-	-	-
r	-	-	-
dt	-	-	-

### **`_barrier_pay_asset_at_expiry_down_out`**

*Pay \$1 if the stock crosses the barrier H from above. PV payment.*

```
_barrier_pay_asset_at_expiry_down_out(s, H):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
H	-	-	-

### **`_barrier_pay_asset_at_expiry_up_out`**

*Pay \$1 if the stock crosses the barrier H from below. PV payment.*

```
_barrier_pay_asset_at_expiry_up_out(s, H):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
H	-	-	-

## 5.16 equity\_option

### **Enumerated Type: *EquityOptionModelTypes***

This enumerated type has the following values:

- BLACKSCHOLES
- ANOTHER

### **Class: *EquityOption***

This class is a parent class for all option classes that require any perturbatory risk.

### **value**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
value(value_dt: Date,
      stock_price: float,
      discount_curve: DiscountCurve,
      dividend_yield: float,
      model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_yield	float	-	-
model	-	-	-

### **delta**

*Calculation of option delta by perturbation of stock price and revaluation.*

```
delta(value_dt: Date,
      stock_price: float,
      discount_curve: DiscountCurve,
      dividend_curve: DiscountCurve,
      model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	-	-	-

## gamma

*Calculation of option gamma by perturbation of stock price and revaluation.*

```
gamma(value_dt: Date,
      stock_price: float,
      discount_curve: DiscountCurve,
      dividend_curve: DiscountCurve,
      model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	-	-	-

## vega

*Calculation of option vega by perturbing vol and revaluation.*

```
vega(value_dt: Date,
      stock_price: float,
      discount_curve: DiscountCurve,
      dividend_curve: DiscountCurve,
      model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	-	-	-

## vanna

*Calculation of option vanna by perturbing delta with respect to the stock price volatility.*

```
vanna(value_dt: Date,
      stock_price: float,
      discount_curve: DiscountCurve,
      dividend_curve: DiscountCurve,
      model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	-	-	-

## theta

*Calculation of option theta by perturbing value date by one calendar date (not a business date) and then doing revaluation and calculating the difference divided by  $dt = 1 / gDaysInYear$ .*

```
theta(value_dt: Date,
      stock_price: float,
      discount_curve: DiscountCurve,
      dividend_curve: DiscountCurve,
      model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	-	-	-

## rho

*Calculation of option rho by perturbing interest rate and revaluation.*

```
rho(value_dt: Date,
     stock_price: float,
     discount_curve: DiscountCurve,
     dividend_curve: DiscountCurve,
     model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	-	-	-

## 5.17 equity\_rainbow\_option

### **Enumerated Type: EquityRainbowOptionTypes**

This enumerated type has the following values:

- CALL\_ON\_MAXIMUM
- PUT\_ON\_MAXIMUM
- CALL\_ON\_MINIMUM
- PUT\_ON\_MINIMUM
- CALL\_ON\_NTH
- PUT\_ON\_NTH

### **Class: EquityRainbowOption(EquityOption)**

class EquityRainbowOption(EquityOption):

### **EquityRainbowOption**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
EquityRainbowOption(expiry_dt: Date,
                    payoff_type: EquityRainbowOptionTypes,
                    payoff_params: List[float],
                    num_assets: int):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
expiry_dt	Date	-	-
payoff_type	EquityRainbowOptionTypes	-	-
payoff_params	List[float]	-	-
num_assets	int	-	-

### **\_validate**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_validate(stock_prices,
          dividend_curves,
          volatilities,
          betas):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
stock_prices	-	-	-
dividend_curves	-	-	-
volatilities	-	-	-
betas	-	-	-

**\_validate\_payoff***PLEASE ADD A FUNCTION DESCRIPTION*

```
_validate_payoff(payload_type, payoff_params, num_assets):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
payoff_type	-	-	-
payoff_params	-	-	-
num_assets	-	-	-

**value***PLEASE ADD A FUNCTION DESCRIPTION*

```
value(value_dt: Date,
      stock_prices: np.ndarray,
      discount_curve: DiscountCurve,
      dividend_curves: (list),
      volatilities: np.ndarray,
      corr_matrix: np.ndarray):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_prices	np.ndarray	-	-
discount_curve	DiscountCurve	-	-
dividend_curves	list or (list	-	-
volatilities	np.ndarray	-	-
corr_matrix	np.ndarray	-	-

**value\_mc***PLEASE ADD A FUNCTION DESCRIPTION*

```
value_mc(value_dt,
         stock_prices,
         discount_curve,
         dividend_curves,
         volatilities,
         corr_matrix,
         num_paths=10000,
         seed=4242):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
stock_prices	-	-	-
discount_curve	-	-	-
dividend_curves	-	-	-
volatilities	-	-	-
corr_matrix	-	-	-
num_paths	-	-	10000
seed	-	-	4242

**\_\_repr\_\_***PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**\_print***Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

**payoff\_value***PLEASE ADD A FUNCTION DESCRIPTION*

```
payoff_value(s, payoff_typeValue, payoff_params):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
payoff_typeValue	-	-	-
payoff_params	-	-	-

**value\_mc\_fast***PLEASE ADD A FUNCTION DESCRIPTION*

```
value_mc_fast(t,
              stock_prices,
              discount_curve,
```

```

dividend_curves,
volatilities,
betas,
num_assets,
payoff_type,
payoff_params,
num_paths=10000,
seed=4242):

```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t	-	-	-
stock_prices	-	-	-
discount_curve	-	-	-
dividend_curves	-	-	-
volatilities	-	-	-
betas	-	-	-
num_assets	-	-	-
payoff_type	-	-	-
payoff_params	-	-	-
num_paths	-	-	10000
seed	-	-	4242



## 5.18 equity\_swap

### **Class: EquitySwap**

Class for managing a standard Equity vs Float leg swap. This is a contract in which an equity payment leg is exchanged for a series of floating rates payments. There is no exchange of principal. The contract is entered into at zero initial cost when spreads are zero. The contract lasts from an effective date to a specified maturity date.

The equity payments are not known fully until the end of the payment period.

The floating rate is not known fully until the end of the preceding payment period. It is set in advance and paid in arrears.

The value of the contract is the NPV of the two coupon streams. Discounting is done on a supplied discount curve which is separate from the curve from which the implied index rates are extracted.

### **EquitySwap**

*Create an equity swap contract given the contract effective date, its maturity, underlying price and quantity, day count convention and return type and other details. The equity leg parameters have default values that can be overwritten if needed. The start date is contractual and is the same as the settlement date for a new swap. It is the date on which interest starts to accrue. The end of the contract is the termination date. This is not adjusted for business days. The adjusted termination date is called the maturity date. This is calculated.*

```
EquitySwap(effective_dt: Date, # Date contract starts or last Equity Reset
            term_dt_or_tenor: (Date, str), # Date contract ends
            eq_leg_type: SwapTypes,
            eq_freq_type: FrequencyTypes,
            eq_dc_type: DayCountTypes,
            strike: float, # Price at effective date
            quantity: float = 1.0, # Quantity at effective date
            eq_payment_lag: int = 0,
            eq_return_type: ReturnTypes = ReturnTypes.TOTAL_RETURN,
            rate_freq_type: FrequencyTypes = FrequencyTypes.MONTHLY,
            rate_dc_type: DayCountTypes = DayCountTypes.ACT_360,
            rate_spread: float = 0.0,
            rate_payment_lag: int = 0,
            cal_type: CalendarTypes = CalendarTypes.WEEKEND,
            bd_type: BusDayAdjustTypes = BusDayAdjustTypes.FOLLOWING,
            dg_type: DateGenRuleTypes = DateGenRuleTypes.BACKWARD,
            end_of_month: bool = False):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
effective_dt	Date	Date contract starts or last Equity Reset	-
term_dt_or_tenor	Date or str	Date contract ends	-
eq_leg_type	SwapTypes	-	-
eq_freq_type	FrequencyTypes	-	-
eq_dc_type	DayCountTypes	-	-
strike	float	Price at effective date	-
quantity	float	Quantity at effective date	1.0
eq_payment_lag	int	-	0
eq_return_type	ReturnTypes	-	ReturnTypes.TOTAL_RETURN
rate_freq_type	FrequencyTypes	-	FrequencyTypes.MONTHLY
rate_dc_type	DayCountTypes	-	DayCountTypes.ACT_360
rate_spread	float	-	0.0
rate_payment_lag	int	-	0
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.FOLLOWING
dg_type	DateGenRuleTypes	-	DateGenRuleTypes.BACKWARD
end_of_month	bool	-	False

## value

*Value the Equity swap on a valuation date.*

```
value(value_dt: Date,
      discount_curve: DiscountCurve,
      index_curve: DiscountCurve = None,
      dividend_curve: DiscountCurve = None,
      current_price: float = None,
      firstFixingRate=None):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
discount_curve	DiscountCurve	-	-
index_curve	DiscountCurve	-	None
dividend_curve	DiscountCurve	-	None
current_price	float	-	None
firstFixingRate	-	-	None

## \_fill\_rate\_notional\_array

*In an equity swap, at every equity reset, the notional of the contract is updated to reflect the new underlying price. This is a helper function that takes the Equity Notional list from Equity Leg and convert it to a Notional array that fits the payment schedule defined for the rate leg.*

```
_fill_rate_notional_array():
```

The function arguments are described in the following table.

**`__repr__`**

*PLEASE ADD A FUNCTION DESCRIPTION*

<code>__repr__()</code> :
---------------------------

The function arguments are described in the following table.

## 5.19 equity\_swap\_leg

### **Class: EquitySwapLeg**

Class for managing the equity leg of an equity swap. An equity leg is a leg with a sequence of flows calculated according to an ISDA schedule and follows the economics of a collection of equity forward contracts.

### EquitySwapLeg

*Create the equity leg of a swap contract giving the contract start date, its maturity, underlying strike price and quantity, payment frequency, day count convention, return type, and other details*

```
EquitySwapLeg(effective_dt: Date, # Contract starts or last equity reset
               term_dt_or_tenor: (Date, str), # Date contract ends
               leg_type: SwapTypes,
               freq_type: FrequencyTypes,
               dc_type: DayCountTypes,
               strike: float, # Price at effective date
               quantity: float = 1.0, # Quantity at effective date
               payment_lag: int = 0,
               return_type: ReturnTypes = ReturnTypes.TOTAL_RETURN,
               cal_type: CalendarTypes = CalendarTypes.WEEKEND,
               bd_type: BusDayAdjustTypes = BusDayAdjustTypes.FOLLOWING,
               dg_type: DateGenRuleTypes = DateGenRuleTypes.BACKWARD,
               end_of_month: bool = False):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
effective_dt	Date	Contract starts or last equity reset	-
term_dt_or_tenor	Date or str	Date contract ends	-
leg_type	SwapTypes	-	-
freq_type	FrequencyTypes	-	-
dc_type	DayCountTypes	-	-
strike	float	Price at effective date	-
quantity	float	Quantity at effective date	1.0
payment_lag	int	-	0
return_type	ReturnTypes	-	ReturnTypes.TOTAL_RETURN
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.FOLLOWING
dg_type	DateGenRuleTypes	-	DateGenRuleTypes.BACKWARD
end_of_month	bool	-	False

### generate\_payment\_dts

*Generate the Equity leg payment dates and accrual factors. Similar to swap float leg, payment values can't be generated, as we do not have index curve, dividend curve and equity price.*

```
generate_payment_dts():
```

The function arguments are described in the following table.

## value

*Value the equity leg with payments from an equity price, quantity, an index curve and an [optional] dividend curve. Discounting is based on a supplied discount curve as of the valuation date supplied.*

```
value(value_dt: Date,
      discount_curve: DiscountCurve,
      index_curve: DiscountCurve,
      dividend_curve: DiscountCurve = None,
      current_price: float = None):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
discount_curve	DiscountCurve	-	-
index_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	None
current_price	float	-	None

## print\_pmnts

*Prints the payment dates, accrual factors, discount factors, cash amounts, their present value and their cumulative PV using the last valuation performed.*

```
print_pmnts():
```

The function arguments are described in the following table.

## print\_valuation

*Prints the valuation dates, accrual factors, discount factors, cash amounts, their present value and their cumulative PV using the last valuation performed.*

```
print_valuation():
```

The function arguments are described in the following table.

## \_\_repr\_\_

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

## 5.20 equity\_vanilla\_option

### **Class: *EquityVanillaOption()***

Class for managing plain vanilla European calls and puts on equities. For American calls and puts see the `EquityAmericanOption` class.

### **EquityVanillaOption**

*Create the Equity Vanilla option object by specifying the expiry date, the option strike, the option type and the number of options.*

```
EquityVanillaOption(expiry_dt: (Date, list),
                    strike_price: (float, np.ndarray),
                    option_type: (OptionTypes, list),
                    num_options: float = 1.0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
expiry_dt	Date or list	-	-
strike_price	float or np.ndarray	-	-
option_type	OptionTypes or list	-	-
num_options	float	-	1.0

### **intrinsic**

*Equity Vanilla Option valuation using Black-Scholes model.*

```
intrinsic(value_dt: (Date, list),
          stock_price: (np.ndarray, float),
          discount_curve: DiscountCurve,
          dividend_curve: DiscountCurve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date or list	-	-
stock_price	np.ndarray or float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-

### **value**

*Equity Vanilla Option valuation using Black-Scholes model.*

```
value(value_dt: (Date, list),
      stock_price: (np.ndarray, float),
      discount_curve: DiscountCurve,
```

```
dividend_curve: DiscountCurve,
model: Model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date or list	-	-
stock_price	np.ndarray or float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	Model	-	-

## delta

*Calculate the analytical delta of a European vanilla option.*

```
delta(value_dt: Date,
       stock_price: float,
       discount_curve: DiscountCurve,
       dividend_curve: DiscountCurve,
       model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	-	-	-

## gamma

*Calculate the analytical gamma of a European vanilla option.*

```
gamma(value_dt: Date,
       stock_price: float,
       discount_curve: DiscountCurve,
       dividend_curve: DiscountCurve,
       model: Model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	Model	-	-



## vega

*Calculate the analytical vega of a European vanilla option.*

```
vega(value_dt: Date,
      stock_price: float,
      discount_curve: DiscountCurve,
      dividend_curve: DiscountCurve,
      model: Model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	Model	-	-

## theta

*Calculate the analytical theta of a European vanilla option.*

```
theta(value_dt: Date,
       stock_price: float,
       discount_curve: DiscountCurve,
       dividend_curve: DiscountCurve,
       model: Model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	Model	-	-

## rho

*Calculate the analytical rho of a European vanilla option.*

```
rho(value_dt: Date,
     stock_price: float,
     discount_curve: DiscountCurve,
     dividend_curve: DiscountCurve,
     model: Model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	Model	-	-

## vanna

*Calculate the analytical vanna of a European vanilla option.*

```
vanna(value_dt: Date,
      stock_price: float,
      discount_curve: DiscountCurve,
      dividend_curve: DiscountCurve,
      model: Model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	Model	-	-

## implied\_volatility

*Calculate the Black-Scholes implied volatility of a European vanilla option.*

```
implied_volatility(value_dt: Date,
                  stock_price: (float, list, np.ndarray),
                  discount_curve: DiscountCurve,
                  dividend_curve: DiscountCurve,
                  price):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float or list,np.ndarray	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
price	-	-	-

## value\_mc\_numpy\_only

*PLEASE ADD A FUNCTION DESCRIPTION*

```

value_mc_numpy_only(value_dt: Date,
                    stock_price: float,
                    discount_curve: DiscountCurve,
                    dividend_curve: DiscountCurve,
                    model: Model,
                    num_paths: int = 10000,
                    seed: int = 4242,
                    use_sobol: int = 0):

```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	Model	-	-
num_paths	int	-	10000
seed	int	-	4242
use_sobol	int	-	0

### value\_mc\_numba\_only

*PLEASE ADD A FUNCTION DESCRIPTION*

```

value_mc_numba_only(value_dt: Date,
                    stock_price: float,
                    discount_curve: DiscountCurve,
                    dividend_curve: DiscountCurve,
                    model: Model,
                    num_paths: int = 10000,
                    seed: int = 4242,
                    use_sobol: int = 0):

```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	Model	-	-
num_paths	int	-	10000
seed	int	-	4242
use_sobol	int	-	0

### value\_mc\_numba\_parallel

*PLEASE ADD A FUNCTION DESCRIPTION*

```
value_mc_numba_parallel(value_dt: Date,
                        stock_price: float,
                        discount_curve: DiscountCurve,
                        dividend_curve: DiscountCurve,
                        model: Model,
                        num_paths: int = 10000,
                        seed: int = 4242,
                        use_sobol: int = 0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	Model	-	-
num_paths	int	-	10000
seed	int	-	4242
use_sobol	int	-	0

## value\_mc\_numpy\_numba

*PLEASE ADD A FUNCTION DESCRIPTION*

```
value_mc_numpy_numba(value_dt: Date,
                     stock_price: float,
                     discount_curve: DiscountCurve,
                     dividend_curve: DiscountCurve,
                     model: Model,
                     num_paths: int = 10000,
                     seed: int = 4242,
                     use_sobol: int = 0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	Model	-	-
num_paths	int	-	10000
seed	int	-	4242
use_sobol	int	-	0

## value\_mc\_nonumba\_nonumpy

*PLEASE ADD A FUNCTION DESCRIPTION*

```
value_mc_nonumba_numpy(value_dt: Date,
                        stock_price: float,
                        discount_curve: DiscountCurve,
                        dividend_curve: DiscountCurve,
                        model: Model,
                        num_paths: int = 10000,
                        seed: int = 4242,
                        use_sobol: int = 0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	Model	-	-
num_paths	int	-	10000
seed	int	-	4242
use_sobol	int	-	0

## value\_mc

*Value European style call or put option using Monte Carlo. This is mainly for educational purposes. Sobol numbers can be used.*

```
value_mc(value_dt: Date,
         stock_price: float,
         discount_curve: DiscountCurve,
         dividend_curve: DiscountCurve,
         model: Model,
         num_paths: int = 10000,
         seed: int = 4242,
         use_sobol: int = 0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
discount_curve	DiscountCurve	-	-
dividend_curve	DiscountCurve	-	-
model	Model	-	-
num_paths	int	-	10000
seed	int	-	4242
use_sobol	int	-	0

**`--repr--`***PLEASE ADD A FUNCTION DESCRIPTION*`--repr__():`

The function arguments are described in the following table.

**`_print`***Simple print function for backward compatibility.*`_print():`

The function arguments are described in the following table.

**`f`***PLEASE ADD A FUNCTION DESCRIPTION*`_f(v, args):`

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
v	-	-	-
args	-	-	-

**`fvega`***PLEASE ADD A FUNCTION DESCRIPTION*`_fvega(v, *args):`

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
v	-	-	-
*args	-	-	-

## 5.21 equity\_variance\_swap

**Class:** *EquityVarianceSwap*

### EquityVarianceSwap

*Create variance swap contract.*

```
EquityVarianceSwap(start_dt: Date,
                    maturity_dt_or_tenor: (Date, str),
                    strike_variance: float,
                    notional: float = ONE_MILLION,
                    pay_strike_flag: bool = True):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
start_dt	Date	-	-
maturity_dt_or_tenor	Date or str	-	-
strike_variance	float	-	-
notional	float	-	ONE_MILLION
pay_strike_flag	bool	-	True

### value

*Calculate the value of the variance swap based on the realised volatility to the valuation date, the forward looking implied volatility to the maturity date using the libor discount curve.*

```
value(value_dt,
      realisedVar,
      fair_strikeVar,
      libor_curve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
realisedVar	-	-	-
fair_strikeVar	-	-	-
libor_curve	-	-	-

### fair\_strike\_approx

*This is an approximation of the fair strike variance by Demeterfi et al. (1999) which assumes that  $\sigma(K) = \sigma(F) - b(K-F)/F$  where  $F$  is the forward stock price and  $\sigma(F)$  is the ATM forward vol.*

```
fair_strike_approx(value_dt,
                   fwdStockPrice,
                   strikes,
                   volatilities):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
fwdStockPrice	-	-	-
strikes	-	-	-
volatilities	-	-	-

## fair\_strike

*Calculate the implied variance according to the volatility surface using a static replication methodology with a specially weighted portfolio of put and call options across a range of strikes using the approximate method set out by Demeterfi et al. 1999.*

```
fair_strike(value_dt,
            stock_price,
            dividend_curve,
            volatility_curve,
            num_call_options,
            num_put_options,
            strike_spacing,
            discount_curve,
            use_forward=True):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
stock_price	-	-	-
dividend_curve	-	-	-
volatility_curve	-	-	-
num_call_options	-	-	-
num_put_options	-	-	-
strike_spacing	-	-	-
discount_curve	-	-	-
use_forward	-	-	True

## f

*PLEASE ADD A FUNCTION DESCRIPTION*

```
f(x): return (2.0/t_mat)*((x-sstar)/sstar-np.log(x/sstar))
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x return (2.0/t_mat)*((x-sstar)/sstar-np.log(x/sstar))	-	-	-



## realised\_variance

*Calculate the realised variance according to market standard calculations which can either use log or percentage returns.*

```
realised_variance(closePrices, useLogs=True):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
closePrices	-	-	-
useLogs	-	-	True

## print\_weights

*Print the list of puts and calls used to replicate the static replication component of the variance swap hedge.*

```
print_weights():
```

The function arguments are described in the following table.

## \_\_repr\_\_

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

## \_print

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

## 5.22 `__init__`



## Chapter 6

# financepy.products.credit

This folder contains a set of credit-related assets ranging from CDS to CDS options, to CDS indices, CDS index options and then to CDS tranches. They are as follows:

- CDS is a credit default swap contract. It includes schedule generation, contract valuation and risk-management functionality.
- CDSBasket is a credit default basket such as a first-to-default basket. The class includes valuation according to the Gaussian copula.
- CDSCurve is a discount curve and survival curve constructed from discount rates and CDS spreads.
- CDSIndexOption is an option on an index of CDS such as CDX or iTraxx. A full valuation model is included.
- CDSIndexPortfolio is a portfolio of CDS contracts.
- CDSOption is an option on a single CDS. The strike is expressed in spread terms and the option is European style. It is different from an option on a CDS index option. A suitable pricing model is provided which adjusts for the risk that the reference credit defaults before the option expiry date.
- CDSTranche is a synthetic CDO tranche. This is a financial derivative which takes a loss if the total loss on the portfolio exceeds a lower threshold K1 and which is wiped out if it exceeds a higher threshold K2. The value depends on the default correlation between the assets in the portfolio of credits. This also includes a valuation model based on the Gaussian copula model.

### ***FinCDSCurve***

This is a curve that has been calibrated to fit the market term structure of CDS contracts given a recovery rate assumption and a IborSingleCurve discount curve. It also contains a IborCurve object for discounting. It has methods for fitting the curve and also for extracting survival probabilities.

## 6.1 cds

### ***Class: CDS***

A class which manages a Credit Default Swap. It performs schedule generation and the valuation and risk management of CDS.

### **CDS**

*Create a CDS from the step-in date, maturity date and cpn*

```
CDS(step_in_dt: Date, # Date protection starts
    maturity_dt_or_tenor: (Date, str), # Date or tenor
    running_cpn: float, # Annualised cpn on premium fee leg
    notional: float = ONE_MILLION,
    long_protection: bool = True,
    freq_type: FrequencyTypes = FrequencyTypes.QUARTERLY,
    dc_type: DayCountTypes = DayCountTypes.ACT_360,
    cal_type: CalendarTypes = CalendarTypes.WEEKEND,
    bd_type: BusDayAdjustTypes = BusDayAdjustTypes.FOLLOWING,
    dg_type: DateGenRuleTypes = DateGenRuleTypes.BACKWARD):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
step_in_dt	Date	Date protection starts	-
maturity_dt_or_tenor	Date or str	Date or tenor	-
running_cpn	float	Annualised cpn on premium fee leg	-
notional	float	-	ONE_MILLION
long_protection	bool	-	True
freq_type	FrequencyTypes	-	FrequencyTypes.QUARTERLY
dc_type	DayCountTypes	-	DayCountTypes.ACT_360
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.FOLLOWING
dg_type	DateGenRuleTypes	-	DateGenRuleTypes.BACKWARD

### ***\_generate\_adjusted\_cds\_payment\_dts***

*Generate CDS payment dates which have been holiday adjusted.*

```
_generate_adjusted_cds_payment_dts():
```

The function arguments are described in the following table.

### ***\_calc\_flows***

*Calculate cash flow amounts on premium leg.*

```
_calc_flows() :
```

The function arguments are described in the following table.

## value

*Valuation of a CDS contract on a specific valuation date given an issuer curve and a contract recovery rate.*

```
value(value_dt,
      issuer_curve,
      contract_recovery_rate,
      pv01_method=0,
      prot_method=0,
      num_steps_per_year=glob_num_steps_per_year) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
issuer_curve	-	-	-
contract_recovery_rate	-	-	-
pv01_method	-	-	0
prot_method	-	-	0
num_steps_per_year	-	-	glob_num_steps_per_year

## credit\_dv01

*Calculation of the change in the value of the CDS contract for a one basis point change in the level of the CDS curve.*

```
credit_dv01(value_dt,
            issuer_curve,
            contract_recovery_rate,
            pv01_method=0,
            prot_method=0,
            num_steps_per_year=glob_num_steps_per_year) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
issuer_curve	-	-	-
contract_recovery_rate	-	-	-
pv01_method	-	-	0
prot_method	-	-	0
num_steps_per_year	-	-	glob_num_steps_per_year

## interest\_dv01

*Calculation of the interest DV01 based on a simple bump of the discount factors and reconstruction of the CDS curve.*

```
interest_dv01(value_dt: Date,
              issuer_curve,
              contract_recovery_rate,
              pv01_method: int = 0,
              prot_method: int = 0,
              num_steps_per_year=glob_num_steps_per_year):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
issuer_curve	-	-	-
contract_recovery_rate	-	-	-
pv01_method	int	-	0
prot_method	int	-	0
num_steps_per_year	-	-	glob_num_steps_per_year

## cash\_settlement\_amount

*Value of the contract on the settlement date including accrued interest.*

```
cash_settlement_amount(value_dt,
                       settle_dt,
                       issuer_curve,
                       contract_recovery_rate,
                       pv01_method=0,
                       prot_method=0,
                       num_steps_per_year=glob_num_steps_per_year):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
settle_dt	-	-	-
issuer_curve	-	-	-
contract_recovery_rate	-	-	-
pv01_method	-	-	0
prot_method	-	-	0
num_steps_per_year	-	-	glob_num_steps_per_year

## clean\_price

*Value of the CDS contract excluding accrued interest.*

```
clean_price(value_dt,
            issuer_curve,
            contract_recovery_rate,
            pv01_method=0,
            prot_method=0,
            num_steps_per_year=glob_num_steps_per_year):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
issuer_curve	-	-	-
contract_recovery_rate	-	-	-
pv01_method	-	-	0
prot_method	-	-	0
num_steps_per_year	-	-	glob_num_steps_per_year

## accrued\_days

*Number of days between the previous coupon and the current step in date.*

```
accrued_days():
```

The function arguments are described in the following table.

## accrued\_interest

*Calculate the amount of accrued interest that has accrued from the previous cpn date (PCD) to the step\_in\_dt of the CDS contract.*

```
accrued_interest():
```

The function arguments are described in the following table.

## protection\_leg\_pv

*Calculates the protection leg PV of the CDS by calling into the fast NUMBA code that has been defined above.*

```
protection_leg_pv(value_dt,
                  issuer_curve,
                  contract_recovery_rate=standard_recovery_rate,
                  num_steps_per_year=glob_num_steps_per_year,
                  protMethod=0):
```

The function arguments are described in the following table.



Argument Name	Type	Description	Default Value
value_dt	-	-	-
issuer_curve	-	-	-
contract_recovery_rate	-	-	standard_recovery_rate
num_steps_per_year	-	-	glob_num_steps_per_year
protMethod	-	-	0

## risky\_pv01

*The risky\_pv01 is the present value of a risky one dollar paid on the premium leg of a CDS contract.*

```
risky_pv01(value_dt,
            issuer_curve,
            pv01_method=0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
issuer_curve	-	-	-
pv01_method	-	-	0

## premium\_leg\_pv

*Value of the premium leg of a CDS.*

```
premium_leg_pv(value_dt,
                issuer_curve,
                pv01_method=0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
issuer_curve	-	-	-
pv01_method	-	-	0

## par\_spread

*Breakeven CDS cpn that would make the value of the CDS contract equal to zero.*

```
par_spread(value_dt,
            issuer_curve,
            contract_recovery_rate=standard_recovery_rate,
            num_steps_per_year=glob_num_steps_per_year,
            pv01_method=0,
            protMethod=0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
issuer_curve	-	-	-
contract_recovery_rate	-	-	standard_recovery_rate
num_steps_per_year	-	-	glob_num_steps_per_year
pv01_method	-	-	0
protMethod	-	-	0

## value\_fast\_approx

*Implementation of fast valuation of the CDS contract using an accurate approximation that avoids curve building.*

```
value_fast_approx(value_dt,
                  flat_cont_interest_rate,
                  flat_cds_curve_spread,
                  curve_recovery=standard_recovery_rate,
                  contract_recovery_rate=standard_recovery_rate):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
flat_cont_interest_rate	-	-	-
flat_cds_curve_spread	-	-	-
curve_recovery	-	-	standard_recovery_rate
contract_recovery_rate	-	-	standard_recovery_rate

## print\_payments

*We only print payments after the current valuation date*

```
print_payments(value_dt, issuer_curve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
issuer_curve	-	-	-

## \_\_repr\_\_

*print out details of the CDS contract and all the calculated cash flows*

```
__repr__():
```

The function arguments are described in the following table.

### **`_print`**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

### **`_risky_pv01_numba`**

*Fast calculation of the risky PV01 of a CDS using NUMBA. The output is a numpy array of the full and clean risky PV01.*

```
_risky_pv01_numba(teff,
                  accrual_factorPCDToNow,
                  paymentTimes,
                  year_frac,
                  npIborTimes,
                  npIborValues,
                  npSurvTimes,
                  npSurvValues,
                  pv01_method):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
teff	-	-	-
accrual_factorPCDToNow	-	-	-
paymentTimes	-	-	-
year_frac	-	-	-
npIborTimes	-	-	-
npIborValues	-	-	-
npSurvTimes	-	-	-
npSurvValues	-	-	-
pv01_method	-	-	-

### **`_protection_leg_pv_numba`**

*Fast calculation of the CDS protection leg PV using NUMBA to speed up the numerical integration over time.*

```
_protection_leg_pv_numba(teff,
                          t_mat,
                          npIborTimes,
                          npIborValues,
                          npSurvTimes,
```

```
npSurvValues,
contract_recovery_rate,
num_steps_per_year,
protMethod) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
teff	-	-	-
t_mat	-	-	-
npIborTimes	-	-	-
npIborValues	-	-	-
npSurvTimes	-	-	-
npSurvValues	-	-	-
contract_recovery_rate	-	-	-
num_steps_per_year	-	-	-
protMethod	-	-	-

## 6.2 cds\_basket

### ***Class: CDSBasket***

### **CDSBasket**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
CDSBasket(step_in_dt: Date,
          maturity_dt: Date,
          notional: float = ONE_MILLION,
          running_cpn: float = 0.0,
          long_protection: bool = True,
          freq_type: FrequencyTypes = FrequencyTypes.QUARTERLY,
          dc_type: DayCountTypes = DayCountTypes.ACT_360,
          cal_type: CalendarTypes = CalendarTypes.WEEKEND,
          bd_type: BusDayAdjustTypes = BusDayAdjustTypes.FOLLOWING,
          dg_type: DateGenRuleTypes = DateGenRuleTypes.BACKWARD):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
step_in_dt	Date	-	-
maturity_dt	Date	-	-
notional	float	-	ONE_MILLION
running_cpn	float	-	0.0
long_protection	bool	-	True
freq_type	FrequencyTypes	-	FrequencyTypes.QUARTERLY
dc_type	DayCountTypes	-	DayCountTypes.ACT_360
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.FOLLOWING
dg_type	DateGenRuleTypes	-	DateGenRuleTypes.BACKWARD

### **value\_legs\_mc**

*Value the legs of the default basket using Monte Carlo. The default times are an input so this valuation is not model dependent.*

```
value_legs_mc(value_dt,
              n_to_default,
              default_times,
              issuer_curves,
              libor_curve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
n_to_default	-	-	-
default_times	-	-	-
issuer_curves	-	-	-
libor_curve	-	-	-

### value\_gaussian\_mc

*Value the default basket using a Gaussian copula model. This depends on the issuer discount and correlation matrix.*

```
value_gaussian_mc(value_dt,
                  n_to_default,
                  issuer_curves,
                  correlation_matrix,
                  libor_curve,
                  num_trials,
                  seed):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
n_to_default	-	-	-
issuer_curves	-	-	-
correlation_matrix	-	-	-
libor_curve	-	-	-
num_trials	-	-	-
seed	-	-	-

### value\_student\_t\_mc

*Value the default basket using the Student-T copula.*

```
value_student_t_mc(value_dt,
                  n_to_default,
                  issuer_curves,
                  correlation_matrix,
                  degrees_of_freedom,
                  libor_curve,
                  num_trials,
                  seed):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
n_to_default	-	-	-
issuer_curves	-	-	-
correlation_matrix	-	-	-
degrees_of_freedom	-	-	-
libor_curve	-	-	-
num_trials	-	-	-
seed	-	-	-

### value\_1f\_gaussian\_homo

Value default basket using 1 factor Gaussian copula and analytical approach which is only exact when all recovery rates are the same.

```
value_1f_gaussian_homo(value_dt,
                        n_to_default,
                        issuer_curves,
                        beta_vector,
                        libor_curve,
                        num_points=50):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
n_to_default	-	-	-
issuer_curves	-	-	-
beta_vector	-	-	-
libor_curve	-	-	-
num_points	-	-	50

### --repr--

print out details of the CDS contract and all of the calculated cash flows

```
__repr__():
```

The function arguments are described in the following table.

## 6.3 cds\_curve

### ***Class: CDSCurve***

Generate a survival probability curve implied by the value of CDS contracts given a Ibor curve and an assumed recovery rate. The recovery rate corresponds to the seniority of the debt for these CDS. A scheme for the interpolation of the survival probabilities is also required.

### **CDSCurve**

*Construct a credit curve from a sequence of maturity-ordered CDS contracts and a Ibor curve using the same recovery rate and the same interpolation method.*

```
CDSCurve(value_dt: Date,
         cds_contracts: list,
         libor_curve,
         recovery_rate,
         use_cache: bool = False,
         interp_method: InterpTypes = InterpTypes.FLAT_FWD_RATES):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
cds_contracts	list	-	-
libor_curve	-	-	-
recovery_rate	-	-	-
use_cache	bool	-	False
interp_method	InterpTypes	-	InterpTypes.FLAT_FWD_RATES

### **\_validate**

*Ensure that contracts are in increasing maturity.*

```
_validate(cds_contracts):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
cds_contracts	-	-	-

### **survival\_prob**

*Extract the survival probability to date dt. This function supports vectorisation.*

```
survival_prob(dt):
```

The function arguments are described in the following table.



Argument Name	Type	Description	Default Value
dt	-	-	-

## df

*Extract the discount factor from the underlying Ibor curve. This function supports vectorisation.*

```
df(dt) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	-	-	-

## \_build\_curve

*Construct the CDS survival curve from a set of CDS contracts*

```
_build_curve() :
```

The function arguments are described in the following table.

## fwd

*Calculate the instantaneous forward rate at the forward date dt using the numerical derivative.*

```
fwd(dt) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	-	-	-

## fwd\_rate

*Calculate the forward rate according between dates date1 and date2 according to the specified day count convention.*

```
fwd_rate(date1, date2, day_count_type) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
date1	-	-	-
date2	-	-	-
day_count_type	-	-	-

**zero\_rate**

*Calculate the zero rate to date dt in the chosen compounding frequency where -1 is continuous is the default.*

```
zero_rate(dt,
          freq_type=FrequencyTypes.CONTINUOUS) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	-	-	-
freq_type	-	-	FrequencyTypes.CONTINUOUS

**\_\_repr\_\_**

*Print out the details of the survival probability curve.*

```
__repr__() :
```

The function arguments are described in the following table.

**\_print**

*Simple print function for backward compatibility.*

```
_print() :
```

The function arguments are described in the following table.

**f**

*Function that returns zero when the survival probability that gives a zero value of the CDS has been determined.*

```
f(q, *args) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
q	-	-	-
*args	-	-	-

## 6.4 cds\_index\_option

### **Class: CDSIndexOption**

Class to manage the pricing and risk management of an option to enter into a CDS index. Different pricing algorithms are presented.

### **CDSIndexOption**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
CDSIndexOption(expiry_dt: Date,
                maturity_dt: Date,
                index_coupon: float,
                strike_coupon: float,
                notional: float = ONE_MILLION,
                long_protection: bool = True,
                freq_type: FrequencyTypes = FrequencyTypes.QUARTERLY,
                dc_type: DayCountTypes = DayCountTypes.ACT_360,
                cal_type: CalendarTypes = CalendarTypes.WEEKEND,
                bd_type: BusDayAdjustTypes = BusDayAdjustTypes.FOLLOWING,
                dg_type: DateGenRuleTypes = DateGenRuleTypes.BACKWARD):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
expiry_dt	Date	-	-
maturity_dt	Date	-	-
index_coupon	float	-	-
strike_coupon	float	-	-
notional	float	-	ONE_MILLION
long_protection	bool	-	True
freq_type	FrequencyTypes	-	FrequencyTypes.QUARTERLY
dc_type	DayCountTypes	-	DayCountTypes.ACT_360
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.FOLLOWING
dg_type	DateGenRuleTypes	-	DateGenRuleTypes.BACKWARD

### **value\_adjusted\_black**

*This approach uses two adjustments to Black's option pricing model to value an option on a CDS index.*

```
value_adjusted_black(value_dt,
                    index_curve,
                    index_recovery,
                    libor_curve,
                    sigma):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
index_curve	-	-	-
index_recovery	-	-	-
libor_curve	-	-	-
sigma	-	-	-

### value\_anderson

*This function values a CDS index option following approach by Anderson (2006). This ensures that a no-arbitrage relationship between the constituent CDS contract and the CDS index is enforced. It models the forward spread as a log-normally distributed quantity and uses the credit triangle to compute the forward RPV01.*

```
value_anderson(value_dt,
               issuer_curves,
               index_recovery,
               sigma):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
issuer_curves	-	-	-
index_recovery	-	-	-
sigma	-	-	-

### \_solve\_for\_x

*Function to solve for the arbitrage free*

```
_solve_for_x(value_dt,
             sigma,
             index_coupon,
             index_recovery,
             libor_curve,
             expH):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
sigma	-	-	-
index_coupon	-	-	-
index_recovery	-	-	-
libor_curve	-	-	-
expH	-	-	-

**`_calc_obj_func`**

*An internal function used in the Anderson valuation.*

```
_calc_obj_func(x,
               value_dt,
               sigma,
               index_coupon,
               index_recovery,
               libor_curve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	-	-	-
value_dt	-	-	-
sigma	-	-	-
index_coupon	-	-	-
index_recovery	-	-	-
libor_curve	-	-	-

**`_calc_index_payer_option_price`**

*Calculates the intrinsic value of the index payer swap and the value of the index payer option which are both returned in an array.*

```
_calc_index_payer_option_price(value_dt,
                               x,
                               sigma,
                               index_coupon,
                               strike_value,
                               libor_curve,
                               index_recovery):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
x	-	-	-
sigma	-	-	-
index_coupon	-	-	-
strike_value	-	-	-
libor_curve	-	-	-
index_recovery	-	-	-

**`__repr__`**

*print out details of the CDS contract and all of the calculated cash flows*

```
__repr__():
```

The function arguments are described in the following table.

### **`_print`**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

## 6.5 cds\_index\_portfolio

### **Class: CDSIndexPortfolio**

This class manages the calculations associated with an equally weighted portfolio of CDS contracts with the same maturity date.

### **CDSIndexPortfolio**

Create *Fin*cds\_indexPortfolio object. Note that all of the inputs have a default value which reflects the CDS market standard.

```
CDSIndexPortfolio(freq_type: FrequencyTypes = FrequencyTypes.QUARTERLY,
                  day_count_type: DayCountTypes = DayCountTypes.ACT_360,
                  cal_type: CalendarTypes = CalendarTypes.WEEKEND,
                  bd_type: BusDayAdjustTypes = BusDayAdjustTypes.FOLLOWING,
                  dg_type: DateGenRuleTypes = DateGenRuleTypes.BACKWARD):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
freq_type	FrequencyTypes	-	FrequencyTypes.QUARTERLY
day_count_type	DayCountTypes	-	DayCountTypes.ACT_360
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.FOLLOWING
dg_type	DateGenRuleTypes	-	DateGenRuleTypes.BACKWARD

### **intrinsic\_rpv01**

Calculation of the risky PV01 of the CDS portfolio by taking the average of the risky PV01s of each contract.

```
intrinsic_rpv01(value_dt,
                step_in_dt,
                maturity_dt,
                issuer_curves):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
step_in_dt	-	-	-
maturity_dt	-	-	-
issuer_curves	-	-	-

### **intrinsic\_protection\_leg\_pv**

Calculation of intrinsic protection leg value of the CDS portfolio by taking the average sum the protection legs of each contract.

```
intrinsic_protection_leg_pv(value_dt,
                             step_in_dt,
                             maturity_dt,
                             issuer_curves):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
step_in_dt	-	-	-
maturity_dt	-	-	-
issuer_curves	-	-	-

## intrinsic\_spread

*Calculation of the intrinsic spread of the CDS portfolio as the one which would make the value of the protection legs equal to the value of the premium legs if all premium legs paid the same spread.*

```
intrinsic_spread(value_dt,
                  step_in_dt,
                  maturity_dt,
                  issuer_curves):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
step_in_dt	-	-	-
maturity_dt	-	-	-
issuer_curves	-	-	-

## average\_spread

*Calculates the average par CDS spread of the CDS portfolio.*

```
average_spread(value_dt,
                step_in_dt,
                maturity_dt,
                issuer_curves):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
step_in_dt	-	-	-
maturity_dt	-	-	-
issuer_curves	-	-	-



## total\_spread

*Calculates the total CDS spread of the CDS portfolio by summing over all of the issuers and adding the spread with no weights.*

```
total_spread(value_dt,
             step_in_dt,
             maturity_dt,
             issuer_curves):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
step_in_dt	-	-	-
maturity_dt	-	-	-
issuer_curves	-	-	-

## min\_spread

*Calculates the minimum par CDS spread across all of the issuers in the CDS portfolio.*

```
min_spread(value_dt,
           step_in_dt,
           maturity_dt,
           issuer_curves):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
step_in_dt	-	-	-
maturity_dt	-	-	-
issuer_curves	-	-	-

## max\_spread

*Calculates the maximum par CDS spread across all of the issuers in the CDS portfolio.*

```
max_spread(value_dt,
           step_in_dt,
           maturity_dt,
           issuer_curves):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
step_in_dt	-	-	-
maturity_dt	-	-	-
issuer_curves	-	-	-

### spread\_adjust\_intrinsic

*Adjust individual CDS discount to reprice CDS index prices. This approach uses an iterative scheme but is slow as it has to use a CDS curve bootstrap required when each trial spread adjustment is made*

```
spread_adjust_intrinsic(value_dt,
                        issuer_curves,
                        index_cpns,
                        index_upfronts,
                        index_maturity_dts,
                        index_recovery_rate,
                        tolerance=1e-6):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
issuer_curves	-	-	-
index_cpns	-	-	-
index_upfronts	-	-	-
index_maturity_dts	-	-	-
index_recovery_rate	-	-	-
tolerance	-	-	1e-6

### hazard\_rate\_adjust\_intrinsic

*Adjust individual CDS discount to reprice CDS index prices. This approach adjusts the hazard rates and so avoids the slowish CDS curve bootstrap required when a spread adjustment is made.*

```
hazard_rate_adjust_intrinsic(value_dt,
                             issuer_curves,
                             index_cpns,
                             index_upfronts,
                             index_maturity_dts,
                             index_recovery_rate,
                             tolerance=1e-6,
                             max_iterations=200):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
issuer_curves	-	-	-
index_cpns	-	-	-
index_up_fronts	-	-	-
index_maturity_dts	-	-	-
index_recovery_rate	-	-	-
tolerance	-	-	1e-6
max_iterations	-	-	200

**\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

## 6.6 cds\_option

### **Class: CDSOption**

Class to manage the pricing and risk-management of an option on a single-name CDS. This is a contract in which the option buyer pays for an option to either buy or sell protection on the underlying CDS at a fixed spread agreed today and to be exercised in the future on a specified expiry date. The option may or may not cancel if there is a credit event before option expiry. This needs to be specified.

### **CDSOption**

*Create a FinCDSOption object with the option expiry date, the maturity date of the underlying CDS, the option strike coupon, notional, whether the option knocks out or not in the event of a credit event before expiry and the payment details of the underlying CDS.*

```
CDSOption(expiry_dt: Date,
          maturity_dt: Date,
          strike_coupon: float,
          notional: float = ONE_MILLION,
          long_protection: bool = True,
          knockout_flag: bool = True,
          freq_type: FrequencyTypes = FrequencyTypes.QUARTERLY,
          dc_type: DayCountTypes = DayCountTypes.ACT_360,
          cal_type: CalendarTypes = CalendarTypes.WEEKEND,
          bd_type: BusDayAdjustTypes = BusDayAdjustTypes.FOLLOWING,
          dg_type: DateGenRuleTypes = DateGenRuleTypes.BACKWARD):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
expiry_dt	Date	-	-
maturity_dt	Date	-	-
strike_coupon	float	-	-
notional	float	-	ONE_MILLION
long_protection	bool	-	True
knockout_flag	bool	-	True
freq_type	FrequencyTypes	-	FrequencyTypes.QUARTERLY
dc_type	DayCountTypes	-	DayCountTypes.ACT_360
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.FOLLOWING
dg_type	DateGenRuleTypes	-	DateGenRuleTypes.BACKWARD

### **value**

*Value the CDS option using Black's model with an adjustment for any Front End Protection. TODO - Should the CDS be created in the init method ?*

```
value(value_dt,
      issuer_curve,
```

```
volatility):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
issuer_curve	-	-	-
volatility	-	-	-

## implied\_volatility

*Calculate the implied CDS option volatility from a price.*

```
implied_volatility(value_dt,
                   issuer_curve,
                   option_value):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
issuer_curve	-	-	-
option_value	-	-	-

## fvol

*Root searching function in the calculation of the CDS implied volatility.*

```
fvol(volatility, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
volatility	-	-	-
*args	-	-	-

## 6.7 cds\_tranche

### **Enumerated Type: *FinLossDistributionBuilder***

This enumerated type has the following values:

- RECURSION
- ADJUSTED\_BINOMIAL
- GAUSSIAN
- LHP

### **Class: *CDSTranche***

class CDSTranche:

### **CDSTranche**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
CDSTranche(step_in_dt: Date,
            maturity_dt: Date,
            k1: float,
            k2: float,
            notional: float = ONE_MILLION,
            running_cpn: float = 0.0,
            long_protection: bool = True,
            freq_type: FrequencyTypes = FrequencyTypes.QUARTERLY,
            dc_type: DayCountTypes = DayCountTypes.ACT_360,
            cal_type: CalendarTypes = CalendarTypes.WEEKEND,
            bd_type: BusDayAdjustTypes = BusDayAdjustTypes.FOLLOWING,
            dg_type: DateGenRuleTypes = DateGenRuleTypes.BACKWARD):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
step_in_dt	Date	-	-
maturity_dt	Date	-	-
k1	float	-	-
k2	float	-	-
notional	float	-	ONE_MILLION
running_cpn	float	-	0.0
long_protection	bool	-	True
freq_type	FrequencyTypes	-	FrequencyTypes.QUARTERLY
dc_type	DayCountTypes	-	DayCountTypes.ACT_360
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.FOLLOWING
dg_type	DateGenRuleTypes	-	DateGenRuleTypes.BACKWARD

**value\_bc***PLEASE ADD A FUNCTION DESCRIPTION*

```

value_bc(value_dt,
         issuer_curves,
         upfront,
         running_cpn,
         corr1,
         corr2,
         num_points=50,
         model=FinLossDistributionBuilder.RECURSION):

```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
issuer_curves	-	-	-
upfront	-	-	-
running_cpn	-	-	-
corr1	-	-	-
corr2	-	-	-
num_points	-	-	50
model	-	-	RECURSION

## 6.8 `__init__`





## Chapter 7

# financepy.products.bonds

This folder contains a suite of bond-related functionality across a set of files and classes. They are as follows:

- Bond is a basic fixed coupon bond with all of the associated duration and convexity measures. It also includes some common spread measures such as the asset swap spread and the option adjusted spread.
- BondZero is a zero coupon bond. This is a bond issued at a deep discount that matures at par. Accrued interest is calculated by interpolating the price growth.
- BondAnnuity is a stream of cash flows that is generated and can be priced.
- BondCallable is a bond that has embedded call and put options. A number of rate models pricing functions have been included to allow such bonds to be priced and risk-managed.
- BondConvertible enables the pricing and risk-management of convertible bonds. The model is a binomial tree implementation of Black-Scholes which allows for discrete dividends, embedded puts and calls, and a delayed start of the conversion option.
- BondFRN enables the pricing and risk-management of a bond with floating rate coupons. Discount margin calculations are provided.
- BondFuture is a bond future that has functionality around determination of the conversion factor and calculation of the invoice price and determination of the cheapest to deliver.
- BondMarket is a database of country-specific bond market conventions that can be referenced. These include settlement days and accrued interest conventions.
- BondMortgage generates the periodic cash flows for an interest-only and a repayment mortgage.
- BondOption is a bond option class that includes a number of valuation models for pricing both European and American style bond options. Models for European options include a Lognormal Price, Hull-White (HW) and Black-Karasinski (BK). The HW valuation is fast as it uses Jamshidian's decomposition trick. American options can also be priced using a HW and BK trinomial tree. The details are abstracted away making it easy to use.
- BondPortfolio is a portfolio of bonds.
- Yield Curve is a class to handle bond yield curves. It uses a variety of shapes to best-fit a set of bond yields.
- Zero curve is a class to perform an exact fit to a set of provided bonds using a piece-wise flat zero rate.

### **Conventions**

- All interest rates are expressed as a fraction of 1. So 3
- All notionals of bond positions are given in terms of a notional amount.
- All bond prices are based on a notional of 100.0.
- The face of a derivatives position is the size of the underlying position.

### **Bond Curves**

These modules create a family of curve types related to the term structures of interest rates. These are best fit yield curves fitting to bond prices which are used for interpolation. A range of curve shapes from polynomials to B-Splines is available. This module describes a curve that is fitted to bond yields calculated from bond market prices supplied by the user. The curve is not guaranteed to fit all of the bond prices exactly and a least squares approach is used. A number of fitting forms are provided which consist of

- Polynomial
- Nelson-Siegel
- Nelson-Siegel-Svensson
- Cubic B-Splines

This fitted curve cannot be used for pricing as yields assume a flat term structure. It can be used for fitting and interpolating yields off a nicely constructed yield curve interpolation curve.

### **FinCurveFitMethod**

This module sets out a range of curve forms that can be fitted to the bond yields. These includes a number of parametric curves that can be used to fit yield curves. These include:

- Polynomials of any degree
- Nelson-Siegel functional form.
- Nelson-Siegel-Svensson functional form.
- B-Splines

## 7.1 bond

### **Enumerated Type: YTMCalcType**

This enumerated type has the following values:

- ZERO
- UK\_DMO
- US\_STREET
- US\_TREASURY
- CFETS

### **Class: Bond**

Class for fixed coupon bonds and performing related analytics. These are bullet bonds which means they have regular coupon payments of a known size that are paid on known dates plus a payment of par at maturity.

### **Bond**

Create Bond object by providing the issue date, maturity Date, coupon frequency, annualised coupon, the accrual convention type, face amount and the number of ex-dividend days. A calendar type is used to determine holidays from which coupon dates might be shifted.

```
Bond(issue_dt: Date,
      maturity_dt: Date,
      coupon: float, # Annualised bond coupon
      freq_type: FrequencyTypes,
      dc_type: DayCountTypes,
      ex_div_days: int = 0,
      cal_type: CalendarTypes = CalendarTypes.WEEKEND,
      bd_type=BusDayAdjustTypes.FOLLOWING,
      dg_type=DateGenRuleTypes.BACKWARD) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
issue_dt	Date	-	-
maturity_dt	Date	-	-
coupon	float	Annualised bond coupon	-
freq_type	FrequencyTypes	-	-
dc_type	DayCountTypes	-	-
ex_div_days	int	-	0
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	-	-	BusDayAdjustTypes.FOLLOWING
dg_type	-	-	DateGenRuleTypes.BACKWARD

### **calculate\_cpn\_dts**

Determine the bond coupon dates. Note that for analytical calculations these are not usually adjusted and so may fall on a weekend or holiday.

```
_calculate_cpn_dts() :
```

The function arguments are described in the following table.

### **`_calculate_payment_dts`**

*For the actual payment dates, they are adjusted, and so we then use the calendar payment dates. Although payments are calculated as though coupon periods are the same length, payments that fall on a Saturday or Sunday can only be made on the next business day*

```
_calculate_payment_dts() :
```

The function arguments are described in the following table.

### **`_calculate_flows`**

*Determine the bond cash flow payment amounts without principal. There is no adjustment based on the adjusted payment dates.*

```
_calculate_flows() :
```

The function arguments are described in the following table.

### **`dirty_price_from_ytm`**

*Calculate the dirty price of bond from its yield to maturity. This function is vectorised with respect to the yield input. It implements a number of standard conventions for calculating the YTM.*

```
dirty_price_from_ytm(settle_dt: Date,
                     ytm: float,
                     convention: YTMCalcType = YTMCalcType.UK_DMO) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
ytm	float	-	-
convention	YTMCalcType	-	YTMCalcType.UK_DMO

### **`principal`**

*Calculate the principal value of the bond based on the face amount from its discount margin and making assumptions about the future Ibor rates.*

```
principal(settle_dt: Date,
          ytm: float,
          face: (float),
          convention: YTMCalcType):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
ytm	float	-	-
face	float or (float	-	-
convention	YTMCalcType	-	-

## dollar\_duration

*Calculate the risk or  $dP/dy$  of the bond by bumping. This is also known as the DV01 in Bloomberg.*

```
dollar_duration(settle_dt: Date,
                ytm: float,
                convention: YTMCalcType = YTMCalcType.UK_DMO):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
ytm	float	-	-
convention	YTMCalcType	-	YTMCalcType.UK_DMO

## macauley\_duration

*Calculate the Macauley duration of the bond on a settlement date given its yield to maturity.*

```
macauley_duration(settle_dt: Date,
                  ytm: float,
                  convention: YTMCalcType = YTMCalcType.UK_DMO):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
ytm	float	-	-
convention	YTMCalcType	-	YTMCalcType.UK_DMO

## modified\_duration

*Calculate the modified duration of the bond on a settlement date given its yield to maturity.*

```
modified_duration(settle_dt: Date,
                  ytm: float,
                  convention: YTMCalcType = YTMCalcType.UK_DMO):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
ytm	float	-	-
convention	YTMCalcType	-	YTMCalcType.UK_DMO

## key\_rate\_durations

*Calculates the key rate durations for a bond. Parameters ——— bond : FinancePy Bond object settle\_dt : FinancePy Date object The settlement date. ytm : float The yield to maturity. key\_rate\_tenors : list of float, optional The tenors of the key rates, default is None which will generate the tenors from 0.25 to 30 years. shift : float, optional The shift used to calculate the key rate durations, default is None which will set the shift to 0.0001. rates: list of float, optional Corresponding yield curve data in line with key\_rate\_tenors If None, flat yield curve is used Returns ——— tuple of (numpy array of float, numpy array of float) A tuple containing the key rate tenors and the key rate durations.*

```
key_rate_durations(bond,
                  settle_dt: Date,
                  ytm: float,
                  key_rate_tenors: list = None,
                  shift: float = None,
                  rates: list = None):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
bond	-	-	-
settle_dt	Date	-	-
ytm	float	-	-
key_rate_tenors	list	-	None
shift	float	-	None
rates	list	-	None

## convexity\_from\_ytm

*Calculate the bond convexity from the yield to maturity. This function is vectorised with respect to the yield input.*

```
convexity_from_ytm(settle_dt: Date,
                  ytm: float,
                  convention: YTMCalcType = YTMCalcType.UK_DMO):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
ytm	float	-	-
convention	YTMCalcType	-	YTMCalcType.UK_DMO

### clean\_price\_from\_ytm

Calculate the bond clean price from the yield to maturity. This function is vectorised with respect to the yield input.

```
clean_price_from_ytm(settle_dt: Date,
                     ytm: float,
                     convention: YTMCalcType = YTMCalcType.UK_DMO):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
ytm	float	-	-
convention	YTMCalcType	-	YTMCalcType.UK_DMO

### clean\_price\_from\_discount\_curve

Calculate the clean bond value using some discount curve to present-value the bond's cash flows back to the curve anchor date and not to the settlement date.

```
clean_price_from_discount_curve(settle_dt: Date,
                               discount_curve: DiscountCurve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
discount_curve	DiscountCurve	-	-

### dirty\_price\_from\_discount\_curve

Calculate the bond price using a provided discount curve to PV the bond's cash flows to the settlement date. As such it is effectively a forward bond price if the settlement date is after the valuation date.

```
dirty_price_from_discount_curve(settle_dt: Date,
                               discount_curve: DiscountCurve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
discount_curve	DiscountCurve	-	-



## current\_yield

*Calculate the current yield of the bond which is the coupon divided by the clean price (not the full price)*

```
current_yield(clean_price):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
clean_price	-	-	-

## yield\_to\_maturity

*Calculate the bond's yield to maturity by solving the price yield relationship using a one-dimensional root solver.*

```
yield_to_maturity(settle_dt: Date,
                  clean_price: float,
                  convention: YTMCalcType = YTMCalcType.US_TREASURY):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
clean_price	float	-	-
convention	YTMCalcType	-	YTMCalcType.US_TREASURY

## \_calc\_pcd\_ncd

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_calc_pcd_ncd(settle_dt: Date):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-

## accrued\_interest

*Calculate the amount of coupon that has accrued between the previous coupon date and the settlement date. Note that for some day count schemes (such as 30E/360) this is not actually the number of days between the previous coupon payment date and settlement date. If the bond trades with ex-coupon dates then you need to use the number of days before the coupon date the ex-coupon date is. You can specify the calendar to be used in the bond constructor - NONE means only calendar days, WEEKEND is only weekends, or you can specify a country calendar for business days.*

```
accrued_interest(settle_dt: Date,
                  face: float = 100.0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
face	float	-	100.0

## asset\_swap\_spread

*Calculate the par asset swap spread of the bond. The discount curve is an Ibor curve that is passed in. This function is vectorised with respect to the clean price.*

```
asset_swap_spread(settle_dt: Date,
                  clean_price: float,
                  discount_curve: DiscountCurve,
                  swapFloatDayCountConventionType=DayCountTypes.ACT_360,
                  swapFloatFrequencyType=FrequencyTypes.SEMI_ANNUAL,
                  swapFloatCalendarType=CalendarTypes.WEEKEND,
                  swapFloatBusDayAdjustRuleType=BusDayAdjustTypes.FOLLOWING,
                  swapFloatDateGenRuleType=DateGenRuleTypes.BACKWARD):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
clean_price	float	-	-
discount_curve	DiscountCurve	-	-
swapFloatDayCountConventionType	-	-	DayCountTypes.ACT_360
swapFloatFrequencyType	-	-	FrequencyTypes.SEMI_ANNUAL
swapFloatCalendarType	-	-	CalendarTypes.WEEKEND
swapFloatBusDayAdjustRuleType	-	-	BusDayAdjustTypes.FOLLOWING
swapFloatDateGenRuleType	-	-	DateGenRuleTypes.BACKWARD

## dirty\_price\_from\_oas

*Calculate the full price of the bond from its OAS given the bond settlement date, a discount curve and the oas as a number.*

```
dirty_price_from_oas(settle_dt: Date,
                     discount_curve: DiscountCurve,
                     oas: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
discount_curve	DiscountCurve	-	-
oas	float	-	-

## option\_adjusted\_spread

Return OAS for bullet bond given settlement date, clean bond price and the discount relative to which the spread is to be computed.

```
option_adjusted_spread(settle_dt: Date,
                       clean_price: float,
                       discount_curve: DiscountCurve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
clean_price	float	-	-
discount_curve	DiscountCurve	-	-

## bond\_payments

Print a list of the unadjusted coupon payment dates used in analytic calculations for the bond.

```
bond_payments(settle_dt: Date, face: (float)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
face	float or (float	-	-

## print\_payments

Print a list of the unadjusted coupon payment dates used in analytic calculations for the bond.

```
print_payments(settle_dt: Date,
               face: float = 100.0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
face	float	-	100.0

## dirty\_price\_from\_survival\_curve

Calculate discounted present value of flows assuming default model. The survival curve treats the coupons as zero recovery payments while the recovery fraction of the par amount is paid at default. For the defaulting principal we discretize the time steps using the coupon payment times. A finer discretization may handle the time value with more accuracy. I reduce any error by averaging period start and period end payment present values.

```
dirty_price_from_survival_curve(settle_dt: Date,
                               discount_curve: DiscountCurve,
                               survival_curve: DiscountCurve,
                               recovery_rate: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
discount_curve	DiscountCurve	-	-
survival_curve	DiscountCurve	-	-
recovery_rate	float	-	-

## clean\_price\_from\_survival\_curve

Calculate clean price value of flows assuming default model. The survival curve treats the coupons as zero recovery payments while the recovery fraction of the par amount is paid at default.

```
clean_price_from_survival_curve(settle_dt: Date,
                                discount_curve: DiscountCurve,
                                survival_curve: DiscountCurve,
                                recovery_rate: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
discount_curve	DiscountCurve	-	-
survival_curve	DiscountCurve	-	-
recovery_rate	float	-	-

## calc\_ror

Calculate the rate of total return(capital return and interest) given a BUY YTM and a SELL YTM of this bond. This function computes the full prices at buying and selling, plus the coupon payments during the period. It returns a tuple which includes a simple rate of return, a compounded IRR and the PnL.

```
calc_ror(begin_dt: Date,
         end_dt: Date,
         begin_ytm: float,
         end_ytm: float,
```

```
convention: YTMCalcType = YTMCalcType.US_STREET):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
begin_dt	Date	-	-
end_dt	Date	-	-
begin_ytm	float	-	-
end_ytm	float	-	-
convention	YTMCalcType	-	YTMCalcType.US_STREET

### **`--repr--`**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

### **`_print`**

*Print a list of the unadjusted coupon payment dates used in analytic calculations for the bond.*

```
_print():
```

The function arguments are described in the following table.

### **`_f`**

*Function used to do root search in price to yield calculation.*

```
_f(ytm, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
ytm	-	-	-
*args	-	-	-

### **`_g`**

*Function used to do root search in price to OAS calculation.*

```
_g(oas, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
oas	-	-	-
*args	-	-	-

## 7.2 bond\_annuity

### ***Class: BondAnnuity***

An annuity is a vector of dates and flows generated according to ISDA standard rules which starts on the next date after the start date (effective date) and runs up to an end date with no principal repayment. Dates are then adjusted according to a specified calendar.

### **BondAnnuity**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
BondAnnuity(maturity_dt: Date,
            cpn: float,
            freq_type: FrequencyTypes,
            cal_type: CalendarTypes = CalendarTypes.WEEKEND,
            bd_type: BusDayAdjustTypes = BusDayAdjustTypes.FOLLOWING,
            dg_type: DateGenRuleTypes = DateGenRuleTypes.BACKWARD,
            dc_type: DayCountTypes = DayCountTypes.ACT_360):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
maturity_dt	Date	-	-
cpn	float	-	-
freq_type	FrequencyTypes	-	-
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.FOLLOWING
dg_type	DateGenRuleTypes	-	DateGenRuleTypes.BACKWARD
dc_type	DayCountTypes	-	DayCountTypes.ACT_360

### **clean\_price\_from\_discount\_curve**

*Calculate the bond price using some discount curve to present-value the bond's cash flows.*

```
clean_price_from_discount_curve(settle_dt: Date,
                               discount_curve: DiscountCurve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
discount_curve	DiscountCurve	-	-

### **dirty\_price\_from\_discount\_curve**

*Calculate the bond price using some discount curve to present-value the bond's cash flows.*

```
dirty_price_from_discount_curve(settle_dt: Date,
                                discount_curve: DiscountCurve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
discount_curve	DiscountCurve	-	-

## calculate\_payments

*PLEASE ADD A FUNCTION DESCRIPTION*

```
calculate_payments(settle_dt: Date,
                   face: (float)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
face	float or (float	-	-

## accrued\_interest

*Calculate the amount of coupon that has accrued between the previous coupon date and the settlement date.*

```
accrued_interest(settle_dt: Date,
                  face: (float)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
face	float or (float	-	-

## print\_payments

*Print a list of the unadjusted coupon payment dates used in analytic calculations for the bond.*

```
print_payments(settle_dt: Date,
               face: (float)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
face	float or (float	-	-



**`--repr--`**

*Print a list of the unadjusted coupon payment dates used in analytic calculations for the bond.*

```
--repr--() :
```

The function arguments are described in the following table.

**`_print`**

*Simple print function for backward compatibility.*

```
_print() :
```

The function arguments are described in the following table.

## 7.3 bond\_callable

### **Enumerated Type: BondModelTypes**

This enumerated type has the following values:

- BLACK
- HO\_LEE
- HULL\_WHITE
- BLACK\_KARASINSKI

### **Enumerated Type: BondOptionTypes**

This enumerated type has the following values:

- EUROPEAN\_CALL
- EUROPEAN\_PUT
- AMERICAN\_CALL
- AMERICAN\_PUT

### **Class: BondEmbeddedOption**

#### **BondEmbeddedOption**

Create a *BondEmbeddedOption* object with a maturity date, coupon and all the bond inputs.

```
BondEmbeddedOption(issue_dt: Date,
                    maturity_dt: Date, # Date
                    coupon: float, # Annualised coupon - 0.03 = 3.00%
                    freq_type: FrequencyTypes,
                    dc_type: DayCountTypes,
                    call_dts: List[Date],
                    call_prices: List[float],
                    put_dts: List[Date],
                    put_prices: List[float]):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
issue_dt	Date	-	-
maturity_dt	Date	Date	-
coupon	float	Annualised coupon - 0.03 = 3.00%	-
freq_type	FrequencyTypes	-	-
dc_type	DayCountTypes	-	-
call_dts	List[Date]	-	-
call_prices	List[float]	-	-
put_dts	List[Date]	-	-
put_prices	List[float]	-	-

## value

Value the bond that settles on the specified date that can have both embedded call and put options. This is done using the specified model and a discount curve.

```
value(settle_dt: Date,
      discount_curve: DiscountCurve,
      model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
discount_curve	DiscountCurve	-	-
model	-	-	-

## \_\_repr\_\_

PLEASE ADD A FUNCTION DESCRIPTION

```
__repr__():
```

The function arguments are described in the following table.

## \_print

PLEASE ADD A FUNCTION DESCRIPTION

```
_print():
```

The function arguments are described in the following table.

## 7.4 bond\_convertible

### **Class: BondConvertible**

Class for convertible bonds. These bonds embed rights to call and put the bond in return for equity. Until then, they are bullet bonds which means they have regular coupon payments of a known size that are paid on known dates plus a payment of par at maturity. As the options are price based, the decision to convert to equity depends on the stock price, the credit quality of the issuer and the level of interest rates.

### **BondConvertible**

Create *BondConvertible* object by providing the bond Maturity date, coupon, frequency type, accrual convention type and then all the details regarding the conversion option including the list of the call and put dates and the corresponding list of call and put prices.

```
BondConvertible(maturity_dt: Date, # bond maturity date
                coupon: float, # annual coupon
                freq_type: FrequencyTypes, # coupon frequency type
                start_convert_dt: Date, # conversion starts on this date
                conversion_ratio: float, # num shares per face of notional
                call_dts: List[Date], # list of call dates
                call_prices: List[float], # list of call prices
                put_dts: List[Date], # list of put dates
                put_prices: List[float], # list of put prices
                dc_type: DayCountTypes, # day count type for accrued
                cal_type: CalendarTypes = CalendarTypes.WEEKEND):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
maturity_dt	Date	bond maturity date	-
coupon	float	annual coupon	-
freq_type	FrequencyTypes	coupon frequency type	-
start_convert_dt	Date	conversion starts on this date	-
conversion_ratio	float	num shares per face of notional	-
call_dts	List[Date]	list of call dates	-
call_prices	List[float]	list of call prices	-
put_dts	List[Date]	list of put dates	-
put_prices	List[float]	list of put prices	-
dc_type	DayCountTypes	day count type for accrued	-
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND

### **\_calculate\_cpn\_dts**

Determine the convertible bond cash flow payment dates.

```
_calculate_cpn_dts(settle_dt: Date):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-

## value

A binomial tree valuation model for a convertible bond that captures the embedded equity option due to the existence of a conversion option which can be invoked after a specific date. The model allows the user to enter a schedule of dividend payment dates but the size of the payments must be in yield terms i.e. a known percentage of currently unknown future stock price is paid. Not a fixed amount. A fixed yield. Following this payment the stock is assumed to drop by the size of the dividend payment. The model also captures the stock dependent credit risk of the cash flows in which the bond price can default at any time with a hazard rate implied by the credit spread and an associated recovery rate. This is the model proposed by Hull (OFODS 6th edition, page 522). The model captures both the issuer's call schedule which is assumed to apply on a list of dates provided by the user, along with a call price. It also captures the embedded owner's put schedule of prices.

```
value(settle_dt: Date,
      stock_price: float,
      stock_volatility: float,
      dividend_dts: List[Date],
      dividend_yields: List[float],
      discount_curve: DiscountCurve,
      credit_spread: float,
      recovery_rate: float = 0.40,
      num_steps_per_year: int = 100):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
stock_price	float	-	-
stock_volatility	float	-	-
dividend_dts	List[Date]	-	-
dividend_yields	List[float]	-	-
discount_curve	DiscountCurve	-	-
credit_spread	float	-	-
recovery_rate	float	-	0.40
num_steps_per_year	int	-	100

## accrued\_days

Calculate number days from previous coupon date to settlement.

```
accrued_days(settle_dt: Date):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-

**accrued\_interest**

*Calculate the amount of coupon that has accrued between the previous coupon date and the settlement date.*

```
accrued_interest(settle_dt: Date,
                  face: (float)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
face	float or (float	-	-

**current\_yield**

*Calculate the current yield of the bond which is the coupon divided by the clean price (not the full price)*

```
current_yield(clean_price: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
clean_price	float	-	-

**\_\_repr\_\_**

*Print a list of the unadjusted coupon payment dates used in analytic calculations for the bond.*

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

**\_value\_convertible**

*PLEASE ADD A FUNCTION DESCRIPTION*

```

_value_convertible(t_mat,
                   face_amount,
                   cpn_times,
                   cpn_flows,
                   call_times,
                   call_prices,
                   put_times,
                   put_prices,
                   conv_ratio,
                   start_convert_time,
                   # Market inputs
                   stock_price,
                   df_times,
                   df_values,
                   dividend_times,
                   dividend_yields,
                   stock_volatility,
                   credit_spread,
                   recovery_rate,
                   # Tree details
                   num_steps_per_year):

```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t_mat	-	-	-
face_amount	-	-	-
cpn_times	-	-	-
cpn_flows	-	-	-
call_times	-	-	-
call_prices	-	-	-
put_times	-	-	-
put_prices	-	-	-
conv_ratio	-	-	-
start_convert_time	-	-	-
stock_price	-	-	-
df_times	-	-	-
df_values	-	-	-
dividend_times	-	-	-
dividend_yields	-	-	-
stock_volatility	-	-	-
credit_spread	-	-	-
recovery_rate	-	-	-
num_steps_per_year	-	-	-

## print\_tree

PLEASE ADD A FUNCTION DESCRIPTION

```
print_tree(array):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
array	-	-	-



## 7.5 bond\_frn

### **Class: BondFRN**

Class for managing floating rate notes that pay a floating index plus a quoted margin.

### **BondFRN**

Create *FinFloatingRateNote* object given its maturity date, its quoted margin, coupon frequency, *DAY COUNT TYPE*. *Face* is the size of the position and *par* is the notional on which price is quoted.

```
BondFRN(issue_dt: Date,
        maturity_dt: Date,
        quoted_margin: float, # Fixed spread paid on top of index
        freq_type: FrequencyTypes,
        dc_type: DayCountTypes,
        cal_type: CalendarTypes = CalendarTypes.WEEKEND):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
issue_dt	Date	-	-
maturity_dt	Date	-	-
quoted_margin	float	Fixed spread paid on top of index	-
freq_type	FrequencyTypes	-	-
dc_type	DayCountTypes	-	-
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND

### **\_calculate\_cpn\_dts**

Determine the bond cashflow payment dates.

```
_calculate_cpn_dts():
```

The function arguments are described in the following table.

### **dirty\_price\_from\_dm**

Calculate the full price of the bond from its discount margin (DM) using standard model based on assumptions about future Ibor rates. The next Ibor payment which has reset is entered, so to is the current Ibor rate from settlement to the next coupon date (NCD). Finally, there is the level of subsequent future Ibor payments and the discount margin.

```
dirty_price_from_dm(settle_dt: Date,
                    next_cpn: float, # The total reset coupon on NCD
                    current_ibor: float, # Ibor discount to NCD
                    future_ibor: float, # Future constant Ibor rates
                    dm: float): # Discount margin
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
next_cpn	float	The total reset coupon on NCD	-
current_ibor	float	Ibor discount to NCD	-
future_ibor	float	Future constant Ibor rates	-
dm	float	Discount margin	-

## principal

*Calculate the clean trade price of the bond based on the face amount from its discount margin and making assumptions about the future Ibor rates.*

```
principal(settle_dt: Date,
          next_cpn: float,
          current_ibor: float,
          future_ibor: float,
          dm: float,
          face: float = 100.0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
next_cpn	float	-	-
current_ibor	float	-	-
future_ibor	float	-	-
dm	float	-	-
face	float	-	100.0

## dollar\_duration

*Calculate the risk or  $dP/dy$  of the bond by bumping. This is also known as the DV01 in Bloomberg.*

```
dollar_duration(settle_dt: Date,
                next_cpn: float,
                current_ibor: float,
                future_ibor: float,
                dm: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
next_cpn	float	-	-
current_ibor	float	-	-
future_ibor	float	-	-
dm	float	-	-

## dollar\_credit\_duration

Calculate the risk or  $dP/dy$  of the bond by bumping.

```
dollar_credit_duration(settle_dt: Date,
                       next_cpn: float,
                       current_ibor: float,
                       future_ibor: float,
                       dm: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
next_cpn	float	-	-
current_ibor	float	-	-
future_ibor	float	-	-
dm	float	-	-

## macauley\_duration

Calculate the Macauley duration of the FRN on a settlement date given its yield to maturity.

```
macauley_duration(settle_dt: Date,
                  next_cpn: float,
                  current_ibor: float,
                  future_ibor: float,
                  dm: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
next_cpn	float	-	-
current_ibor	float	-	-
future_ibor	float	-	-
dm	float	-	-

## modified\_duration

Calculate the modified duration of the bond on a settlement date using standard model based on assumptions about future Ibor rates. The next Ibor payment which has reset is entered, so to is the current Ibor rate from settlement to the next coupon date (NCD). Finally, there is the level of subsequent future Ibor payments and the discount margin.

```
modified_duration(settle_dt: Date,
                  next_cpn: float,
                  current_ibor: float,
                  future_ibor: float,
                  dm: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
next_cpn	float	-	-
current_ibor	float	-	-
future_ibor	float	-	-
dm	float	-	-

### modified\_credit\_duration

*Calculate the modified duration of the bond on a settlement date using standard model based on assumptions about future Ibor rates. The next Ibor payment which has reset is entered, so to is the current Ibor rate from settlement to the next coupon date (NCD). Finally, there is the level of subsequent future Ibor payments and the discount margin.*

```
modified_credit_duration(settle_dt: Date,
                        next_cpn: float,
                        current_ibor: float,
                        future_ibor: float,
                        dm: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
next_cpn	float	-	-
current_ibor	float	-	-
future_ibor	float	-	-
dm	float	-	-

### convexity\_from\_dm

*Calculate the bond convexity from the discount margin (DM) using a standard model based on assumptions about future Ibor rates. The next Ibor payment which has reset is entered, so to is the current Ibor rate from settlement to the next coupon date (NCD). Finally, there is the level of subsequent future Ibor payments and the discount margin.*

```
convexity_from_dm(settle_dt: Date,
                  next_cpn: float,
                  current_ibor: float,
                  future_ibor: float,
                  dm: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
next_cpn	float	-	-
current_ibor	float	-	-
future_ibor	float	-	-
dm	float	-	-

### clean\_price\_from\_dm

Calculate the bond clean price from the discount margin using standard model based on assumptions about future Ibor rates. The next Ibor payment which has reset is entered, so to is the current Ibor rate from settlement to the next coupon date (NCD). Finally, there is the level of subsequent future Ibor payments and the discount margin.

```
clean_price_from_dm(settle_dt: Date,
                    next_cpn: float,
                    current_ibor: float,
                    future_ibor: float,
                    dm: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
next_cpn	float	-	-
current_ibor	float	-	-
future_ibor	float	-	-
dm	float	-	-

### discount\_margin

Calculate the bond's yield to maturity by solving the price yield relationship using a one-dimensional root solver.

```
discount_margin(settle_dt: Date,
                next_cpn: float,
                current_ibor: float,
                future_ibor: float,
                clean_price: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
next_cpn	float	-	-
current_ibor	float	-	-
future_ibor	float	-	-
clean_price	float	-	-

**accrued\_interest**

*Calculate the amount of coupon that has accrued between the previous coupon date and the settlement date. Ex-dividend dates are not handled. Contact me if you need this functionality.*

```
accrued_interest(settle_dt: Date,
                  next_cpn: float,
                  face: (float)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
next_cpn	float	-	-
face	float or (float	-	-

**print\_payments**

*Print a list of the unadjusted coupon payment dates used in analytic calculations for the bond.*

```
print_payments(settle_dt: Date):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-

**\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

**f**

*Function used to do solve root search in DM calculation*

```
_f(dm, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dm	-	-	-
*args	-	-	-

## 7.6 bond\_future

### **Class: BondFuture**

Class for managing futures contracts on government bonds that follows CME conventions and related analytics.

### **BondFuture**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
BondFuture(ticker_name: str,
            first_delivery_dt: Date,
            last_delivery_dt: Date,
            contract_size: int,
            cpn: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
ticker_name	str	-	-
first_delivery_dt	Date	-	-
last_delivery_dt	Date	-	-
contract_size	int	-	-
cpn	float	-	-

### **conversion\_factor**

*Determine the conversion factor for a specific bond using CME convention. To do this we need to know the contract standard coupon and must round the bond maturity (starting its life on the first delivery date) to the nearest 3 month multiple and then calculate the bond clean price.*

```
conversion_factor(bond: Bond):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
bond	Bond	-	-

### **principal\_invoice\_price**

*The principal invoice price as defined by the CME.*

```
principal_invoice_price(bond: Bond,
                        futures_price: float):
```

The function arguments are described in the following table.



Argument Name	Type	Description	Default Value
bond	Bond	-	-
futures_price	float	-	-

## total\_invoice\_amount

*PLEASE ADD A FUNCTION DESCRIPTION*

```
total_invoice_amount(settle_dt: Date,
                     bond: Bond,
                     futures_price: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
bond	Bond	-	-
futures_price	float	-	-

## cheapest\_to\_deliver

*Determination of CTD as deliverable bond with the lowest cost to buy versus what is received when the bond is delivered.*

```
cheapest_to_deliver(bonds: list,
                    bond_clean_prices: list,
                    futures_price: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
bonds	list	-	-
bond_clean_prices	list	-	-
futures_price	float	-	-

## delivery\_gain\_loss

*Determination of what is received when the bond is delivered.*

```
delivery_gain_loss(bond: Bond,
                  bond_clean_price: float,
                  futures_price: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
bond	Bond	-	-
bond_clean_price	float	-	-
futures_price	float	-	-

**--repr--**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

## 7.7 bond\_market

### ***Enumerated Type: BondMarkets***

This enumerated type has the following values:

- AUSTRIA
- BELGIUM
- CYPRUS
- ESTONIA
- FINLAND
- FRANCE
- GERMANY
- GREECE
- IRELAND
- ITALY
- LATVIA
- LITHUANIA
- LUXEMBOURG
- MALTA
- NETHERLANDS
- PORTUGAL
- SLOVAKIA
- SLOVENIA
- SPAIN
- ESM
- EFSF
- BULGARIA
- CROATIA
- CZECH.REPUBLIC
- DENMARK
- HUNGARY
- POLAND
- ROMANIA
- SWEDEN
- JAPAN
- SWITZERLAND
- UNITED\_KINGDOM
- UNITED\_STATES
- AUSTRALIA
- NEW\_ZEALAND
- NORWAY
- SOUTH\_AFRICA

### **get\_bond\_market\_conventions**

*Returns the day count convention for accrued interest, the frequency and the number of days from trade date to settlement date. This is for Treasury markets. And for secondary bond markets.*

```
get_bond_market_conventions(country):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
country	-	-	-

## 7.8 bond\_mortgage

### *Enumerated Type: BondMortgageTypes*

This enumerated type has the following values:

- REPAYMENT
- INTEREST\_ONLY

### *Class: BondMortgage*

A mortgage is a vector of dates and flows generated in order to repay a fixed amount given a known interest rate. Payments are all the same amount but with a varying mixture of interest and repayment of principal.

### **BondMortgage**

*Create the mortgage using start and end dates and principal.*

```
BondMortgage(start_dt: Date,
              end_dt: Date,
              principal: float,
              freq_type: FrequencyTypes = FrequencyTypes.MONTHLY,
              cal_type: CalendarTypes = CalendarTypes.WEEKEND,
              bd_type: BusDayAdjustTypes = BusDayAdjustTypes.FOLLOWING,
              dg_type: DateGenRuleTypes = DateGenRuleTypes.BACKWARD,
              dc_type: DayCountTypes = DayCountTypes.ACT_360):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
start_dt	Date	-	-
end_dt	Date	-	-
principal	float	-	-
freq_type	FrequencyTypes	-	FrequencyTypes.MONTHLY
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.FOLLOWING
dg_type	DateGenRuleTypes	-	DateGenRuleTypes.BACKWARD
dc_type	DayCountTypes	-	DayCountTypes.ACT_360

### **repayment\_amount**

*Determine monthly repayment amount based on current zero rate.*

```
repayment_amount(zero_rate: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
zero_rate	float	-	-

**generate\_flows**

*Generate the bond flow amounts.*

```
generate_flows(zero_rate: float,
               mortgage_type: BondMortgageTypes):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
zero_rate	float	-	-
mortgage_type	BondMortgageTypes	-	-

**print\_leg**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
print_leg():
```

The function arguments are described in the following table.

**\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

## 7.9 bond\_option

### **Enumerated Type: *BondModelTypes***

This enumerated type has the following values:

- BLACK
- HO\_LEE
- HULL\_WHITE
- BLACK\_KARASINSKI

### **Class: *BondOption()***

Class for options on fixed coupon bonds. These are options to either buy or sell a bond on or before a specific future expiry date at a strike price that is set on trade date. A European option only allows the bond to be exercised into on a specific expiry date. An American option allows the option holder to exercise early, potentially allowing earlier coupons to be received.

### **BondOption**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
BondOption(bond: Bond,
            expiry_dt: Date,
            strike_price: float,
            option_type: OptionTypes):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
bond	Bond	-	-
expiry_dt	Date	-	-
strike_price	float	-	-
option_type	OptionTypes	-	-

### **value**

*Value a bond option (option on a bond) using a specified model which include the Hull-White, Black-Karasinski and Black-Derman-Toy model which are all implemented as short rate tree models.*

```
value(value_dt: Date,
      discount_curve: DiscountCurve,
      model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
discount_curve	DiscountCurve	-	-
model	-	-	-

**--repr--**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.



## 7.10 bond\_portfolio

**Class: *BondPortfolio***

### BondPortfolio

XXX

```
BondPortfolio(bonds: (list),
              bondWeights: (list, np.ndarray)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
bonds	list or (list	-	-
bondWeights	list or np.ndarray	-	-

### calculate\_flows

*Determine the bond cashflow payment amounts without principal*

```
_calculate_flows():
```

The function arguments are described in the following table.

### dollar\_duration

*Calculate the risk or  $dP/dy$  of the bond by bumping. This is also known as the DV01 in Bloomberg.*

```
dollar_duration(settle_dt: Date,
                ytm: float,
                convention: YTMCalcType = YTMCalcType.UK_DMO):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
ytm	float	-	-
convention	YTMCalcType	-	YTMCalcType.UK_DMO

### macauley\_duration

*Calculate the Macauley duration of the bond on a settlement date given its yield to maturity.*

```
macauley_duration(settle_dt: Date,
                  ytm: float,
                  convention: YTMCalcType = YTMCalcType.UK_DMO):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
ytm	float	-	-
convention	YTMCalcType	-	YTMCalcType.UK_DMO

## modified\_duration

*Calculate the modified duration of the bond on a settlement date given its yield to maturity.*

```
modified_duration(settle_dt: Date,
                  ytm: float,
                  convention: YTMCalcType = YTMCalcType.UK_DMO):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
ytm	float	-	-
convention	YTMCalcType	-	YTMCalcType.UK_DMO

## convexity\_from\_ytm

*Calculate the bond convexity from the yield to maturity. This function is vectorised with respect to the yield input.*

```
convexity_from_ytm(settle_dt: Date,
                   ytm: float,
                   convention: YTMCalcType = YTMCalcType.UK_DMO):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
ytm	float	-	-
convention	YTMCalcType	-	YTMCalcType.UK_DMO

## clean\_price\_from\_ytm

*Calculate the bond clean price from the yield to maturity. This function is vectorised with respect to the yield input.*

```
clean_price_from_ytm(settle_dt: Date,
                     ytm: float,
                     convention: YTMCalcType = YTMCalcType.UK_DMO):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
ytm	float	-	-
convention	YTMCalcType	-	YTMCalcType.UK_DMO

### clean\_price\_from\_discount\_curve

Calculate the clean bond value using some discount curve to present-value the bond's cash flows back to the curve anchor date and not to the settlement date.

```
clean_price_from_discount_curve(settle_dt: Date,
                               discount_curve: DiscountCurve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
discount_curve	DiscountCurve	-	-

### dirty\_price\_from\_discount\_curve

Calculate the bond price using a provided discount curve to PV the bond's cash flows to the settlement date. As such it is effectively a forward bond price if the settlement date is after the valuation date.

```
dirty_price_from_discount_curve(settle_dt: Date,
                               discount_curve: DiscountCurve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
discount_curve	DiscountCurve	-	-

### current\_yield

Calculate the current yield of the bond which is the coupon divided by the clean price (not the full price)

```
current_yield(clean_price):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
clean_price	-	-	-

### yield\_to\_maturity

Calculate the bond's yield to maturity by solving the price yield relationship using a one-dimensional root solver.

```
yield_to_maturity(settle_dt: Date,
                  clean_price: float,
                  convention: YTMCalcType = YTMCalcType.US_TREASURY):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
clean_price	float	-	-
convention	YTMCalcType	-	YTMCalcType.US_TREASURY

## accrued\_interest

*PLEASE ADD A FUNCTION DESCRIPTION*

```
accrued_interest(settle_dt: Date,
                  num_ex_dividend_days: int = 0,
                  cal_type: CalendarTypes = CalendarTypes.WEEKEND):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
num_ex_dividend_days	int	-	0
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND

## print\_payments

*Print a list of the unadjusted coupon payment dates used in analytic calculations for the bond.*

```
print_payments(settle_dt: Date,
               face: (float)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
face	float or (float	-	-

## dirty\_price\_from\_survival\_curve

*Calculate discounted present value of flows assuming default model. The survival curve treats the coupons as zero recovery payments while the recovery fraction of the par amount is paid at default. For the defaulting principal we discretise the time steps using the coupon payment times. A finer discretisation may handle the time value with more accuracy. I reduce any error by averaging period start and period end payment present values.*

```
dirty_price_from_survival_curve(settle_dt: Date,
                               discount_curve: DiscountCurve,
                               survival_curve: DiscountCurve,
                               recovery_rate: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
discount_curve	DiscountCurve	-	-
survival_curve	DiscountCurve	-	-
recovery_rate	float	-	-

### **clean\_price\_from\_survival\_curve**

*Calculate clean price value of flows assuming default model. The survival curve treats the coupons as zero recovery payments while the recovery fraction of the par amount is paid at default.*

```
clean_price_from_survival_curve(settle_dt: Date,
                                discount_curve: DiscountCurve,
                                survival_curve: DiscountCurve,
                                recovery_rate: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
discount_curve	DiscountCurve	-	-
survival_curve	DiscountCurve	-	-
recovery_rate	float	-	-

### **\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

### **\_print**

*Print a list of the unadjusted coupon payment dates used in analytic calculations for the bond.*

```
_print():
```

The function arguments are described in the following table.

## 7.11 bond\_zero

### **Class: BondZero**

A zero coupon bond is a bond which doesn't pay any periodic payments. Instead, it is issued at a discount. The entire face value of the bond is paid out at maturity. It is issued as a deep discount bond.

There is a special convention for accrued interest in which

Accrued interest = (par - issue price) \* D

where  $D = (\text{settle\_dt} - \text{issue\_dt}) / (\text{maturity\_dt} - \text{issue\_dt})$ .

### **BondZero**

Create BondZero object by providing the issue date, maturity Date, face amount and issue price.

```
BondZero(issue_dt: Date,
          maturity_dt: Date,
          issue_price: float,           # Issue price usually discounted
          ):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
issue_dt	Date	-	-
maturity_dt	Date	-	-
issue_price	float	Issue price usually discounted	-

### **dirty\_price\_from\_ytm**

Calculate the full price of bond from its yield to maturity. This function is vectorised with respect to the yield input. It implements a number of standard conventions for calculating the YTM.

```
dirty_price_from_ytm(settle_dt: Date,
                     ytm: float,
                     convention: YTMCalcType = YTMCalcType.ZERO):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
ytm	float	-	-
convention	YTMCalcType	-	YTMCalcType.ZERO

### **principal**

Calculate the principal value of the bond based on the face amount from its discount margin and making assumptions about the future Ibor rates.

```
principal(settle_dt: Date,
          ytm: float,
          face: (float),
          convention: YTMCalcType = YTMCalcType.ZERO):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
ytm	float	-	-
face	float or (float	-	-
convention	YTMCalcType	-	YTMCalcType.ZERO

## dollar\_duration

*Calculate the risk or  $dP/dy$  of the bond by bumping. This is also known as the DV01 in Bloomberg.*

```
dollar_duration(settle_dt: Date,
                ytm: float,
                convention: YTMCalcType = YTMCalcType.ZERO):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
ytm	float	-	-
convention	YTMCalcType	-	YTMCalcType.ZERO

## macauley\_duration

*Calculate the Macauley duration of the bond on a settlement date given its yield to maturity.*

```
macauley_duration(settle_dt: Date,
                  ytm: float,
                  convention: YTMCalcType = YTMCalcType.ZERO):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
ytm	float	-	-
convention	YTMCalcType	-	YTMCalcType.ZERO

## modified\_duration

*Calculate the modified duration of the bond on a settlement date given its yield to maturity.*

```
modified_duration(settle_dt: Date,
                  ytm: float,
                  convention: YTMCalcType = YTMCalcType.ZERO):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
ytm	float	-	-
convention	YTMCalcType	-	YTMCalcType.ZERO

### convexity\_from\_ytm

*Calculate the bond convexity from the yield to maturity. This function is vectorised with respect to the yield input.*

```
convexity_from_ytm(settle_dt: Date,
                   ytm: float,
                   convention: YTMCalcType = YTMCalcType.ZERO):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
ytm	float	-	-
convention	YTMCalcType	-	YTMCalcType.ZERO

### clean\_price\_from\_ytm

*Calculate the bond clean price from the yield to maturity. This function is vectorised with respect to the yield input.*

```
clean_price_from_ytm(settle_dt: Date,
                    ytm: float,
                    convention: YTMCalcType = YTMCalcType.ZERO):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
ytm	float	-	-
convention	YTMCalcType	-	YTMCalcType.ZERO

### clean\_price\_from\_discount\_curve

*Calculate the clean bond value using some discount curve to present-value the bond's cash flows back to the curve anchor date and not to the settlement date.*



```
clean_price_from_discount_curve(settle_dt: Date,
                               discount_curve: DiscountCurve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
discount_curve	DiscountCurve	-	-

### dirty\_price\_from\_discount\_curve

*Calculate the bond price using a provided discount curve to PV the bond's cash flows to the settlement date. As such it is effectively a forward bond price if the settlement date is after the valuation date.*

```
dirty_price_from_discount_curve(settle_dt: Date,
                               discount_curve: DiscountCurve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
discount_curve	DiscountCurve	-	-

### current\_yield

*Calculate the current yield of the bond which is the coupon divided by the clean price (not the full price). The coupon of a zero coupon bond is defined as: (par - issue\_price) / tenor*

```
current_yield(clean_price):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
clean_price	-	-	-

### yield\_to\_maturity

*Calculate the bond's yield to maturity by solving the price yield relationship using a one-dimensional root solver.*

```
yield_to_maturity(settle_dt: Date,
                  clean_price: float,
                  convention: YTMCalcType = YTMCalcType.ZERO):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
clean_price	float	-	-
convention	YTMCalcType	-	YTMCalcType.ZERO

## accrued\_interest

Calculate the amount of coupon that has accrued between the previous coupon date and the settlement date. Note that for some day count schemes (such as 30E/360) this is not actually the number of days between the previous coupon payment date and settlement date. If the bond trades with ex-coupon dates then you need to supply the number of days before the coupon date the ex-coupon date is. You can specify the calendar to be used - NONE means only calendar days, WEEKEND is only weekends or you can specify a country calendar for business days.

```
accrued_interest(settle_dt: Date,
                 face: (float)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
face	float or (float	-	-

## asset\_swap\_spread

Calculate the par asset swap spread of the bond. The discount curve is a Ibor curve that is passed in. This function is vectorised with respect to the clean price.

```
asset_swap_spread(settle_dt: Date,
                  clean_price: float,
                  discount_curve: DiscountCurve,
                  swapFloatDayCountConventionType=DayCountTypes.ACT_360,
                  swapFloatFrequencyType=FrequencyTypes.SEMI_ANNUAL,
                  swapFloatCalendarType=CalendarTypes.WEEKEND,
                  swapFloatBusDayAdjustRuleType=BusDayAdjustTypes.FOLLOWING,
                  swapFloatDateGenRuleType=DateGenRuleTypes.BACKWARD):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
clean_price	float	-	-
discount_curve	DiscountCurve	-	-
swapFloatDayCountConventionType	-	-	DayCountTypes.ACT_360
swapFloatFrequencyType	-	-	FrequencyTypes.SEMI_ANNUAL
swapFloatCalendarType	-	-	CalendarTypes.WEEKEND
swapFloatBusDayAdjustRuleType	-	-	BusDayAdjustTypes.FOLLOWING
swapFloatDateGenRuleType	-	-	DateGenRuleTypes.BACKWARD

## dirty\_price\_from\_oas

Calculate the full price of the bond from its OAS given the bond settlement date, a discount curve and the oas as a number.

```
dirty_price_from_oas(settle_dt: Date,
                     discount_curve: DiscountCurve,
                     oas: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
discount_curve	DiscountCurve	-	-
oas	float	-	-

## option\_adjusted\_spread

Return OAS for bullet bond given settlement date, clean bond price and the discount relative to which the spread is to be computed.

```
option_adjusted_spread(settle_dt: Date,
                       clean_price: float,
                       discount_curve: DiscountCurve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
clean_price	float	-	-
discount_curve	DiscountCurve	-	-

## bond\_payments

Print a list of the unadjusted coupon payment dates used in analytic calculations for the bond.

```
bond_payments(settle_dt: Date,
              face: (float)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
face	float or (float	-	-

## print\_bond\_payments

Print a list of the unadjusted coupon payment dates used in analytic calculations for the bond.

```
print_bond_payments(settle_dt: Date,
                    face: (float) = 100.0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
face	float or (float	-	100.0

### dirty\_price\_from\_survival\_curve

*Calculate discounted present value of flows assuming default model. The survival curve treats the coupons as zero recovery payments while the recovery fraction of the par amount is paid at default. For the defaulting principal we discretize the time steps using the coupon payment times. A finer discretization may handle the time value with more accuracy. I reduce any error by averaging period start and period end payment present values.*

```
dirty_price_from_survival_curve(settle_dt: Date,
                                discount_curve: DiscountCurve,
                                survival_curve: DiscountCurve,
                                recovery_rate: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
discount_curve	DiscountCurve	-	-
survival_curve	DiscountCurve	-	-
recovery_rate	float	-	-

### clean\_price\_from\_survival\_curve

*Calculate clean price value of flows assuming default model. The survival curve treats the coupons as zero recovery payments while the recovery fraction of the par amount is paid at default.*

```
clean_price_from_survival_curve(settle_dt: Date,
                                 discount_curve: DiscountCurve,
                                 survival_curve: DiscountCurve,
                                 recovery_rate: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
discount_curve	DiscountCurve	-	-
survival_curve	DiscountCurve	-	-
recovery_rate	float	-	-

**calc\_ror**

*TODO: TIDY THIS UP !!!!!!!!!!!!!!! Calculates the rate of total return (capital return and interest) given a BUY YTM and a SELL YTM of this bond. This function computes the full prices at buying and selling, plus the coupon payments during the period. It returns a tuple which includes a simple rate of return, a compounded IRR and the PnL.*

```
calc_ror(begin_dt: Date,
         end_dt: Date,
         begin_ytm: float,
         end_ytm: float,
         convention: YTMCalcType = YTMCalcType.ZERO):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
begin_dt	Date	-	-
end_dt	Date	-	-
begin_ytm	float	-	-
end_ytm	float	-	-
convention	YTMCalcType	-	YTMCalcType.ZERO

**\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

*Print a list of the unadjusted coupon payment dates used in analytic calculations for the bond.*

```
_print():
```

The function arguments are described in the following table.

**\_f**

*Function used to do root search in price to yield calculation.*

```
_f(ytm, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
ytm	-	-	-
*args	-	-	-

**g**

*Function used to do root search in price to OAS calculation.*

```
_g(oas, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
oas	-	-	-
*args	-	-	-

## 7.12 yield\_curve

### **Class: *BondYieldCurve()***

Class to do fitting of the yield curve and to enable interpolation of yields. Because yields assume a flat term structure for each bond, this class does not allow discounting to be done and so does not inherit from *FinDiscountCurve*. It should only be used for visualisation and simple interpolation but not for full term-structure-consistent pricing.

### **BondYieldCurve**

*Fit the curve to a set of bond yields using the type of curve specified. Bounds can be provided if you wish to enforce lower and upper limits on the respective model parameters.*

```
BondYieldCurve(settle_dt: Date,
               bonds: list,
               ylds: (np.ndarray, list),
               curveFit):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
bonds	list	-	-
ylds	np.ndarray or list	-	-
curveFit	-	-	-

### **interpolated\_yield**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
interpolated_yield(maturity_dt: Date):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
maturity_dt	Date	-	-

### **plot**

*Display yield curve.*

```
plot(title):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
title	-	-	-

**--repr--**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.



## 7.13 yield\_curve\_model

### ***Class: FinCurveFitMethod()***

class FinCurveFitMethod():

### ***Class: CurveFitPolynomial()***

class CurveFitPolynomial():

### **CurveFitPolynomial**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
CurveFitPolynomial(power=3):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
power	-	-	3

### **interpolated\_yield**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_interpolated_yield(t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t	-	-	-

### **repr**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

### **print**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

**Class: CurveFitNelsonSiegel()**

```
class CurveFitNelsonSiegel():
```

**CurveFitNelsonSiegel**

*Fairly permissive bounds. Only tau\_1 is 1-100*

```
CurveFitNelsonSiegel(tau=None, bounds=[(-1, -1, -1, 0.5), (1, 1, 1, 100)]):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
tau	-	-	None
bounds	-	-	[(-1, -1, -1, 0.5), (1, 1, 1, 100)]

**interpolated\_yield**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_interpolated_yield(t, beta_1=None, beta_2=None,
                    beta_3=None, tau=None):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t	-	-	-
beta_1	-	-	None
beta_2	-	-	None
beta_3	-	-	None
tau	-	-	None

**\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

**Class: CurveFitNelsonSiegelSvensson()**

class CurveFitNelsonSiegelSvensson():

**CurveFitNelsonSiegelSvensson**

Create object to store calibration and functional form of NSS parametric fit.

```
CurveFitNelsonSiegelSvensson(tau_1=None, tau_2=None,
                             bounds=[(0, -1, -1, -1, 0, 1), (1, 1, 1, 1, 10, 100)]):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
tau_1	-	-	None
tau_2	-	-	None
bounds	-	-	[(0, -1, -1, -1, 0, 1), (1, 1, 1, 1, 10, 100)]

**\_interpolated\_yield**

PLEASE ADD A FUNCTION DESCRIPTION

```
_interpolated_yield(t, beta_1=None, beta_2=None, beta_3=None,
                   beta_4=None, tau_1=None, tau_2=None):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t	-	-	-
beta_1	-	-	None
beta_2	-	-	None
beta_3	-	-	None
beta_4	-	-	None
tau_1	-	-	None
tau_2	-	-	None

**\_\_repr\_\_**

PLEASE ADD A FUNCTION DESCRIPTION

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

Simple print function for backward compatibility.

```
_print():
```

The function arguments are described in the following table.

### ***Class: CurveFitBSpline()***

```
class CurveFitBSpline():
```

### **CurveFitBSpline**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
CurveFitBSpline(power=3, knots=[1, 3, 5, 10]):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
power	-	-	3
knots	-	-	[1, 3, 5, 10]

### **interpolated\_yield**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_interpolated_yield(t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t	-	-	-

### **\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

### **print**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

## 7.14 zero\_curve

**Class: *BondZeroCurve(DiscountCurve)***

### BondZeroCurve

*Fit a discount curve to a set of bond yields using the type of curve specified.*

```
BondZeroCurve(value_dt: Date,
               bonds: list,
               clean_prices: list,
               interp_type: InterpTypes = InterpTypes.FLAT_FWD_RATES):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
bonds	list	-	-
clean_prices	list	-	-
interp_type	InterpTypes	-	InterpTypes.FLAT_FWD_RATES

### \_bootstrap\_zero\_rates

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_bootstrap_zero_rates():
```

The function arguments are described in the following table.

### zero\_rate

*Calculate the zero rate to maturity date.*

```
zero_rate(dt: Date,
          frequencyType: FrequencyTypes = FrequencyTypes.CONTINUOUS):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	Date	-	-
frequencyType	FrequencyTypes	-	FrequencyTypes.CONTINUOUS

### df

*PLEASE ADD A FUNCTION DESCRIPTION*

```
df(dt: Date):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	Date	-	-

## survival\_prob

*PLEASE ADD A FUNCTION DESCRIPTION*

```
survival_prob(dt: Date):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	Date	-	-

## fwd

*Calculate the continuous forward rate at the forward date.*

```
fwd(dt: Date):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dt	Date	-	-

## fwd\_rate

*Calculate the forward rate according to the specified day count convention.*

```
fwd_rate(date1: Date,
         date2: Date,
         day_count_type: DayCountTypes):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
date1	Date	-	-
date2	Date	-	-
day_count_type	DayCountTypes	-	-

## plot

*Display yield curve.*

```
plot(title: str):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
title	str	-	-

### **`--repr--`**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
--repr__():
```

The function arguments are described in the following table.

### **`_print`**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

### **`_f`**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_f(df, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
df	-	-	-
*args	-	-	-

## 7.15 `__init__`





## Chapter 8

# financepy.products.rates

### Funding

This folder contains a set of funding-related products. These reflect contracts linked to funding indices such as Ibors and Overnight index rate swaps (OIS). It includes:

#### ***IborDeposit***

This is the basic Ibor instrument in which a party borrows an amount for a specified term and rate unsecured.

#### ***FinInterestRateFuture***

This is a class to handle interest rate futures contracts. This is an exchange-traded contract to receive or pay Ibor on a specified future date. It can be used to build the Libor term structure.

#### ***IborFRA***

This is a class to manage Forward Rate Agreements (FRAs) in which one party agrees to lock in a forward Ibor rate.

### ***Swaps***

#### ***FinFixedIborSwap***

This is a contract to exchange fixed rate coupons for floating Ibor rates. This class has functionality to value the swap contract and to calculate its risk.

#### ***FinFixedIborSwap - IN PROGRESS***

This is a contract to exchange fixed rate coupons for floating Ibor rates. This class has functionality to value the swap contract and to calculate its risk.

***IborIborSwap - IN PROGRESS***

This is a contract to exchange IBOR rates with different terms, also known as a basis swap. This class has functionality to value the swap contract and to calculate its risk.

***FinFixedOISwap - IN PROGRESS***

This is an OIS, a contract to exchange fixed rate coupons for the overnight index rate. This class has functionality to value the swap contract and to calculate its risk.

***IborOISwap - IN PROGRESS***

This is a contract to exchange overnight index rates for Ibor rates. This class has functionality to value the swap contract and to calculate its risk.

***Currency Swaps******FinFixedFixedCcySwap - IN PROGRESS***

This is a contract to exchange fixed rate coupons in two different currencies. This class has functionality to value the swap contract and to calculate its risk.

***IborIborCcySwap - IN PROGRESS***

This is a contract to exchange IBOR coupons in two different currencies. This class has functionality to value the swap contract and to calculate its risk.

***FinOIS***

This is a contract to exchange the daily compounded Overnight index swap rate for a fixed rate agreed at contract initiation.

***FinOISCurve***

This is a discount curve that is extracted by bootstrapping a set of OIS rates. The internal representation of the curve are discount factors on each of the OIS dates. Between these dates, discount factors are interpolated according to a specified scheme.

***IborSingleCurve***

This is a discount curve that is extracted by bootstrapping a set of Ibor deposits, Ibor FRAs and Ibor swap prices. The internal representation of the curve are discount factors on each of the deposit, FRA and swap maturity dates. Between these dates, discount factors are interpolated according to a specified scheme - see below.

## ***Options***

### ***IborCapFloor***

### ***IborSwaption***

This is a contract to buy or sell an option to enter into a swap to either pay or receive a fixed swap rate at a specific future expiry date. The model includes code that prices a payer or receiver swaption with the following models:

- Black's Model - Shifted Black Model - SABR - Shifted SABR - Hull-White Tree Model - Black-Karasinski Tree Model - Black-Derman-Toy Tree Model

### ***IborBermudanSwaption***

This is a contract to buy or sell an option to enter into a swap to either pay or receive a fixed swap rate at a specific future expiry date on specific coupon dates starting on a designated expiry date. The model includes code that prices a payer or receiver swaption with the following models:

- Hull-White Tree Model - Black-Karasinski Tree Model - Black-Derman-Toy Tree Model

It is also possible to price this using a Ibor Market Model. However for the moment this must be done directly via the Monte-Carlo implementation of the LMM found in `FinModelRatesLMM`.

## 8.1 bermudan\_swaption

### **Class: *IborBermudanSwaption***

This is the class for the Bermudan-style swaption, an option to enter into a swap (payer or receiver of the fixed coupon), that starts in the future and with a fixed maturity, at a swap rate fixed today. This swaption can be exercised on any of the fixed coupon payment dates after the first exercise date.

### **IborBermudanSwaption**

*Create a Bermudan swaption contract. This is an option to enter into a payer or receiver swap at a fixed coupon on all the fixed # leg coupon dates until the exercise date inclusive.*

```
IborBermudanSwaption(settle_dt: Date,
                      exercise_dt: Date,
                      maturity_dt: Date,
                      fixed_leg_type: SwapTypes,
                      exercise_type: FinExerciseTypes,
                      fixed_coupon: float,
                      fixed_freq_type: FrequencyTypes,
                      fixed_dc_type: DayCountTypes,
                      notional=ONE_MILLION,
                      float_freq_type=FrequencyTypes.QUARTERLY,
                      float_dc_type=DayCountTypes.THIRTY_E_360,
                      cal_type=CalendarTypes.WEEKEND,
                      bd_type=BusDayAdjustTypes.FOLLOWING,
                      dg_type=DateGenRuleTypes.BACKWARD) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
exercise_dt	Date	-	-
maturity_dt	Date	-	-
fixed_leg_type	SwapTypes	-	-
exercise_type	FinExerciseTypes	-	-
fixed_coupon	float	-	-
fixed_freq_type	FrequencyTypes	-	-
fixed_dc_type	DayCountTypes	-	-
notional	-	-	ONE_MILLION
float_freq_type	-	-	FrequencyTypes.QUARTERLY
float_dc_type	-	-	DayCountTypes.THIRTY_E_360
cal_type	-	-	CalendarTypes.WEEKEND
bd_type	-	-	BusDayAdjustTypes.FOLLOWING
dg_type	-	-	DateGenRuleTypes.BACKWARD

### **value**

*Value the Bermudan swaption using the specified model and a discount curve. The choices of model are the*

*Hull-White model, the Black-Karasinski model and the Black-Derman-Toy model.*

```
value(value_dt,
      discount_curve,
      model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
discount_curve	-	-	-
model	-	-	-

## **print\_swaption\_value**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
print_swaption_value():
```

The function arguments are described in the following table.

## **\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

## **\_print**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_print():
```

The function arguments are described in the following table.

## 8.2 callable\_swap

## 8.3 dual\_curve

### **Class: *IborDualCurve(DiscountCurve)***

Constructs an index curve as implied by the prices of Ibor deposits, FRAs and IRS. Discounting is assumed to be at a discount rate that is an input and usually derived from OIS rates.

### **IborDualCurve**

*Create an instance of a Ibor curve given a valuation date and a set of ibor deposits, ibor FRAs and ibor swaps. Some of these may be left None and the algorithm will just use what is provided. An interpolation method has also to be provided. The default is to use a linear interpolation for swap rates on coupon dates and to then assume flat forwards between these coupon dates. The curve will assign a discount factor of 1.0 to the valuation date.*

```
IborDualCurve(value_dt: Date,
               discount_curve: DiscountCurve,
               ibor_deposits: list,
               ibor_fras: list,
               ibor_swaps: list,
               interp_type: InterpTypes = InterpTypes.FLAT_FWD_RATES,
               check_refit: bool = False): # Set to True to test it works
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
discount_curve	DiscountCurve	-	-
ibor_deposits	list	-	-
ibor_fras	list	-	-
ibor_swaps	list	-	-
interp_type	InterpTypes	-	InterpTypes.FLAT_FWD_RATES
check_refit	bool	Set to True to test it works	False

### **\_build\_curve**

*Build curve based on interpolation.*

```
_build_curve():
```

The function arguments are described in the following table.

### **\_validate\_inputs**

*Validate the inputs for each of the Ibor products.*

```
_validate_inputs(ibor_deposits,
                 ibor_fras,
```



```
ibor_swaps):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
ibor_deposits	-	-	-
ibor_fras	-	-	-
ibor_swaps	-	-	-

### **`_build_curve_using_1d_solver`**

*Construct the discount curve using a bootstrap approach. This is the non-linear slower method that allows the user to choose a number of interpolation approaches between the swap rates and other rates. It involves the use of a solver.*

```
_build_curve_using_1d_solver():
```

The function arguments are described in the following table.

### **`_check_refits`**

*Ensure that the Ibor curve refits the calibration instruments.*

```
_check_refits(depoTol, fraTol, swapTol):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
depoTol	-	-	-
fraTol	-	-	-
swapTol	-	-	-

### **`__repr__`**

*Print out the details of the Ibor curve.*

```
__repr__():
```

The function arguments are described in the following table.

### **`_print`**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

**f***Root search objective function for swaps*

```
_f(df, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
df	-	-	-
*args	-	-	-

**g***Root search objective function for swaps*

```
_g(df, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
df	-	-	-
*args	-	-	-

## 8.4 ibor\_basis\_swap

### ***Class: IborBasisSwap***

Class for managing an Ibor-Ibor basis swap contract. This is a contract in which a floating leg with one LIBOR tenor is exchanged for a floating leg payment in a different LIBOR tenor. There is no exchange of par. The contract is entered into at zero initial cost. The contract lasts from an effective date to a specified maturity date.

The value of the contract is the NPV of the two coupon streams. Discounting is done on a supplied discount curve which can be different from the two index discount from which the implied index rates are extracted.

### **IborBasisSwap**

*Create a Ibor basis swap contract giving the contract start date, its maturity, frequency and day counts on the two floating legs and notional. The floating leg parameters have default values that can be overwritten if needed. The start date is contractual and is the same as the settlement date for a new swap. It is the date on which interest starts to accrue. The end of the contract is the termination date. This is not adjusted for business days. The adjusted termination date is called the maturity date. This is calculated.*

```
IborBasisSwap(effective_dt: Date, # Date interest starts to accrue
               term_dt_or_tenor: (Date, str), # Date contract ends
               leg1Type: SwapTypes,
               leg1FreqType: FrequencyTypes = FrequencyTypes.QUARTERLY,
               leg1DayCountType: DayCountTypes = DayCountTypes.THIRTY_E_360,
               leg1Spread: float = 0.0,
               leg2FreqType: FrequencyTypes = FrequencyTypes.QUARTERLY,
               leg2DayCountType: DayCountTypes = DayCountTypes.THIRTY_E_360,
               leg2Spread: float = 0.0,
               notional: float = ONE_MILLION,
               cal_type: CalendarTypes = CalendarTypes.WEEKEND,
               bd_type: BusDayAdjustTypes = BusDayAdjustTypes.FOLLOWING,
               dg_type: DateGenRuleTypes = DateGenRuleTypes.BACKWARD):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
effective_dt	Date	Date interest starts to accrue	-
term_dt_or_tenor	Date or str	Date contract ends	-
leg1Type	SwapTypes	-	-
leg1FreqType	FrequencyTypes	-	FrequencyTypes.QUARTERLY
leg1DayCountType	DayCountTypes	-	DayCountTypes.THIRTY_E_360
leg1Spread	float	-	0.0
leg2FreqType	FrequencyTypes	-	FrequencyTypes.QUARTERLY
leg2DayCountType	DayCountTypes	-	DayCountTypes.THIRTY_E_360
leg2Spread	float	-	0.0
notional	float	-	ONE_MILLION
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.FOLLOWING
dg_type	DateGenRuleTypes	-	DateGenRuleTypes.BACKWARD

## value

*Value the interest rate swap on a value date given a single Ibor discount curve and an index curve for the Ibors on each swap leg.*

```
value(value_dt: Date,
      discount_curve: DiscountCurve,
      index_curveLeg1: DiscountCurve = None,
      index_curveLeg2: DiscountCurve = None,
      firstFixingRateLeg1=None,
      firstFixingRateLeg2=None):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
discount_curve	DiscountCurve	-	-
index_curveLeg1	DiscountCurve	-	None
index_curveLeg2	DiscountCurve	-	None
firstFixingRateLeg1	-	-	None
firstFixingRateLeg2	-	-	None

## print\_float\_leg\_1\_pv

*Prints the fixed leg amounts without any valuation details. Shows the dates and sizes of the promised fixed leg flows.*

```
print_float_leg_1_pv():
```

The function arguments are described in the following table.

**print\_float\_leg\_2\_pv**

*Prints the fixed leg amounts without any valuation details. Shows the dates and sizes of the promised fixed leg flows.*

```
print_float_leg_2_pv():
```

The function arguments are described in the following table.

**print\_payments**

*Prints the fixed leg amounts without any valuation details. Shows the dates and sizes of the promised fixed leg flows.*

```
print_payments():
```

The function arguments are described in the following table.

**\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

*Print a list of the unadjusted coupon payment dates used in analytic calculations for the bond.*

```
_print():
```

The function arguments are described in the following table.

## 8.5 ibor\_cap\_floor

### **Enumerated Type: *IborCapFloorModelTypes***

This enumerated type has the following values:

- BLACK
- SHIFTED\_BLACK
- SABR

### **Class: *IborCapFloor()***

Class for Caps and Floors. These are contracts which observe a Ibor reset L on a future start date and then make a payoff at the end of the Ibor period which is  $\text{Max}[L-K,0]$  for a cap and  $\text{Max}[K-L,0]$  for a floor. This is then day count adjusted for the Ibor period and then scaled by the contract notional to produce a valuation. A number of models can be selected from.

### **IborCapFloor**

*Initialise IborCapFloor object.*

```
IborCapFloor(start_dt: Date,
              maturity_dt_or_tenor: (Date, str),
              option_type: FinCapFloorTypes,
              strike_rate: float,
              last_fixing: Optional[float] = None,
              freq_type: FrequencyTypes = FrequencyTypes.QUARTERLY,
              dc_type: DayCountTypes = DayCountTypes.THIRTY_E_360_ISDA,
              notional: float = ONE_MILLION,
              cal_type: CalendarTypes = CalendarTypes.WEEKEND,
              bd_type: BusDayAdjustTypes = BusDayAdjustTypes.FOLLOWING,
              dg_type: DateGenRuleTypes = DateGenRuleTypes.BACKWARD):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
start_dt	Date	-	-
maturity_dt_or_tenor	Date or str	-	-
option_type	FinCapFloorTypes	-	-
strike_rate	float	-	-
last_fixing	Optional[float]	-	None
freq_type	FrequencyTypes	-	FrequencyTypes.QUARTERLY
dc_type	DayCountTypes	-	DayCountTypes.THIRTY_E_360_ISDA
notional	float	-	ONE_MILLION
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.FOLLOWING
dg_type	DateGenRuleTypes	-	DateGenRuleTypes.BACKWARD

**\_generate\_dts***PLEASE ADD A FUNCTION DESCRIPTION*

```
_generate_dts():
```

The function arguments are described in the following table.

**value**

*Value the cap or floor using the chosen model which specifies the volatility of the Ibor rate to the cap start date.*

```
value(value_dt, libor_curve, model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
libor_curve	-	-	-
model	-	-	-

**value\_caplet\_floor\_let**

*Value the caplet or floorlet using a specific model.*

```
value_caplet_floor_let(value_dt,
                        caplet_start_dt,
                        caplet_end_dt,
                        libor_curve,
                        model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
caplet_start_dt	-	-	-
caplet_end_dt	-	-	-
libor_curve	-	-	-
model	-	-	-

**print\_leg**

*Prints the cap floor payment amounts.*

```
print_leg():
```

The function arguments are described in the following table.

**--repr--***PLEASE ADD A FUNCTION DESCRIPTION*

```
--repr__():
```

The function arguments are described in the following table.

**\_print***PLEASE ADD A FUNCTION DESCRIPTION*

```
_print():
```

The function arguments are described in the following table.



## 8.6 ibor\_conventions

### ***Class: IborConventions()***

class IborConventions():

### **IborConventions**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
IborConventions(currencyName: str,  
                 indexName: str = "LIBOR"):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
currencyName	str	-	-
indexName	str	-	"LIBOR"

## 8.7 ibor\_deposit

### **Class: *IborDeposit***

An Ibor deposit is an agreement to borrow money interbank at the Ibor fixing rate starting on the start date and repaid on the maturity date with the interest amount calculated according to a day count convention and dates calculated according to a calendar and business day adjustment rule.

Care must be taken to calculate the correct start (settlement) date. Start with the trade (value) date which is typically today, we may need to add on a number of business days (spot days) to get to the settlement date. The maturity date is then calculated by adding on the deposit tenor/term to the settlement date and adjusting for weekends and holidays according to the calendar and adjustment type.

Note that for over-night (ON) depos the settlement date is today with maturity in one business day. For tomorrow-next (TN) depos the settlement is in one business day with maturity on the following business day. For later maturity deposits, settlement is usually in 1-3 business days. The number of days depends on the currency and jurisdiction of the deposit contract.

### **IborDeposit**

*Create a Libor deposit object which takes the start date when the amount of notional is borrowed, a maturity date or a tenor and the deposit rate. If a tenor is used then this is added to the start date and the calendar and business day adjustment method are applied if the maturity date fall on a holiday. Note that in order to calculate the start date you add the spot business days to the trade date which usually today.*

```
IborDeposit(start_dt: Date, # When the interest starts to accrue
            maturity_dt_or_tenor: (Date, str), # Repayment of interest
            deposit_rate: float, # MM rate using simple interest
            dc_type: DayCountTypes, # How year fraction is calculated
            notional: float = 100.0, # Amount borrowed
            cal_type: CalendarTypes=CalendarTypes.WEEKEND, # Maturity date
            bd_type: BusDayAdjustTypes=BusDayAdjustTypes.MODIFIED_FOLLOWING):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
start_dt	Date	When the interest starts to accrue	-
maturity_dt_or_tenor	Date or str	Repayment of interest	-
deposit_rate	float	MM rate using simple interest	-
dc_type	DayCountTypes	How year fraction is calculated	-
notional	float	Amount borrowed	100.0
cal_type	CalendarTypes	Maturity date	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.MODIFIED_FOLL

### **maturity\_df**

*Returns the maturity date discount factor that would allow the Libor curve to reprice the contractual market deposit rate. Note that this is a forward discount factor that starts on settlement date.*

```
_maturity_df():
```

The function arguments are described in the following table.

## value

*Determine the value of an existing Libor Deposit contract given a valuation date and a Libor curve. This is simply the PV of the future repayment plus interest discounted on the current Libor curve.*

```
value(value_dt: Date,
      libor_curve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
libor_curve	-	-	-

## print\_payments

*Print the date and size of the future repayment.*

```
print_payments(value_dt: Date):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-

## \_\_repr\_\_

*Print the contractual details of the Libor deposit.*

```
__repr__():
```

The function arguments are described in the following table.

## \_print

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_print():
```

The function arguments are described in the following table.

## 8.8 ibor\_fra

### ***Class: IborFRA***

Class for managing LIBOR forward rate agreements. A forward rate agreement is an agreement to exchange a fixed pre-agreed rate for a floating rate linked to LIBOR that is not known until some specified future fixing date. The FRA payment occurs on or soon after this date on the FRA settlement date. Typically the timing gap is two days.

A FRA is used to hedge a Ibor quality loan or lend of some agreed notional amount. This period starts on the settlement date of the FRA and ends on the maturity date of the FRA. For example a 1x4 FRA relates to a Ibor starting in 1 month for a loan period ending in 4 months. Hence it links to 3-month Ibor rate. The amount received by a payer of fixed rate at settlement is:

$$\text{acc}(1,2) * (\text{Ibor}(1,2) - \text{FRA RATE}) / (1 + \text{acc}(0,1) * \text{Ibor}(0,1))$$

So the value at time 0 is

$$\text{acc}(1,2) * (\text{FWD Ibor}(1,2) - \text{FRA RATE}) * \text{df}(0,2)$$

If the base date of the curve is before the value date then we forward adjust this amount to that value date. For simplicity I have assumed that the fixing date and the settlement date are the same date. This should be amended later.

The valuation below incorporates a dual curve approach.

## IborFRA

*Create a Forward Rate Agreement object.*

```
IborFRA(start_dt: Date, # The date the FRA starts to accrue
        # End of the Ibor rate period
        maturity_dt_or_tenor: (Date, str),
        fraRate: float, # The fixed contractual FRA rate
        dc_type: DayCountTypes, # For interest period
        notional: float = 100.0,
        payFixedRate: bool = True, # True if the FRA rate is being paid
        cal_type: CalendarTypes = CalendarTypes.WEEKEND,
        bd_type: BusDayAdjustTypes = BusDayAdjustTypes.MODIFIED_FOLLOWING):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
start_dt	Date	The date the FRA starts to accrue	-
maturity_dt_or_tenor	Date or str	-	-
fraRate	float	The fixed contractual FRA rate	-
dc_type	DayCountTypes	For interest period	-
notional	float	-	100.0
payFixedRate	bool	True if the FRA rate is being paid	True
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.MODIFIED_FOLI

## value

*Determine mark to market value of a FRA contract based on the market FRA rate. We allow the pricing to have a different curve for the Libor index and the discounting of promised cash flows.*

```
value(value_dt: Date,
      discount_curve: DiscountCurve,
      index_curve: DiscountCurve = None):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
discount_curve	DiscountCurve	-	-
index_curve	DiscountCurve	-	None

## maturity\_df

*Determine the maturity date index discount factor needed to refit the market FRA rate. In a dual-curve world, this is not the discount rate discount factor but the index curve discount factor.*

```
maturity_df(index_curve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
index_curve	-	-	-

## print\_payments

*Determine the value of the Deposit given a Ibor curve.*

```
print_payments(value_dt):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-

## \_\_repr\_\_

PLEASE ADD A FUNCTION DESCRIPTION

```
__repr__():
```

The function arguments are described in the following table.

**\_print***PLEASE ADD A FUNCTION DESCRIPTION*

```
_print():
```

The function arguments are described in the following table.

## 8.9 ibor\_future

### **Class: *IborFuture***

#### **IborFuture**

Create an interest rate futures contract which has the same conventions as those traded on the CME. The current `_dt`, the tenor of the future, the number of the future and the accrual convention and the contract size should be provided.

```
IborFuture(today_dt: Date,
           future_number: int, # The number of the future after today_dt
           futureTenor: str = "3M", # '1M', '2M', '3M'
           dc_type: DayCountTypes = DayCountTypes.ACT_360,
           contract_size: float = ONE_MILLION):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
today_dt	Date	-	-
future_number	int	The number of the future after today_dt	-
futureTenor	str	'1M', '2M', '3M'	"3M"
dc_type	DayCountTypes	-	DayCountTypes.ACT_360
contract_size	float	-	ONE_MILLION

#### **to\_fra**

Convert the futures contract to a *IborFRA* object so it can be used to bootstrap a *Ibor* curve. For this we need to adjust the futures rate using the convexity correction.

```
to_fra(futures_price, convexity):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
futures_price	-	-	-
convexity	-	-	-

#### **futures\_rate**

Calculate implied futures rate from the futures price.

```
futures_rate(futures_price):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
futures_price	-	-	-

**fra\_rate**

Convert futures price and convexity to a FRA rate using the BBG negative convexity (in percent). This is then divided by 100 before being added to the futures rate.

```
fra_rate(futures_price, convexity):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
futures_price	-	-	-
convexity	-	-	-

**convexity**

Calculation of the convexity adjustment between FRAs and interest rate futures using the Hull-White model as described in technical note in link below: <http://www-2.rotman.utoronto.ca/hull/TechnicalNotes/TechnicalNote1.pdf> NOTE THIS DOES NOT APPEAR TO AGREE WITH BLOOMBERG!! INVESTIGATE.

```
convexity(value__dt, volatility, mean_reversion):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value__dt	-	-	-
volatility	-	-	-
mean_reversion	-	-	-

**\_\_repr\_\_**

Print a list of the unadjusted coupon payment \_dts used in analytic calculations for the bond.

```
__repr__():
```

The function arguments are described in the following table.



## 8.10 ibor\_lmm\_products

**Class:** *IborLMMProducts()*

### IborLMMProducts

Create a European-style swaption by defining the exercise date of the swaption, and all of the details of the underlying interest rate swap including the fixed coupon and the details of the fixed and the floating leg payment schedules.

```
IborLMMProducts(settle_dt: Date,
                 maturity_dt: Date,
                 float_freq_type: FrequencyTypes = FrequencyTypes.QUARTERLY,
                 float_dc_type: DayCountTypes = DayCountTypes.THIRTY_E_360,
                 cal_type: CalendarTypes = CalendarTypes.WEEKEND,
                 bd_type: BusDayAdjustTypes = BusDayAdjustTypes.FOLLOWING,
                 dg_type: DateGenRuleTypes = DateGenRuleTypes.BACKWARD):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
maturity_dt	Date	-	-
float_freq_type	FrequencyTypes	-	FrequencyTypes.QUARTERLY
float_dc_type	DayCountTypes	-	DayCountTypes.THIRTY_E_360
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.FOLLOWING
dg_type	DateGenRuleTypes	-	DateGenRuleTypes.BACKWARD

### simulate\_1f

Run the one-factor simulation of the evolution of the forward Ibors to generate and store all of the Ibor forward rate paths.

```
simulate_1f(discount_curve,
            vol_curve: IborCapVolCurve,
            num_paths: int = 1000,
            numeraireIndex: int = 0,
            use_sobol: bool = True,
            seed: int = 42):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
discount_curve	-	-	-
vol_curve	IborCapVolCurve	-	-
num_paths	int	-	1000
numeraireIndex	int	-	0
use_sobol	bool	-	True
seed	int	-	42

## simulate\_mf

Run the simulation to generate and store all of the Ibor forward rate paths. This is a multi-factorial version so the user must input a numpy array consisting of a column for each factor and the number of rows must equal the number of grid times on the underlying simulation grid. **CHECK THIS.**

```
simulate_mf(discount_curve,
            numFactors: int,
            lambdas: np.ndarray,
            num_paths: int = 10000,
            numeraireIndex: int = 0,
            use_sobol: bool = True,
            seed: int = 42):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
discount_curve	-	-	-
numFactors	int	-	-
lambdas	np.ndarray	-	-
num_paths	int	-	10000
numeraireIndex	int	-	0
use_sobol	bool	-	True
seed	int	-	42

## simulate\_nf

Run the simulation to generate and store all of the Ibor forward rate paths using a full factor reduction of the fwd-fwd correlation matrix using Cholesky decomposition.

```
simulate_nf(discount_curve,
            vol_curve: IborCapVolCurve,
            corr_matrix: np.ndarray,
            model_type: ModelLMMModelTypes,
            num_paths: int = 1000,
            numeraire_index: int = 0,
            use_sobol: bool = True,
            seed: int = 42):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
discount_curve	-	-	-
vol_curve	IborCapVolCurve	-	-
corr_matrix	np.ndarray	-	-
model_type	ModelLMMModelTypes	-	-
num_paths	int	-	1000
numeraire_index	int	-	0
use_sobol	bool	-	True
seed	int	-	42

## value\_swaption

Value a swaption in the LMM model using simulated paths of the forward curve. This relies on pricing the fixed leg of the swap and assuming that the floating leg will be worth par. As a result we only need simulate Ibors with the frequency of the fixed leg.

```
value_swaption(settle_dt: Date,
               exercise_dt: Date,
               maturity_dt: Date,
               swaption_type: SwapTypes,
               fixed_coupon: float,
               fixed_freq_type: FrequencyTypes,
               fixed_dc_type: DayCountTypes,
               notional: float = ONE_MILLION,
               float_freq_type: FrequencyTypes = FrequencyTypes.QUARTERLY,
               float_dc_type: DayCountTypes = DayCountTypes.THIRTY_E_360,
               cal_type: CalendarTypes = CalendarTypes.WEEKEND,
               bd_type: BusDayAdjustTypes = BusDayAdjustTypes.FOLLOWING,
               dg_type: DateGenRuleTypes = DateGenRuleTypes.BACKWARD):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
exercise_dt	Date	-	-
maturity_dt	Date	-	-
swaption_type	SwapTypes	-	-
fixed_coupon	float	-	-
fixed_freq_type	FrequencyTypes	-	-
fixed_dc_type	DayCountTypes	-	-
notional	float	-	ONE_MILLION
float_freq_type	FrequencyTypes	-	FrequencyTypes.QUARTERLY
float_dc_type	DayCountTypes	-	DayCountTypes.THIRTY_E_360
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.FOLLOWING
dg_type	DateGenRuleTypes	-	DateGenRuleTypes.BACKWARD

## value\_cap\_floor

Value a cap or floor in the LMM.

```
value_cap_floor(settle_dt: Date,
               maturity_dt: Date,
               cap_floor_type: FinCapFloorTypes,
               cap_floor_rate: float,
               freq_type: FrequencyTypes = FrequencyTypes.QUARTERLY,
               dc_type: DayCountTypes = DayCountTypes.ACT_360,
               notional: float = ONE_MILLION,
               cal_type: CalendarTypes = CalendarTypes.WEEKEND,
               bd_type: BusDayAdjustTypes = BusDayAdjustTypes.FOLLOWING,
               dg_type: DateGenRuleTypes = DateGenRuleTypes.BACKWARD):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
maturity_dt	Date	-	-
cap_floor_type	FinCapFloorTypes	-	-
cap_floor_rate	float	-	-
freq_type	FrequencyTypes	-	FrequencyTypes.QUARTERLY
dc_type	DayCountTypes	-	DayCountTypes.ACT_360
notional	float	-	ONE MILLION
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.FOLLOWING
dg_type	DateGenRuleTypes	-	DateGenRuleTypes.BACKWARD

### **`__repr__`**

*Function to allow us to print the LMM Products details.*

```
__repr__():
```

The function arguments are described in the following table.

### **`_print`**

*Alternative print method.*

```
_print():
```

The function arguments are described in the following table.

## 8.11 ibor\_single\_curve

### ***Class: IborSingleCurve(DiscountCurve)***

Constructs one discount and index curve as implied by prices of Ibor deposits, FRAs and IRS. Discounting is assumed to be at Libor and the value of the floating leg (including a notional) is assumed to be par. This approach has been overtaken since 2008 as OIS discounting has become the agreed discounting approach for ISDA derivatives. This curve method is therefore intended for those happy to assume simple Libor discounting.

The curve date is the date on which we are performing the valuation based on the information available on the curve date. Typically it is the date on which an amount of 1 unit paid has a present value of 1. This class inherits from FinDiscountCurve and so it has all of the methods that that class has.

There are two main curve-building approaches:

1) The first uses a bootstrap that interpolates swap rates linearly for coupon dates that fall between the swap maturity dates. With this, we can solve for the discount factors iteratively without need of a solver. This will give us a set of discount factors on the grid dates that refit the market exactly. However, when extracting discount factors, we will then assume flat forward rates between these coupon dates. There is no contradiction as it is as though we had been quoted a swap curve with all of the market swap rates, and with an additional set as though the market quoted swap rates at a higher frequency than the market.

2) The second uses a bootstrap that uses only the swap rates provided but which also assumes that forwards are flat between these swap maturity dates. This approach is non-linear and so requires a solver. Consequently it is slower. Its advantage is that we can switch interpolation schemes to provide a smoother or other functional curve shape which may have a more economically justifiable shape. However the root search makes it slower.

### **IborSingleCurve**

*Create an instance of a FinIbor curve given a valuation date and a set of ibor deposits, ibor FRAs and ibor swaps. Some of these may be left None and the algorithm will just use what is provided. An interpolation method has also to be provided. The default is to use a linear interpolation for swap rates on coupon dates and to then assume flat forwards between these coupon dates. The curve will assign a discount factor of 1.0 to the valuation date. If no instrument is starting on the valuation date, the curve is then assumed to be flat out to the first instrument using its zero rate.*

```
IborSingleCurve(value_dt: Date, # This is the trade date (not T+2)
                 ibor_deposits: list,
                 ibor_fras: list,
                 ibor_swaps: list,
                 interp_type: InterpTypes = InterpTypes.FLAT_FWD_RATES,
                 check_refit: bool = False): # Set to True to test it works
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	This is the trade date (not T+2)	-
ibor_deposits	list	-	-
ibor_fras	list	-	-
ibor_swaps	list	-	-
interp_type	InterpTypes	-	InterpTypes.FLAT_FWD_RATES
check_refit	bool	Set to True to test it works	False

## **`_build_curve`**

*Build curve based on interpolation.*

```
_build_curve() :
```

The function arguments are described in the following table.

## **`_validate_inputs`**

*Validate the inputs for each of the Ibor products.*

```
_validate_inputs(ibor_deposits,
                 ibor_fras,
                 ibor_swaps) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
ibor_deposits	-	-	-
ibor_fras	-	-	-
ibor_swaps	-	-	-

## **`_build_curve_using_1d_solver`**

*Construct the discount curve using a bootstrap approach. This is the non-linear slower method that allows the user to choose a number of interpolation approaches between the swap rates and other rates. It involves the use of a solver.*

```
_build_curve_using_1d_solver() :
```

The function arguments are described in the following table.

## **`_build_curve_using_quadratic_minimiser`**

*Construct the discount curve using a minimisation approach. This is the This enables a more complex interpolation scheme.*

```
_build_curve_using_quadratic_minimiser():
```

The function arguments are described in the following table.

### **`_build_curve_linear_swap_rate_interpolation`**

*Construct the discount curve using a bootstrap approach. This is the linear swap rate method that is fast and exact as it does not require the use of a solver. It is also market standard.*

```
_build_curve_linear_swap_rate_interpolation():
```

The function arguments are described in the following table.

### **`_check_refits`**

*Ensure that the Ibor curve refits the calibration instruments.*

```
_check_refits(depoTol, fraTol, swapTol):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
depoTol	-	-	-
fraTol	-	-	-
swapTol	-	-	-

### **`__repr__`**

*Print out the details of the Ibor curve.*

```
__repr__():
```

The function arguments are described in the following table.

### **`_print`**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

**f***Root search objective function for IRS*

```
_f(df, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
df	-	-	-
*args	-	-	-

**g***Root search objective function for FRAs*

```
_g(df, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
df	-	-	-
*args	-	-	-

**\_cost\_function***Root search objective function for swaps*

```
_cost_function(dfs, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
dfs	-	-	-
*args	-	-	-



## 8.12 ibor\_swap

### ***Class: IborSwap***

Class for managing a standard Fixed vs IBOR swap. This is a contract in which a fixed payment leg is exchanged for a series of floating rates payments linked to some IBOR index rate. There is no exchange of principal. The contract is entered into at zero initial cost. The contract lasts from a start date to a specified maturity date.

The floating rate is not known fully until the end of the preceding payment period. It is set in advance and paid in arrears.

The value of the contract is the NPV of the two coupon streams. Discounting is done on a supplied discount curve which is separate from the curve from which the implied index rates are extracted.

### **IborSwap**

*Create an interest rate swap contract giving the contract start date, its maturity, fixed coupon, fixed leg frequency, fixed leg day count convention and notional. The floating leg parameters have default values that can be overwritten if needed. The start date is contractual and is the same as the settlement date for a new swap. It is the date on which interest starts to accrue. The end of the contract is the termination date. This is not adjusted for business days. The adjusted termination date is called the maturity date. This is calculated.*

```
IborSwap(effective_dt: Date, # Date interest starts to accrue
         term_dt_or_tenor: (Date, str), # Date contract ends
         fixed_leg_type: SwapTypes,
         fixed_coupon: float, # Fixed coupon (annualised)
         fixed_freq_type: FrequencyTypes,
         fixed_dc_type: DayCountTypes,
         notional: float = ONE_MILLION,
         float_spread: float = 0.0,
         float_freq_type: FrequencyTypes = FrequencyTypes.QUARTERLY,
         float_dc_type: DayCountTypes = DayCountTypes.THIRTY_E_360,
         cal_type: CalendarTypes = CalendarTypes.WEEKEND,
         bd_type: BusDayAdjustTypes = BusDayAdjustTypes.FOLLOWING,
         dg_type: DateGenRuleTypes = DateGenRuleTypes.BACKWARD):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
effective_dt	Date	Date interest starts to accrue	-
term_dt_or_tenor	Date or str	Date contract ends	-
fixed_leg_type	SwapTypes	-	-
fixed_coupon	float	Fixed coupon (annualised)	-
fixed_freq_type	FrequencyTypes	-	-
fixed_dc_type	DayCountTypes	-	-
notional	float	-	ONE_MILLION
float_spread	float	-	0.0
float_freq_type	FrequencyTypes	-	FrequencyTypes.QUARTERLY
float_dc_type	DayCountTypes	-	DayCountTypes.THIRTY_E_360
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.FOLLOWING
dg_type	DateGenRuleTypes	-	DateGenRuleTypes.BACKWARD

## value

*Value the interest rate swap on a value date given a single Ibor discount curve.*

```
value(value_dt: Date,
      discount_curve: DiscountCurve,
      index_curve: DiscountCurve = None,
      firstFixingRate=None):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
discount_curve	DiscountCurve	-	-
index_curve	DiscountCurve	-	None
firstFixingRate	-	-	None

## pv01

*Calculate the value of 1 basis point coupon on the fixed leg.*

```
pv01(value_dt, discount_curve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
discount_curve	-	-	-

## swap\_rate

*Calculate the fixed leg coupon that makes the swap worth zero. If the valuation date is before the swap payments start then this is the forward swap rate as it starts in the future. The swap rate is then a forward*

swap rate and so we use a forward discount factor. If the swap fixed leg has begun then we have a spot starting swap. The swap rate can also be calculated in a dual curve approach but in this case the first fixing on the floating leg is needed.

```
swap_rate(value_dt: Date,
          discount_curve: DiscountCurve,
          index_curve: DiscountCurve = None,
          first_fixing: float = None):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
discount_curve	DiscountCurve	-	-
index_curve	DiscountCurve	-	None
first_fixing	float	-	None

### cash\_settled\_pv01

Calculate the forward value of an annuity of a forward starting swap using a single flat discount rate equal to the swap rate. This is used in the pricing of a cash-settled swaption in the *IborSwaption* class. This method does not affect the standard valuation methods.

```
cash_settled_pv01(value_dt,
                  flat_swap_rate,
                  freq_type):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
flat_swap_rate	-	-	-
freq_type	-	-	-

### print\_fixed\_leg\_pv

Prints the fixed leg amounts without any valuation details. Shows the dates and sizes of the promised fixed leg flows.

```
print_fixed_leg_pv():
```

The function arguments are described in the following table.

### print\_float\_leg\_pv

Prints the fixed leg amounts without any valuation details. Shows the dates and sizes of the promised fixed leg flows.

```
print_float_leg_pv() :
```

The function arguments are described in the following table.

### **print\_payments**

*Prints the fixed leg amounts without any valuation details. Shows the dates and sizes of the promised fixed leg flows.*

```
print_payments() :
```

The function arguments are described in the following table.

### **\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__() :
```

The function arguments are described in the following table.

### **\_print**

*Print a list of the unadjusted coupon payment dates used in analytic calculations for the bond.*

```
_print() :
```

The function arguments are described in the following table.

## 8.13 ibor\_swaption

### **Class: *IborSwaption()***

This is the class for the European-style swaption, an option to enter into a swap (payer or receiver of the fixed coupon), that starts in the future and with a fixed maturity, at a swap rate fixed today.

### **IborSwaption**

*Create a European-style swaption by defining the exercise date of the swaption, and all of the details of the underlying interest rate swap including the fixed coupon and the details of the fixed and the floating leg payment schedules. Bermudan style swaption should be priced using the *IborBermudanSwaption* class.*

```
IborSwaption(settle_dt: Date,
              exercise_dt: Date,
              maturity_dt: Date,
              fixed_leg_type: SwapTypes,
              fixed_coupon: float,
              fixed_freq_type: FrequencyTypes,
              fixed_dc_type: DayCountTypes,
              notional: float = ONE_MILLION,
              float_freq_type: FrequencyTypes = FrequencyTypes.QUARTERLY,
              float_dc_type: DayCountTypes = DayCountTypes.THIRTY_E_360,
              cal_type: CalendarTypes = CalendarTypes.WEEKEND,
              bd_type: BusDayAdjustTypes = BusDayAdjustTypes.FOLLOWING,
              dg_type: DateGenRuleTypes = DateGenRuleTypes.BACKWARD):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
settle_dt	Date	-	-
exercise_dt	Date	-	-
maturity_dt	Date	-	-
fixed_leg_type	SwapTypes	-	-
fixed_coupon	float	-	-
fixed_freq_type	FrequencyTypes	-	-
fixed_dc_type	DayCountTypes	-	-
notional	float	-	ONE_MILLION
float_freq_type	FrequencyTypes	-	FrequencyTypes.QUARTERLY
float_dc_type	DayCountTypes	-	DayCountTypes.THIRTY_E_360
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.FOLLOWING
dg_type	DateGenRuleTypes	-	DateGenRuleTypes.BACKWARD

### **value**

*Valuation of a Ibor European-style swaption using a choice of models on a specified valuation date. Models include *FinModelBlack*, *FinModelBlackShifted*, *SABR*, *SABRShifted*, *FinModelHW*, *FinModelBK* and *FinModelBDT*. The last two involved a tree-based valuation.*

```
value(value_dt,
      discount_curve,
      model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
discount_curve	-	-	-
model	-	-	-

### cash\_settled\_value

*Valuation of a Ibor European-style swaption using a cash settled approach which is a market convention that used Black's model and that discounts all of the future payments at a flat swap rate. Note that the Black volatility for this valuation should in general not equal the Black volatility for the standard arbitrage-free valuation.*

```
cash_settled_value(value_dt: Date,
                  discount_curve,
                  swap_rate: float,
                  model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
discount_curve	-	-	-
swap_rate	float	-	-
model	-	-	-

### print\_swap\_fixed\_leg

*PLEASE ADD A FUNCTION DESCRIPTION*

```
print_swap_fixed_leg():
```

The function arguments are described in the following table.

### print\_swap\_float\_leg

*PLEASE ADD A FUNCTION DESCRIPTION*

```
print_swap_float_leg():
```

The function arguments are described in the following table.

**--repr--**

*Function to allow us to print the swaption details.*

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

*Alternative print method.*

```
_print():
```

The function arguments are described in the following table.

## 8.14 ois

### ***Enumerated Type: FinCompoundingTypes***

This enumerated type has the following values:

- COMPOUNDED
- OVERNIGHT\_COMPOUNDED\_ANNUAL\_RATE
- AVERAGED
- AVERAGED\_DAILY

### ***Class: OIS***

Class for managing overnight index rate swaps (OIS) and Fed Fund swaps. This is a contract in which a fixed payment leg is exchanged for a payment which pays the rolled-up overnight index rate (OIR). There is no exchange of par. The contract is entered into at zero initial cost.

NOTE: This class is almost identical to IborSwap but will possibly deviate as distinctions between the two become clear to me. If not they will be converged (or inherited) to avoid duplication.

The contract lasts from a start date to a specified maturity date. The fixed coupon is the OIS fixed rate for the corresponding tenor which is set at contract initiation.

The floating rate is not known fully until the end of each payment period. Its calculated at the contract maturity and is based on daily observations of the overnight index rate which are compounded according to a specific convention. Hence the OIS floating rate is determined by the history of the OIS rates.

In its simplest form, there is just one fixed rate payment and one floating rate payment at contract maturity. However when the contract becomes longer than one year the floating and fixed payments become periodic, usually with annual exchanges of cash.

The value of the contract is the NPV of the two coupon streams. Discounting is done on the OIS curve which is itself implied by the term structure of market OIS rates.

## OIS

*Create an overnight index swap contract giving the contract start date, its maturity, fixed coupon, fixed leg frequency, fixed leg day count convention and notional. The floating leg parameters have default values that can be overwritten if needed. The start date is contractual and is the same as the settlement date for a new swap. It is the date on which interest starts to accrue. The end of the contract is the termination date. This is not adjusted for business days. The adjusted termination date is called the maturity date. This is calculated.*

```
OIS(effective_dt: Date, # Date interest starts to accrue
    term_dt_or_tenor: (Date, str), # Date contract ends
    fixed_leg_type: SwapTypes,
    fixed_coupon: float, # Fixed coupon (annualised)
    fixed_freq_type: FrequencyTypes,
    fixed_dc_type: DayCountTypes,
    notional: float = ONE_MILLION,
    payment_lag: int = 0, # Number of days after period payment occurs
    float_spread: float = 0.0,
    float_freq_type: FrequencyTypes = FrequencyTypes.ANNUAL,
    float_dc_type: DayCountTypes = DayCountTypes.THIRTY_E_360,
    cal_type: CalendarTypes = CalendarTypes.WEEKEND,
```



```
bd_type: BusDayAdjustTypes = BusDayAdjustTypes.FOLLOWING,
dg_type: DateGenRuleTypes = DateGenRuleTypes.BACKWARD):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
effective_dt	Date	Date interest starts to accrue	-
term_dt_or_tenor	Date or str	Date contract ends	-
fixed_leg_type	SwapTypes	-	-
fixed_coupon	float	Fixed coupon (annualised)	-
fixed_freq_type	FrequencyTypes	-	-
fixed_dc_type	DayCountTypes	-	-
notional	float	-	ONE.MILLION
payment_lag	int	Number of days after period payment occurs	0
float_spread	float	-	0.0
float_freq_type	FrequencyTypes	-	FrequencyTypes.ANNUAL
float_dc_type	DayCountTypes	-	DayCountTypes.THIRTY_E
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.FOLLOW
dg_type	DateGenRuleTypes	-	DateGenRuleTypes.BACKWA

## value

Value the interest rate swap on a value date given a single Ibor discount curve.

```
value(value_dt: Date,
      ois_curve: DiscountCurve,
      first_fixing_rate=None):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
ois_curve	DiscountCurve	-	-
first_fixing_rate	-	-	None

## pv01

Calculate the value of 1 basis point coupon on the fixed leg.

```
pv01(value_dt, discount_curve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
discount_curve	-	-	-

**swap\_rate**

*Calculate the fixed leg coupon that makes the swap worth zero. If the valuation date is before the swap payments start then this is the forward swap rate as it starts in the future. The swap rate is then a forward swap rate and so we use a forward discount factor. If the swap fixed leg has begun then we have a spot starting swap.*

```
swap_rate(value_dt, ois_curve, first_fixing_rate=None):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
ois_curve	-	-	-
first_fixing_rate	-	-	None

**print\_fixed\_leg\_pv**

*Prints the fixed leg amounts without any valuation details. Shows the dates and sizes of the promised fixed leg flows.*

```
print_fixed_leg_pv():
```

The function arguments are described in the following table.

**print\_float\_leg\_pv**

*Prints the fixed leg amounts without any valuation details. Shows the dates and sizes of the promised fixed leg flows.*

```
print_float_leg_pv():
```

The function arguments are described in the following table.

**print\_payments**

*Prints the fixed leg amounts without any valuation details. Shows the dates and sizes of the promised fixed leg flows.*

```
print_payments():
```

The function arguments are described in the following table.

**\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

### **`_print`**

*Print a list of the unadjusted coupon payment dates used in analytic calculations for the bond.*

```
_print():
```

The function arguments are described in the following table.

## 8.15 ois\_basis\_swap

### ***Class: OISBasisSwap***

Class for managing an Ibor-OIS basis swap contract. This is a contract in which a floating leg with one LIBOR tenor is exchanged for a floating leg payment of an overnight index swap. There is no exchange of par. The contract is entered into at zero initial cost. The contract lasts from a start date to a specified maturity date.

The value of the contract is the NPV of the two coupon streams. Discounting is done on a supplied discount curve which is separate from the discount from which the implied index rates are extracted.

### **OISBasisSwap**

*Create a Ibor basis swap contract giving the contract start date, its maturity, frequency and day counts on the two floating legs and notional. The floating leg parameters have default values that can be overwritten if needed. The start date is contractual and is the same as the settlement date for a new swap. It is the date on which interest starts to accrue. The end of the contract is the termination date. This is not adjusted for business days. The adjusted termination date is called the maturity date. This is calculated.*

```
OISBasisSwap(effective_dt: Date, # Date interest starts to accrue
              term_dt_or_tenor: (Date, str), # Date contract ends
              iborType: SwapTypes,
              iborFreqType: FrequencyTypes = FrequencyTypes.QUARTERLY,
              iborDayCountType: DayCountTypes = DayCountTypes.THIRTY_E_360,
              iborSpread: float = 0.0,
              oisFreqType: FrequencyTypes = FrequencyTypes.QUARTERLY,
              oisDayCountType: DayCountTypes = DayCountTypes.THIRTY_E_360,
              oisSpread: float = 0.0,
              oisPaymentLag: int = 0,
              notional: float = ONE_MILLION,
              cal_type: CalendarTypes = CalendarTypes.WEEKEND,
              bd_type: BusDayAdjustTypes = BusDayAdjustTypes.FOLLOWING,
              dg_type: DateGenRuleTypes = DateGenRuleTypes.BACKWARD):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
effective_dt	Date	Date interest starts to accrue	-
term_dt_or_tenor	Date or str	Date contract ends	-
iborType	SwapTypes	-	-
iborFreqType	FrequencyTypes	-	FrequencyTypes.QUARTERLY
iborDayCountType	DayCountTypes	-	DayCountTypes.THIRTY_E_360
iborSpread	float	-	0.0
oisFreqType	FrequencyTypes	-	FrequencyTypes.QUARTERLY
oisDayCountType	DayCountTypes	-	DayCountTypes.THIRTY_E_360
oisSpread	float	-	0.0
oisPaymentLag	int	-	0
notional	float	-	ONE_MILLION
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.FOLLOWING
dg_type	DateGenRuleTypes	-	DateGenRuleTypes.BACKWARD

## value

*Value the interest rate swap on a value date given a single Ibor discount curve and an index curve for the Ibors on each swap leg.*

```
value(value_dt: Date,
      discount_curve: DiscountCurve,
      indexIborCurve: DiscountCurve = None,
      indexOISCurve: DiscountCurve = None,
      firstFixingRateLeg1=None,
      firstFixingRateLeg2=None):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
discount_curve	DiscountCurve	-	-
indexIborCurve	DiscountCurve	-	None
indexOISCurve	DiscountCurve	-	None
firstFixingRateLeg1	-	-	None
firstFixingRateLeg2	-	-	None

## print\_payments

*Prints the fixed leg amounts without any valuation details. Shows the dates and sizes of the promised fixed leg flows.*

```
print_payments():
```

The function arguments are described in the following table.

**--repr--**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

*Print a list of the unadjusted coupon payment dates used in analytic calculations for the bond.*

```
_print():
```

The function arguments are described in the following table.

## 8.16 ois\_curve

### **Class: OISCurve(DiscountCurve)**

Constructs a discount curve as implied by the prices of Overnight Index Rate swaps. The curve date is the date on which we are performing the valuation based on the information available on the curve date. Typically it is the date on which an amount of 1 unit paid has a present value of 1. This class inherits from FinDiscountCurve and so it has all of the methods that that class has.

The construction of the curve is assumed to depend on just the OIS curve, i.e. it does not include information from Ibor-OIS basis swaps. For this reason I call it a one-curve.

### **OISCurve**

*Create an instance of an overnight index rate swap curve given a valuation date and a set of OIS rates. Some of these may be left None and the algorithm will just use what is provided. An interpolation method has also to be provided. The default is to use a linear interpolation for swap rates on coupon dates and to then assume flat forwards between these coupon dates. The curve will assign a discount factor of 1.0 to the valuation date.*

```
OISCurve(value_dt: Date,
         ois_deposits: list,
         ois_fras: list,
         ois_swaps: list,
         interp_type: InterpTypes = InterpTypes.FLAT_FWD_RATES,
         check_refit: bool = False): # Set to True to test it works
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
ois_deposits	list	-	-
ois_fras	list	-	-
ois_swaps	list	-	-
interp_type	InterpTypes	-	InterpTypes.FLAT_FWD_RATES
check_refit	bool	Set to True to test it works	False

### **\_build\_curve**

*Build curve based on interpolation.*

```
_build_curve():
```

The function arguments are described in the following table.

### **\_validate\_inputs**

*Validate the inputs for each of the Libor products.*

```
_validate_inputs(oisDeposits,
                 oisFRAs,
                 oisSwaps):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
oisDeposits	-	-	-
oisFRAs	-	-	-
oisSwaps	-	-	-

### **`_build_curve_using_1d_solver`**

*Construct the discount curve using a bootstrap approach. This is the non-linear slower method that allows the user to choose a number of interpolation approaches between the swap rates and other rates. It involves the use of a solver.*

```
_build_curve_using_1d_solver():
```

The function arguments are described in the following table.

### **`_build_curve_linear_swap_rate_interpolation`**

*Construct the discount curve using a bootstrap approach. This is the linear swap rate method that is fast and exact as it does not require the use of a solver. It is also market standard.*

```
_build_curve_linear_swap_rate_interpolation():
```

The function arguments are described in the following table.

### **`_check_refits`**

*Ensure that the Libor curve refits the calibration instruments.*

```
_check_refits(depoTol, fraTol, swapTol):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
depoTol	-	-	-
fraTol	-	-	-
swapTol	-	-	-



**`--repr--`**

*Print out the details of the Libor curve.*

```
--repr__():
```

The function arguments are described in the following table.

**`_print`**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

**`_fois`**

*Extract the implied overnight index rate assuming it is flat over period in question.*

```
_fois(oir, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
oir	-	-	-
*args	-	-	-

**`_f`**

*Root search objective function for OIS*

```
_f(df, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
df	-	-	-
*args	-	-	-

**`_g`**

*Root search objective function for swaps*

```
_g(df, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
df	-	-	-
*args	-	-	-

## 8.17 swap\_fixed\_leg

### **Class: SwapFixedLeg**

Class for managing the fixed leg of a swap. A fixed leg is a leg with a sequence of flows calculated according to an ISDA schedule and with a coupon that is fixed over the life of the swap.

### **SwapFixedLeg**

*Create the fixed leg of a swap contract giving the contract start date, its maturity, fixed coupon, fixed leg frequency, fixed leg day count convention and notional.*

```
SwapFixedLeg(effective_dt: Date, # Date interest starts to accrue
             end_dt: (Date, str), # Date contract ends
             leg_type: SwapTypes,
             coupon: (float),
             freq_type: FrequencyTypes,
             dc_type: DayCountTypes,
             notional: float = ONE_MILLION,
             principal: float = 0.0,
             payment_lag: int = 0,
             cal_type: CalendarTypes = CalendarTypes.WEEKEND,
             bd_type: BusDayAdjustTypes = BusDayAdjustTypes.FOLLOWING,
             dg_type: DateGenRuleTypes = DateGenRuleTypes.BACKWARD,
             end_of_month: bool = False):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
effective_dt	Date	Date interest starts to accrue	-
end_dt	Date or str	Date contract ends	-
leg_type	SwapTypes	-	-
coupon	float or (float	-	-
freq_type	FrequencyTypes	-	-
dc_type	DayCountTypes	-	-
notional	float	-	ONE_MILLION
principal	float	-	0.0
payment_lag	int	-	0
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.FOLLOWING
dg_type	DateGenRuleTypes	-	DateGenRuleTypes.BACKWARD
end_of_month	bool	-	False

### **generate\_payments**

*These are generated immediately as they are for the entire life of the swap. Given a valuation date we can determine which cash flows are in the future and value the swap The schedule allows for a specified lag in*

*the payment date Nothing is paid on the swap effective date and so the first payment date is the first actual payment date.*

```
generate_payments():
```

The function arguments are described in the following table.

## value

*PLEASE ADD A FUNCTION DESCRIPTION*

```
value(value_dt: Date,
      discount_curve: DiscountCurve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
discount_curve	DiscountCurve	-	-

## print\_payments

*Prints the fixed leg dates, accrual factors, discount factors, cash amounts, their present value and their cumulative PV using the last valuation performed.*

```
print_payments():
```

The function arguments are described in the following table.

## print\_valuation

*Prints the fixed leg dates, accrual factors, discount factors, cash amounts, their present value and their cumulative PV using the last valuation performed.*

```
print_valuation():
```

The function arguments are described in the following table.

## \_\_repr\_\_

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

*Print a list of the unadjusted coupon payment dates used in analytic calculations for the bond.*

```
_print():
```

The function arguments are described in the following table.

## 8.18 swap\_float\_leg

### **Class: SwapFloatLeg**

Class for managing the floating leg of a swap. A float leg consists of a sequence of flows calculated according to an ISDA schedule and with a coupon determined by an index curve which changes over life of the swap.

### **SwapFloatLeg**

*Create the fixed leg of a swap contract giving the contract start date, its maturity, fixed coupon, fixed leg frequency, fixed leg day count convention and notional.*

```
SwapFloatLeg(effective_dt: Date, # Date interest starts to accrue
              end_dt: (Date, str), # Date contract ends
              leg_type: SwapTypes,
              spread: (float),
              freq_type: FrequencyTypes,
              dc_type: DayCountTypes,
              notional: float = ONE_MILLION,
              principal: float = 0.0,
              payment_lag: int = 0,
              cal_type: CalendarTypes = CalendarTypes.WEEKEND,
              bd_type: BusDayAdjustTypes = BusDayAdjustTypes.FOLLOWING,
              dg_type: DateGenRuleTypes = DateGenRuleTypes.BACKWARD,
              end_of_month: bool = False):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
effective_dt	Date	Date interest starts to accrue	-
end_dt	Date or str	Date contract ends	-
leg_type	SwapTypes	-	-
spread	float or (float	-	-
freq_type	FrequencyTypes	-	-
dc_type	DayCountTypes	-	-
notional	float	-	ONE_MILLION
principal	float	-	0.0
payment_lag	int	-	0
cal_type	CalendarTypes	-	CalendarTypes.WEEKEND
bd_type	BusDayAdjustTypes	-	BusDayAdjustTypes.FOLLOWING
dg_type	DateGenRuleTypes	-	DateGenRuleTypes.BACKWARD
end_of_month	bool	-	False

### **generate\_payment\_dts**

*Generate the floating leg payment dates and accrual factors. The coupons cannot be generated yet as we do not have the index curve.*

```
generate_payment_dts() :
```

The function arguments are described in the following table.

## value

*Value the floating leg with payments from an index curve and discounting based on a supplied discount curve as of the valuation date supplied. For an existing swap, the user must enter the next fixing coupon.*

```
value(value_dt: Date, # This should be the settlement date
      discount_curve: DiscountCurve,
      index_curve: DiscountCurve,
      firstFixingRate: float = None):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	This should be the settlement date	-
discount_curve	DiscountCurve	-	-
index_curve	DiscountCurve	-	-
firstFixingRate	float	-	None

## print\_payments

*Prints the fixed leg dates, accrual factors, discount factors, cash amounts, their present value and their cumulative PV using the last valuation performed.*

```
print_payments() :
```

The function arguments are described in the following table.

## print\_valuation

*Prints the fixed leg dates, accrual factors, discount factors, cash amounts, their present value and their cumulative PV using the last valuation performed.*

```
print_valuation() :
```

The function arguments are described in the following table.

## \_\_repr\_\_

PLEASE ADD A FUNCTION DESCRIPTION

```
__repr__() :
```

The function arguments are described in the following table.

**\_print**

*Print a list of the unadjusted coupon payment dates used in analytic calculations for the bond.*

```
_print():
```

The function arguments are described in the following table.



**8.19** `--init--`

## Chapter 9

# financepy.products.fx

### FX Derivatives

#### *Overview*

These modules price and produce the sensitivity measures needed to hedge a range of FX Options and other derivatives with an FX underlying.

#### *FX Forwards*

Calculate the price and breakeven forward FX Rate of an FX Forward contract.

#### *FX Vanilla Option*

#### *FX Option*

This is a class from which other classes inherit and is used to perform simple perturbatory calculation of option Greeks.

#### *FX Barrier Options*

#### *FX Basket Options*

#### *FX Digital Options*

#### *FX Fixed Lookback Option*

#### *FX Float Lookback Option*

#### *FX Rainbow Option*

#### *FX Variance Swap*

## 9.1 fx\_barrier\_option

### **Enumerated Type: FinFXBarrierTypes**

This enumerated type has the following values:

- DOWN\_AND\_OUT\_CALL
- DOWN\_AND\_IN\_CALL
- UP\_AND\_OUT\_CALL
- UP\_AND\_IN\_CALL
- UP\_AND\_OUT\_PUT
- UP\_AND\_IN\_PUT
- DOWN\_AND\_OUT\_PUT
- DOWN\_AND\_IN\_PUT

### **Class: FXBarrierOption(FXOption)**

class FXBarrierOption(FXOption):

### **FXBarrierOption**

Create FX Barrier option product. This is an option that cancels if the FX rate crosses a barrier during the life of the option.

```
FXBarrierOption(expiry_dt: Date,
                 strike_fx_rate: float, # 1 unit of foreign in domestic
                 currency_pair: str, # FORDOM
                 option_type: FinFXBarrierTypes,
                 barrier_level: float,
                 num_obs_per_year: int,
                 notional: float,
                 notional_currency: str):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
expiry_dt	Date	-	-
strike_fx_rate	float	1 unit of foreign in domestic	-
currency_pair	str	FORDOM	-
option_type	FinFXBarrierTypes	-	-
barrier_level	float	-	-
num_obs_per_year	int	-	-
notional	float	-	-
notional_currency	str	-	-

### **value**

Value FX Barrier Option using Black-Scholes model with closed-form analytical models.

```
value(value_dt,
      spot_fx_rate,
      dom_discount_curve,
      for_discount_curve,
      model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
spot_fx_rate	-	-	-
dom_discount_curve	-	-	-
for_discount_curve	-	-	-
model	-	-	-

## value\_mc

*Value the FX Barrier Option using Monte Carlo.*

```
value_mc(value_dt,
         spot_fx_rate,
         dom_interest_rate,
         process_type,
         model_params,
         num_ann_steps=552,
         num_paths=5000,
         seed=4242):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
spot_fx_rate	-	-	-
dom_interest_rate	-	-	-
process_type	-	-	-
model_params	-	-	-
num_ann_steps	-	-	552
num_paths	-	-	5000
seed	-	-	4242

## \_\_repr\_\_

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

*Print a list of the unadjusted coupon payment dates used in analytic calculations for the bond.*

```
_print():
```

The function arguments are described in the following table.

## 9.2 fx\_digital\_option

### **Class: FXDigitalOption**

class FXDigitalOption:

### **FXDigitalOption**

Create the FX Digital Option object. Inputs include expiry date, strike, currency pair, option type (call or put), notional and the currency of the notional. And adjustment for spot days is enabled. All currency rates must be entered in the price in domestic currency of one unit of foreign. And the currency pair should be in the form FORDOM where FOR is the foreign currency pair currency code and DOM is the same for the domestic currency.

```
FXDigitalOption(expiry_dt: Date,
                 strike_fx_rate: (float, np.ndarray),
                 currency_pair: str, # FORDOM
                 option_type: (OptionTypes, list),
                 notional: float,
                 prem_currency: str,
                 spot_days: int = 0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
expiry_dt	Date	-	-
strike_fx_rate	float or np.ndarray	-	-
currency_pair	str	FORDOM	-
option_type	OptionTypes or list	-	-
notional	float	-	-
prem_currency	str	-	-
spot_days	int	-	0

### **value**

Valuation of a digital option using Black-Scholes model. This allows for 4 cases - first upper barriers that when crossed pay out cash (calls) and lower barriers than when crossed from above cause a cash payout (puts) PLUS the fact that the cash payment can be in domestic or foreign currency.

```
value(value_dt,
      spot_fx_rate, # 1 unit of foreign in domestic
      dom_discount_curve,
      for_discount_curve,
      model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
spot_fx_rate	-	1 unit of foreign in domestic	-
dom_discount_curve	-	-	-
for_discount_curve	-	-	-
model	-	-	-

## 9.3 fx\_double\_digital\_option

### **Class: FXDoubleDigitalOption**

class FXDoubleDigitalOption:

### **FXDoubleDigitalOption**

Create the FX Double Digital Option object. Inputs include expiry date, upper strike, lower strike, currency pair, option type notional and the currency of the notional. An adjustment for spot days is enabled. All currency rates must be entered in the price in domestic currency of one unit of foreign. And the currency pair should be in the form FORDOM where FOR is the foreign currency pair currency code and DOM is the same for the domestic currency.

```
FXDoubleDigitalOption(expiry_dt: Date,
                      upper_strike: (float, np.ndarray),
                      lower_strike: (float, np.ndarray),
                      currency_pair: str, # FORDOM
                      notional: float,
                      prem_currency: str,
                      spot_days: int = 0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
expiry_dt	Date	-	-
upper_strike	float or np.ndarray	-	-
lower_strike	float or np.ndarray	-	-
currency_pair	str	FORDOM	-
notional	float	-	-
prem_currency	str	-	-
spot_days	int	-	0

### **value**

Valuation of a double digital option using Black-Scholes model. The option pays out the notional in the premium currency if the fx rate is between the upper and lower strike at maturity. The valuation is equivalent to the valuation of the difference of the value of two digital puts, one with the upper and the other with the lower strike

```
value(value_dt,
      spot_fx_rate, # 1 unit of foreign in domestic
      dom_discount_curve,
      for_discount_curve,
      model):
```

The function arguments are described in the following table.



Argument Name	Type	Description	Default Value
value_dt	-	-	-
spot_fx_rate	-	1 unit of foreign in domestic	-
dom_discount_curve	-	-	-
for_discount_curve	-	-	-
model	-	-	-

## 9.4 fx\_fixed\_lookback\_option

**Class:** *FXFixedLookbackOption*

### FXFixedLookbackOption

Create option with expiry date, option type and the option strike

```
FXFixedLookbackOption(expiry_dt: Date,
                       option_type: OptionTypes,
                       optionStrike: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
expiry_dt	Date	-	-
option_type	OptionTypes	-	-
optionStrike	float	-	-

### value

Value FX Fixed Lookback Option using Black Scholes model and analytical formulae.

```
value(value_dt: Date,
      stock_price: float,
      dom_discount_curve: DiscountCurve,
      for_discount_curve: DiscountCurve,
      volatility: float,
      stock_min_max: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
dom_discount_curve	DiscountCurve	-	-
for_discount_curve	DiscountCurve	-	-
volatility	float	-	-
stock_min_max	float	-	-

### value\_mc

Value FX Fixed Lookback option using Monte Carlo.

```
value_mc(value_dt: Date,
         spot_fx_rate: float, # FORDOM
         domestic_curve: DiscountCurve,
         foreign_curve: DiscountCurve,
         volatility: float,
```

```
spot_fx_rateMinMax: float,
num_paths: int = 10000,
num_steps_per_year: int = 252,
seed: int = 4242):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
spot_fx_rate	float	FORDOM	-
domestic_curve	DiscountCurve	-	-
foreign_curve	DiscountCurve	-	-
volatility	float	-	-
spot_fx_rateMinMax	float	-	-
num_paths	int	-	10000
num_steps_per_year	int	-	252
seed	int	-	4242

## 9.5 fx\_float\_lookback\_option

### **Class: FXFloatLookbackOption(FXOption)**

This is an FX option in which the strike of the option is not fixed but is set at expiry to equal the minimum fx rate in the case of a call or the maximum fx rate in the case of a put.

### **FXFloatLookbackOption**

Create the FX Float Look Back Option by specifying the expiry date and the option type.

```
FXFloatLookbackOption(expiry_dt: Date,
                      option_type: OptionTypes):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
expiry_dt	Date	-	-
option_type	OptionTypes	-	-

### **value**

Valuation of the Floating Lookback option using Black-Scholes using the formulae derived by Goldman, Sosin and Gatto (1979).

```
value(value_dt: Date,
      stock_price: float,
      domestic_curve: DiscountCurve,
      foreign_curve: DiscountCurve,
      volatility: float,
      stock_min_max: float):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
domestic_curve	DiscountCurve	-	-
foreign_curve	DiscountCurve	-	-
volatility	float	-	-
stock_min_max	float	-	-

### **value\_mc**

PLEASE ADD A FUNCTION DESCRIPTION

```
value_mc(value_dt,
         stock_price,
         domestic_curve,
```

```
foreign_curve,
volatility,
stock_min_max,
num_paths=10000,
num_steps_per_year=252,
seed=4242):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
stock_price	-	-	-
domestic_curve	-	-	-
foreign_curve	-	-	-
volatility	-	-	-
stock_min_max	-	-	-
num_paths	-	-	10000
num_steps_per_year	-	-	252
seed	-	-	4242

## 9.6 fx\_forward

### **Class: FXForward**

#### **FXForward**

*Creates a FinFXForward which allows the owner to buy the FOR against the DOM currency at the strike\_fx\_rate and to pay it in the notional currency.*

```
FXForward(expiry_dt: Date,
          strike_fx_rate: float, # PRICE OF 1 UNIT OF FOREIGN IN DOM CCY
          currency_pair: str, # FOR DOM
          notional: float,
          notional_currency: str, # must be FOR or DOM
          spot_days: int = 0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
expiry_dt	Date	-	-
strike_fx_rate	float	PRICE OF 1 UNIT OF FOREIGN IN DOM CCY	-
currency_pair	str	FOR DOM	-
notional	float	-	-
notional_currency	str	must be FOR or DOM	-
spot_days	int	-	0

#### **value**

*Calculate the value of an FX forward contract where the current FX rate is the spot\_fx\_rate.*

```
value(value_dt,
      spot_fx_rate, # 1 unit of foreign in domestic
      dom_discount_curve,
      for_discount_curve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
spot_fx_rate	-	1 unit of foreign in domestic	-
dom_discount_curve	-	-	-
for_discount_curve	-	-	-

#### **forward**

*Calculate the FX Forward rate that makes the value of the FX contract equal to zero.*

```
forward(value_dt,
        spot_fx_rate, # 1 unit of foreign in domestic
```

```
dom_discount_curve,
for_discount_curve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
spot_fx_rate	-	1 unit of foreign in domestic	-
dom_discount_curve	-	-	-
for_discount_curve	-	-	-

### **`--repr--`**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

### **`_print`**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

## 9.7 fx\_mkt\_conventions

### **Enumerated Type: *FinFXATMMethod***

This enumerated type has the following values:

- SPOT
- FWD
- FWD\_DELTA\_NEUTRAL
- FWD\_DELTA\_NEUTRAL\_PREM\_ADJ

### **Enumerated Type: *FinFXDeltaMethod***

This enumerated type has the following values:

- SPOT\_DELTA
- FORWARD\_DELTA
- SPOT\_DELTA\_PREM\_ADJ
- FORWARD\_DELTA\_PREM\_ADJ

### **Class: *FinFXRate()***

class FinFXRate():

### **FinFXRate**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
FinFXRate(ccy1,
           ccy2,
           rate):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
ccy1	-	-	-
ccy2	-	-	-
rate	-	-	-



## 9.8 fx\_one\_touch\_option

### **Class: *FXOneTouchOption(FXOption)***

A `FinFXOneTouchOption` is an option in which the buyer receives one unit of currency if the FX rate touches a barrier at any time before the option expiry date and zero otherwise. The single barrier payoff must define whether the option pays or cancels if the barrier is touched and also when the payment is made (at hit time or option expiry). All of these variants are members of the `FinTouchOptionTypes` type.

### **FXOneTouchOption**

Create the one touch option by defining its expiry date and the barrier level and a payment size if it is a cash

```
FXOneTouchOption(expiry_dt: Date,
                  option_type: TouchOptionTypes,
                  barrier_rate: float,
                  payment_size: float = 1.0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
expiry_dt	Date	-	-
option_type	TouchOptionTypes	-	-
barrier_rate	float	-	-
payment_size	float	-	1.0

### **value**

*FX One-Touch Option valuation using the Black-Scholes model assuming a continuous (American) barrier from value date to expiry. Handles both cash-or-nothing and asset-or-nothing options.*

```
value(value_dt: Date,
      spot_fx_rate: (float, np.ndarray),
      dom_discount_curve: DiscountCurve,
      for_discount_curve: DiscountCurve,
      model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
spot_fx_rate	float or np.ndarray	-	-
dom_discount_curve	DiscountCurve	-	-
for_discount_curve	DiscountCurve	-	-
model	-	-	-

**\_\_repr\_\_***PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**\_print***Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

**value\_mc**

*Touch Option valuation using the Black-Scholes model and Monte Carlo simulation. Accuracy is not great when compared to the analytical result as we only observe the barrier a finite number of times. The convergence is slow.*

```
value_mc(value_dt: Date,
         stock_price: float,
         domCurve: DiscountCurve,
         forCurve: DiscountCurve,
         model,
         num_paths: int = 10000,
         num_steps_per_year: int = 252,
         seed: int = 4242):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	Date	-	-
stock_price	float	-	-
domCurve	DiscountCurve	-	-
forCurve	DiscountCurve	-	-
model	-	-	-
num_paths	int	-	10000
num_steps_per_year	int	-	252
seed	int	-	4242

**\_barrier\_pay\_one\_at\_hit\_pv\_down**

*Pay \$1 if the stock crosses the barrier H from above. PV payment.*

```
_barrier_pay_one_at_hit_pv_down(s, H, r, dt):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
H	-	-	-
r	-	-	-
dt	-	-	-

### **`_barrier_pay_one_at_hit_pv_up`**

*Pay \$1 if the stock crosses the barrier H from below. PV payment.*

```
_barrier_pay_one_at_hit_pv_up(s, H, r, dt):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
H	-	-	-
r	-	-	-
dt	-	-	-

### **`_barrier_pay_asset_at_expiry_down_out`**

*Pay \$1 if the stock crosses the barrier H from above. PV payment.*

```
_barrier_pay_asset_at_expiry_down_out(s, H):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
H	-	-	-

### **`_barrier_pay_asset_at_expiry_up_out`**

*Pay \$1 if the stock crosses the barrier H from below. PV payment.*

```
_barrier_pay_asset_at_expiry_up_out(s, H):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
H	-	-	-

## 9.9 fx\_option

### ***Class: FXOption***

#### **delta**

*Calculate the option delta (FX rate sensitivity) by adding on a small bump and calculating the change in the option price.*

```
delta(value_dt,
      spot_fx_rate,
      discount_curve,
      dividend_curve,
      model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
spot_fx_rate	-	-	-
discount_curve	-	-	-
dividend_curve	-	-	-
model	-	-	-

#### **gamma**

*Calculate the option gamma (delta sensitivity) by adding on a small bump and calculating the change in the option delta.*

```
gamma(value_dt, spot_fx_rate, discount_curve, dividend_curve,
      model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
spot_fx_rate	-	-	-
discount_curve	-	-	-
dividend_curve	-	-	-
model	-	-	-

#### **vega**

*Calculate the option vega (volatility sensitivity) by adding on a small bump and calculating the change in the option price.*

```
vega(value_dt, spot_fx_rate, discount_curve, dividend_curve, model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
spot_fx_rate	-	-	-
discount_curve	-	-	-
dividend_curve	-	-	-
model	-	-	-

## theta

*Calculate the option theta (calendar time sensitivity) by moving forward one day and calculating the change in the option price.*

```
theta(value_dt, spot_fx_rate, discount_curve, dividend_curve, model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
spot_fx_rate	-	-	-
discount_curve	-	-	-
dividend_curve	-	-	-
model	-	-	-

## rho

*Calculate the option rho (interest rate sensitivity) by perturbing the discount curve and revaluing.*

```
rho(value_dt, spot_fx_rate, discount_curve, dividend_curve, model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
spot_fx_rate	-	-	-
discount_curve	-	-	-
dividend_curve	-	-	-
model	-	-	-

## 9.10 fx\_rainbow\_option

### **Enumerated Type: FXRainbowOptionTypes**

This enumerated type has the following values:

- CALL\_ON\_MAXIMUM
- PUT\_ON\_MAXIMUM
- CALL\_ON\_MINIMUM
- PUT\_ON\_MINIMUM
- CALL\_ON\_NTH
- PUT\_ON\_NTH

### **Class: FXRainbowOption(EquityOption)**

class FXRainbowOption(EquityOption):

### **FXRainbowOption**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
FXRainbowOption(expiry_dt: Date,
                 payoff_type: FXRainbowOptionTypes,
                 payoff_params: List[float],
                 num_assets: int):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
expiry_dt	Date	-	-
payoff_type	FXRainbowOptionTypes	-	-
payoff_params	List[float]	-	-
num_assets	int	-	-

### **validate**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
validate(stock_prices,
         dividend_yields,
         volatilities,
         betas):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
stock_prices	-	-	-
dividend_yields	-	-	-
volatilities	-	-	-
betas	-	-	-

**validate\_payoff***PLEASE ADD A FUNCTION DESCRIPTION*

```
validate_payoff(payload_type, payoff_params, num_assets):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
payoff_type	-	-	-
payoff_params	-	-	-
num_assets	-	-	-

**value***PLEASE ADD A FUNCTION DESCRIPTION*

```
value(value_dt,
      stock_prices,
      dom_discount_curve,
      for_discount_curve,
      volatilities,
      betas):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
stock_prices	-	-	-
dom_discount_curve	-	-	-
for_discount_curve	-	-	-
volatilities	-	-	-
betas	-	-	-

**value\_mc***PLEASE ADD A FUNCTION DESCRIPTION*

```
value_mc(value_dt,
         expiry_dt,
         stock_prices,
         discount_curve,
         dividend_yields,
         volatilities,
         betas,
         num_paths=10000,
         seed=4242):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
expiry_dt	-	-	-
stock_prices	-	-	-
discount_curve	-	-	-
dividend_yields	-	-	-
volatilities	-	-	-
betas	-	-	-
num_paths	-	-	10000
seed	-	-	4242

## payoff\_value

*PLEASE ADD A FUNCTION DESCRIPTION*

```
payoff_value(s, payoff_typeValue, payoff_params):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
payoff_typeValue	-	-	-
payoff_params	-	-	-

## value\_mc\_fast

*PLEASE ADD A FUNCTION DESCRIPTION*

```
value_mc_fast(t,
              stock_prices,
              discount_curve,
              dividend_yields,
              volatilities,
              betas,
              num_assets,
              payoff_type,
              payoff_params,
              num_paths=10000,
              seed=4242):
```

The function arguments are described in the following table.



Argument Name	Type	Description	Default Value
t	-	-	-
stock_prices	-	-	-
discount_curve	-	-	-
dividend_yields	-	-	-
volatilities	-	-	-
betas	-	-	-
num_assets	-	-	-
payoff_type	-	-	-
payoff_params	-	-	-
num_paths	-	-	10000
seed	-	-	4242

## 9.11 fx\_vanilla\_option

### **Class: FXVanillaOption()**

This is a class for an FX Option trade. It permits the user to calculate the price of an FX Option trade which can be expressed in a number of ways depending on the investor or hedgers currency. It also allows the calculation of the options delta in a number of forms as well as the various Greek risk sensitivities.

### **FXVanillaOption**

Create the FX Vanilla Option object. Inputs include expiry date, strike, currency pair, option type (call or put), notional and the currency of the notional. And adjustment for spot days is enabled. All currency rates must be entered in the price in domestic currency of one unit of foreign. And the currency pair should be in the form FORDOM where FOR is the foreign currency pair currency code and DOM is the same for the domestic currency.

```
FXVanillaOption(expiry_dt: Date,
                 # 1 unit of foreign in domestic
                 strike_fx_rate: (float, np.ndarray),
                 currency_pair: str, # FORDOM
                 option_type: (OptionTypes, list),
                 notional: float,
                 prem_currency: str,
                 spot_days: int = 0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
expiry_dt	Date	-	-
strike_fx_rate	float or np.ndarray	-	-
currency_pair	str	FORDOM	-
option_type	OptionTypes or list	-	-
notional	float	-	-
prem_currency	str	-	-
spot_days	int	-	0

### **value**

This function calculates the value of the option using a specified model with the resulting value being in domestic i.e. ccy2 terms. Recall that Domestic = CCY2 and Foreign = CCY1 and FX rate is in price in domestic of one unit of foreign currency.

```
value(value_dt,
      spot_fx_rate, # 1 unit of foreign in domestic
      dom_discount_curve,
      for_discount_curve,
      model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
spot_fx_rate	-	1 unit of foreign in domestic	-
dom_discount_curve	-	-	-
for_discount_curve	-	-	-
model	-	-	-

## delta\_bump

*Calculation of the FX option delta by bumping the spot FX rate by 1 cent of its value. This gives the FX spot delta. For speed we prefer to use the analytical calculation of the derivative given below.*

```
delta_bump(value_dt,
           spot_fx_rate,
           ccy1DiscountCurve,
           ccy2DiscountCurve,
           model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
spot_fx_rate	-	-	-
ccy1DiscountCurve	-	-	-
ccy2DiscountCurve	-	-	-
model	-	-	-

## delta

*Calculation of the FX Option delta. There are several definitions of delta and so we are required to return a dictionary of values. The definitions can be found on Page 44 of Foreign Exchange Option Pricing by Iain Clark, published by Wiley Finance.*

```
delta(value_dt,
      spot_fx_rate,
      dom_discount_curve,
      for_discount_curve,
      model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
spot_fx_rate	-	-	-
dom_discount_curve	-	-	-
for_discount_curve	-	-	-
model	-	-	-

## fast\_delta

*Calculation of the FX Option delta. Used in the determination of the volatility surface. Avoids discount curve interpolation so it should be slightly faster than the full calculation of delta.*

```
fast_delta(t,
           s,
           rd,
           rf,
           vol):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t	-	-	-
s	-	-	-
rd	-	-	-
rf	-	-	-
vol	-	-	-

## gamma

*This function calculates the FX Option Gamma using the spot delta.*

```
gamma(value_dt,
       spot_fx_rate, # value of a unit of foreign in domestic currency
       dom_discount_curve,
       for_discount_curve,
       model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
spot_fx_rate	-	value of a unit of foreign in domestic currency	-
dom_discount_curve	-	-	-
for_discount_curve	-	-	-
model	-	-	-

## vega

*This function calculates the FX Option Vega using the spot delta.*

```
vega(value_dt,
      spot_fx_rate, # value of a unit of foreign in domestic currency
      dom_discount_curve,
      for_discount_curve,
      model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
spot_fx_rate	-	value of a unit of foreign in domestic currency	-
dom_discount_curve	-	-	-
for_discount_curve	-	-	-
model	-	-	-

## theta

*This function calculates the time decay of the FX option.*

```
theta(value_dt,
      spot_fx_rate, # value of a unit of foreign in domestic currency
      dom_discount_curve,
      for_discount_curve,
      model):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
spot_fx_rate	-	value of a unit of foreign in domestic currency	-
dom_discount_curve	-	-	-
for_discount_curve	-	-	-
model	-	-	-

## implied\_volatility

*This function determines the implied volatility of an FX option given a price and the other option details. It uses a one-dimensional Newton root search algorithm to determine the implied volatility.*

```
implied_volatility(value_dt,
                  stock_price,
                  discount_curve,
                  dividend_curve,
                  price):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
stock_price	-	-	-
discount_curve	-	-	-
dividend_curve	-	-	-
price	-	-	-

**value\_mc**

*Calculate the value of an FX Option using Monte Carlo methods. This function can be used to validate the risk measures calculated above or used as the starting code for a model exotic FX product that cannot be priced analytically. This function uses Numpy vectorisation for speed of execution.*

```
value_mc(value_dt,
         spot_fx_rate,
         dom_discount_curve,
         for_discount_curve,
         model,
         num_paths=10000,
         seed=4242):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
spot_fx_rate	-	-	-
dom_discount_curve	-	-	-
for_discount_curve	-	-	-
model	-	-	-
num_paths	-	-	10000
seed	-	-	4242

**--repr--**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**\_print**

*Simple print function for backward compatibility.*

```
_print():
```

The function arguments are described in the following table.

**f**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
f(volatility, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
volatility	-	-	-
*args	-	-	-

## fvega

*PLEASE ADD A FUNCTION DESCRIPTION*

```
fvega(volatility, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
volatility	-	-	-
*args	-	-	-

## fast\_delta

*Calculation of the FX Option delta. Used in the determination of the volatility surface. Avoids discount curve interpolation so it should be slightly faster than the full calculation of delta.*

```
fast_delta(s, t, k, rd, rf, vol, deltaTypeValue, option_type_value):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
t	-	-	-
k	-	-	-
rd	-	-	-
rf	-	-	-
vol	-	-	-
deltaTypeValue	-	-	-
option_type_value	-	-	-

## 9.12 fx\_variance\_swap

**Class:** *FinFXVarianceSwap*

### FinFXVarianceSwap

*Create variance swap contract.*

```
FinFXVarianceSwap(effective_dt: Date,
                  maturity_dt_or_tenor: [Date, str],
                  strike_variance: float,
                  notional: float = ONE_MILLION,
                  pay_strike_flag: bool = True):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
effective_dt	Date	-	-
maturity_dt_or_tenor	[Date,str]	-	-
strike_variance	float	-	-
notional	float	-	ONE_MILLION
pay_strike_flag	bool	-	True

### value

*Calculate the value of the variance swap based on the realised volatility to the valuation date, the forward looking implied volatility to the maturity date using the libor discount curve.*

```
value(value_dt,
      realisedVar,
      fair_strikeVar,
      libor_curve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
realisedVar	-	-	-
fair_strikeVar	-	-	-
libor_curve	-	-	-

### fair\_strike\_approx

*This is an approximation of the fair strike variance by Demeterfi et al. (1999) which assumes that  $\sigma(K) = \sigma(F) - b(K-F)/F$  where  $F$  is the forward stock price and  $\sigma(F)$  is the ATM forward vol.*

```
fair_strike_approx(value_dt,
                  fwdStockPrice,
                  strikes,
                  volatilities):
```



The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
fwdStockPrice	-	-	-
strikes	-	-	-
volatilities	-	-	-

## fair\_strike

*Calculate the implied variance according to the volatility surface using a static replication methodology with a specially weighted portfolio of put and call options across a range of strikes using the approximate method set out by Demeterfi et al. 1999.*

```
fair_strike(value_dt,
            stock_price,
            dividend_curve,
            volatility_curve,
            num_call_options,
            num_put_options,
            strike_spacing,
            discount_curve,
            use_forward=True):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
stock_price	-	-	-
dividend_curve	-	-	-
volatility_curve	-	-	-
num_call_options	-	-	-
num_put_options	-	-	-
strike_spacing	-	-	-
discount_curve	-	-	-
use_forward	-	-	True

## f

*PLEASE ADD A FUNCTION DESCRIPTION*

```
f(x): return (2.0/t_mat)*((x-sstar)/sstar-np.log(x/sstar))
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x return (2.0/t_mat)*((x-sstar)/sstar-np.log(x/sstar))	-	-	-

**realised\_variance**

*Calculate the realised variance according to market standard calculations which can either use log or percentage returns.*

```
realised_variance(closePrices, useLogs=True):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
closePrices	-	-	-
useLogs	-	-	True

**print\_strikes**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
print_strikes():
```

The function arguments are described in the following table.

## 9.13 `__init__`

# Chapter 10

## financepy.models

### Models

#### Overview

This folder contains a range of models used in the various derivative pricing models implemented in the product folder. These include credit models for valuing portfolio credit products such as CDS Tranches, Monte-Carlo based models of stochastic processes used to value equity, FX and interest rate derivatives, and some generic implementations of models such as a tree-based Hull White model. Because the models are useful across a range of products, it is better to factor them out of the product/asset class categorisation as it avoids any unnecessary duplication.

In addition we seek to make the interface to these models rely only on fast types such as floats and integers and Numpy arrays.

These modules hold all of the models used by FinancePy across asset classes.

The general philosophy is to separate where possible product and models so that these models have as little product knowledge as possible.

Also, Numba is used extensively, resulting in code speedups of between x 10 and x 100.

### Generic Arbitrage-Free Models

There are the following arbitrage-free models:

- `black` is Black's model for pricing forward starting contracts (in the forward measure) assuming the forward is lognormally distributed.
- `black_shifted` is Black's model for pricing forward starting contracts (in the forward measure) assuming the forward plus a shift is lognormally distributed. CHECK
- `bachelier` prices options assuming the underlying evolves according to a Gaussian (normal) process.
- `sabr` is a stochastic volatility model for forward values with a closed form approximate solution for the implied volatility. It is widely used for pricing European style interest rate options, specifically caps and floors and also swaptions.
- `sabr_shifted` is a stochastic volatility model for forward value with a closed form approximate solution for the implied volatility. It is widely used for pricing European style interest rate options, specifically caps and floors and also swaptions.

The following asset-specific models have been implemented:

## Equity Models

- `heston_model`
- `process_simulator`

## Interest Rate Models

### *Equilibrium Rate Models*

There are two main short rate models.

- CIR is a short rate model where the randomness component is proportional to the square root of the short rate. This model implementation is not arbitrage-free across the term structure.
- Vasicek is a short rate model that assumes mean-reversion and normal volatility. It has a closed form solution for bond prices. It does not have the flexibility to fit a term structure of interest rates. For that you need to use the more flexible Hull-White model.

### *Arbitrage Free Rate Models*

- BKTTree is a short rate model in which the log of the short rate follows a mean-reverting normal process. It refits the interest rate term structure. It is implemented as a trinomial tree and allows valuation of European and American-style rate-based options.
- HWTTree is a short rate model in which the short rate follows a mean-reverting normal process. It fits the interest rate term structure. It is implemented as a trinomial tree and allows valuation of European and American-style rate-based options. It also implements Jamshidian's decomposition of the bond option for European options.

## Credit Models

- `GaussianCopula1F` is a Gaussian copula one-factor model. This class includes functions that calculate the portfolio loss distribution. This is numerical but deterministic.
- `GaussianCopulaLHP` is a Gaussian copula one-factor model in the limit that the number of credits tends to infinity. This is an asymptotic analytical solution.
- `GaussianCopula` is a Gaussian copula model which is multifactor model. It has a Monte-Carlo implementation.
- `LossDbnBuilder` calculates the loss distribution.
- `MertonFirm` is a model of the firm as proposed by Merton (1974).

## FX Models

## 10.1 bachelier

### ***Class: Bachelier()***

Bacheliers Model which prices call and put options in the forward measure assuming the underlying rate follows a normal process.

### **Bachelier**

*Create FinModel black using parameters.*

```
Bachelier(volatility):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
volatility	-	-	-

### **value**

*Price a call or put option using Bachelier's model.*

```
value(forward_rate, # Forward rate F
      strike_rate,  # Strike Rate K
      time_to_expiry, # Time to Expiry (years)
      df,           # Discount Factor to expiry date
      call_or_put): # Call or put
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
forward_rate	-	Forward rate F	-
strike_rate	-	Strike Rate K	-
time_to_expiry	-	Time to Expiry (years)	-
df	-	Discount Factor to expiry date	-
call_or_put	-	Call or put	-

### ***\_\_repr\_\_***

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

## 10.2 bdt\_tree

### **Class: *BDTTree()***

class BDTTree():

### **BDTTree**

*Constructs the Black-Derman-Toy rate model in the case when the volatility is assumed to be constant. The short rate process simplifies and is given by  $d(\log(r)) = \theta(t) * dt + \sigma * dW$ . Although*

```
BDTTree(sigma: float,
        num_time_steps: int = 100):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
sigma	float	-	-
num_time_steps	int	-	100

### **build\_tree**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
build_tree(treeMat, df_times, df_values):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
treeMat	-	-	-
df_times	-	-	-
df_values	-	-	-

### **bond\_option**

*Value a bond option that can have European or American exercise using the Black-Derman-Toy model. The model uses a binomial tree.*

```
bond_option(t_exp, strike_price, face_amount,
            cpn_times, cpn_flows, exercise_type):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t_exp	-	-	-
strike_price	-	-	-
face_amount	-	-	-
cpn_times	-	-	-
cpn_flows	-	-	-
exercise_type	-	-	-

## bermudan\_swaption

*Swaption that can be exercised on specific dates over the exercise period. Due to non-analytical bond price we need to extend tree out to bond maturity and take into account cash flows through time.*

```
bermudan_swaption(t_exp, t_mat, strike, face_amount,
                  cpn_times, cpn_flows, exercise_type):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t_exp	-	-	-
t_mat	-	-	-
strike	-	-	-
face_amount	-	-	-
cpn_times	-	-	-
cpn_flows	-	-	-
exercise_type	-	-	-

## callable\_puttable\_bond\_tree

*Option that can be exercised at any time over the exercise period. Due to non-analytical bond price we need to extend tree out to bond maturity and take into account cash flows through time.*

```
callable_puttable_bond_tree(cpn_times, cpn_flows,
                           call_times, call_prices,
                           put_times, put_prices,
                           face_amount):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
cpn_times	-	-	-
cpn_flows	-	-	-
call_times	-	-	-
call_prices	-	-	-
put_times	-	-	-
put_prices	-	-	-
face_amount	-	-	-



**--repr--***PLEASE ADD A FUNCTION DESCRIPTION*`__repr__():`

The function arguments are described in the following table.

**option\_exercise\_types\_to\_int***PLEASE ADD A FUNCTION DESCRIPTION*`option_exercise_types_to_int(option_exercise_type):`

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
option_exercise_type	-	-	-

**f***PLEASE ADD A FUNCTION DESCRIPTION*`f(x0, m, q_matrix, rt, df_end, dt, sigma):`

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x0	-	-	-
m	-	-	-
q_matrix	-	-	-
rt	-	-	-
df_end	-	-	-
dt	-	-	-
sigma	-	-	-

**search\_root***PLEASE ADD A FUNCTION DESCRIPTION*`search_root(x0, m, q_matrix, rt, df_end, dt, sigma):`

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x0	-	-	-
m	-	-	-
q_matrix	-	-	-
rt	-	-	-
df_end	-	-	-
dt	-	-	-
sigma	-	-	-

### bermudan\_swaption\_tree\_fast

*Option to enter into a swap that can be exercised on coupon payment dates after the start of the exercise period. Due to non-analytical bond price we need to extend tree out to bond maturity and take into account cash flows through time.*

```
bermudan_swaption_tree_fast(t_exp, t_mat,
                             strike_price,
                             face_amount,
                             cpn_times,
                             cpn_flows,
                             exercise_type_int,
                             _df_times,
                             _df_values,
                             _tree_times,
                             _Q, _rt, _dt):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t_exp	-	-	-
t_mat	-	-	-
strike_price	-	-	-
face_amount	-	-	-
cpn_times	-	-	-
cpn_flows	-	-	-
exercise_type_int	-	-	-
_df_times	-	-	-
_df_values	-	-	-
_tree_times	-	-	-
_Q	-	-	-
_rt	-	-	-
_dt	-	-	-

### american\_bond\_option\_tree\_fast

*Option to buy or sell bond at a specified strike price that can be exercised over the exercise period depending on choice of exercise type. Due to non-analytical bond price we need to extend tree out to bond maturity and take into account cash flows through time.*

```
american_bond_option_tree_fast(t_exp, t_mat,
                               strike_price, face_amount,
                               cpn_times, cpn_flows,
                               exercise_type_int,
                               _df_times, _df_values,
                               _tree_times, _Q,
                               _rt, _dt):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t_exp	-	-	-
t_mat	-	-	-
strike_price	-	-	-
face_amount	-	-	-
cpn_times	-	-	-
cpn_flows	-	-	-
exercise_type_int	-	-	-
_df_times	-	-	-
_df_values	-	-	-
_tree_times	-	-	-
_Q	-	-	-
_rt	-	-	-
_dt	-	-	-

### callable\_puttable\_bond\_tree\_fast

*Value a bond with embedded put and call options that can be exercised at any time over the specified list of put and call dates. Due to non-analytical bond price we need to extend tree out to bond maturity and take into account cash flows through time.*

```
callable_puttable_bond_tree_fast(cpn_times, cpn_flows,
                                 call_times, call_prices,
                                 put_times, put_prices, face_amount,
                                 _sigma, _a, _q_matrix, # IS SIGMA USED ?
                                 _pu, _pm, _pd, _rt, _dt, _tree_times,
                                 _df_times, _df_values):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
cpn_times	-	-	-
cpn_flows	-	-	-
call_times	-	-	-
call_prices	-	-	-
put_times	-	-	-
put_prices	-	-	-
face_amount	-	-	-
_sigma	-	IS SIGMA USED ?	-
_a	-	IS SIGMA USED ?	-
_q_matrix	-	IS SIGMA USED ?	-
_pu	-	-	-
_pm	-	-	-
_pd	-	-	-
_rt	-	-	-
_dt	-	-	-
_tree_times	-	-	-
_df_times	-	-	-
_df_values	-	-	-

## build\_tree\_fast

*PLEASE ADD A FUNCTION DESCRIPTION*

```
build_tree_fast(sigma, tree_times, num_time_steps, discount_factors):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
sigma	-	-	-
tree_times	-	-	-
num_time_steps	-	-	-
discount_factors	-	-	-

## 10.3 bk\_tree

### **Class: *BKTree()***

class BKTree():

### **BKTree**

*Constructs the Black Karasinski rate model. The speed of mean reversion  $a$  and volatility are passed in. The short rate process is given by  $d(\log(r)) = (\theta(t) - a \cdot \log(r)) \cdot dt + \sigma \cdot dW$*

```
BKTree(sigma: float,
        a: float,
        num_time_steps: int = 100):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
sigma	float	-	-
a	float	-	-
num_time_steps	int	-	100

### **build\_tree**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
build_tree(t_mat, df_times, df_values):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t_mat	-	-	-
df_times	-	-	-
df_values	-	-	-

### **bond\_option**

*Value a bond option that has European or American exercise using the Black-Karasinski model. The model uses a trinomial tree.*

```
bond_option(t_exp, strike_price, face_amount,
             cpn_times, cpn_flows, exercise_type):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t_exp	-	-	-
strike_price	-	-	-
face_amount	-	-	-
cpn_times	-	-	-
cpn_flows	-	-	-
exercise_type	-	-	-

## bermudan\_swaption

*Swaption that can be exercised on specific dates over the exercise period. Due to non-analytical bond price we need to extend tree out to bond maturity and take into account cash flows through time.*

```
bermudan_swaption(t_exp, t_mat, strike_price, face_amount,
                  cpn_times, cpn_flows, exercise_type):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t_exp	-	-	-
t_mat	-	-	-
strike_price	-	-	-
face_amount	-	-	-
cpn_times	-	-	-
cpn_flows	-	-	-
exercise_type	-	-	-

## callable\_puttable\_bond\_tree

*Option that can be exercised at any time over the exercise period. Due to non-analytical bond price we need to extend tree out to bond maturity and take into account cash flows through time.*

```
callable_puttable_bond_tree(cpn_times, cpn_flows,
                           call_times, call_prices,
                           put_times, put_prices,
                           face):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
cpn_times	-	-	-
cpn_flows	-	-	-
call_times	-	-	-
call_prices	-	-	-
put_times	-	-	-
put_prices	-	-	-
face	-	-	-

**--repr--***PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

**option\_exercise\_types\_to\_int***PLEASE ADD A FUNCTION DESCRIPTION*

```
option_exercise_types_to_int(optionExerciseType):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
optionExerciseType	-	-	-

**f***PLEASE ADD A FUNCTION DESCRIPTION*

```
f(alpha, nm, Q, P, dX, dt, N):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
alpha	-	-	-
nm	-	-	-
Q	-	-	-
P	-	-	-
dX	-	-	-
dt	-	-	-
N	-	-	-

**fprime***PLEASE ADD A FUNCTION DESCRIPTION*

```
fprime(alpha, nm, Q, P, dX, dt, N):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
alpha	-	-	-
nm	-	-	-
Q	-	-	-
P	-	-	-
dX	-	-	-
dt	-	-	-
N	-	-	-

## search\_root

*PLEASE ADD A FUNCTION DESCRIPTION*

```
search_root(x0, nm, Q, P, dX, dt, N):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x0	-	-	-
nm	-	-	-
Q	-	-	-
P	-	-	-
dX	-	-	-
dt	-	-	-
N	-	-	-

## search\_root\_deriv

*PLEASE ADD A FUNCTION DESCRIPTION*

```
search_root_deriv(x0, nm, Q, P, dX, dt, N):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x0	-	-	-
nm	-	-	-
Q	-	-	-
P	-	-	-
dX	-	-	-
dt	-	-	-
N	-	-	-

## bermudan\_swaption\_tree\_fast

*Option to enter into a swap that can be exercised on coupon payment dates after the start of the exercise*



*period. Due to multiple exercise times we need to extend tree out to bond maturity and take into account cash flows through time.*

```
bermudan_swaption_tree_fast(t_exp, t_mat,
                             strike_price, face_amount,
                             cpn_times, cpn_flows,
                             exercise_type_int,
                             _df_times, _df_values,
                             _tree_times, _Q,
                             _pu, _pm, _pd,
                             _rt, _dt, _a):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t_exp	-	-	-
t_mat	-	-	-
strike_price	-	-	-
face_amount	-	-	-
cpn_times	-	-	-
cpn_flows	-	-	-
exercise_type_int	-	-	-
_df_times	-	-	-
_df_values	-	-	-
_tree_times	-	-	-
_Q	-	-	-
_pu	-	-	-
_pm	-	-	-
_pd	-	-	-
_rt	-	-	-
_dt	-	-	-
_a	-	-	-

### american\_bond\_option\_tree\_fast

*Option that can be exercised at any time over the exercise period. Due to non-analytical bond price we need to extend tree out to bond maturity and take into account cash flows through time.*

```
american_bond_option_tree_fast(t_exp, t_mat,
                                strike_price, face_amount,
                                cpn_times, cpn_flows,
                                exercise_type_int,
                                _df_times, _df_values,
                                _tree_times, _Q,
                                _pu, _pm, _pd,
                                _rt,
                                _dt, _a):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t_exp	-	-	-
t_mat	-	-	-
strike_price	-	-	-
face_amount	-	-	-
cpn_times	-	-	-
cpn_flows	-	-	-
exercise_type_int	-	-	-
_df_times	-	-	-
_df_values	-	-	-
_tree_times	-	-	-
_Q	-	-	-
_pu	-	-	-
_pm	-	-	-
_pd	-	-	-
_rt	-	-	-
_dt	-	-	-
_a	-	-	-

## callable\_puttable\_bond\_tree\_fast

*Value a bond with embedded put and call options that can be exercised at any time over the specified list of put and call dates. Due to non-analytical bond price we need to extend tree out to bond maturity and take into account cash flows through time.*

```
callable_puttable_bond_tree_fast(cpn_times, cpn_flows,
                                call_times, call_prices,
                                put_times, put_prices, face_amount,
                                _sigma, _a, _Q, # IS SIGMA USED ?
                                _pu, _pm, _pd, _rt, _dt, _tree_times,
                                _df_times, _df_values):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
cpn_times	-	-	-
cpn_flows	-	-	-
call_times	-	-	-
call_prices	-	-	-
put_times	-	-	-
put_prices	-	-	-
face_amount	-	-	-
_sigma	-	IS SIGMA USED ?	-
_a	-	IS SIGMA USED ?	-
_Q	-	IS SIGMA USED ?	-
_pu	-	-	-
_pm	-	-	-
_pd	-	-	-
_rt	-	-	-
_dt	-	-	-
_tree_times	-	-	-
_df_times	-	-	-
_df_values	-	-	-

## build\_tree\_fast

*Calibrate the tree to a term structure of interest rates.*

```
build_tree_fast(a, sigma, tree_times, num_time_steps, discount_factors):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
a	-	-	-
sigma	-	-	-
tree_times	-	-	-
num_time_steps	-	-	-
discount_factors	-	-	-

## 10.4 black

### *Enumerated Type: BlackTypes*

This enumerated type has the following values:

- ANALYTICAL
- CRR\_TREE

### *Class: Black()*

Blacks Model which prices call and put options in the forward measure according to the Black-Scholes equation.

## Black

Create *FinModel* black using parameters.

```
Black(volatility, implementation_type=BlackTypes.ANALYTICAL,
      num_steps=0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
volatility	-	-	-
implementation_type	-	-	BlackTypes.ANALYTICAL
num_steps	-	-	0

## value

Price a derivative using Black's model which values in the forward measure following a change of measure.

```
value(forward_rate, # Forward rate F
      strike_rate, # Strike Rate K
      time_to_expiry, # Time to Expiry (years)
      df, # df RFR to expiry date
      option_type): # Call or put
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
forward_rate	-	Forward rate F	-
strike_rate	-	Strike Rate K	-
time_to_expiry	-	Time to Expiry (years)	-
df	-	df RFR to expiry date	-
option_type	-	Call or put	-

## delta

*Calculate delta using Black's model which values in the forward measure following a change of measure.*

```
delta(forward_rate,    # Forward rate F
      strike_rate,     # Strike Rate K
      time_to_expiry,  # Time to Expiry (years)
      df,              # RFR to expiry date
      option_type):    # Call or put
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
forward_rate	-	Forward rate F	-
strike_rate	-	Strike Rate K	-
time_to_expiry	-	Time to Expiry (years)	-
df	-	RFR to expiry date	-
option_type	-	Call or put	-

## gamma

*Calculate gamma using Black's model which values in the forward measure following a change of measure.*

```
gamma(forward_rate,    # Forward rate F
      strike_rate,     # Strike Rate K
      time_to_expiry,  # Time to Expiry (years)
      df,              # RFR to expiry date
      option_type):    # Call or put
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
forward_rate	-	Forward rate F	-
strike_rate	-	Strike Rate K	-
time_to_expiry	-	Time to Expiry (years)	-
df	-	RFR to expiry date	-
option_type	-	Call or put	-

## theta

*Calculate theta using Black's model which values in the forward measure following a change of measure.*

```
theta(forward_rate,    # Forward rate F
      strike_rate,     # Strike Rate K
      time_to_expiry,  # Time to Expiry (years)
      df,              # Discount Factor to expiry date
      option_type):    # Call or put
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
forward_rate	-	Forward rate F	-
strike_rate	-	Strike Rate K	-
time_to_expiry	-	Time to Expiry (years)	-
df	-	Discount Factor to expiry date	-
option_type	-	Call or put	-

## vega

Calculate vega using Black's model which values in the forward measure following a change of measure.

```
vega(forward_rate,    # Forward rate F
     strike_rate,     # Strike Rate K
     time_to_expiry,  # Time to Expiry (years)
     df,              # df RFR to expiry date
     option_type):    # Call or put
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
forward_rate	-	Forward rate F	-
strike_rate	-	Strike Rate K	-
time_to_expiry	-	Time to Expiry (years)	-
df	-	df RFR to expiry date	-
option_type	-	Call or put	-

## \_\_repr\_\_

PLEASE ADD A FUNCTION DESCRIPTION

```
__repr__():
```

The function arguments are described in the following table.

## f\_european

Function to determine ststar for pricing European options on future contracts.

```
_f_european(sigma, args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
sigma	-	-	-
args	-	-	-

**`_f_european_vega`**

*Function to calculate the Vega of European options on future contracts.*

```
_f_european_vega(sigma, args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
sigma	-	-	-
args	-	-	-

**`_f_american`**

*Function to determine ststar for pricing American options on future contracts.*

```
_f_american(sigma, args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
sigma	-	-	-
args	-	-	-

**`_f_american_vega`**

*Function to calculate the Vega of American options on future contracts.*

```
_f_american_vega(sigma, args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
sigma	-	-	-
args	-	-	-

**`_estimate_vol_from_price`**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_estimate_vol_from_price(fwd, t, k, european_option_type, european_price):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
fwd	-	-	-
t	-	-	-
k	-	-	-
european_option_type	-	-	-
european_price	-	-	-

## black\_value

*Price a derivative using Black model.*

```
black_value(fwd, t, k, r, v, option_type):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
fwd	-	-	-
t	-	-	-
k	-	-	-
r	-	-	-
v	-	-	-
option_type	-	-	-

## black\_delta

*Return delta of a derivative using Black model.*

```
black_delta(fwd, t, k, r, v, option_type):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
fwd	-	-	-
t	-	-	-
k	-	-	-
r	-	-	-
v	-	-	-
option_type	-	-	-

## black\_gamma

*Return gamma of a derivative using Black model.*

```
black_gamma(fwd, t, k, r, v, option_type):
```

The function arguments are described in the following table.



Argument Name	Type	Description	Default Value
fwd	-	-	-
t	-	-	-
k	-	-	-
r	-	-	-
v	-	-	-
option_type	-	-	-

## black\_vega

*Return vega of a derivative using Black model.*

```
black_vega(fwd, t, k, r, v, option_type):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
fwd	-	-	-
t	-	-	-
k	-	-	-
r	-	-	-
v	-	-	-
option_type	-	-	-

## black\_theta

*Return theta of a derivative using Black model.*

```
black_theta(fwd, t, k, r, v, option_type):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
fwd	-	-	-
t	-	-	-
k	-	-	-
r	-	-	-
v	-	-	-
option_type	-	-	-

## calculate\_d1\_d2

*PLEASE ADD A FUNCTION DESCRIPTION*

```
calculate_d1_d2(f, t, k, v):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
f	-	-	-
t	-	-	-
k	-	-	-
v	-	-	-

## implied\_volatility

*Calculate the Black implied volatility of a European/American options on futures contracts using Newton with a fallback to bisection.*

```
implied_volatility(fwd, t, r, k, price, option_type, debug_print=True):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
fwd	-	-	-
t	-	-	-
r	-	-	-
k	-	-	-
price	-	-	-
option_type	-	-	-
debug_print	-	-	True

## 10.5 black\_scholes

### *Enumerated Type: BlackScholesTypes*

This enumerated type has the following values:

- DEFAULT
- ANALYTICAL
- CRR\_TREE
- BARONE\_ADESI
- LSMC
- Bjerksund\_Stensland
- FINITE\_DIFFERENCE
- PSOR

### *Class: BlackScholes(Model)*

```
class BlackScholes(Model):
```

## BlackScholes

*PLEASE ADD A FUNCTION DESCRIPTION*

```
BlackScholes(volatility: (float, np.ndarray),
              bs_type: BlackScholesTypes = BlackScholesTypes.DEFAULT,
              num_steps_per_year=52,
              num_paths=10000,
              seed=42,
              use_sobol=False,
              params=None):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
volatility	float or np.ndarray	-	-
bs_type	BlackScholesTypes	-	BlackScholesTypes.DEFAULT
num_steps_per_year	-	-	52
num_paths	-	-	10000
seed	-	-	42
use_sobol	-	-	False
params	-	-	None

## value

*PLEASE ADD A FUNCTION DESCRIPTION*

```
value(spot_price: float,
      time_to_expiry: float,
      strike_price: float,
      risk_free_rate: float,
```

```
dividend_rate: float,  
option_type: OptionTypes):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
spot_price	float	-	-
time_to_expiry	float	-	-
strike_price	float	-	-
risk_free_rate	float	-	-
dividend_rate	float	-	-
option_type	OptionTypes	-	-

## 10.6 black\_scholes\_analytic

### bs\_value

*Price a derivative using Black-Scholes model.*

```
bs_value(s, t, k, r, q, v, option_type_value):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
t	-	-	-
k	-	-	-
r	-	-	-
q	-	-	-
v	-	-	-
option_type_value	-	-	-

### bs\_delta

*Price a derivative using Black-Scholes model.*

```
bs_delta(s, t, k, r, q, v, option_type_value):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
t	-	-	-
k	-	-	-
r	-	-	-
q	-	-	-
v	-	-	-
option_type_value	-	-	-

### bs\_gamma

*Price a derivative using Black-Scholes model.*

```
bs_gamma(s, t, k, r, q, v, option_type_value):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
t	-	-	-
k	-	-	-
r	-	-	-
q	-	-	-
v	-	-	-
option_type_value	-	-	-

## bs\_vega

*Price a derivative using Black-Scholes model.*

```
bs_vega(s, t, k, r, q, v, option_type_value):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
t	-	-	-
k	-	-	-
r	-	-	-
q	-	-	-
v	-	-	-
option_type_value	-	-	-

## bs\_theta

*Price a derivative using Black-Scholes model.*

```
bs_theta(s, t, k, r, q, v, option_type_value):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
t	-	-	-
k	-	-	-
r	-	-	-
q	-	-	-
v	-	-	-
option_type_value	-	-	-

## bs\_rho

*Price a derivative using Black-Scholes model.*

```
bs_rho(s, t, k, r, q, v, option_type_value):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
t	-	-	-
k	-	-	-
r	-	-	-
q	-	-	-
v	-	-	-
option_type_value	-	-	-

## bs\_vanna

*Price a derivative using Black-Scholes model.*

```
bs_vanna(s, t, k, r, q, v, option_type_value):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
t	-	-	-
k	-	-	-
r	-	-	-
q	-	-	-
v	-	-	-
option_type_value	-	-	-

## f

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_f(sigma, args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
sigma	-	-	-
args	-	-	-

## fvega

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_fvega(sigma, args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
sigma	-	-	-
args	-	-	-

## **bs\_intrinsic**

*Calculate the Black-Scholes implied volatility of a European vanilla option using Newton with a fallback to bisection.*

```
bs_intrinsic(s, t, k, r, q, option_type_value):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
t	-	-	-
k	-	-	-
r	-	-	-
q	-	-	-
option_type_value	-	-	-

## **bs\_implied\_volatility**

*Calculate the Black-Scholes implied volatility of a European vanilla option using Newton with a fallback to bisection.*

```
bs_implied_volatility(s, t, k, r, q, price, option_type_value):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
t	-	-	-
k	-	-	-
r	-	-	-
q	-	-	-
price	-	-	-
option_type_value	-	-	-

## **\_fcall**

*Function to determine ststar for pricing American call options.*



```
_fcall(si, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
si	-	-	-
*args	-	-	-

## **fput**

*Function to determine sstar for pricing American put options.*

```
_fput(si, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
si	-	-	-
*args	-	-	-

## **baw\_value**

*American Option Pricing Approximation using the Barone-Adesi-Whaley approximation for the Black Scholes Model*

```
baw_value(s, t, k, r, q, v, phi):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
t	-	-	-
k	-	-	-
r	-	-	-
q	-	-	-
v	-	-	-
phi	-	-	-

## **bjerkhund\_stensland\_value**

*Price American Option using the Bjerkhund-Stensland approximation (1993) for the Black Scholes Model*

```
bjerkhund_stensland_value(s, t, k, r, q, v, option_type_value):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
t	-	-	-
k	-	-	-
r	-	-	-
q	-	-	-
v	-	-	-
option_type_value	-	-	-

## 10.7 black\_scholes\_mc

### `_value_mc_nonumba_nonumpy`

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_value_mc_nonumba_nonumpy(s, t, K, option_type, r, q, v,
                           num_paths, seed, use_sobol):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
t	-	-	-
K	-	-	-
option_type	-	-	-
r	-	-	-
q	-	-	-
v	-	-	-
num_paths	-	-	-
seed	-	-	-
use_sobol	-	-	-

### `_value_mc_numpy_only`

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_value_mc_numpy_only(s, t, K, option_type, r, q, v, num_paths,
                     seed, use_sobol):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
t	-	-	-
K	-	-	-
option_type	-	-	-
r	-	-	-
q	-	-	-
v	-	-	-
num_paths	-	-	-
seed	-	-	-
use_sobol	-	-	-

### `_value_mc_numpy_numba`

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_value_mc_numpy_numba(s, t, K, option_type, r, q, v, num_paths, seed,
                      use_sobol):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
t	-	-	-
K	-	-	-
option_type	-	-	-
r	-	-	-
q	-	-	-
v	-	-	-
num_paths	-	-	-
seed	-	-	-
use_sobol	-	-	-

### **`_value_mc_numba_only`**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_value_mc_numba_only(s, t, K, option_type, r, q, v, num_paths, seed,
                     use_sobol):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
t	-	-	-
K	-	-	-
option_type	-	-	-
r	-	-	-
q	-	-	-
v	-	-	-
num_paths	-	-	-
seed	-	-	-
use_sobol	-	-	-

### **`_value_mc_numba_parallel`**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
_value_mc_numba_parallel(s, t, K, option_type, r, q, v, num_paths, seed,
                         use_sobol):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
t	-	-	-
K	-	-	-
option_type	-	-	-
r	-	-	-
q	-	-	-
v	-	-	-
num_paths	-	-	-
seed	-	-	-
use_sobol	-	-	-

## 10.8 black\_scholes\_mc\_tests

### value\_mc1

*PLEASE ADD A FUNCTION DESCRIPTION*

```
value_mc1(s0, t, k, r, q, v, num_paths, seed):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s0	-	-	-
t	-	-	-
k	-	-	-
r	-	-	-
q	-	-	-
v	-	-	-
num_paths	-	-	-
seed	-	-	-

### value\_mc2

*PLEASE ADD A FUNCTION DESCRIPTION*

```
value_mc2(s0, t, K, r, q, v, num_paths, seed):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s0	-	-	-
t	-	-	-
K	-	-	-
r	-	-	-
q	-	-	-
v	-	-	-
num_paths	-	-	-
seed	-	-	-

### value\_mc3

*PLEASE ADD A FUNCTION DESCRIPTION*

```
value_mc3(s0, t, K, r, q, v, num_paths, seed):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s0	-	-	-
t	-	-	-
K	-	-	-
r	-	-	-
q	-	-	-
v	-	-	-
num_paths	-	-	-
seed	-	-	-

## value\_mc4

*PLEASE ADD A FUNCTION DESCRIPTION*

```
value_mc4(s0, t, K, r, q, v, num_paths, seed):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s0	-	-	-
t	-	-	-
K	-	-	-
r	-	-	-
q	-	-	-
v	-	-	-
num_paths	-	-	-
seed	-	-	-

## value\_mc5

*PLEASE ADD A FUNCTION DESCRIPTION*

```
value_mc5(s0, t, K, r, q, v, num_paths, seed):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s0	-	-	-
t	-	-	-
K	-	-	-
r	-	-	-
q	-	-	-
v	-	-	-
num_paths	-	-	-
seed	-	-	-

## 10.9 black\_shifted

### **Class: BlackShifted()**

Blacks Model which prices call and put options in the forward measure according to the Black-Scholes equation. This model also allows the distribution to be shifted to the negative in order to allow for negative interest rates.

### **BlackShifted**

Create FinModel black using parameters.

```
BlackShifted(volatility, shift, implementation=0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
volatility	-	-	-
shift	-	-	-
implementation	-	-	0

### **value**

Price a derivative using Black's model which values in the forward measure following a change of measure. The sign of the shift is the same as Matlab.

```
value(forward_rate,      # Forward rate
      strike_rate,      # Strike Rate
      time_to_expiry,    # time to expiry in years
      df,                # Discount Factor to expiry date
      call_or_put):      # Call or put
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
forward_rate	-	Forward rate	-
strike_rate	-	Strike Rate	-
time_to_expiry	-	time to expiry in years	-
df	-	Discount Factor to expiry date	-
call_or_put	-	Call or put	-

### **\_\_repr\_\_**

PLEASE ADD A FUNCTION DESCRIPTION

```
__repr__():
```

The function arguments are described in the following table.



## 10.10 bond\_analytics

## 10.11 cir\_mc

### **Enumerated Type: CIRNumericalScheme**

This enumerated type has the following values:

- EULER
- LOGNORMAL
- MILSTEIN
- KAHLJACKEL
- EXACT

### **Class: CIR\_MC()**

class CIR\_MC():

## CIR\_MC

*PLEASE ADD A FUNCTION DESCRIPTION*

```
CIR_MC(a, b, sigma):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
a	-	-	-
b	-	-	-
sigma	-	-	-

### **\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

### **meanr**

*Mean value of a CIR process after time t*

```
meanr(r0, a, b, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
r0	-	-	-
a	-	-	-
b	-	-	-
t	-	-	-

## variancer

*Variance of a CIR process after time  $t$*

```
variancer(r0, a, b, sigma, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
r0	-	-	-
a	-	-	-
b	-	-	-
sigma	-	-	-
t	-	-	-

## zero\_price

*Price of a zero coupon bond in CIR model.*

```
zero_price(r0, a, b, sigma, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
r0	-	-	-
a	-	-	-
b	-	-	-
sigma	-	-	-
t	-	-	-

## draw

*Draw a next rate from the CIR model in Monte Carlo.*

```
draw(rt, a, b, sigma, dt):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
rt	-	-	-
a	-	-	-
b	-	-	-
sigma	-	-	-
dt	-	-	-

## rate\_path\_mc

*Generate a path of CIR rates using a number of numerical schemes.*

```
rate_path_mc(r0, a, b, sigma, t, dt, seed, scheme):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
r0	-	-	-
a	-	-	-
b	-	-	-
sigma	-	-	-
t	-	-	-
dt	-	-	-
seed	-	-	-
scheme	-	-	-

## zero\_price\_mc

*Determine the CIR zero price using Monte Carlo.*

```
zero_price_mc(r0, a, b, sigma, t, dt, num_paths, seed, scheme):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
r0	-	-	-
a	-	-	-
b	-	-	-
sigma	-	-	-
t	-	-	-
dt	-	-	-
num_paths	-	-	-
seed	-	-	-
scheme	-	-	-

## 10.12 equity\_barrier\_models

### value\_bs

*This values a single option. Because of its structure it cannot easily be vectorised which is why it has been wrapped. # number of observations per year*

```
value_bs(t, k, h, s, r, q, v, option_type, nobs):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t	-	-	-
k	-	-	-
h	-	-	-
s	-	-	-
r	-	-	-
q	-	-	-
v	-	-	-
option_type	-	-	-
nobs	-	-	-

## 10.13 equity\_crr\_tree

### crr\_tree\_val

*Value an American option using a Binomial Tree*

```
crr_tree_val(stock_price,
             interest_rate, # continuously compounded
             dividend_rate, # continuously compounded
             volatility, # Black scholes volatility
             num_steps_per_year,
             time_to_expiry,
             option_type,
             strike_price,
             isEven):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
stock_price	-	-	-
interest_rate	-	continuously compounded	-
dividend_rate	-	continuously compounded	-
volatility	-	Black scholes volatility	-
num_steps_per_year	-	-	-
time_to_expiry	-	-	-
option_type	-	-	-
strike_price	-	-	-
isEven	-	-	-

### crr\_tree\_val\_avg

*Calculate the average values off the tree using an even and an odd number of time steps.*

```
crr_tree_val_avg(stock_price,
                 interest_rate, # continuously compounded
                 dividend_rate, # continuously compounded
                 volatility, # Black scholes volatility
                 num_steps_per_year,
                 time_to_expiry,
                 option_type,
                 strike_price):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
stock_price	-	-	-
interest_rate	-	continuously compounded	-
dividend_rate	-	continuously compounded	-
volatility	-	Black scholes volatility	-
num_steps_per_year	-	-	-
time_to_expiry	-	-	-
option_type	-	-	-
strike_price	-	-	-

## 10.14 equity\_lsmc

### **Enumerated Type: FIT\_TYPES**

This enumerated type has the following values:

- HERMITE\_E
- LAGUERRE
- HERMITE
- LEGENDRE
- CHEBYCHEV
- POLYNOMIAL

### **equity\_lsmc**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
equity_lsmc(spot_price,
            risk_free_rate,
            dividend_yield,
            sigma,
            num_paths,
            num_steps_per_year,
            time_to_expiry,
            option_type_value,
            strike_price,
            poly_degree,
            fit_type_value,
            use_sobol,
            seed):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
spot_price	-	-	-
risk_free_rate	-	-	-
dividend_yield	-	-	-
sigma	-	-	-
num_paths	-	-	-
num_steps_per_year	-	-	-
time_to_expiry	-	-	-
option_type_value	-	-	-
strike_price	-	-	-
poly_degree	-	-	-
fit_type_value	-	-	-
use_sobol	-	-	-
seed	-	-	-



## 10.15 finite\_difference

### dx

PLEASE ADD A FUNCTION DESCRIPTION

```
dx(x, wind=0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	-	-	-
wind	-	-	0

### dxx

PLEASE ADD A FUNCTION DESCRIPTION

```
dxx(x):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	-	-	-

### calculate\_fd\_matrix

1d finite difference solution for pdes of the form  $0 = dV/dt + A V$   $A = -risk\_free\_rate + mu d/dx + 1/2 var d^2/dx^2$  using the theta scheme  $[1 - theta dt A] V(t) = [1 + (1 - theta) dt A] V(t + dt)$

```
calculate_fd_matrix(x, r, mu, var, dt, theta, wind=0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	-	-	-
r	-	-	-
mu	-	-	-
var	-	-	-
dt	-	-	-
theta	-	-	-
wind	-	-	0

### fd\_roll\_backwards

PLEASE ADD A FUNCTION DESCRIPTION

```
fd_roll_backwards(res, theta, Ai=None, Ae=None):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
res	-	-	-
theta	-	-	-
Ai	-	-	None
Ae	-	-	None

## fd\_roll\_forwards

*PLEASE ADD A FUNCTION DESCRIPTION*

```
fd_roll_forwards(res, theta, Ai=None, Ae=None):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
res	-	-	-
theta	-	-	-
Ai	-	-	None
Ae	-	-	None

## smooth\_digital

*PLEASE ADD A FUNCTION DESCRIPTION*

```
smooth_digital(xl, xu, strike):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
xl	-	-	-
xu	-	-	-
strike	-	-	-

## digital

*PLEASE ADD A FUNCTION DESCRIPTION*

```
digital(x, strike):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	-	-	-
strike	-	-	-

**smooth\_call***PLEASE ADD A FUNCTION DESCRIPTION*

```
smooth_call(xl, xu, strike):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
xl	-	-	-
xu	-	-	-
strike	-	-	-

**option\_payoff***PLEASE ADD A FUNCTION DESCRIPTION*

```
option_payoff(s, strike, smooth, dig, option_type):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
strike	-	-	-
smooth	-	-	-
dig	-	-	-
option_type	-	-	-

**black\_scholes\_fd***PLEASE ADD A FUNCTION DESCRIPTION*

```
black_scholes_fd(spot_price, volatility, time_to_expiry,
                 strike_price, risk_free_rate,
                 dividend_yield, option_type,
                 num_time_steps=None, num_samples=2000,
                 num_std=5, theta=0.5, wind=0,
                 digital=False,
                 smooth=False, update=False):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
spot_price	-	-	-
volatility	-	-	-
time_to_expiry	-	-	-
strike_price	-	-	-
risk_free_rate	-	-	-
dividend_yield	-	-	-
option_type	-	-	-
num_time_steps	-	-	None
num_samples	-	-	2000
num_std	-	-	5
theta	-	-	0.5
wind	-	-	0
digital	-	-	False
smooth	-	-	False
update	-	-	False

## 10.16 finite\_difference\_PSOR

### black\_scholes\_fd\_PSOR

*Solve Black-Scholes equation using projected successive over-relaxation. Parameters: acc: Keep iterating until this accuracy is achieved d.omega: Larger numbers lead to bigger changes in omega with each iteration max\_iter: Maximum number of iterations in PSOR step. Set to 0 to allow any number of iterations.*

```
black_scholes_fd_PSOR(spot_price, volatility, time_to_expiry,
                      strike_price, risk_free_rate, dividend_yield,
                      option_type, num_time_steps=None, num_samples=2000,
                      num_std=5, theta=0.5, wind=0, digital=False,
                      smooth=False, acc=1e-13, d_omega=5e-5, max_iter=0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
spot_price	-	-	-
volatility	-	-	-
time_to_expiry	-	-	-
strike_price	-	-	-
risk_free_rate	-	-	-
dividend_yield	-	-	-
option_type	-	-	-
num_time_steps	-	-	None
num_samples	-	-	2000
num_std	-	-	5
theta	-	-	0.5
wind	-	-	0
digital	-	-	False
smooth	-	-	False
acc	-	-	1e-13
d_omega	-	-	5e-5
max_iter	-	-	0

### PSOR\_roll\_backwards

*PLEASE ADD A FUNCTION DESCRIPTION*

```
PSOR_roll_backwards(Ae, Ai, res_k, omega, acc=1e-13, max_iter=0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
Ae	-	-	-
Ai	-	-	-
res_k	-	-	-
omega	-	-	-
acc	-	-	1e-13
max_iter	-	-	0

## PSOR

*Projected Successive Over Relaxation - Parameters: Ai (np.array): Implicit finite difference matrix omega (float): Number between 1 and 2 weighted average of previous and current iteration initial\_value (np.array): Vector produced by previous iteration z\_ip1 (matrix): Matrix for updating to next timestep max\_iter (int): Maximum number of iterations before raising an error # (max\_iter=0 means no maximum) acc (float): Accuracy. The maximum acceptable square difference # between two iterations Returns: res\_k (np.array): Vector for next time step nloops: Number of iterations required to achieve required accuracy*

```
PSOR(Ai, omega, initial_value, z_ip1, max_iter=0, acc=1e-13):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
Ai	-	-	-
omega	-	-	-
initial_value	-	-	-
z_ip1	-	-	-
max_iter	-	-	0
acc	-	-	1e-13

## 10.17 gauss\_copula

### default\_times\_gc

*Generate a matrix of default times by credit and trial using a Gaussian copula model using a full rank correlation matrix.*

```
default_times_gc(issuer_curves,  
                 correlation_matrix,  
                 num_trials,  
                 seed):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
issuer_curves	-	-	-
correlation_matrix	-	-	-
num_trials	-	-	-
seed	-	-	-

## 10.18 gauss\_copula\_lhp

### tr\_surv\_prob\_lhp

*Get the approximated tranche survival probability of a portfolio of credits in the one-factor GC model using the large portfolio limit which assumes a homogenous portfolio with an infinite number of credits. This approach is very fast but not so accurate as the adjusted binomial.*

```
tr_surv_prob_lhp(k1,
                 k2,
                 num_credits,
                 survival_probs,
                 recovery_rates,
                 beta):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
k1	-	-	-
k2	-	-	-
num_credits	-	-	-
survival_probs	-	-	-
recovery_rates	-	-	-
beta	-	-	-

### portfolio\_cdf\_lhp

*PLEASE ADD A FUNCTION DESCRIPTION*

```
portfolio_cdf_lhp(k, num_credits, qvector, recovery_rates,
                 beta, num_points):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
k	-	-	-
num_credits	-	-	-
qvector	-	-	-
recovery_rates	-	-	-
beta	-	-	-
num_points	-	-	-

### exp\_min\_lk

*PLEASE ADD A FUNCTION DESCRIPTION*

```
exp_min_lk(k, p, r, n, beta):
```



The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
k	-	-	-
p	-	-	-
r	-	-	-
n	-	-	-
beta	-	-	-

## lhp\_density

*PLEASE ADD A FUNCTION DESCRIPTION*

```
lhp_density(k, p, r, beta):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
k	-	-	-
p	-	-	-
r	-	-	-
beta	-	-	-

## lhp\_analytical\_density\_base\_corr

*PLEASE ADD A FUNCTION DESCRIPTION*

```
lhp_analytical_density_base_corr(k, p, r, beta, dbeta_dk):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
k	-	-	-
p	-	-	-
r	-	-	-
beta	-	-	-
dbeta_dk	-	-	-

## lhp\_analytical\_density

*PLEASE ADD A FUNCTION DESCRIPTION*

```
lhp_analytical_density(k, p, r, beta):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
k	-	-	-
p	-	-	-
r	-	-	-
beta	-	-	-

**exp\_min\_lk***PLEASE ADD A FUNCTION DESCRIPTION*

```
exp_min_lk(k, p, r, n, beta):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
k	-	-	-
p	-	-	-
r	-	-	-
n	-	-	-
beta	-	-	-

**prob\_l\_greater\_than\_k***PLEASE ADD A FUNCTION DESCRIPTION*

```
prob_l_greater_than_k(K, P, R, beta):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
K	-	-	-
P	-	-	-
R	-	-	-
beta	-	-	-

## 10.19 gauss\_copula\_lhplus

### **Class: LHPlusModel()**

Large Homogenous Portfolio model with extra asset. Used for approximating full Gaussian copula.

### **LHPlusModel**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
LHPlusModel(P, R, H, beta, P0, R0, H0, beta_0):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
P	-	-	-
R	-	-	-
H	-	-	-
beta	-	-	-
P0	-	-	-
R0	-	-	-
H0	-	-	-
beta_0	-	-	-

### **prob\_loss\_gt\_k**

Returns  $P(L_i K)$  where  $L$  is the portfolio loss given by model.

```
prob_loss_gt_k(K):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
K	-	-	-

### **exp\_min\_lk\_integral**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
exp_min_lk_integral(K, dK):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
K	-	-	-
dK	-	-	-

**exp\_min\_lk***PLEASE ADD A FUNCTION DESCRIPTION*`exp_min_lk(K) :`

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
K	-	-	-

**exp\_min\_lk2***PLEASE ADD A FUNCTION DESCRIPTION*`exp_min_lk2(K) :`

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
K	-	-	-

**tranche\_survival\_prob***PLEASE ADD A FUNCTION DESCRIPTION*`tranche_survival_prob(k1, k2) :`

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
k1	-	-	-
k2	-	-	-

## 10.20 gauss\_copula\_onefactor

### loss\_dbn\_recursion\_gcd

*Full construction of the loss distribution of a portfolio of credits where losses have been calculate as number of units based on the GCD.*

```
loss_dbn_recursion_gcd(num_credits,
                        default_probs,
                        loss_units,
                        beta_vector,
                        num_integration_steps):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
num_credits	-	-	-
default_probs	-	-	-
loss_units	-	-	-
beta_vector	-	-	-
num_integration_steps	-	-	-

### homog\_basket\_loss\_dbn

*Calculate the loss distribution of a CDS default basket where the portfolio is equally weighted and the losses in the portfolio are homo- geneous i.e. the credits have the same recovery rates.*

```
homog_basket_loss_dbn(survival_probs,
                       recovery_rates,
                       beta_vector,
                       num_integration_steps):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
survival_probs	-	-	-
recovery_rates	-	-	-
beta_vector	-	-	-
num_integration_steps	-	-	-

### tranche\_surv\_prob\_recursion

*Get the tranche survival probability of a portfolio of credits in the one-factor GC model using a full recursion calculation of the loss distribution and survival probabilities to some time horizon.*

```
tranche_surv_prob_recursion(k1,
                             k2,
                             num_credits,
                             survival_probs,
```

```
recovery_rates,
beta_vector,
num_integration_steps):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
k1	-	-	-
k2	-	-	-
num_credits	-	-	-
survival_probs	-	-	-
recovery_rates	-	-	-
beta_vector	-	-	-
num_integration_steps	-	-	-

### gauss\_approx\_tranche\_loss

*PLEASE ADD A FUNCTION DESCRIPTION*

```
gauss_approx_tranche_loss(k1, k2, mu, sigma):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
k1	-	-	-
k2	-	-	-
mu	-	-	-
sigma	-	-	-

### tranch\_surv\_prob\_gaussian

*Get the approximated tranche survival probability of a portfolio of credits in the one-factor GC model using a Gaussian fit of the conditional loss distribution and survival probabilities to some time horizon. Note that the losses in this fit are allowed to be negative.*

```
tranch_surv_prob_gaussian(k1,
                           k2,
                           num_credits,
                           survival_probs,
                           recovery_rates,
                           beta_vector,
                           num_integration_steps):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
k1	-	-	-
k2	-	-	-
num_credits	-	-	-
survival_probs	-	-	-
recovery_rates	-	-	-
beta_vector	-	-	-
num_integration_steps	-	-	-

### loss\_dbn\_hetero\_adj\_binomial

*Get the portfolio loss distribution using the adjusted binomial approximation to the conditional loss distribution.*

```
loss_dbn_hetero_adj_binomial(num_credits,
                             default_probs,
                             loss_ratio,
                             beta_vector,
                             num_integration_steps):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
num_credits	-	-	-
default_probs	-	-	-
loss_ratio	-	-	-
beta_vector	-	-	-
num_integration_steps	-	-	-

### tranche\_surv\_prob\_adj\_binomial

*Get the approximated tranche survival probability of a portfolio of credits in the one-factor GC model using the adjusted binomial fit of the conditional loss distribution and survival probabilities to some time horizon. This approach is both fast and highly accurate.*

```
tranche_surv_prob_adj_binomial(k1,
                                k2,
                                num_credits,
                                survival_probs,
                                recovery_rates,
                                beta_vector,
                                num_integration_steps):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
k1	-	-	-
k2	-	-	-
num_credits	-	-	-
survival_probs	-	-	-
recovery_rates	-	-	-
beta_vector	-	-	-
num_integration_steps	-	-	-



## 10.21 gbm\_process\_simulator

### **Class: *FinGBMProcess()***

class FinGBMProcess():

#### **get\_paths**

*Get a matrix of simulated GBM asset values by path and time step. Inputs are the number of paths and time steps, the time horizon and the initial asset value, volatility and random number seed.*

```
get_paths(num_paths: int,
          num_time_steps: int,
          t: float,
          mu: float,
          stock_price: float,
          volatility: float,
          seed: int):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
num_paths	int	-	-
num_time_steps	int	-	-
t	float	-	-
mu	float	-	-
stock_price	float	-	-
volatility	float	-	-
seed	int	-	-

#### **get\_paths\_assets**

*Get a matrix of simulated GBM asset values by asset, path and time step. Inputs are the number of assets, paths and time steps, the time- horizon and the initial asset values, volatilities and betas.*

```
get_paths_assets(num_assets,
                 num_paths,
                 num_time_steps,
                 t,
                 mus,
                 stock_prices,
                 volatilities,
                 corr_matrix,
                 seed):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
num_assets	-	-	-
num_paths	-	-	-
num_time_steps	-	-	-
t	-	-	-
mus	-	-	-
stock_prices	-	-	-
volatilities	-	-	-
corr_matrix	-	-	-
seed	-	-	-

## get\_paths

*Get the simulated GBM process for a single asset with many paths and time steps. Inputs include the number of time steps, paths, the drift  $\mu$ , stock price, volatility and a seed.*

```
get_paths(num_paths,
          num_time_steps,
          t,
          mu,
          stock_price,
          volatility,
          seed):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
num_paths	-	-	-
num_time_steps	-	-	-
t	-	-	-
mu	-	-	-
stock_price	-	-	-
volatility	-	-	-
seed	-	-	-

## get\_paths\_assets

*Get the simulated GBM process for a number of assets and paths and num time steps. Inputs include the number of assets, paths, the vector of  $\mu$ s, stock prices, volatilities, a correlation matrix and a seed.*

```
get_paths_assets(num_assets,
                 num_paths,
                 num_time_steps,
                 t,
                 mus,
                 stock_prices,
                 volatilities,
                 corr_matrix,
                 seed):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
num_assets	-	-	-
num_paths	-	-	-
num_time_steps	-	-	-
t	-	-	-
mus	-	-	-
stock_prices	-	-	-
volatilities	-	-	-
corr_matrix	-	-	-
seed	-	-	-

### get\_assets

*Get the simulated GBM process for a number of assets and paths for one time step. Inputs include the number of assets, paths, the vector of mus, stock prices, volatilities, a correlation matrix and a seed.*

```
get_assets(num_assets,
           num_paths,
           t,
           mus,
           stock_prices,
           volatilities,
           corr_matrix,
           seed):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
num_assets	-	-	-
num_paths	-	-	-
t	-	-	-
mus	-	-	-
stock_prices	-	-	-
volatilities	-	-	-
corr_matrix	-	-	-
seed	-	-	-

## 10.22 heston

### **Enumerated Type: HestonNumericalScheme**

This enumerated type has the following values:

- EULER
- EULERLOG
- QUADEXP

### **Class: Heston()**

class Heston():

### **Heston**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
Heston(v0, kappa, theta, sigma, rho):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
v0	-	-	-
kappa	-	-	-
theta	-	-	-
sigma	-	-	-
rho	-	-	-

### **value\_mc**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
value_mc(value_dt,
         option,
         stock_price,
         interest_rate,
         dividend_yield,
         num_paths,
         num_steps_per_year,
         seed,
         scheme=HestonNumericalScheme.EULERLOG):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
option	-	-	-
stock_price	-	-	-
interest_rate	-	-	-
dividend_yield	-	-	-
num_paths	-	-	-
num_steps_per_year	-	-	-
seed	-	-	-
scheme	-	-	HestonNumericalScheme.EULERLOG

## value\_lewis

*PLEASE ADD A FUNCTION DESCRIPTION*

```
value_lewis(value_dt,
            option,
            stock_price,
            interest_rate,
            dividend_yield):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
option	-	-	-
stock_price	-	-	-
interest_rate	-	-	-
dividend_yield	-	-	-

## phi

*PLEASE ADD A FUNCTION DESCRIPTION*

```
phi(k_in,):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
k_in	-	-	-

## phi\_transform

*PLEASE ADD A FUNCTION DESCRIPTION*

```
phi_transform(x):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	-	-	-

## integrant

*PLEASE ADD A FUNCTION DESCRIPTION*

```
integrant(k): return 2.0 * np.real(np.exp(-1j * k * x))
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
---------------	------	-------------	---------------

## value\_lewis\_rouah

*PLEASE ADD A FUNCTION DESCRIPTION*

```
value_lewis_rouah(value_dt,
                   option,
                   stock_price,
                   interest_rate,
                   dividend_yield):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
option	-	-	-
stock_price	-	-	-
interest_rate	-	-	-
dividend_yield	-	-	-

## f

*PLEASE ADD A FUNCTION DESCRIPTION*

```
f(k_in):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
k_in	-	-	-

**value\_weber***PLEASE ADD A FUNCTION DESCRIPTION*

```
value_weber(value_dt,
            option,
            stock_price,
            interest_rate,
            dividend_yield):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
option	-	-	-
stock_price	-	-	-
interest_rate	-	-	-
dividend_yield	-	-	-

**f***PLEASE ADD A FUNCTION DESCRIPTION*

```
f(s, b):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
b	-	-	-

**integrand***PLEASE ADD A FUNCTION DESCRIPTION*

```
integrand(u):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
u	-	-	-

**value\_gatheral***PLEASE ADD A FUNCTION DESCRIPTION*

```
value_gatheral(value_dt,
               option,
```

```
stock_price,
interest_rate,
dividend_yield):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
value_dt	-	-	-
option	-	-	-
stock_price	-	-	-
interest_rate	-	-	-
dividend_yield	-	-	-

## ff

*PLEASE ADD A FUNCTION DESCRIPTION*

```
ff(j):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
j	-	-	-

## integrand

*PLEASE ADD A FUNCTION DESCRIPTION*

```
integrand(u):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
u	-	-	-

## get\_paths

*PLEASE ADD A FUNCTION DESCRIPTION*

```
get_paths(s0, r, q, v0, kappa, theta, sigma, rho, t, dt, num_paths,
seed, scheme):
```

The function arguments are described in the following table.



Argument Name	Type	Description	Default Value
s0	-	-	-
r	-	-	-
q	-	-	-
v0	-	-	-
kappa	-	-	-
theta	-	-	-
sigma	-	-	-
rho	-	-	-
t	-	-	-
dt	-	-	-
num_paths	-	-	-
seed	-	-	-
scheme	-	-	-

## 10.23 hw\_tree

### **Enumerated Type: FinHWEuropeanCalcType**

This enumerated type has the following values:

- JAMSHIDIAN
- EXPIRY\_ONLY
- EXPIRY\_TREE

### **Class: HWTree()**

class HWTree():

### **HWTree**

*Constructs the Hull-White rate model. The speed of mean reversion  $a$  and volatility are passed in. The short rate process is given by  $dr = (\theta(t) - ar) * dt + \sigma * dW$ . The model will switch to use Jamshidian's approach where possible unless the useJamshidian flag is set to false in which case it uses the trinomial Tree.*

```
HWTree(sigma,
        a,
        num_time_steps=100,
        europeanCalcType=FinHWEuropeanCalcType.EXPIRY_TREE):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
sigma	-	-	-
a	-	-	-
num_time_steps	-	-	100
europeanCalcType	-	-	EXPIRY_TREE

### **option\_on\_zcb**

*Price an option on a zero coupon bond using analytical solution of Hull-White model. User provides bond face and option strike and expiry date and maturity date.*

```
option_on_zcb(t_exp, t_mat,
               strike, face_amount,
               df_times, df_values):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t_exp	-	-	-
t_mat	-	-	-
strike	-	-	-
face_amount	-	-	-
df_times	-	-	-
df_values	-	-	-

### european\_bond\_option\_jamshidian

*Valuation of a European bond option using the Jamshidian deconstruction of the bond into a strip of zero coupon bonds with the short rate that would make the bond option be at the money forward.*

```
european_bond_option_jamshidian(t_exp,
                                strike_price,
                                face,
                                cpn_times,
                                cpn_amounts,
                                df_times,
                                df_values):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t_exp	-	-	-
strike_price	-	-	-
face	-	-	-
cpn_times	-	-	-
cpn_amounts	-	-	-
df_times	-	-	-
df_values	-	-	-

### european\_bond\_option\_expiry\_only

*Price a European option on a coupon-paying bond using a tree to generate short rates at the expiry date and then to use the analytical solution of zero coupon bond prices in the HW model to calculate the corresponding bond price. User provides bond object and option details.*

```
european_bond_option_expiry_only(t_exp,
                                strike_price,
                                face_amount,
                                cpn_times,
                                cpn_amounts):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t_exp	-	-	-
strike_price	-	-	-
face_amount	-	-	-
cpn_times	-	-	-
cpn_amounts	-	-	-

### option\_on\_zero\_coupon\_bond\_tree

Price an option on a zero coupon bond using a HW trinomial tree. The discount curve was already supplied to the tree build.

```
option_on_zero_coupon_bond_tree(t_exp,
                                t_mat,
                                strike_price,
                                face_amount):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t_exp	-	-	-
t_mat	-	-	-
strike_price	-	-	-
face_amount	-	-	-

### bermudan\_swaption

Swaption that can be exercised on specific dates over the exercise period. Due to non-analytical bond price we need to extend tree out to bond maturity and take into account cash flows through time.

```
bermudan_swaption(t_exp, t_mat, strike, face,
                   cpn_times, cpn_flows, exercise_type):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t_exp	-	-	-
t_mat	-	-	-
strike	-	-	-
face	-	-	-
cpn_times	-	-	-
cpn_flows	-	-	-
exercise_type	-	-	-

### bond\_option

Value a bond option that can have European or American exercise. This is done using a trinomial tree that

*we extend out to bond maturity. For European bond options, Jamshidian's model is faster and is used instead i.e. not this function.*

```
bond_option(t_exp, strike_price, face_amount,
            cpn_times, cpn_flows, exercise_type):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t_exp	-	-	-
strike_price	-	-	-
face_amount	-	-	-
cpn_times	-	-	-
cpn_flows	-	-	-
exercise_type	-	-	-

## callable\_puttable\_bond\_tree

*PLEASE ADD A FUNCTION DESCRIPTION*

```
callable_puttable_bond_tree(cpn_times,
                            cpn_flows,
                            call_times,
                            call_prices,
                            put_times,
                            put_prices,
                            face_amount):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
cpn_times	-	-	-
cpn_flows	-	-	-
call_times	-	-	-
call_prices	-	-	-
put_times	-	-	-
put_prices	-	-	-
face_amount	-	-	-

## df\_tree

*Discount factor as seen from now to time t\_mat as long as the time is on the tree grid.*

```
df_tree(t_mat):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t_mat	-	-	-

## build\_tree

*Build the trinomial tree.*

```
build_tree(treeMat, df_times, df_values):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
treeMat	-	-	-
df_times	-	-	-
df_values	-	-	-

## \_\_repr\_\_

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

## option\_exercise\_types\_to\_int

*PLEASE ADD A FUNCTION DESCRIPTION*

```
option_exercise_types_to_int(optionExerciseType):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
optionExerciseType	-	-	-

## p\_fast

*Forward discount factor as seen at some time  $t$  which may be in the future for payment at time  $T$  where  $r_t$  is the delta-period short rate seen at time  $t$  and  $p_t$  is the discount factor to time  $t$ ,  $p_{t+dt}$  is the one period discount factor to time  $t+dt$  and  $p_T$  is the discount factor from now until the payment of the 1 dollar of the discount factor.*

```
p_fast(t, T, r_t, delta, p_t, p_{t+dt}, p_T, _sigma, _a):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t	-	-	-
T	-	-	-
r_t	-	-	-
delta	-	-	-
pt	-	-	-
ptd	-	-	-
pT	-	-	-
_sigma	-	-	-
_a	-	-	-

## build\_tree\_fast

*Fast tree construction using Numba.*

```
build_tree_fast(a, sigma, tree_times, num_time_steps, discount_factors):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
a	-	-	-
sigma	-	-	-
tree_times	-	-	-
num_time_steps	-	-	-
discount_factors	-	-	-

## american\_bond\_option\_tree\_fast

*Value an option on a bond with coupons that can have European or American exercise. Some minor issues to do with handling coupons on the option expiry date need to be solved.*

```
american_bond_option_tree_fast(t_exp,
                                strike_price,
                                face_amount,
                                cpn_times,
                                cpn_amounts,
                                exercise_typeInt,
                                _sigma,
                                _a,
                                _Q,
                                _pu, _pm, _pd,
                                _r_t,
                                _dt,
                                _tree_times,
                                _df_times, _df_values):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t_exp	-	-	-
strike_price	-	-	-
face_amount	-	-	-
cpn_times	-	-	-
cpn_amounts	-	-	-
exercise_typeInt	-	-	-
_sigma	-	-	-
_a	-	-	-
_Q	-	-	-
_pu	-	-	-
_pm	-	-	-
_pd	-	-	-
_r_t	-	-	-
_dt	-	-	-
_tree_times	-	-	-
_df_times	-	-	-
_df_values	-	-	-

## bermudan\_swaption\_tree\_fast

*Option to enter into a swap that can be exercised on coupon payment dates after the start of the exercise period. Due to multiple exercise times we need to extend tree out to bond maturity and take into account cash flows through time.*

```
bermudan_swaption_tree_fast(t_exp, t_mat, strike_price, face_amount,
                             cpn_times, cpn_flows,
                             exercise_typeInt,
                             _df_times, _df_values,
                             _tree_times, _Q, _pu, _pm, _pd, _r_t, _dt, _a):
```

The function arguments are described in the following table.



Argument Name	Type	Description	Default Value
t_exp	-	-	-
t_mat	-	-	-
strike_price	-	-	-
face_amount	-	-	-
cpn_times	-	-	-
cpn_flows	-	-	-
exercise_typeInt	-	-	-
_df_times	-	-	-
_df_values	-	-	-
_tree_times	-	-	-
_Q	-	-	-
_pu	-	-	-
_pm	-	-	-
_pd	-	-	-
_r_t	-	-	-
_dt	-	-	-
_a	-	-	-

## callable\_puttable\_bond\_tree\_fast

*Value an option on a bond with coupons that can have European or American exercise. Some minor issues to do with handling coupons on the option expiry date need to be solved.*

```
callable_puttable_bond_tree_fast(cpn_times, cpn_flows,
                                call_times, call_prices,
                                put_times, put_prices, face,
                                _sigma, _a, _Q, # IS SIGMA USED ?
                                _pu, _pm, _pd, _r_t, _dt, _tree_times,
                                _df_times, _df_values):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
cpn_times	-	-	-
cpn_flows	-	-	-
call_times	-	-	-
call_prices	-	-	-
put_times	-	-	-
put_prices	-	-	-
face	-	-	-
_sigma	-	IS SIGMA USED ?	-
_a	-	IS SIGMA USED ?	-
_Q	-	IS SIGMA USED ?	-
_pu	-	-	-
_pm	-	-	-
_pd	-	-	-
_r_t	-	-	-
_dt	-	-	-
_tree_times	-	-	-
_df_times	-	-	-
_df_values	-	-	-

### **fwd\_dir\_ty\_bond\_price**

*Price a coupon bearing bond on the option expiry date and return the difference from a strike price. This is used in a root search to find the future expiry time  $shor\_t$  rate that makes the bond price equal to the option strike price. It is a key step in the Jamshidian bond decomposition approach. The strike is a clean price.*

```
fwd_dir_ty_bond_price(r_t, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
r_t	-	-	-
*args	-	-	-

## 10.24 Imm\_mc

### **Enumerated Type: ModelLMMModelTypes**

This enumerated type has the following values:

- LMM.ONE\_FACTOR
- LMM.HW\_M\_FACTOR
- LMM.FULL\_N\_FACTOR

### **Imm\_print\_forwards**

*Helper function to display the simulated Ibor rates.*

```
Imm_print_forwards(fwds):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
fwds	-	-	-

### **Imm\_swaption\_vol\_approx**

*Implements Rebonato's approximation for the swap rate volatility to be used when pricing a swaption that expires in period  $a$  for a swap maturing at the end of period  $b$  taking into account the forward volatility term structure (zetas) and the forward-forward correlation matrix  $\rho$ .*

```
Imm_swaption_vol_approx(a, b, fwd0, taus, zetas, rho):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
a	-	-	-
b	-	-	-
fwd0	-	-	-
taus	-	-	-
zetas	-	-	-
rho	-	-	-

### **Imm\_sim\_swaption\_vol**

*Calculates the swap rate volatility using the forwards generated in the simulation to see how it compares to Rebonatto estimate.*

```
Imm_sim_swaption_vol(a, b, fwd0, fwds, taus):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
a	-	-	-
b	-	-	-
fwd0	-	-	-
fwds	-	-	-
taus	-	-	-

### lmm\_fwd\_fwd\_correlation

*Extract forward forward correlation matrix at some future time index from the simulated forward rates and return the matrix.*

```
lmm_fwd_fwd_correlation(numForwards, num_paths, i_time, fwds):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
numForwards	-	-	-
num_paths	-	-	-
i_time	-	-	-
fwds	-	-	-

### lmm\_price\_caps\_black

*Price a strip of capfloorlets using Black's model using the time grid of the LMM model. The prices can be compared with the LMM model prices.*

```
lmm_price_caps_black(fwd0, volCaplet, p, K, taus):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
fwd0	-	-	-
volCaplet	-	-	-
p	-	-	-
K	-	-	-
taus	-	-	-

### sub\_matrix

*Returns a submatrix of correlation matrix at later time step in the LMM simulation which is then used to generate correlated Gaussian RVs.*

```
sub_matrix(t, N):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t	-	-	-
N	-	-	-

## cholesky\_np

*Numba-compliant wrapper around Numpy cholesky function.*

```
cholesky_np(rho):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
rho	-	-	-

## lmm\_simulate\_fwds\_nf

*Full N-Factor Arbitrage-free simulation of forward Ibor discount in the spot measure given an initial forward curve, volatility term structure and full rank correlation structure. Cholesky decomposition is used to extract the factor weights. The number of forwards at time 0 is given. The 3D matrix of forward rates by path, time and forward point is returned. WARNING: NEED TO CHECK THAT CORRECT VOLATILITY IS BEING USED (OFF BY ONE BUG NEEDS TO BE RULED OUT)*

```
lmm_simulate_fwds_nf(num_fwds, num_paths, fwd0, zetas, correl, taus, seed):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
num_fwds	-	-	-
num_paths	-	-	-
fwd0	-	-	-
zetas	-	-	-
correl	-	-	-
taus	-	-	-
seed	-	-	-

## lmm\_simulate\_fwds\_1f

*One factor Arbitrage-free simulation of forward Ibor discount in the spot measure following Hull Page 768. Given an initial forward curve, volatility term structure. The 3D matrix of forward rates by path, time and forward point is returned. This function is kept mainly for its simplicity and speed. NB: The Gamma volatility has an initial entry of zero. This differs from Hull's indexing by one and so is why I do not subtract 1 from the index as Hull does in his equation 32.14. The Number of Forwards is the number of points on the initial curve to the trade maturity date. But be careful: a cap that matures in 10 years with quarterly caplets has 40 forwards BUT the last forward to reset occurs at 9.75 years. You should not simulate beyond this time. If you give the model 10 years as in the Hull examples, you need to simulate 41 (or in this case 11) forwards as the final cap or ratchet has its reset in 10 years.*

```
lmm_simulate_fwds_1f(num_fwds, num_paths, numeraireIndex, fwd0, gammas,
                    taus, use_sobol, seed):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
num_fwds	-	-	-
num_paths	-	-	-
numeraireIndex	-	-	-
fwd0	-	-	-
gammas	-	-	-
taus	-	-	-
use_sobol	-	-	-
seed	-	-	-

### **lmm\_simulate\_fwds\_mf**

*Multi-Factor Arbitrage-free simulation of forward Ibor discount in the spot measure following Hull Page 768. Given an initial forward curve, volatility factor term structure. The 3D matrix of forward rates by path, time and forward point is returned.*

```
lmm_simulate_fwds_mf(num_fwds, numFactors, num_paths, numeraireIndex,
                    fwd0, lambdas, taus, use_sobol, seed):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
num_fwds	-	-	-
numFactors	-	-	-
num_paths	-	-	-
numeraireIndex	-	-	-
fwd0	-	-	-
lambdas	-	-	-
taus	-	-	-
use_sobol	-	-	-
seed	-	-	-

### **lmm\_cap\_flr\_pricer**

*Function to price a strip of cap or floorlets in accordance with the simulated forward curve dynamics.*

```
lmm_cap_flr_pricer(num_fwds, num_paths, K, fwd0, fwds, taus, isCap):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
num_fwds	-	-	-
num_paths	-	-	-
K	-	-	-
fwd0	-	-	-
fwds	-	-	-
taus	-	-	-
isCap	-	-	-

## lmm\_swap\_pricer

*Function to reprice a basic swap using the simulated forward Ibors.*

```
lmm_swap_pricer(cpn, num_periods, num_paths, fwd0, fwds, taus):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
cpn	-	-	-
num_periods	-	-	-
num_paths	-	-	-
fwd0	-	-	-
fwds	-	-	-
taus	-	-	-

## lmm\_swaption\_pricer

*Function to price a European swaption using the simulated forward discount.*

```
lmm_swaption_pricer(strike, a, b, num_paths, fwd0, fwds, taus, isPayer):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
strike	-	-	-
a	-	-	-
b	-	-	-
num_paths	-	-	-
fwd0	-	-	-
fwds	-	-	-
taus	-	-	-
isPayer	-	-	-

## lmm\_ratchet\_caplet\_pricer

*Price a ratchet using the simulated Ibor rates.*

```
lmm_ratchet_caplet_pricer(spd, num_periods, num_paths, fwd0, fwds, taus):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
spd	-	-	-
num_periods	-	-	-
num_paths	-	-	-
fwd0	-	-	-
fwds	-	-	-
taus	-	-	-

### lmm\_flexi\_cap\_pricer

*Price a flexicap using the simulated Ibor rates.*

```
lmm_flexi_cap_pricer(maxCaplets, K, num_periods, num_paths,
                     fwd0, fwds, taus):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
maxCaplets	-	-	-
K	-	-	-
num_periods	-	-	-
num_paths	-	-	-
fwd0	-	-	-
fwds	-	-	-
taus	-	-	-

### lmm\_sticky\_caplet\_pricer

*Price a sticky cap using the simulated Ibor rates.*

```
lmm_sticky_caplet_pricer(spread, num_periods, num_paths, fwd0, fwds, taus):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
spread	-	-	-
num_periods	-	-	-
num_paths	-	-	-
fwd0	-	-	-
fwds	-	-	-
taus	-	-	-



## 10.25 loss\_dbn\_builder

### indep\_loss\_dbn\_heterogeneous\_adj\_binomial

*PLEASE ADD A FUNCTION DESCRIPTION*

```
indep_loss_dbn_heterogeneous_adj_binomial(num_credits,
                                           cond_probs,
                                           loss_ratio):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
num_credits	-	-	-
cond_probs	-	-	-
loss_ratio	-	-	-

### portfolio\_gcd

*PLEASE ADD A FUNCTION DESCRIPTION*

```
portfolio_gcd(actual_losses):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
actual_losses	-	-	-

### indep\_loss\_dbn\_recursion\_gcd

*PLEASE ADD A FUNCTION DESCRIPTION*

```
indep_loss_dbn_recursion_gcd(num_credits,
                              cond_default_probs,
                              loss_units):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
num_credits	-	-	-
cond_default_probs	-	-	-
loss_units	-	-	-

## 10.26 merton\_firm

### **Class: MertonFirm()**

Implementation of the Merton Firm Value Model according to the original formulation by Merton with the inputs being the asset value of the firm, the liabilities (bond face), the time to maturity in years, the risk-free rate, the asset growth rate and the asset value volatility.

### **MertonFirm**

Create an object that holds all of the model parameters. These parameters may be vectorised.

```
MertonFirm(assetValue: (float, list, np.ndarray),
            bondFace: (float, list, np.ndarray),
            timeToMaturity: (float, list, np.ndarray),
            risk_free_rate: (float, list, np.ndarray),
            assetGrowthRate: (float, list, np.ndarray),
            assetVolatility: (float, list, np.ndarray)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
assetValue	float or list,np.ndarray	-	-
bondFace	float or list,np.ndarray	-	-
timeToMaturity	float or list,np.ndarray	-	-
risk_free_rate	float or list,np.ndarray	-	-
assetGrowthRate	float or list,np.ndarray	-	-
assetVolatility	float or list,np.ndarray	-	-

### **leverage**

Calculate the leverage.

```
leverage() :
```

The function arguments are described in the following table.

### **asset\_value**

Calculate the asset value.

```
asset_value() :
```

The function arguments are described in the following table.

**debt\_face\_value**

*Calculate the asset value.*

```
debt_face_value() :
```

The function arguments are described in the following table.

**equity\_vol**

*Calculate the equity volatility.*

```
equity_vol() :
```

The function arguments are described in the following table.

**equity\_value**

*Calculate the equity value.*

```
equity_value() :
```

The function arguments are described in the following table.

**debt\_value**

*Calculate the debt value*

```
debt_value() :
```

The function arguments are described in the following table.

**credit\_spread**

*Calculate the credit spread from the debt value.*

```
credit_spread() :
```

The function arguments are described in the following table.

**prob\_default**

*Calculate the default probability. This is not risk-neutral so it uses the real world drift rather than the risk-free rate.*

```
prob_default() :
```

The function arguments are described in the following table.

### **dist\_default**

*Calculate the distance to default. This is not risk-neutral so it uses the real world drift rather than the risk-free rate.*

```
dist_default() :
```

The function arguments are described in the following table.

### **--repr--**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__() :
```

The function arguments are described in the following table.

## 10.27 merton\_firm\_mkt

### **Class: MertonFirmMkt(MertonFirm)**

Market Extension of the Merton Firm Model according to the original formulation by Merton with the inputs being the equity value of the firm, the liabilities (bond face), the time to maturity in years, the risk-free rate, the asset growth rate and the equity volatility. The asset value and asset volatility are computed internally by solving two non-linear simultaneous equations.

### **MertonFirmMkt**

Create an object that holds all of the model parameters. These parameters may be vectorised.

```
MertonFirmMkt(equity_value: (float, list, np.ndarray),
               bondFace: (float, list, np.ndarray),
               timeToMaturity: (float, list, np.ndarray),
               risk_free_rate: (float, list, np.ndarray),
               assetGrowthRate: (float, list, np.ndarray),
               equity_volatility: (float, list, np.ndarray)):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
equity_value	float or list,np.ndarray	-	-
bondFace	float or list,np.ndarray	-	-
timeToMaturity	float or list,np.ndarray	-	-
risk_free_rate	float or list,np.ndarray	-	-
assetGrowthRate	float or list,np.ndarray	-	-
equity_volatility	float or list,np.ndarray	-	-

### **\_solve\_for\_asset\_value\_and\_vol**

PLEASE ADD A FUNCTION DESCRIPTION

```
_solve_for_asset_value_and_vol():
```

The function arguments are described in the following table.

### **\_\_repr\_\_**

PLEASE ADD A FUNCTION DESCRIPTION

```
__repr__():
```

The function arguments are described in the following table.

**fobj**

*Find value of asset value and vol that fit equity value and vol*

```
_fobj(x, *args):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	-	-	-
*args	-	-	-

## 10.28 model

***Class: Model()***

class Model():

### **Model**

*PLEASE ADD A FUNCTION DESCRIPTION*

Model () :
------------

The function arguments are described in the following table.

## 10.29 option\_implied\_dbn

### option\_implied\_dbn

*This function calculates the option smile/skew-implied probability density function times the interval width.*

```
option_implied_dbn(s, t, r, q, strikes, sigmas):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
s	-	-	-
t	-	-	-
r	-	-	-
q	-	-	-
strikes	-	-	-
sigmas	-	-	-



## 10.30 process\_simulator

### ***Enumerated Type: ProcessTypes***

This enumerated type has the following values:

- GBM
- CIR
- HESTON
- VASICEK
- CEV
- JUMP\_DIFFUSION

### ***Enumerated Type: FinHestonNumericalScheme***

This enumerated type has the following values:

- EULER
- EULERLOG
- QUADEXP

### ***Enumerated Type: FinGBMNumericalScheme***

This enumerated type has the following values:

- NORMAL
- ANTITHETIC

### ***Enumerated Type: FinVasicekNumericalScheme***

This enumerated type has the following values:

- NORMAL
- ANTITHETIC

### ***Enumerated Type: CIRNumericalScheme***

This enumerated type has the following values:

- EULER
- LOGNORMAL
- MILSTEIN
- KAHLJACKEL
- EXACT

### ***Class: FinProcessSimulator()***

```
class FinProcessSimulator():
```

### **FinProcessSimulator**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
FinProcessSimulator() :
```

The function arguments are described in the following table.

## get\_process

*PLEASE ADD A FUNCTION DESCRIPTION*

```
get_process(process_type,
            t,
            model_params,
            numAnnSteps,
            num_paths,
            seed) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
process_type	-	-	-
t	-	-	-
model_params	-	-	-
numAnnSteps	-	-	-
num_paths	-	-	-
seed	-	-	-

## get\_heston\_paths

*PLEASE ADD A FUNCTION DESCRIPTION*

```
get_heston_paths(num_paths,
                 numAnnSteps,
                 t,
                 drift,
                 s0,
                 v0,
                 kappa,
                 theta,
                 sigma,
                 rho,
                 scheme,
                 seed) :
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
num_paths	-	-	-
numAnnSteps	-	-	-
t	-	-	-
drift	-	-	-
s0	-	-	-
v0	-	-	-
kappa	-	-	-
theta	-	-	-
sigma	-	-	-
rho	-	-	-
scheme	-	-	-
seed	-	-	-

## get\_gbm\_paths

*PLEASE ADD A FUNCTION DESCRIPTION*

```
get_gbm_paths(num_paths, numAnnSteps, t, mu, stock_price, sigma, scheme, seed):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
num_paths	-	-	-
numAnnSteps	-	-	-
t	-	-	-
mu	-	-	-
stock_price	-	-	-
sigma	-	-	-
scheme	-	-	-
seed	-	-	-

## get\_vasicek\_paths

*PLEASE ADD A FUNCTION DESCRIPTION*

```
get_vasicek_paths(num_paths,
                  numAnnSteps,
                  t,
                  r0,
                  kappa,
                  theta,
                  sigma,
                  scheme,
                  seed):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
num_paths	-	-	-
numAnnSteps	-	-	-
t	-	-	-
r0	-	-	-
kappa	-	-	-
theta	-	-	-
sigma	-	-	-
scheme	-	-	-
seed	-	-	-

## get\_cir\_paths

*PLEASE ADD A FUNCTION DESCRIPTION*

```
get_cir_paths(num_paths,
              numAnnSteps,
              t,
              r0,
              kappa,
              theta,
              sigma,
              scheme,
              seed):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
num_paths	-	-	-
numAnnSteps	-	-	-
t	-	-	-
r0	-	-	-
kappa	-	-	-
theta	-	-	-
sigma	-	-	-
scheme	-	-	-
seed	-	-	-

## 10.31 rates\_ho\_lee

### ***Class: ModelRatesHoLee***

class ModelRatesHoLee:

### **ModelRatesHoLee**

*Construct Ho-Lee model using single parameter of volatility. The dynamical equation is  $dr = \theta(t) dt + \sigma * dW$ . Any no-arbitrage fitting is done within functions below.*

```
ModelRatesHoLee(sigma):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
sigma	-	-	-

### **zcb**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
zcb(rt1, t1, t2, discount_curve):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
rt1	-	-	-
t1	-	-	-
t2	-	-	-
discount_curve	-	-	-

### **option\_on\_zcb**

*Price an option on a zero coupon bond using analytical solution of Hull-White model. User provides bond face and option strike and expiry date and maturity date.*

```
option_on_zcb(t_exp, t_mat,
               strike_price, face_amount,
               df_times, df_values):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t_exp	-	-	-
t_mat	-	-	-
strike_price	-	-	-
face_amount	-	-	-
df_times	-	-	-
df_values	-	-	-

**\_\_repr\_\_**

PLEASE ADD A FUNCTION DESCRIPTION

```
__repr__():
```

The function arguments are described in the following table.

### **p\_fast**

*Forward discount factor as seen at some time  $t$  which may be in the future for payment at time  $T$  where  $R_t$  is the delta-period short rate seen at time  $t$  and  $pt$  is the discount factor to time  $t$ ,  $ptd$  is the one period discount factor to time  $t+dt$  and  $pT$  is the discount factor from now until the payment of the 1 dollar of the discount factor.*

```
p_fast(t, T, Rt, delta, pt, ptd, pT, _sigma):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
t	-	-	-
T	-	-	-
Rt	-	-	-
delta	-	-	-
pt	-	-	-
ptd	-	-	-
pT	-	-	-
_sigma	-	-	-

## 10.32 sabr

### ***Class: SABR()***

SABR - Stochastic alpha beta rho model by Hagan et al. which is a stochastic volatility model where alpha controls the implied volatility, beta is the exponent on the the underlying assets process so beta = 0 is normal and beta = 1 is lognormal, rho is the correlation between the underlying and the volatility process.

### **SABR**

*Create SABR with all of the model parameters. We will also provide functions below to assist with the calibration of the value of alpha.*

```
SABR(alpha, beta, rho, nu):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
alpha	-	-	-
beta	-	-	-
rho	-	-	-
nu	-	-	-

### **black\_vol**

*Black volatility from SABR model using Hagan et al. approx.*

```
black_vol(f, k, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
f	-	-	-
k	-	-	-
t	-	-	-

### **black\_vol\_with\_alpha**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
black_vol_with_alpha(alpha, f, k, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
alpha	-	-	-
f	-	-	-
k	-	-	-
t	-	-	-

## value

Price an option using Black's model which values in the forward measure following a change of measure.

```
value(forward_rate,    # Forward rate
      strike_rate,     # Strike Rate
      time_to_expiry,  # time to expiry in years
      df,              # Discount Factor to expiry date
      call_or_put):    # Call or put
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
forward_rate	-	Forward rate	-
strike_rate	-	Strike Rate	-
time_to_expiry	-	time to expiry in years	-
df	-	Discount Factor to expiry date	-
call_or_put	-	Call or put	-

## set\_alpha\_from\_black\_vol

Estimate the value of the alpha coefficient of the SABR model by solving for the value of alpha that makes the SABR black vol equal to the input black vol. This uses a numerical 1D solver.

```
set_alpha_from_black_vol(blackVol,
                        forward,
                        strike,
                        time_to_expiry):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
blackVol	-	-	-
forward	-	-	-
strike	-	-	-
time_to_expiry	-	-	-

## fn

PLEASE ADD A FUNCTION DESCRIPTION

```
fn(x): return np.sqrt(
```



The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
---------------	------	-------------	---------------

### **set\_alpha\_from\_atm\_black\_vol**

*We solve cubic equation for the unknown variable alpha for the special ATM case of the strike equalling the forward following Hagan and al. equation (3.3). We take the smallest real root as the preferred solution. This is useful for calibrating the model when beta has been chosen.*

```
set_alpha_from_atm_black_vol(blackVol, atmStrike, time_to_expiry):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
blackVol	-	-	-
atmStrike	-	-	-
time_to_expiry	-	-	-

### **\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

### **\_x**

*Return function x used in Hagan's 2002 SABR lognormal vol expansion.*

```
_x(rho, z):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
rho	-	-	-
z	-	-	-

### **vol\_function\_sabr**

*Black volatility implied by SABR model.*

```
vol_function_sabr(params, f, k, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
params	-	-	-
f	-	-	-
k	-	-	-
t	-	-	-

### **vol\_function\_sabr\_beta\_one**

*This is the SABR function with the exponent beta set equal to 1 so only 3 parameters are free. The first parameter is alpha, then nu and the third parameter is rho. Check the order as it is not the same as main SABR fn*

```
vol_function_sabr_beta_one(params, f, k, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
params	-	-	-
f	-	-	-
k	-	-	-
t	-	-	-

### **vol\_function\_sabr\_beta\_half**

*Black volatility implied by SABR model.*

```
vol_function_sabr_beta_half(params, f, k, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
params	-	-	-
f	-	-	-
k	-	-	-
t	-	-	-

## 10.33 sabr\_shifted

### **Class: SABRShifted()**

SABR - Shifted Stochastic alpha beta rho model by Hagan et al. is a stochastic volatility model where alpha controls the implied volatility, beta is the exponent on the the underlying assets process so beta = 0 is normal and beta = 1 is lognormal, rho is the correlation between the underlying and the volatility process. The shift allows negative rates.

### **SABRShifted**

Create SABRShifted with all of the model parameters. We also provide functions below to assist with the calibration of the value of alpha.

```
SABRShifted(alpha, beta, rho, nu, shift):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
alpha	-	-	-
beta	-	-	-
rho	-	-	-
nu	-	-	-
shift	-	-	-

### **black\_vol**

Black volatility from SABR model using Hagan et al. approx.

```
black_vol(f, k, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
f	-	-	-
k	-	-	-
t	-	-	-

### **black\_vol\_with\_alpha**

PLEASE ADD A FUNCTION DESCRIPTION

```
black_vol_with_alpha(alpha, f, k, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
alpha	-	-	-
f	-	-	-
k	-	-	-
t	-	-	-

## value

Price an option using Black's model which values in the forward measure following a change of measure.

```
value(forward_rate,    # Forward rate F
      strike_rate,     # Strike Rate K
      time_to_expiry,  # Time to Expiry (years)
      df,              # Discount Factor to expiry date
      call_or_put):    # Call or put
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
forward_rate	-	Forward rate F	-
strike_rate	-	Strike Rate K	-
time_to_expiry	-	Time to Expiry (years)	-
df	-	Discount Factor to expiry date	-
call_or_put	-	Call or put	-

## set\_alpha\_from\_black\_vol

Estimate the value of the alpha coefficient of the SABR model by solving for the value of alpha that makes the SABR black vol equal to the input black vol. This uses a numerical 1D solver.

```
set_alpha_from_black_vol(blackVol,
                        forward,
                        strike,
                        time_to_expiry):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
blackVol	-	-	-
forward	-	-	-
strike	-	-	-
time_to_expiry	-	-	-

## fn

PLEASE ADD A FUNCTION DESCRIPTION

```
fn(x): return np.sqrt(
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
---------------	------	-------------	---------------

### **set\_alpha\_from\_atm\_black\_vol**

*We solve cubic equation for the unknown variable alpha for the special ATM case of the strike equalling the forward following Hagan and al. equation (3.3). We take the smallest real root as the preferred solution. This is useful for calibrating the model when beta has been chosen.*

```
set_alpha_from_atm_black_vol(blackVol, atmStrike,
                             time_to_expiry):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
blackVol	-	-	-
atmStrike	-	-	-
time_to_expiry	-	-	-

### **\_\_repr\_\_**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

### **\_X**

*Return function x used in Hagan's 2002 SABR lognormal vol expansion.*

```
_x(rho, z):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
rho	-	-	-
z	-	-	-

### **vol\_function\_shifted\_sabr**

*Black volatility implied by SABR model.*

```
vol_function_shifted_sabr(params, f, k, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
params	-	-	-
f	-	-	-
k	-	-	-
t	-	-	-

## 10.34 sobol

### get\_gaussian\_sobol

*Sobol Gaussian quasi random points generator based on graycode order. The generated points follow a normal distribution.*

```
get_gaussian_sobol(num_points, dimension):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
num_points	-	-	-
dimension	-	-	-

### get\_uniform\_sobol

*Sobol uniform quasi random points generator based on graycode order. This function returns a 2D Numpy array of values where the number of rows is the number of draws and the number of columns is the number of dimensions of the random values. Each dimension has the same number of random draws. Each column of random numbers is ordered so as not to correlate, i.e be independent from any other column.*

```
get_uniform_sobol(num_points, dimension):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
num_points	-	-	-
dimension	-	-	-

## 10.35 student\_t\_copula

### ***Class: StudentTCopula()***

class StudentTCopula():

#### **default\_times**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
default_times(issuer_curves,  
              correlation_matrix,  
              degreesOfFreedom,  
              num_trials,  
              seed):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
issuer_curves	-	-	-
correlation_matrix	-	-	-
degreesOfFreedom	-	-	-
num_trials	-	-	-
seed	-	-	-



## 10.36 vasicek\_mc

**Class: *ModelRatesVasicek()***

class ModelRatesVasicek():

### ModelRatesVasicek

*PLEASE ADD A FUNCTION DESCRIPTION*

```
ModelRatesVasicek(a, b, sigma):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
a	-	-	-
b	-	-	-
sigma	-	-	-

**`__repr__`**

*PLEASE ADD A FUNCTION DESCRIPTION*

```
__repr__():
```

The function arguments are described in the following table.

### meanr

*PLEASE ADD A FUNCTION DESCRIPTION*

```
meanr(r0, a, b, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
r0	-	-	-
a	-	-	-
b	-	-	-
t	-	-	-

### variancer

*PLEASE ADD A FUNCTION DESCRIPTION*

```
variancer(a, b, sigma, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
a	-	-	-
b	-	-	-
sigma	-	-	-
t	-	-	-

## zero\_price

*PLEASE ADD A FUNCTION DESCRIPTION*

```
zero_price(r0, a, b, sigma, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
r0	-	-	-
a	-	-	-
b	-	-	-
sigma	-	-	-
t	-	-	-

## rate\_path\_mc

*PLEASE ADD A FUNCTION DESCRIPTION*

```
rate_path_mc(r0, a, b, sigma, t, dt, seed):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
r0	-	-	-
a	-	-	-
b	-	-	-
sigma	-	-	-
t	-	-	-
dt	-	-	-
seed	-	-	-

## zero\_price\_mc

*PLEASE ADD A FUNCTION DESCRIPTION*

```
zero_price_mc(r0, a, b, sigma, t, dt, num_paths, seed):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
r0	-	-	-
a	-	-	-
b	-	-	-
sigma	-	-	-
t	-	-	-
dt	-	-	-
num_paths	-	-	-
seed	-	-	-

## 10.37 volatility\_fns

### Enumerated Type: VolFuncTypes

This enumerated type has the following values:

- CLARK
- SABR
- SABR\_BETA\_ONE
- SABR\_BETA\_HALF
- BBG
- CLARK5
- SVI
- SSVI

### vol\_function\_clark

*Volatility Function in book by Iain Clark generalised to allow for higher than quadratic power. Care needs to be taken to avoid overfitting. The exact reference is Clark Page 59.*

```
vol_function_clark(params, f, k, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
params	-	-	-
f	-	-	-
k	-	-	-
t	-	-	-

### vol\_function\_bloomberg

*Volatility Function similar to the one used by Bloomberg. It is a quadratic function in the spot delta of the option. It can therefore go negative so it requires a good initial guess when performing the fitting to avoid this happening. The first parameter is the quadratic coefficient i.e.  $\sigma(K) = a * D * D + b * D + c$  where  $a = \text{params}[0]$ ,  $b = \text{params}[1]$ ,  $c = \text{params}[2]$  and  $D$  is the spot delta.*

```
vol_function_bloomberg(params, f, k, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
params	-	-	-
f	-	-	-
k	-	-	-
t	-	-	-

## vol\_function\_svi

*Volatility Function proposed by Gatheral in 2004. Increasing  $a$  results in a vertical translation of the smile in the positive direction. Increasing  $b$  decreases the angle between the put and call wing, i.e. tightens the smile. Increasing  $\rho$  results in a counter-clockwise rotation of the smile. Increasing  $m$  results in a horizontal translation of the smile in the positive direction. Increasing  $\sigma$  reduces the at-the-money curvature of the smile.*

```
vol_function_svi(params, f, k, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
params	-	-	-
f	-	-	-
k	-	-	-
t	-	-	-

## phi\_ssvi

*PLEASE ADD A FUNCTION DESCRIPTION*

```
phi_ssvi(theta, gamma):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
theta	-	-	-
gamma	-	-	-

## ssvi

*This is the total variance  $w = \sigma(t) \times \sigma(t) (0,t) \times t$*

```
ssvi(x, gamma, sigma, rho, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	-	-	-
gamma	-	-	-
sigma	-	-	-
rho	-	-	-
t	-	-	-

**ssvi1***PLEASE ADD A FUNCTION DESCRIPTION*

```
ssvi1(x, gamma, sigma, rho, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	-	-	-
gamma	-	-	-
sigma	-	-	-
rho	-	-	-
t	-	-	-

**ssvi2***PLEASE ADD A FUNCTION DESCRIPTION*

```
ssvi2(x, gamma, sigma, rho, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	-	-	-
gamma	-	-	-
sigma	-	-	-
rho	-	-	-
t	-	-	-

**ssvit***PLEASE ADD A FUNCTION DESCRIPTION*

```
ssvit(x, gamma, sigma, rho, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	-	-	-
gamma	-	-	-
sigma	-	-	-
rho	-	-	-
t	-	-	-

**g***PLEASE ADD A FUNCTION DESCRIPTION*

```
g(x, gamma, sigma, rho, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	-	-	-
gamma	-	-	-
sigma	-	-	-
rho	-	-	-
t	-	-	-

**dminus***PLEASE ADD A FUNCTION DESCRIPTION*

```
dminus(x, gamma, sigma, rho, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	-	-	-
gamma	-	-	-
sigma	-	-	-
rho	-	-	-
t	-	-	-

**density\_ssvi***PLEASE ADD A FUNCTION DESCRIPTION*

```
density_ssvi(x, gamma, sigma, rho, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	-	-	-
gamma	-	-	-
sigma	-	-	-
rho	-	-	-
t	-	-	-

**ssvi\_local\_varg***PLEASE ADD A FUNCTION DESCRIPTION*

```
ssvi_local_varg(x, gamma, sigma, rho, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
x	-	-	-
gamma	-	-	-
sigma	-	-	-
rho	-	-	-
t	-	-	-

**vol\_function\_ssvi***Volatility Function proposed by Gatheral in 2004.*

```
vol_function_ssvi(params, f, k, t):
```

The function arguments are described in the following table.

Argument Name	Type	Description	Default Value
params	-	-	-
f	-	-	-
k	-	-	-
t	-	-	-



**10.38** `--init--`