

Adaptiv Analytics

2019.1

Quantitative Implementation Details

Empowering
the Financial World

FIS

Copyright, Confidentiality, and Disclaimer

Copyright © 2018 Fidelity National Information Services, Inc. This document contains confidential and proprietary information of Fidelity Information Services, LLC and/or its affiliates and subsidiaries (collectively “FIS”). In limited circumstances this document may be copied and/or distributed to an FIS client and its employees on a “need to know” basis in order to fulfil their responsibilities. Any further copying, reproduction, or distribution without express written consent of FIS is strictly prohibited. All rights reserved worldwide.

CONFIDENTIALITY STATEMENT: This document contains information that is confidential or proprietary to FIS (or its direct and indirect subsidiaries). By accepting this document, you agree that: (1) if there is any pre-existing contract containing disclosure and use restrictions between your company and FIS, you and your company will use this information in reliance on and subject to the terms of any such pre-existing contract; or (2) if there is no contractual relationship between you or your company and FIS, you and your Company agree to protect this information and not reproduce, disclose or use the information in any way, except as may be required by law.

DISCLAIMER: The screens and illustrations are representative of those created by the software, and are not always exact copies of what appears on the computer monitor. Companies, names and data used in examples herein are fictitious unless otherwise noted. The material in this document is for information only, and is subject to change without notice. FIS reserves the right to make changes in the product design and installation software without reservation and without notice to users.

Document last updated 22 November 2019.

Contents

1	Copyright, Confidentiality, and Disclaimer	ii
I	Preliminaries	1
2	About this document	2
2.1	Intended Use	2
2.2	Built-for-Purpose	2
2.3	Model Calibration	2
2.4	Other Resources	2
2.4.1	Deal Skins Guide	2
2.4.2	Integrated documentation	3
2.4.3	Interfacing Guide	3
2.4.4	Theory Guide	3
3	General Concepts	4
3.1	Price Factors	4
3.1.1	Base Currency	4
3.1.2	Price Factors and Risk Factors	4
3.1.3	Historical Prices (Rate Fixings)	4
3.1.4	Interpolation Methods	4
3.1.5	Extrapolation Methods	5
3.2	Valuation Models	5
3.2.1	Dual Curve Pricing	5
3.2.2	Forecast and Discount Rate Correction	6
3.2.3	Respect Default	6
3.3	Deals	6
3.3.1	Deal Skin vs Atomic Deals	6
3.3.2	Nested Deal Skins	6
3.3.3	Structured Deals	6
3.3.4	Day Count	6
3.3.5	Date Adjustment	7
3.3.6	Date Roll Conventions	7
3.3.7	Issue Data	7
II	Price Factors	8
4	Asset Prices	9
4.1	Interpretation of an Asset Price	9
4.1.1	Spot Asset Prices	9
4.1.2	Forward Asset prices	9
4.1.3	Minimum Asset Price	10
4.1.4	Common Properties	10
4.2	FX Rate	10

4.2.1	Overview	10
4.2.2	Price Factor Dependency	10
4.2.3	Properties	10
4.3	Equity Price	12
4.3.1	Overview	12
4.3.2	Price Factor Dependency	12
4.3.3	Properties	12
4.4	Commodity Price	13
4.4.1	Overview	13
4.4.2	Price Factor Dependency	13
4.4.3	Properties	14
4.5	ETF Price	14
4.5.1	Overview	14
4.5.2	Price Factor Dependency	14
4.5.3	Properties	14
4.6	Futures Price	15
4.6.1	Overview	15
4.6.2	Price Factor Dependency	15
4.6.3	Properties	15
5	Futures Basis Price Factors	16
5.1	Interpretation of Futures Basis	16
5.1.1	Common Properties	16
5.1.2	Assumptions	16
5.2	Futures Basis	16
5.2.1	Overview	16
5.2.2	Price Factor Dependency	17
5.2.3	Properties	17
5.3	Bond Futures Basis	17
5.3.1	Overview	17
5.3.2	Price Factor Dependency	17
5.3.3	Properties	17
5.3.4	Assumptions	18
5.3.5	Limitations	18
6	Interest Rates	19
6.1	Interest Rate	19
6.1.1	Overview	19
6.1.2	Price Factor Dependency	19
6.1.3	Properties	19
6.1.4	Assumptions	20
6.2	Discount Rate	20
6.2.1	Overview	20
6.2.2	Price Factor Dependency	20
6.2.3	Properties	20
7	Cost Of Carry	22
7.1	Dividend Rate	22
7.1.1	Overview	22
7.1.2	Price Factor Dependency	23
7.1.3	Properties	23
7.1.4	Assumptions	23
7.2	Convenience Yield	23
7.2.1	Overview	23

7.2.2	Price Factor Dependency	24
7.2.3	Properties	24
7.2.4	Assumptions	24
7.2.5	Limitations	25
8	Mortgage Price Factors	26
8.1	Prepayment Rate	26
8.1.1	Overview	26
8.1.2	Price Factor Dependency	26
8.1.3	Properties	26
9	Credit Price Factors	27
9.1	Survival Probability	27
9.1.1	Overview	27
9.1.2	Price Factor Dependency	27
9.1.3	Properties	27
9.1.4	Assumptions	27
9.2	Credit Rating	28
9.2.1	Overview	28
9.2.2	Price Factor Dependency	28
9.2.3	Properties	28
9.3	Recovery Rate	28
9.3.1	Overview	28
9.3.2	Price Factor Dependency	28
9.3.3	Properties	29
9.4	Spreads & Spread Ratios	29
9.4.1	Benchmark Spread	29
9.4.2	Generic Spread	29
9.4.3	Long Term Spread Ratio	29
9.4.4	Spot Spread Ratio	29
10	Energy Price Factors	30
10.1	Interpretation of Energy Price Factors	30
10.1.1	Common Properties	30
10.2	Forward Price	30
10.2.1	Overview	30
10.2.2	Price Factor Dependency	31
10.2.3	Properties	31
10.2.4	Assumptions	31
10.2.5	Limitations	32
10.2.6	Flooring	32
10.3	Forward Spread	32
10.3.1	Overview	32
10.3.2	Price Factor Dependency	33
10.3.3	Properties	33
10.4	Forward Price Sample	33
10.4.1	Overview	33
10.4.2	Price Factor Dependency	33
10.4.3	Properties	33
10.5	Reference Price	34
10.5.1	Overview	34
10.5.2	Price Factor Dependency	34
10.5.3	Properties	35
10.5.4	Limitations	35

11 Volatility	36
11.1 Interpretation of Volatility Price Factors	36
11.1.1 Sticky Delta	36
11.2 Asset Price Volatility	36
11.2.1 Volatility Representations	36
11.2.2 Common Properties	36
11.2.3 Assumptions	37
11.2.4 FX Volatility	37
11.2.5 Equity Price Volatility	38
11.2.6 Commodity Price Volatility	40
11.3 Interest Rate and Interest Yield Volatility	41
11.3.1 Volatility Representations	41
11.3.2 Common Properties	41
11.3.3 Assumptions	42
11.3.4 Interest Rate Volatility	42
11.3.5 Interest Yield Volatility	42
11.4 Energy Volatility	43
11.4.1 Forward Price Volatility	43
11.4.2 Reference Volatility	43
12 Implied Correlations	45
12.1 Interpretation of Implied Correlations	45
12.1.1 Overview	45
12.1.2 Common Properties	45
12.2 Correlation	45
12.2.1 Price Factor Dependency	45
12.2.2 Properties	45
12.2.3 Assumptions	45
12.2.4 Limitations	46
12.3 CMS Rate Correlation	46
12.3.1 Overview	46
12.3.2 Price Factor Dependency	47
12.3.3 Properties	47
12.4 Forward Price Correlation	47
12.4.1 Overview	47
12.4.2 Price Factor Dependency	47
12.4.3 Properties	47
III Stochastic Models	48
13 Stochastic Simulation	49
13.1 Overview	49
13.1.1 Simulation of Price Factors	50
13.2 Common Assumptions and Limitations	50
13.2.1 Discrete Realisations	50
13.2.2 Copulas	51
13.2.3 Variance Reduction	51
13.2.4 Shared State Variables	51
14 Asset Price Models	52
14.1 Overview	52
14.1.1 Classes of Asset Price Models	52
14.1.2 Common Properties	53

14.1.3	Common Assumptions and Limitations	53
14.2	Drift To Forward Asset Price Model	55
14.2.1	Overview	55
14.2.2	Properties	55
14.2.3	Assumptions and Limitations	55
14.3	GBM Asset Price Model	56
14.3.1	Overview	56
14.3.2	Properties	56
14.3.3	Assumptions and Limitations	56
14.4	GBM Asset Price Term Structure Model	57
14.4.1	Overview	57
14.4.2	Properties	57
14.4.3	Assumptions and Limitations	58
14.5	GOU Asset Price Model	60
14.5.1	Overview	60
14.5.2	Properties	60
14.5.3	Assumptions and Limitations	60
14.6	GOU Asset Price Term Structure Model	61
14.6.1	Overview	61
14.6.2	Properties	61
14.6.3	Assumptions and Limitations	61
14.7	Multi-Factor GBM Asset Price Model	63
14.7.1	Overview	63
14.7.2	Properties	63
14.7.3	Assumptions and Limitations	64
14.7.4	Weight Normalisation	64
14.7.5	Zero Volatility	64
14.8	Multi-Factor GBM Asset Price Term Structure Model	66
14.8.1	Overview	66
14.8.2	Properties	67
14.8.3	Assumptions and Limitations	67
14.9	Trolle-Schwartz Stochastic Volatility Commodity Spot Model	68
14.9.1	Overview	68
14.9.2	Properties	68
14.9.3	Assumptions and Limitations	69
15	Joint Models	71
15.1	Overview	71
15.1.1	Heston models	71
15.1.2	Common Properties	71
15.1.3	Common Assumptions and Limitations	72
15.2	Heston 1 Factor Model	73
15.2.1	Overview	73
15.2.2	Configuration	73
15.2.3	Properties	74
15.2.4	Assumptions and Limitations	74
15.3	Heston 2 Factor Model	76
15.3.1	Overview	76
15.3.2	Configuration	76
15.3.3	Properties	76
15.3.4	Assumptions and Limitations	77
16	Energy Price Models	78
16.1	Overview	78

16.1.1	Common Assumptions and Limitations	78
16.2	Clelow-Strickland Forward Price Model	78
16.2.1	Overview	78
16.2.2	Properties	79
16.2.3	Assumptions and Limitations	79
16.3	Multi-Factor Clelow-Strickland Forward Price Model	80
16.3.1	Overview	80
16.3.2	Properties	80
16.3.3	Assumptions and Limitations	80
16.4	Andersen Forward Price Model	81
16.4.1	Overview	81
16.4.2	Properties	81
16.4.3	Assumptions and Limitations	82
16.5	Andersen Markov Stochastic Volatility Forward Price Model	83
16.5.1	Overview	83
16.5.2	Properties	83
16.5.3	Assumptions and Limitations	84
17	Energy Price Spread Models	85
17.1	Overview	85
17.1.1	Common Assumptions and Limitations	85
17.2	Ornstein-Uhlenbeck Forward Spread Model	86
17.2.1	Overview	86
17.2.2	Properties	86
17.2.3	Assumptions and Limitations	86
17.3	Ornstein-Uhlenbeck Forward Spread TS Model	87
17.3.1	Overview	87
17.3.2	Properties	87
17.3.3	Assumptions and Limitations	87
18	Interest Rate Models	88
18.1	Overview	88
18.1.1	Spread Curves and All-in Curves	88
18.1.2	Common Properties	88
18.1.3	Common Assumptions and Limitations	89
18.2	Drift To Forward Interest Rate Model	90
18.2.1	Overview	90
18.2.2	Properties	90
18.2.3	Assumptions and Limitations	90
18.3	Gaussian Key Rates Interest Rate Model	91
18.3.1	Overview	91
18.3.2	Properties	91
18.3.3	Assumptions and Limitations	92
18.4	Hull-White 1 Factor Interest Rate Model	93
18.4.1	Overview	93
18.4.2	Properties	93
18.4.3	Assumptions and Limitations	94
18.5	Hull White 2 Factor Interest Rate Model	95
18.5.1	Overview	95
18.5.2	Properties	95
18.5.3	Assumptions and Limitations	96
18.6	Jump Cox-Ingersoll-Ross Interest Rate Model	98
18.6.1	Overview	98
18.6.2	Properties	99

18.6.3	Assumptions and Limitations	100
18.7	Market Interest Rate Model	101
18.7.1	Overview	101
18.7.2	Properties	101
18.7.3	Assumptions and Limitations	102
18.8	Multi-Factor GOU Interest Rate Model	103
18.8.1	Overview	103
18.8.2	Properties	103
18.8.3	Assumptions and Limitations	104
18.9	PCA Interest Rate Model	105
18.9.1	Overview	105
18.9.2	Properties	106
18.9.3	Assumptions and Limitations	106
18.10	Transition Interest Rate Model	107
18.10.1	Overview	107
18.10.2	Properties	107
18.10.3	Assumptions and Limitations	107
19	Volatility Models	108
19.1	Overview	108
19.1.1	Classes of Volatility Model	108
19.1.2	Common Assumptions and Limitations	108
19.2	Simple volatility models	109
19.2.1	Overview	109
19.2.2	Forward Price Volatility Model	110
19.2.3	Price Index Volatility Model	110
19.2.4	Beta Asset Price Volatility Model	111
19.3	PCA Volatility Models	112
19.3.1	Overview	112
19.3.2	PCA FX Volatility Model	112
19.3.3	PCA Asset Price Volatility Model	113
19.3.4	PCA Interest Rate Volatility Model	113
19.3.5	PCA Interest Yield Volatility Model	113
20	Survival Probability Models	115
20.1	Overview	115
20.1.1	Survival Probabilities	115
20.1.2	Common Assumptions and Limitations	115
20.2	Drift To Forward Survival Probability Model	117
20.2.1	Overview	117
20.2.2	Properties	117
20.2.3	Assumptions and Limitations	117
20.3	Transition Survival Probability Model	118
20.3.1	Overview	118
20.3.2	Properties	118
20.3.3	Assumptions and Limitations	118
20.4	Exponential Vasicek Hazard Rate Model	119
20.4.1	Overview	119
20.4.2	Properties	119
20.4.3	Assumptions and Limitations	119
20.5	Hull-White Hazard Rate Model	120
20.5.1	Overview	120
20.5.2	Properties	120
20.5.3	Assumptions and Limitations	120

20.6	Jump Cox-Ingersoll-Ross Hazard Rate Model	121
20.6.1	Overview	121
20.6.2	Assumptions and Limitations	121
20.7	Multi-Factor GOU Hazard Rate Model	122
20.7.1	Overview	122
20.7.2	Properties	122
20.7.3	Assumptions and Limitations	123
20.8	Multi-Factor GBM Hazard Rate Model	124
20.8.1	Overview	124
20.8.2	Properties	124
20.8.3	Assumptions and Limitations	125
21	Price Index Models	126
21.1	Overview	126
21.1.1	Common Properties	126
21.1.2	Common Assumptions and Limitations	127
21.2	Price Index Drift Model	128
21.2.1	Overview	128
21.2.2	Properties	128
21.2.3	Assumptions and Limitations	128
21.3	GBM Price Index Model	129
21.3.1	Overview	129
21.3.2	Properties	129
21.3.3	Assumptions and Limitations	129
21.4	GBM Price Index Drift Model	130
21.4.1	Overview	130
21.4.2	Properties	130
21.4.3	Assumptions and Limitations	130
22	Credit Rating Models	131
22.1	Overview	131
22.1.1	Common Assumptions and Limitations	131
22.2	Hull-White Credit Rating Model	132
22.2.1	Overview	132
22.2.2	Properties	132
22.2.3	Assumptions and Limitations	132
22.3	IRC Credit Rating Model	134
22.3.1	Overview	134
22.3.2	Properties	134
22.3.3	Assumptions and Limitations	135
22.4	Multi-Factor Diffusion Credit Rating Model	136
22.4.1	Overview	136
22.4.2	Properties	136
22.4.3	Assumptions and Limitations	137
22.5	Counterparty Conditioning Credit Rating Model	138
22.5.1	Overview	138
22.5.2	Properties	138
22.5.3	Assumptions and Limitations	138
23	Credit Pool Loss Models	139
23.1	Overview	139
23.1.1	Common Properties	139
23.1.2	Common Assumptions and Limitations	139
23.2	Generalized Poisson Realized Loss Model	140

23.2.1	Overview	140
23.2.2	Properties	140
23.2.3	Assumptions and Limitations	140
23.3	Geometric Ornstein-Uhlenbeck Expected Loss Model	141
23.3.1	Overview	141
23.3.2	Properties	142
23.3.3	Assumptions and Limitations	142
24	Recovery Rate Models	143
24.1	Overview	143
24.1.1	Common Assumptions and Limitations	143
24.2	IRC Recovery Rate Model	144
24.2.1	Overview	144
24.2.2	Properties	144
24.2.3	Assumptions and Limitations	144
24.3	Multi-Factor Diffusion Recovery Rate Model	145
24.3.1	Overview	145
24.3.2	Properties	145
24.3.3	Assumptions and Limitations	146
25	Exposure at Default Models	147
25.1	Diffusion Exposure At Default Model	147
25.1.1	Overview	147
25.1.2	Properties	147
25.1.3	Assumptions and Limitations	147
26	Implied Models	148
26.1	Overview	148
26.2	Clellow Strickland Implied Forward Price Model (CSImpliedForwardPriceModel) . .	148
26.2.1	Properties	148
26.3	GBM Asset Price Term Structure Model (Implied) (GBMAssetPriceTSMModelImplied) .	148
26.3.1	Properties	148
26.4	Heston 1 Factor Asset Price Model (Implied) (Heston1FactorAssetPriceModelImplied)	148
26.4.1	Properties	148
26.5	Heston 2 Factor Asset Price Model (Implied) (Heston2FactorAssetPriceModelImplied)	148
26.5.1	Properties	148
26.6	Hull White 1 Factor Implied Inflation Rate Model (HullWhite1FactorImpliedInflationRateModel)	149
26.6.1	Properties	149
26.7	Hull White 1 Factor Implied Interest Rate Model (HullWhite1FactorImpliedInterestRateModel)	149
26.7.1	Properties	149
26.8	Hull White 2 Factor Implied Interest Rate Model (HullWhite2FactorImpliedInterestRateModel)	149
26.8.1	Properties	149
26.9	Multi-Factor GBM Asset Price Term Structure Model (Implied) (MultiGBMAssetPriceTSMModelImplied)	149
26.9.1	Properties	149
26.10	Script Model Hybrid 1-Factor Hull-White Implied (ScriptModelHybridHullWhiteImplied)	150
26.10.1	Properties	150
26.11	Script Model Interest Rate Hull White Implied (ScriptModelInterestRateHullWhiteImplied)	150
26.11.1	Properties	150

IV Model Calibrations	151
27 Calibration	152
27.1 Overview	152
27.1.1 Common Properties	152
27.1.2 Common Assumptions and Limitations	155
28 Asset Price Model Calibrations	158
28.1 GBM Asset Price Model	158
28.1.1 Overview	158
28.1.2 Calibration Method	158
28.1.3 Properties	158
28.1.4 Assumptions and Limitations	158
28.2 GBM Asset Price Term Structure Model	159
28.2.1 Overview	159
28.2.2 Calibration Method	159
28.2.3 Properties	160
28.2.4 Assumptions and Limitations	161
28.3 GOU Asset Price Model	162
28.3.1 Overview	162
28.3.2 Calibration Method	162
28.3.3 Properties	162
28.3.4 Assumptions and Limitations	163
28.4 Multi-Factor GBM Asset Price Model	164
28.4.1 Overview	164
28.4.2 Calibration Method	164
28.4.3 Properties	165
28.4.4 Assumptions and Limitations	166
28.5 Multi-Factor GBM Asset Price Term Structure Model	167
28.5.1 Overview	167
28.5.2 Calibration Method	167
28.5.3 Properties	167
28.5.4 Assumptions and Limitations	167
28.6 Multi-Factor GBM Asset Price Term Structure Model (Implied)	168
28.6.1 Overview	168
28.6.2 Calibration Method	168
28.6.3 Properties	168
28.6.4 Assumptions and Limitations	169
29 Joint Model Calibrations	170
29.1 Heston Asset Price Model	170
29.1.1 Overview	170
29.1.2 Calibration Method	170
29.1.3 Properties	171
29.1.4 Assumptions and Limitations	172
30 Interest Rate Model Calibrations	173
30.1 Gaussian Key Rates Interest Rate Model	173
30.1.1 Overview	173
30.1.2 Calibration Method	173
30.1.3 Properties	173
30.1.4 Assumptions and Limitations	173
30.2 Jump Cox-Ingersoll-Ross Interest Rate Model	174
30.2.1 Overview	174

30.2.2	Calibration Method	174
30.2.3	Properties	174
30.2.4	Assumptions and Limitations	174
30.3	Hull-White 1-Factor Interest Rate Model	175
30.3.1	Overview	175
30.3.2	Calibration Method	175
30.3.3	Properties	176
30.3.4	Assumptions and Limitations	176
30.4	Hull-White 2-Factor Interest Rate Model	178
30.4.1	Overview	178
30.4.2	Calibration Method	178
30.4.3	Properties	178
30.4.4	Assumptions and Limitations	179
30.5	Market Interest Rate Model	180
30.5.1	Overview	180
30.5.2	Calibration Method	180
30.5.3	Properties	181
30.5.4	Assumptions and Limitations	182
30.6	Multi-Factor GOU Interest Rate Model	183
30.6.1	Overview	183
30.6.2	Calibration Method	183
30.6.3	Properties	183
30.6.4	Assumptions and Limitations	183
30.7	PCA Interest Rate Model	184
30.7.1	Overview	184
30.7.2	Calibration Method	184
30.7.3	Properties	185
30.7.4	Assumptions and Limitations	185
31	Price Index Calibrations	186
31.1	GBM Price Index Model	186
31.1.1	Overview	186
31.1.2	Calibration Method	186
31.1.3	Properties	186
31.1.4	Assumptions and Limitations	186
31.2	GBM Price Index Drift Model	187
31.2.1	Overview	187
31.2.2	Calibration Method	187
31.2.3	Properties	187
31.2.4	Assumptions and Limitations	187
32	Volatility Model Calibrations	188
32.1	Simple Volatility Models	188
32.1.1	Overview	188
32.1.2	Calibration Method	188
32.1.3	Properties	189
32.1.4	Assumptions and Limitations	190
32.2	Beta Asset Price Volatility Model	191
32.2.1	Overview	191
32.2.2	Calibration Method	191
32.2.3	Properties	192
32.2.4	Assumptions and Limitations	193
32.3	PCA Volatility Model Calibrations	194
32.3.1	Overview	194

32.3.2	Calibration Method	194
32.3.3	Properties	194
32.3.4	Assumptions and Limitations	195
33	Energy Model Calibrations	196
33.1	Clelow-Strickland Forward Price Model	196
33.1.1	Overview	196
33.1.2	Calibration Method	196
33.1.3	Properties	197
33.1.4	Assumptions and Limitations	197
33.2	Multi Factor Clelow-Strickland Forward Price Model	198
33.2.1	Overview	198
33.2.2	Calibration Method	198
33.2.3	Properties	198
33.2.4	Assumptions and Limitations	198
33.3	Ornstein-Uhlenbeck Forward Spread Model	200
33.3.1	Overview	200
33.3.2	Calibration Method	200
33.3.3	Properties	201
33.3.4	Assumptions and Limitations	201
33.4	Ornstein-Uhlenbeck Forward Spread Term Structured Model	202
33.4.1	Overview	202
33.4.2	Calibration Method	202
33.4.3	Properties	202
33.4.4	Assumptions and Limitations	203
34	Hazard Rate Calibrations	204
34.1	Jump Cox-Ingersoll-Ross Hazard Rate Model	204
34.1.1	Overview	204
34.1.2	Calibration Method	204
34.1.3	Properties	204
34.1.4	Assumptions and Limitations	204
34.2	Exponential Vasicek Hazard Rate Model	205
34.2.1	Overview	205
34.2.2	Calibration Method	205
34.2.3	Properties	205
34.2.4	Assumptions and Limitations	205
34.3	Hull-White Hazard Rate Model	206
34.3.1	Overview	206
34.3.2	Calibration Method	206
34.3.3	Properties	206
34.3.4	Assumptions and Limitations	206
34.4	Multi-Factor GBM Hazard Rate Model	207
34.4.1	Overview	207
34.4.2	Calibration Method	207
34.4.3	Properties	207
34.4.4	Assumptions and Limitations	208
34.5	Multi-Factor GOU Hazard Rate Model	209
34.5.1	Overview	209
34.5.2	Calibration Method	209
34.5.3	Properties	209
34.5.4	Assumptions and Limitations	209
35	Credit Rating Models	210

35.1	Hull-White Credit Rating Model	210
35.1.1	Overview	210
35.1.2	Calibration Method	210
35.1.3	Properties	211
35.1.4	Assumptions and Limitations	211
35.2	Multi-Factor Diffusion Credit Rating Model	212
35.2.1	Overview	212
35.2.2	Calibration Method	212
35.2.3	Properties	212
35.2.4	Assumptions and Limitations	212
36	Correlations Calibrations	213
36.1	Correlations Calibration	213
36.1.1	Overview	213
36.1.2	Calibration Method	213
36.1.3	Properties	214
36.1.4	Assumptions and Limitations	214
V	OTC Derivatives: Asset Prices	215
37	Asset Price Derivatives	216
37.1	Overview	216
37.2	Common Properties	216
37.2.1	Barrier Monitoring Frequency	216
37.2.2	Barrier Price	216
37.2.3	Barrier Type	216
37.2.4	Basket	216
37.2.5	Buy Sell	217
37.2.6	Cash Payoff	217
37.2.7	Cash Rebate	217
37.2.8	Expiry Date	217
37.2.9	Forward Price Date	217
37.2.10	Lower Barrier:	217
37.2.11	Maturity Date	217
37.2.12	Option on Forward	217
37.2.13	Option Style	217
37.2.14	Option Type	217
37.2.15	Payment Timing	217
37.2.16	Payoff Type	218
37.2.17	Sampling Data	218
37.2.18	Settlement Style	218
37.2.19	Strike Price	218
37.2.20	Upper Barrier	218
37.3	Assumptions	218
37.3.1	Value of an Underlying Asset	218
37.3.2	No Arbitrage	219
37.3.3	Spot Price Dynamics	219
37.3.4	Valuation of Quanto and Compo Payoffs	220
37.3.5	European Option Valuation	220
37.3.6	American Option Valuation	220
37.3.7	Barrier Option Valuation	221
37.3.8	Double Barrier Option Valuation	222
37.3.9	Discrete Asian Option Valuation	223

37.3.10	Discrete Double Asian Option Valuation	224
37.3.11	Continuous Asian Option Valuation	227
37.3.12	Baskets of Asset Prices	228
37.3.13	Chooser Option Valuation	230
37.3.14	Cliquet Option Valuation	230
37.3.15	Compound Option Valuation	231
37.3.16	Lookback Option Valuation	232
37.3.17	Gap Option Valuation	233
37.3.18	Forward Strip Option Valuation	234
37.3.19	Partial-Time Barrier Option Valuation	234
37.4	Limitations	236
37.4.1	Interpretation of an Asset Price Factor	236
37.4.2	Minimum Price	236
37.4.3	No Settlement Lags	236
37.4.4	Cash Settled	237
37.4.5	Approximation for American Options	237
37.4.6	Exercise of American Options	237
37.4.7	Early Call Exercise	237
37.4.8	Lifetime Management of American Options	237
37.4.9	No American Exercise for Baskets of Returns	237
37.4.10	Volatility for Barrier Options	237
37.4.11	Symmetric Double Barrier Types	238
37.4.12	No Explicit Barrier Monitoring Schedules	238
37.4.13	No Partial-day Barrier Monitoring	238
37.4.14	Barrier Touching	238
37.4.15	Lifetime Management of Barrier Options	239
38	FX	240
38.1	FX Valuation Models	240
38.1.1	Common Properties	240
38.1.2	Assumptions	241
38.1.3	Limitations	241
38.2	FX Forward Deal Types	243
38.2.1	FX Spot	243
38.2.2	FX Forward	244
38.2.3	FX Forward Strip	245
38.2.4	FX Non-Deliverable Forward	246
38.2.5	FX Time Option	247
38.2.6	FX Average Rate Forward Strip	249
38.2.7	FX Average Rate Forward (Explicit)	251
38.2.8	FX Average Strike Forward	252
38.2.9	FX Average Strike Forward (Explicit)	254
38.2.10	FX Swap	255
38.3	FX Option Deal Types	257
38.3.1	FX Option	257
38.3.2	FX Binary Option	259
38.3.3	FX Basket Option	261
38.3.4	FX Chooser Option	263
38.3.5	FX Cliquet Option	264
38.3.6	FX Compound Option	266
38.3.7	FX Lookback Option	267
38.3.8	FX Gap Option	269
38.3.9	FX Forward Strip Option	270
38.4	FX Asian Option Deal Types	271

38.4.1	FX Discrete (Explicit) Asian Option	271
38.4.2	FX Discrete Asian Option	272
38.4.3	FX Discrete (Explicit) Double Asian Option	274
38.4.4	FX Basket Discrete (Explicit) Asian Option	276
38.4.5	FX Basket Discrete Asian Option	277
38.4.6	FX Continuous Asian Option	279
38.4.7	FX Basket Continuous Asian Option	280
38.5	FX Barrier Option Deal Types	281
38.5.1	FX Barrier Option	281
38.5.2	FX Barrier Binary Option	282
38.5.3	FX Double Barrier Option	283
38.5.4	FX One Touch Option	284
38.5.5	FX No Touch Option	285
38.5.6	FX Double One Touch Option	286
38.5.7	FX Double No Touch Option	287
38.5.8	FX Partial-Time Barrier Option	288
38.6	FX Variance Swap Deal Types	290
38.6.1	FX Variance Swap	290
38.6.2	FX Volatility Swap	293
39	Equity	296
39.1	Equity Valuation Models	296
39.1.1	Common Properties	296
39.1.2	Assumptions	297
39.1.3	Limitations	297
39.2	Equity Position Deal Types	298
39.2.1	Equity	298
39.2.2	Equity Basket	299
39.2.3	Equity Position	301
39.2.4	ETF	302
39.3	Equity Forward Deal Types	303
39.3.1	Equity Forward	303
39.3.2	Equity Basket Forward	304
39.3.3	Equity Average Rate Forward	305
39.3.4	Equity Average Rate Forward (Explicit)	307
39.3.5	Equity Average Strike Forward	309
39.3.6	Equity Average Strike Forward (Explicit)	311
39.4	Equity Swap Deal Types	313
39.4.1	Overview	313
39.4.2	Properties	313
39.4.3	Assumptions	317
39.4.4	Limitations	317
39.4.5	Equity Swap	318
39.4.6	Equity Basket Swap	320
39.4.7	Equity Swap Leg	322
39.4.8	Equity Swaplet List	323
39.4.9	Equity-Linked Fixed Interest Cashflow List	325
39.4.10	Equity-Linked Floating Interest Cashflow List	327
39.5	Equity Option Deal Types	330
39.5.1	Equity Option	330
39.5.2	Equity Binary Option	332
39.5.3	Equity Basket Option	334
39.5.4	Equity Chooser Option	336
39.5.5	Equity Cliquet Option	337

39.5.6	Equity Compound Option	339
39.5.7	Equity Gap Option	341
39.5.8	Equity Lookback Option	342
39.6	Equity Asian Option Deal Types	344
39.6.1	Equity Discrete (Explicit) Asian Option	344
39.6.2	Equity Discrete (Explicit) Double Asian Option	345
39.6.3	Equity Basket Discrete (Explicit) Asian Option	347
39.7	Equity Barrier Option Deal Types	349
39.7.1	Equity Barrier Option	349
39.7.2	Equity Barrier Binary Option	350
39.7.3	Equity Double Barrier Option	351
39.7.4	Equity One Touch Option	353
39.7.5	Equity No Touch Option	354
39.7.6	Equity Double One Touch Option	355
39.7.7	Equity Double No Touch Option	356
39.7.8	Equity Partial-Time Barrier Option	357
39.8	Equity Variance Swap Deal Types	359
39.8.1	Equity Variance Swap	359
39.8.2	Equity Volatility Swap	362
40	Commodity	365
40.1	Commodity Valuation Models	365
40.1.1	Common Properties	365
40.1.2	Assumptions	366
40.1.3	Limitations	366
40.2	Commodity Forward Deal Types	367
40.2.1	Commodity Forward	367
40.2.2	Commodity Average Rate Forward	368
40.2.3	Commodity Average Rate Forward (Explicit)	370
40.2.4	Commodity Average Strike Forward	372
40.2.5	Commodity Average Strike Forward (Explicit)	374
40.2.6	Commodity Basket Forward	376
40.2.7	Commodity Basket Average Rate Forward	377
40.2.8	Commodity Basket Average Rate Forward (Explicit)	379
40.3	Commodity Swap Deal Types	381
40.3.1	Overview	381
40.3.2	Properties	381
40.3.3	Assumptions	381
40.3.4	Limitations	381
40.3.5	Commodity Swap	382
40.3.6	Commodity Basket Swap	384
40.3.7	Commodity Swap Leg	386
40.3.8	Commodity Swaplet List	387
40.4	Commodity Option Deal Types	389
40.4.1	Commodity Option	389
40.4.2	Commodity Binary Option	391
40.4.3	Commodity Basket Option	393
40.4.4	Commodity Chooser Option	395
40.4.5	Commodity Cliquet Option	396
40.4.6	Commodity Compound Option	398
40.4.7	Commodity Gap Option	400
40.4.8	Commodity Lookback Option	401
40.5	Commodity Asian Option Deal Types	403
40.5.1	Commodity Discrete (Explicit) Asian Option	403

40.5.2	Commodity Discrete (Explicit) Double Asian Option	404
40.5.3	Commodity Basket Discrete (Explicit) Asian Option	406
40.6	Commodity Barrier Option Deal Types	408
40.6.1	Commodity Barrier Option	408
40.6.2	Commodity Barrier Binary Option	409
40.6.3	Commodity Double Barrier Option	410
40.6.4	Commodity One Touch Option	412
40.6.5	Commodity No Touch Option	413
40.6.6	Commodity Double One Touch Option	414
40.6.7	Commodity Double No Touch Option	415
40.6.8	Commodity Partial-Time Barrier Option	416
40.7	Commodity Variance Swap Deal Types	418
40.7.1	Commodity Variance Swap	418
40.7.2	Commodity Volatility Swap	421

VI OTC Derivatives: Interest Rates 424

41 Interest Rates 425

41.1	Fixed Rate Deposit	425
41.1.1	Overview	425
41.1.2	Price Factor Dependency	425
41.1.3	Properties	425
41.1.4	Deal Representation	427
41.1.5	Valuation	427
41.2	Fixed Rate Loan	428
41.2.1	Overview	428
41.2.2	Price Factor Dependency	428
41.2.3	Properties	428
41.2.4	Deal Representation	428
41.2.5	Valuation	428
41.3	Cap/Floor	429
41.3.1	Overview	429
41.3.2	Price Factor Dependency	429
41.3.3	Properties	429
41.3.4	Deal Representation	432
41.3.5	Valuation	432
41.4	Digital Cap/Floor	433
41.4.1	Overview	433
41.4.2	Price Factor Dependency	433
41.4.3	Properties	433
41.4.4	Deal Representation	433
41.4.5	Valuation	433
41.5	FRA	434
41.5.1	Overview	434
41.5.2	Price Factor Dependency	434
41.5.3	Properties	434
41.5.4	Deal Representation	434
41.5.5	Valuation	434
41.5.6	Tuning Parameters and Valuation Settings	435
41.5.7	Assumptions	436
41.5.8	Limitations	436

42 Interest Cashflow Lists 437

42.1	Fixed Interest Cashflow List	437
42.1.1	Overview	437
42.1.2	Price Factor Dependency	437
42.1.3	Properties	437
42.1.4	Deal Representation	439
42.1.5	Valuation	439
42.1.6	Tuning Parameters and Valuation Settings	439
42.1.7	Assumptions	440
42.2	Floating Interest Cashflow List	441
42.2.1	Deal	441
42.2.2	Standard Valuation Model (CFFloatingInterestListValuation)	446
42.2.3	Hull-White Valuation Model (CapHullWhiteValuation)	449
43	Swaps	451
43.0.1	Overview	451
43.0.2	Properties	451
43.0.3	Tuning Parameters and Valuation Settings	456
43.0.4	Assumptions	456
43.0.5	Limitations	456
43.1	Interest Rate Swap	456
43.1.1	Overview	456
43.1.2	Price Factor Dependency	456
43.1.3	Properties	457
43.1.4	Deal Representation	457
43.1.5	Valuation	457
43.2	Overnight Index Swap	458
43.2.1	Overview	458
43.2.2	Price Factor Dependency	458
43.2.3	Properties	458
43.2.4	Deal Representation	458
43.2.5	Valuation	458
43.3	Basis Swap	459
43.3.1	Overview	459
43.3.2	Price Factor Dependency	459
43.3.3	Properties	459
43.3.4	Deal Representation	459
43.3.5	Valuation	459
43.4	Currency Swap	460
43.4.1	Overview	460
43.4.2	Price Factor Dependency	460
43.4.3	Properties	460
43.4.4	Deal Representation	460
43.4.5	Valuation	460
43.5	MtM Cross Currency Swap	461
43.5.1	Overview	461
43.5.2	Price Factor Dependency	461
43.5.3	Properties	461
43.5.4	Deal Representation	462
43.5.5	Valuation	462
43.5.6	Tuning Parameters and Valuation Settings	463
43.5.7	Assumptions	463
43.5.8	Limitations	463
44	Swaptions	465

44.1	Swaption	465
44.1.1	Overview	465
44.1.2	Deal Representation	465
44.1.3	Properties	465
44.1.4	Standard Valuation Model (SwaptionValuation)	469
44.1.5	Hull-White Valuation Model (SwaptionHullWhiteValuation)	471
44.2	American and Bermudan Swaptions and Cancellable Swaps	473
44.2.1	Bermudan Swaption	479
44.2.2	American Swaption	480
44.2.3	Cancellable Swap	481
45	Fixed Income	482
45.1	FRN Forward	482
45.1.1	Overview	482
45.1.2	Price Factor Dependency	482
45.1.3	Properties	482
45.1.4	Deal Representation	486
45.1.5	Valuation	486
45.2	Bond Forward	487
45.2.1	Overview	487
45.2.2	Price Factor Dependency	487
45.2.3	Properties	487
45.2.4	Deal Representation	489
45.2.5	Valuation	489
45.3	Bond Option	490
45.3.1	Overview	490
45.3.2	Price Factor Dependency	490
45.3.3	Properties	490
45.3.4	Deal Representation	490
45.3.5	Valuation	490
45.3.6	Tuning Parameters and Valuation Settings	490
45.3.7	Assumptions	491
45.3.8	Limitations	492
45.4	Treasury Lock	494
45.4.1	Overview	494
45.4.2	Price Factor Dependency	494
45.4.3	Properties	494
45.4.4	Deal Representation	495
45.4.5	Valuation	495
45.4.6	Tuning Parameters and Valuation Settings	495
45.4.7	Assumptions	495
45.4.8	Limitations	495
VII	OTC Derivatives: Credit	496
46	Default Swaps	497
46.1	Common Properties	497
46.1.1	Accrual Day Count	497
46.1.2	Accrued To End Period	497
46.1.3	Accrue Fee	497
46.1.4	Amortisation	497
46.1.5	Buy Sell	497
46.1.6	Calendars	497

46.1.7	Currency	497
46.1.8	Digital Recovery	498
46.1.9	Discount Rate	498
46.1.10	Effective Date	498
46.1.11	First Coupon Date	498
46.1.12	ISDA Standard	498
46.1.13	Is Digital	498
46.1.14	Maturity Date	498
46.1.15	Pay Frequency	498
46.1.16	Pay Rate	498
46.1.17	Penultimate Coupon Date	498
46.1.18	Principal	498
46.1.19	Protection Paid At Maturity	499
46.1.20	Recovery Rate	499
46.1.21	Survival Probability	499
46.1.22	Upfront	499
46.1.23	Upfront Date	499
46.2	Common Date Generation	499
46.3	Credit Default Swap	501
46.3.1	Overview	501
46.3.2	Price Factor Dependency	501
46.3.3	Properties	501
46.3.4	Deal Representation	501
46.3.5	Valuation	502
46.4	Credit Default Swap (Explicit)	503
46.4.1	Overview	503
46.4.2	Price Factor Dependency	503
46.4.3	Properties	503
46.4.4	Deal Representation	503
46.4.5	Valuation	503
46.4.6	Tuning Parameters and Valuation Settings	504
46.4.7	Assumptions	505
46.4.8	Limitations	506
46.5	Index Default Swap	507
46.5.1	Overview	507
46.5.2	Price Factor Dependency	507
46.5.3	Properties	507
46.5.4	Deal Representation	507
46.5.5	Valuation	508
47	Total Return Swaps	509
47.1	Total Return Swaps Container	509
47.1.1	Overview	509
47.1.2	Price Factor Dependency	509
47.1.3	Properties	509
47.1.4	Deal Representation	511
47.1.5	Valuation	511
47.1.6	Assumptions	512
47.1.7	Limitations	512
VIII	OTC Derivatives: Energy	514
48	Energy	515

48.1	Energy Valuation Models	515
48.1.1	Common Properties	515
48.1.2	Assumptions	516
48.1.3	Limitations	517
48.2	Energy Cashflow Products	518
48.2.1	Energy Cashflow Products Valuation Models	518
48.2.2	Energy Physical Fixed	519
48.2.3	Floating Energy Cashflow List	521
48.2.4	Energy Fixed-Float Swap	522
48.3	Energy Option Deal Types	524
48.3.1	Energy Option Valuation Models	524
48.3.2	Energy Option	526
48.3.3	Energy Cap/Floor	528
48.4	Energy Swaption Deal Types	529
48.4.1	Energy Swaption	529

IX OTC Derivatives: Mortgages & Securities Lending 531

49 Mortgage 532

49.1	Mortgage Deal Types	532
49.1.1	Overview	532
49.1.2	Properties	532
49.1.3	Valuation	533
49.1.4	Assumptions	533
49.1.5	Limitations	534
49.1.6	Fixed MBS Bond	535
49.1.7	Floating MBS Bond	536

50 Securities Lending 537

50.1	Security Lending Set	537
50.1.1	Overview	537
50.1.2	Price Factor Dependency	537
50.1.3	Properties	537
50.1.4	Deal Representation	538
50.1.5	Valuation	538
50.1.6	Tuning Parameters and Valuation Settings	538
50.1.7	Assumptions	539
50.1.8	Limitations	539
50.2	Security Lending Leg	541
50.2.1	Overview	541
50.2.2	Price Factor Dependency	541
50.2.3	Properties	541
50.2.4	Deal Representation	541
50.2.5	Valuation	541
50.2.6	Tuning Parameters and Valuation Settings	542
50.2.7	Assumptions	542
50.2.8	Limitations	542
50.3	Security Collateral Leg	543
50.3.1	Overview	543
50.3.2	Price Factor Dependency	543
50.3.3	Properties	543
50.3.4	Deal Representation	544
50.3.5	Valuation	544

50.3.6	Tuning Parameters and Valuation Settings	544
50.3.7	Assumptions	544
50.3.8	Limitations	544
X	Exchange-Traded Derivatives	545
51	Futures	546
51.1	Futures Valuation Models	546
51.1.1	Common Properties	546
51.1.2	Tuning Parameters and Valuation Settings	548
51.1.3	Assumptions	549
51.1.4	Limitations	551
51.2	FX Futures Deal Types	553
51.2.1	FX Futures	553
51.2.2	FX Futures Option	554
51.3	Equity Futures Deal Types	555
51.3.1	Equity Futures	555
51.3.2	Equity Futures Option	556
51.4	Interest Rate Futures Deal Types	557
51.4.1	Interest Rate Futures	557
51.4.2	Interest Rate Futures Option	559
51.4.3	Bond Futures	560
51.4.4	Bond Futures Option	561
51.5	Energy Futures Deal Types	563
51.5.1	Energy Futures	563
51.5.2	Energy Futures Option	565
XI	Calculations	566
52	Credit Monte Carlo Calculation	567
52.1	Parameter tuning - Scenario Time Grid	567
XII	Glossary	568
53	Glossary	569
XIII	Bibliography	571

Part I

Preliminaries

Chapter 2

About this document

2.1 Intended Use

The models describe in this document are primarily selected for the purpose of credit and market risk regulation calculations, where modelling methodologies are selected for both model accuracy as well as computational speed within simulation.

2.2 Built-for-Purpose

Models are chosen for performance unless otherwise specified. Models are implemented as published in the Theory Guide, with reference to literature where relevant. The models are suitable for use with all calculations unless otherwise stated in the theory guide, subject to client approval and acceptance as part of implemented solution. Adaptiv cannot provide guidance on the suitability of a model's use or how to judge its results, as this is subject to a client's specific use case and implementation. Clients can request enhancements, new models, or use the Adaptiv Analytics extensibility language to ensure the model meets their internal model policies.

2.3 Model Calibration

Wherever possible parameters for calibrating or tuning of models are exposed to the user. Documentation of their use by the models is provided in the Theory Guide. Instances where parameters are not exposed to the user are also stated in Theory Guide. The user should carry out analysis and testing to select appropriate values for these parameters based on configuration, application, and input data.

2.4 Other Resources

Throughout this document there are references to other Adaptiv Analytics documents which contain specialised information according to the type of document. The documents referenced are, the Deal Skins Guide, the Integrated documentation, the Interfacing Guide, and the Theory Guide. Where appropriate, in addition to external resources referenced by the Adaptiv Analytics Theory Guide, additional external references relevant to this document are provided throughout and links consolidated in the Bibliography section.

2.4.1 Deal Skins Guide

The Deal Skins guide [2] contains information about the variant and atomic underlying deals associated with each deal skin that is available in Adaptiv Analytics.

2.4.2 Integrated documentation

The Integrated documentation contains details about each of the properties of price factors and portfolio deals. For users of AA studio, this documentation can be displayed by pressing F1 whilst selecting an item (price factor or deal) in the corresponding tab in Adaptiv Analytics.

2.4.3 Interfacing Guide

The Interfacing Guide [5] describes the supported interfaces between input and output XML documents and Adaptiv Analytics. Additionally, it provides information about how to catch errors and generate diagnostics information.

2.4.4 Theory Guide

The Theory Guide [7] presents the details and theory behind the different calculations implemented in Adaptiv Analytics. This document is intended for a quantitative audience. There is a comprehensive bibliography at the end of the Theory Guide, which references the primary resources for our selected models.

Chapter 3

General Concepts

3.1 Price Factors

3.1.1 Base Currency

The base currency of an Adaptiv Analytics configuration is the default currency of the system. Prices are interpreted as denominated in base currency when no other currency is specified. Calculation results are converted to base currency for aggregation. The base currency is defined in the market data file.

3.1.2 Price Factors and Risk Factors

A price factor is a representation of market rates which could be simulated and pass into a valuation model. Some price factors are directly observe from market data but the majority of price factors are not directly observable and require some transformation from the observable market prices, such as bootstrapping. For example, the interest rate price factor is expressed as a continuously compounded zero coupon yield.

A price factor model, which calculates the future state of a price factor under Monte Carlo simulation, has a vector of *risk factor* processes, which are the underlying source of the randomness in the model. See the Theory Guide for details about how price factors and risk factors are defined in Adaptiv Analytics [7, § 1 [Price Factors](#)].

3.1.3 Historical Prices (Rate Fixings)

Price factors provide current values of prices, as of the base calculation date, and simulated values for subsequent dates. However, sometimes valuation models require historically realized prices; any price required for a date before the base calculation date is assumed by Adaptiv Analytics to be historically realized. Historically realized prices may be stored in a rate fixing archive for common use by valuation models; rate fixings are described in [7, § 1.7 [Rate Fixings](#)]. Some deals allow historical prices to be specified in deal properties; when such deal-specific prices are specified, they override the common values in the rate fixings archive. Deal-specific historical prices may also be used to override the price value on the base date; otherwise, the initial price factor value is used on the base date. When a historical price is missing both from deal data and from the rate fixing file, then usually the initial price factor value is used instead.

3.1.4 Interpolation Methods

3.1.4.1 Curves

The interpolation methods used by Adaptiv Analytics are described in detail in the Theory Guide [7, § A.1. [General Interpolation Methods](#)]. It is possible to override the default interpolation methods,

please refer to the Interfacing Guide for details of how this can be done [5, § A.5 Price Factor Interpolation]. It is also possible to define custom interpolations, for details of how this can be done please refer to the Extensibility Guide [3].

3.1.4.2 Surfaces

For details about surface interpolation in Adaptiv Analytics see the Theory Guide [7, § A.3.2 Standard Surface Interpolation].

3.1.5 Extrapolation Methods

3.1.5.1 Surfaces

Two extrapolation methods are supported, Flat and Linear. Default extrapolation method on all dimensions of the surface is Flat. Specified extrapolation method applies to all dimensions of the surface. Extrapolation methods need to be explicitly specified in the price factor data in the market data file, please refer to the Interfacing Guide for details of how this can be done [5, § A.5 Price Factor Interpolation].

3.1.5.2 Example

Suppose we have the following Surface representing an Interest rate volatility surface.

```
InterestRateVol.EUR, Surface=[3, Flat, (0, 1, 0.25, 0.2), (1, 2, 0.5, 0.25), (0, 1, 1, 0.4)]
```

In $(0, 1, 0.25, 0.2)$, the first three elements specify the coordinates and the fourth is the actual value, so for this case: 0 is the moneyness, 1 is time to expiry and 0.25 is the tenor. Note that for InterestRateVol moneyness is Spot-Strike and tenors are year fraction.

3.1.5.3 Surface Construction

This is the procedure that Adaptiv Analytics follows to construct the surface

```
3, Flat, (0, 1, 0.25, 0.2), (1, 2, 0.5, 0.25), (0, 1, 1, 0.4)
```

- (1) Adaptiv Analytics parses the string and set the dimension to 3 and extrapolation method to Flat.
- (2) As the dimension is 3, Curve will be null and X and Y will be used to represent the surface.
- (3) For each of the collection of coordinates value below Adaptiv Analytics does the following (only the first collection is used for simplicity),


```
(0, 1, 0.25, 0.2), (1, 2, 0.5, 0.25), (0, 1, 1, 0.4)
```

 - (a) It will insert the third coordinate (i.e. 0.25) to X at the appropriate position.
 - (b) It creates a new surface with dimension $3 - 1 = 2$ and
 - (i) It will insert 1 to X at the appropriate position.
 - (ii) It creates a new surface with dimension $2 - 1 = 1$ and as dimension is 1 now, it will create a curve $(0, 0.2)$ and assign it to the Curve property of the surface.

3.2 Valuation Models

3.2.1 Dual Curve Pricing

Adaptiv Analytics supports dual curve pricing.

3.2.2 Forecast and Discount Rate Correction

The forecast rate and the discount rate are correlated and therefore there in theory should be an adjustment between the two. However, this is not currently executed in Adaptiv Analytics.

3.2.3 Respect Default

This valuation model parameter, which is present on several valuation products for which issuers are required, is used in calculations such as the jump to default stress test where the default event occurs. If `Respect Default` is set to `Yes` then it introduces dependencies on the (Issuer) Credit Rating and Recovery Rate price factors.

3.3 Deals

3.3.1 Deal Skin vs Atomic Deals

The elementary product types of Adaptiv Analytics are *atomic deals*. However, for the purposes of deal mapping it is often convenient to use a simplified representation or *deal skin*. When the deal skin is built it expands into the corresponding set of underlying deals. Deal skins are explained in detail in the Deal Skins section of the Analytics Workspace User Guide [1]. The mapping from deal skins to the underlying atomic deals can be found in the Deal Skins Guide [2].

Most deal skins are valued using the `DealSkinValuation` model. This valuation model simply sums the value of the child deals. A small number of deal skin types use alternate valuation models. These are where correct pricing requires more than simply summing the child deals.

3.3.2 Nested Deal Skins

It is possible to have nested deal skins in Adaptiv Analytics. For details about this see the Nested Deal Skins section of the Extensibility Guide [3].

3.3.3 Structured Deals

Structured deals can be used in Adaptiv Analytics to combine under a single deal any set of instruments supported in Adaptiv Analytics, to be represented as a single transactions. For example, an interest rate collar may be represented as a single transaction, by means of a structured deal which contains a cap and floor with different strikes.

3.3.3.1 Deferred Premiums

Deferred premiums are not included in the base option products in Adaptiv Analytics. These type of deal should be represented by a `Structured Deal` containing an option (the option leg) and a separate cashflow leg (the premium leg).

3.3.4 Day Count

A day count is a rule for calculating the year fraction between two dates, for example to calculate interest over accrual period or discount factors. In Adaptiv Analytics, day counts are specified as deal properties. Adaptiv Analytics supports the following day count conventions: ACT 365, ACT 360, ACT365 ISDA, 30 360, 30E 360, 1 1, BUS 252, ACT ACT ICMA and ACT ACT AFB. For example 30 360 represents 12 months in a year each with 30 days. Note the Brazilian day count convention BUS 252 require a holiday calendar to determine business days. For more details, see the Theory Guide [7, § 1.2 Day Count Conventions].

3.3.5 Date Adjustment

When a nominal date falls on a non-business day, it must often be adjusted to fall on a nearby business day; this process is called date adjustment. In Adaptiv Analytics, date adjustments are specified as deal properties. Adaptiv Analytics supports the following date adjustment conventions: `None`, `Modified Following`, `Following`, `Preceding`, and `Modified Preceding`. For more details, see the Theory Guide [7, § [I.1.6 Date Adjustment](#)].

3.3.6 Date Roll Conventions

A date roll convention is a method for generating a periodic sequence of dates from a base date and a frequency. The conventions specify how to convert a frequency in years, months, weeks, or days into a date increment while possibly preserving or approximating features such as position within a month. In Adaptiv Analytics, date roll conventions are specified as deal properties. Adaptiv Analytics supports the following date roll conventions: `Standard`, `Monthly IMM`, `Standard IMM`, `AUD IMM`, `Day Of Month`, and `Month End`. For more details, see the Theory Guide [7, § [I.3.1 Roll Conventions](#)].

3.3.7 Issue Data

Issue deals are specified in an issue data file. The issue data file can either be referenced from the framework configuration file or, alternatively, from a calculation request. Deals which make use of issue data have an `Issue Identifier` property, which has two string fields, `Series` and `Contract`, and these reference into the issue data. Each issue deal in the issue data file specifies a `Series` and `Contract` attribute. For further details on the issue data file see the Interfacing Guide [5].

Part II

Price Factors

Chapter 4

Asset Prices

Asset price factors comprise equity prices, cash and carry commodity prices, and foreign exchange (FX). These are distinct price factors in Adaptiv Analytics, but they are all modeled as spot prices with dividends, convenience yields, or carry rates; consequently they share many common features. Asset prices are described in detail in the Theory Guide [7, § 1.3 Asset Prices].

4.1 Interpretation of an Asset Price

All asset prices in Adaptiv Analytics represent the price for *immediate settlement* at t and do not incorporate a conventional spot settlement lag such as $t+2$. The price for immediate settlement would be the same as the price for conventional spot settlement if no discounting was applied. Nevertheless, asset prices are often informally referred to as ‘spot prices’ in Adaptiv Analytics documentation.

4.1.1 Spot Asset Prices

Spot asset prices are defined as follows:

Theory Guide 1.3.1

The asset price factors are equity prices, commodity prices and foreign exchange (FX) rates. The price factor value $S(t)$ is the spot price of the asset (price for immediate delivery) in the *asset currency*. The asset currency is specified by a property of price factor: either the Currency property for equity and commodity prices, or the Domestic Currency property for FX rates. If the property is not specified then the asset currency defaults to the base currency. The initial asset price $S(0)$ is specified by the Spot property of the price factor.

4.1.2 Forward Asset prices

Forward asset prices are defined as follows:

Theory Guide 1.3.2

For equity and commodity prices, the forward asset price at time t for delivery at time T is given by the no-arbitrage formula

$$F(t, T) = S(t) \frac{Q(t, T)}{D(t, T)}, \quad (4.1.1)$$

where $D(t, T)$ is the discount factor from the asset's interest rate price factor, and $Q(t, T)$ is discount factor from the asset's dividend rate (for equity) or convenience yield (for commodity) price factor.

The asset's interest rate price factor is the repo interest rate for this asset. The asset's interest rate price factor is specified by the Interest Rate property on the asset price factor. If the property is not specified then Analytics uses the interest rate price factor with the same name as the asset currency.

4.1.3 Minimum Asset Price

All asset prices are floored at a minimum. This is in part to ensure that values of certain quantities (e.g., relative returns, geometric stochastic dynamics) remain finite.

Theory Guide [1.3.1](#)

All asset prices are floored at a minimum asset price, $S_{\min} = 10^{-10}$.

4.1.4 Common Properties

4.1.4.1 Spot

The `Spot` property of the price factor specifies the initial price for immediate delivery without any modification by a calculation, such as simulation, drifting, or stressing. See section [4.1.1](#) for more details.

4.1.4.2 Interest Rate

The `Interest Rate` property of the price factor is used to calculate arbitrage-free forward prices; it is the no-arbitrage rate, not accounting for dividends, at which the asset price increases from today to the settlement date. If this property is empty, then the `Currency` will be used in its place.

4.2 FX Rate

4.2.1 Overview

An FX Rate price factor represents the price of one unit of one currency in terms of another. The unit currency is called the foreign currency and the price currency is called the domestic currency. Adaptiv Analytics may be configured to represent FX rates according to market convention, but by default it converts all currencies directly to base currency with the convention that the base currency is the domestic currency.

FX Rate price factors are described in the Theory Guide [[7](#), § [1.3.1.1 FX Rates](#)].

For the representation of FX Rates in Adaptiv Analytics see the Interfacing Guide [[5](#), § [A.4.1.31 FxRate](#)].

4.2.2 Price Factor Dependency

Fx Rate

- └ Interest Rate (§ [6.1](#))
- └ Parent FX Rate (§ [4.2](#))

4.2.3 Properties

4.2.3.1 Properties Common to Asset Prices

Properties common to all Asset Price price factors can be found in section [4.1.4](#).

4.2.3.2 Domestic Currency

This property allows the domestic currency to be specified explicitly. When it is empty, the domestic currency defaults to the base currency unless the `Foreign Currency` is explicitly specified and is not the FX Rate ID, in which case the domestic currency defaults to the FX Rate ID.

4.2.3.3 Foreign Currency

This property allows the foreign currency to be specified explicitly. When it is empty, the foreign currency defaults to the FX Rate ID.

4.2.3.4 Priority

This attribute is used to determine the quote direction of a currency pair that is not directly represented by an FX Rate price factor. See section 4.2.3.9 for details. Priority defaults to 0 when it is not specified.

4.2.3.5 Base Currency

The base currency of an Adaptiv Analytics configuration (3.1.1) is represented by an FX Rate price factor. It will be created automatically by Adaptiv Analytics if it is not present in the market data. By definition, both the domestic and foreign currencies of the base currency FX Rate are the base currency and the spot price is 1. An FX Rate need not have the base currency as either the domestic or the foreign currency, but it must be possible to convert any factor currency to base currency by chaining together the product of FX rates.

4.2.3.6 Factor Currency

The factor currency of an FX Rate price factor is the currency named by its ID. The `Interest Rate` of an FX Rate price factor applies to the factor currency. Every currency supported in a configuration of Adaptiv Analytics must be represented by an FX Rate price factor. The factor currency must be either the domestic or the foreign currency of an FX Rate price factor.

4.2.3.7 Domestic and Foreign Currencies

The spot price of an FX Rate is quoted in the number of units of domestic currency for 1 unit of foreign currency.

4.2.3.8 Parent Currency

FX Rate price factors form a tree, where the root is the base currency of the market data file. For example, in this tree EUR is the base currency:

```

EUR → USD → JPY
  ↳ → GBP

```

The parent currency of an FX Rate is either the base currency, or else whichever of the domestic and foreign currencies is not the factor currency. It may be visualized as the next currency on the path from the factor currency to the base currency in the currency tree. For example, the parent currency of JPY is USD. The parent currency of GBP, USD, and EUR is EUR.

4.2.3.9 Quote Direction for Rates that are not Price Factors

The quote direction for a single FX Rate price factor is always determined by the price factor itself, according to which currency is domestic and which foreign. But in the example tree above, EUR/JPY and GBP/JPY are not represented by price factors. These rates must be calculated by chaining together FX Rate price factors.

In these cases, the quote direction is determined by the `Priority` property of the two price factors with the factor IDs that match the currencies. Lower numbers have higher priority. Whichever currency has the higher priority (lower number) is treated as the foreign currency in the quote direction. For example, if in the tree above the priority of GBP is 2 and the priority of JPY is 8, then the quote direction of GBP/JPY is JPY per 1 GBP. Ties are resolved by giving higher priority to the currency string that has alphabetical precedence.

4.3 Equity Price

4.3.1 Overview

An Equity Price price factor represents the price of one unit of an equity denominated in its `Currency`. The asset will also be simulated in the currency of its denomination; hence, the Brownian motion of the asset diffusion is a Brownian motion under the risk neutral measure in this specific economy, which may be different from that of the base currency.

Equity Price price factors are described in the Theory Guide [7, § 1.3 Asset Prices].

For the representation of Equity Prices in Adaptiv Analytics see the Interfacing Guide [5, § A.4.1.19 EquityPrice].

4.3.2 Price Factor Dependency

Equity Price

- └ Credit Rating (§ 9.2)
- └ Dividend Rate (§ 7.1)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

Credit Rating (§ 9.2): Equity prices depend on the credit rating identified by `Issuer` when they respect default. There is no dependency otherwise.

Dividend Rate (§ 7.1): Equity prices depend on the associated dividend rate to calculate forward prices. This price factor must have the same ID as the equity price factor.

Interest Rate (§ 6.1): Equity prices depend on the associated `Interest Rate` to calculate forward prices. If the `Interest Rate` property is not populated, the Interest Rate Price factor corresponding to the ID of the Equity Currency is used.

4.3.3 Properties

4.3.3.1 Properties Common to Asset Prices

Properties common to all Asset Price price factors can be found in section 4.1.4.

4.3.3.2 Currency

The `Currency` property identifies the currency in which the equity price is denominated. When it is empty, the base currency is used.

4.3.3.3 Issuer

The `Issuer` property identifies the `Credit Rating` used to determine whether the equity issuer has defaulted. Note that there is no default value for the `Issuer`; if it is empty, the equity issuer will never default regardless of the `Respect Default` property.

4.3.3.4 Jump level

The `Jump Level` property determines the equity price consequent on default of the issuer as follows:

Theory Guide [1.3.1](#)

Equity price factors have an optional `Issuer` property and a `Respect Default` property. Suppose the price factor has an issuer, `Respect Default` is `Yes` and the issuer's credit rating is being simulated. If the issuer reaches default at time τ on a given scenario then the equity price is set to $\max(S(t)\alpha, S_{\min})$ for $t \geq \tau$, where α is the `Jump Level` ($0 \leq \alpha \leq 1$), and the equity price volatility is set to $\sigma_{\min} = 10^{-4}$.

4.3.3.5 Respect Default

The `Respect Default` property determines whether the equity price is affected by default of the issuer. When the `Respect Default` property of the equity price is set to `Yes`, then the equity price will be set to the level implied by the `Jump Factor` when the `Issuer` credit rating is `Default`.

4.4 Commodity Price

4.4.1 Overview

A `Commodity Price` price factor represents the price of one unit of a commodity denominated in its `Currency`. The asset will also be simulated in the currency of its denomination; hence, the Brownian motion of the asset diffusion is a Brownian motion under the risk neutral measure in this specific economy, which may be different from that of the base currency.

`Commodity Price` price factors are used for derivatives where the underlying asset has a strong non-arbitrage relationship between the spot price and forward curve. Also where there is no, or little, seasonality and mean reversion. When these features are prevalent then `Adaptiv Analytics` models using energy prices (Section [10](#)) may be more appropriate.

`Commodity Price` price factors are described in the Theory Guide [\[7, § 1.3 Asset Prices\]](#).

For the representation of `Commodity Prices` in `Adaptiv Analytics` see the Interfacing Guide [\[5, § A.4.1.5 CommodityPrice\]](#).

4.4.2 Price Factor Dependency

`Commodity Price`

- └ `Convenience Yield` (§ [7.2](#))
- └ `FX Rate` (§ [4.2](#))
- └ `Interest Rate` (§ [6.1](#))

Convenience Yield (§ [7.2](#)): Commodity prices depend on the associated convenience yield to calculate forward prices. This price factor must have the same ID as the commodity price factor.

Interest Rate (§ [6.1](#)): Commodity prices depend on the associated `Interest Rate` to calculate forward prices. If the `Interest Rate` property is not populated, the `Interest Rate Price` factor corresponding to the ID of the commodity currency is used.

4.4.3 Properties

4.4.3.1 Properties Common to Asset Prices

Properties common to all Asset Price price factors can be found in section [4.1.4](#).

4.4.3.2 Currency

The `Currency` property identifies the currency in which the commodity price is denominated. When it is empty, the base currency is used.

4.5 ETF Price

4.5.1 Overview

An ETF Price price factor represents the price of one unit of an exchange traded fund (ETF) denominated in its `Currency`. ETFs are investment securities which are traded on stock exchanges. They can contain a variety of assets such as equities, commodities, or bonds and behave much like equities. The notable difference is that they don't pay dividends. In the same way as Equity Price (section [4.3](#)), ETF Price price factors are simulated in the currency of its denomination.

The Asset Prices section of the Theory Guide [[7](#), § [1.3 Asset Prices](#)] is largely applicable to ETF Price.

For the representation of ETF Prices in Adaptiv Analytics see the Interfacing Guide [[5](#), § [A.4.1.21 ETFPrice](#)].

4.5.2 Price Factor Dependency

ETF Price

- └ FX Rate (§ [4.2](#))
- └ Interest Rate (§ [6.1](#))

FX Rate (§ [4.2](#)): ETF Prices depend on the associated FX Rate to calculate the spot and forward price in base currency. If the `Currency` property is not populated, it is assumed to be in base currency.

Interest Rate (§ [6.1](#)): ETF Prices depend on the associated Interest Rate to calculate forward prices. If the `Interest Rate` property is not populated, the Interest Rate Price factor corresponding to the ID of the `Currency` is used.

4.5.3 Properties

4.5.3.1 Properties Common to Asset Prices

Properties common to all Asset Price price factors can be found in section [4.1.4](#).

4.5.3.2 Currency

The `Currency` property identifies the currency in which the ETF Price is denominated. When it is empty, the base currency is used.

4.5.3.3 Underlying Type

The type of underlying asset. This property can be used to put ETF Price price factors into appropriate factor groups in market VaR calculations.

4.6 Futures Price

4.6.1 Overview

A Futures Price price factor represents the value of a position in a futures contract. If the current futures price is specified then the futures price at time t is set to the forward price at time t , plus a proportion of the initial futures basis (see section 5.2) that declines linearly to zero as the valuation date approaches the settlement date.

If the current futures price is not specified then futures and forward prices are assumed to be equal.

The Futures Price price factor is only used by the MtM Futures valuation models, see section X.

For the representation of futures prices in Adaptiv Analytics see the FuturesPrice price factor section of the Interfacing Guide [5, § A.4.1.30 FuturesPrice].

4.6.2 Price Factor Dependency

No price factor dependencies.

4.6.3 Properties

4.6.3.1 Properties Common to Asset Prices

Properties common to all Asset Price price factors can be found in section 4.1.4.

4.6.3.2 Price

The current futures price.

Chapter 5

Futures Basis Price Factors

5.1 Interpretation of Futures Basis

5.1.1 Common Properties

Basis: The current futures basis.

Property Aliases: Collection of aliases for given factor properties. Aliases are used when exporting data to external systems or for display purposes to improve the legibility of a property for a human user. An example is that internally terms are often stored as year quantities (e.g. 0.5), and these may be aliased to term strings instead (e.g. 6M).

5.1.2 Assumptions

5.1.2.1 Forward Evolution

In Adaptiv Analytics the futures basis price factors don't support any evolution model; it is assumed that the basis declines linearly to zero as the valuation date approaches the settlement date.

5.2 Futures Basis

5.2.1 Overview

The futures basis is the difference between the mark-to-market futures price and its theoretical forward price. Future basis are important because when we price options on futures is necessary to have the right value for the underlying future. If the futures prices is off-market, the effect is magnified in option valuations and sensitivities. For the representation of the futures basis price factors in Adaptiv Analytics see the `FuturesBasis` price factor section of the Interfacing Guide [5, § A.4.1.29 [FuturesBasis](#)].

The Adaptiv Analytics standard futures and futures option valuation models have a dependency on this price factor so it must be populated when using those model. In many asset classes the future basis might be negligible and is generally not material for credit risk calculations. Users may choose to set the futures basis to zero using proxy rules to avoid missing data warnings.

If a contract is specified on a futures deal and the `Use Futures Basis` property is `Yes` on the corresponding valuation model then the futures price at time t is set to the forward price at time t plus a proportion of the basis from the futures basis price factor that declines linearly to zero as the valuation date approaches the settlement date. If the contract is specified on a futures deal, but the `Use Futures Basis` property is `No` on the corresponding valuation model, then basis is calculated using a futures price price factor.

If the contract is not specified on a futures deal then futures and forward prices are assumed to be equal.

5.2.2 Price Factor Dependency

No price factor dependencies.

5.2.3 Properties

Properties common to Futures Basis Price Factors can be found in section 5.1.1. There are no unique properties on the Future Basis Price Factor.

5.3 Bond Futures Basis

5.3.1 Overview

The bond futures basis is the most important case of a futures basis. In concept, each bond future position is associated with a basket of deliverable bonds, whereby if the position is held to expiry, the seller has to deliver bonds to the buyer in settlement. It is this choice of deliverable bond from the basket that affords value to the seller.

In practice, the value of bond futures basis is the difference between the bond futures price and the theoretical forward price, which is calculated as forward value of the cheapest to deliver bond issue divided by conversion factor. Adaptiv Analytics does not model the underlying basket of deliverable bonds, or try to value the implicit delivery options.

The `Use Futures Basis` valuation model property is supported by Bond Futures Basis Price Factor, with similar behaviour to the Futures Basis (section 5.2.1). For the representation of bond futures basis in Adaptiv Analytics see the FuturesBasis price factor section of the Interfacing Guide [5, § A.4.1.29 [FuturesBasis](#)].

5.3.2 Price Factor Dependency

No price factor dependencies.

5.3.3 Properties

Properties common to Futures Basis Price Factors can be found in section 5.1.1. Additional properties of Bond Futures Basis Price Factors are as follows:

CTD Conversion Factor: Used to equalise the difference between the notional underlying bond and the real bonds eligible for delivery. Must be positive.

CTD Coupon Interval: Cheapest-to-deliver coupon interval, e.g. 6M.

CTD Coupon Rate: Cheapest-to-deliver coupon rate, e.g. 2.75%.

CTD Day Count: Specifies the day count convention used. It can take values ACT 365, ACT 360, ACT365 ISDA, 30 360, 30E 360, 1 1, BUS 252, ACT ACT ICMA and ACT ACT AFB. For example 30 360 represents 12 months in a year each with 30 days.

CTD First Coupon Date: Cheapest-to-deliver first coupon date.

CTD Issue Date: Cheapest-to-deliver issue date. Must be before cheapest-to-deliver maturity date.

CTD Maturity Date: Cheapest-to-deliver maturity date.

CTD Penultimate Coupon Date: Cheapest-to-deliver penultimate coupon date.

5.3.4 Assumptions

5.3.4.1 Delivery Basket:

The delivery basket is not explicitly modelled in Adaptiv Analytics. Instead, the details of the Cheapest to Deliver (CTD) bond are entered via Market Data on the Bond Futures Basis Price factor.

In Adaptiv Analytics, it is assumed that the CTD issue does not change, although this is theoretically possible under some circumstances such as changing market conditions. The value of the delivery option is thence assumed to be identical to the Bond Futures Basis, and is calculated as the difference between CTD bond forward / conversion factor and MTM futures price.

The Bond Futures basis should converge to zero (i.e., the value of the CTD bond) at settlement, with time horizons between today and the settlement date determined by linear interpolation.

5.3.5 Limitations

5.3.5.1 AUD and NZD Bond Futures

AUD and NZD bond futures contain the concept of a delivery basket of bonds, but do not use the concept of cheapest to deliver. Instead, the bond futures are settled against the average yield of the (exactly 4) deliverable bonds in the basket.

This concept is not supported in Adaptiv Analytics.

Chapter 6

Interest Rates

6.1 Interest Rate

6.1.1 Overview

Adaptiv Analytics defines the interest rate price factor as a continuously compounded zero coupon rate. It is defined in Adaptiv Analytics as follows:

Theory Guide [1.6.2](#)

The initial zero-coupon rates and discount factors are given by $r(0, t) = r(t)$ and $D(0, t) = e^{-r(t)t}$, where $r(\tau)$ is the initial zero-coupon rate curve (Curve), which is defined on a set of tenors τ_1, \dots, τ_n , where $0 \leq \tau_1 < \dots < \tau_n$. A typical set of tenors is $\tau_1 = 1/365$ (1d), $\tau_2 = 1/12$ (1m), $\tau_3 = 1/4$ (3m), $\tau_4 = 1/2$ (6m), $\tau_5 = 1$ (1y), $\tau_6 = 2$ (2y), and so on.

For more details see the the Theory Guide [7, § [1.6 Interest Rates](#)].

In Adaptiv Analytics, there are two types of interest rate: base rates and spread rates. A spread rate is an interest rate price factor that is defined relative to another Interest Rate Price Factor, the parent rate. A base rate is an interest rate price factor without a parent rate. The parent rate of spread rate can be either a base rate or another spread rate.

For the representation of interest rates in Adaptiv Analytics see the `InterestRate` price factor section of the Interfacing Guide [5, § [A.4.1.41 InterestRate](#)].

6.1.2 Price Factor Dependency

Interest Rate

└ Parent Interest Rate (§ [6.1](#))

6.1.3 Properties

The properties of Interest Rate Price Factors are as follows:

Day Count: The `Day Count` attribute defaults to `ACT_365`. The `BUS_252`, used by Brazilian products, requires an special interpolation method in which only business days are considered when calculating accrual dates.

Sub Type: The `Sub Type` property was added to Adaptiv Analytics to distinguish basis spread, credit spread, and flat spread (OAS) for the purposes of stochastic model assignment and risk factor decomposition. This is a deprecated property included only when different stochastic models should be assigned to the base interest rate curve and the interest rate spread curves, then it is necessary to define the spread curves as a spread subtype.

Floor: It is possible to specify a floor value on the interest rate price factor in Adaptiv Analytics. This floor applies to both spot and forward interest rates. The mechanism for flooring the initial rate as well as for flooring of simulated rates (for Monte Carlo simulations) is explained in detail in the Theory Guide [7, § 1.6.4 [Flooring of Interest Rates](#)].

In the case of spread rates the floored initial spread rate is calculated so that the floored sum of the floored parent rate and spread rate is equal to the sum of the floored parent rate and the floored spread rates. For more details, see the Theory Guide [7, § 1.6.5 [Base and Spread Rates](#)].

6.1.4 Assumptions

6.1.4.1 Interest Rate for Base Currency

The interest rate curve for the base currency defaults to one with the same ID as the base currency, if it is not populated.

6.2 Discount Rate

6.2.1 Overview

`Discount Rate` is a wrapper for an `Interest Rate` price factor; it is an indirect reference to an interest rate. Its purpose is to provide an easy way to substitute one interest rate for another. By convention, as the name suggests, the interest rate to be substituted is used for discounting a deal's cashflows. For more details, see the Theory Guide [7, § 1.6.6.1 [Discount Rate Price Factors](#)].

6.2.2 Price Factor Dependency

`Discount Rate`

└ `Interest Rate` (§ 6.1)

6.2.3 Properties

The properties of Interest Rate Price Factors are as follows:

Interest Rate: The ID of the interest rate price factor to load. If this field is omitted or is set to an empty string then the ID of the discount rate is used to load the interest rate price factor.

6.2.3.1 Conventional Usage

Valuation models in Adaptiv Analytics respect this convention by requesting a `Discount Rate` price factor rather than an `Interest Rate` price factor when fetching an interest rate to be used for discounting cashflows. Many deals identify this interest rate with a property called `Discount Rate`. However, there is no systemic mechanism to force the use of a `Discount Rate` price factor for discounting, nor to prevent the price factor to be used for some other purpose, such as a reference rate. For instance, if a bespoke valuation model were substituted for one of the standard models in Adaptiv Analytics, it would be up to the model writer to follow the convention.

6.2.3.2 Population Often Not Required

Because the valuation models in Adaptiv Analytics request `Discount Rate` price factors, they appear as price factor dependencies for Adaptiv Analytics deals. However, it is not necessary to populate `Discount Rate` price factors in the market data file unless the ability to substitute discount rates is required. When a `Discount Rate` price factor is requested by a valuation model but not present in the market data file, Adaptiv Analytics automatically creates one with the same ID as that requested and populates the `Interest Rate` property with that ID, so that the interest rate used for discounting is the one specified by the deal. Adaptiv Analytics does not issue warnings when it automatically creates `Discount Rate` price factors.

6.2.3.3 Example of Use

An example in which discount rate indirection is useful is for the calculation of the Funding Valuation Adjustment on uncollateralised deals which are discounted with risky rates. Risk-free interest rates can be substituted globally for the risky ones by a stress that modifies the `Interest Rate` property of `Discount Rate` factors.

Chapter 7

Cost Of Carry

7.1 Dividend Rate

7.1.1 Overview

Dividends in Adaptiv Analytics are specified as interest rate curves.

Theory Guide 1.3.2

Dividend rate and convenience yield price factors are similar to interest rate price factors. The asset's dividend rate/convenience yield price factor has the same name as the asset. Any of the price factor models of Section 1.6 can be used for dividend rate/convenience yield price factors. Dividend rate price factors have an optional floor rate, which is applied in the same way as Section 1.6.4. Convenience yields are net of storage costs; convenience yields are not floored.

If no price factor model is specified for a dividend rate/convenience yield price factor then the discount factors are given by $Q(t, T) = Q(0, T - t) = e^{-q(t)(T-t)}$, where $q(t)$ is the initial dividend rate/convenience yield curve.

Interest rate curves are specified in time relative to the base calculation date, not absolute calendar time. Therefore, dividend curves must be updated daily when calendar dependent features such as discrete payments or seasonal variations in a continuous rate are desired.

Dividend rate inherits from the interest rate price factor, and as such shares the same representation as a continuously compounded zero coupon yield.

Theory Guide 1.3.2.1

The initial dividend rate curve $q(t)$ can be derived from discrete dividends using the no-arbitrage relationship between spot and forward prices. The spot price is the discounted forward price plus the value of the dividends that the spot purchaser gets, but the forward purchaser does not:

$$S(0) = F(0, t)D(0, t) + \sum_{0 < s_i \leq t} H_i D(0, t_i), \quad (7.1.1)$$

where H_i is the known or projected dividend that is paid at time t_i and has ex-dividend date s_i (where $s_i \leq t_i$). Forward prices are given by Equation (4.1.1) and the initial dividend factor is given by $Q(0, t) = e^{-q(t)t}$. If forward prices are derived from discrete dividends according to Equation (7.1.1) then the implied dividend rate is given by

$$q(t) = \frac{1}{t} \log \left(\frac{S(0)}{S(0) - \sum_{0 < s_i \leq t} H_i D(0, t_i)} \right). \quad (7.1.2)$$

The curve $q(t)t$ is constant on each interval $[s_i, s_{i+1})$ and zero before the first ex-dividend date s_1 . Therefore, the discrete representation of the implied dividend rate curve should have points at each ex-dividend date s_i and at the day before each s_i .

For the representation of dividend rates in Adaptiv Analytics see the `DividendRate` price factor section of the Interfacing Guide [5, § [A.4.1.14 DividendRate](#)].

7.1.2 Price Factor Dependency

No price factor dependencies.

7.1.3 Properties

The properties of Dividend Rate Price Factors are as follows:

Curve: A list of dividend rates for a discrete set of tenors (in fractions of 365 days).

Floor: Optional floor rate. If specified then the initial dividend rate curve is modified to ensure rates are greater than or equal to the floor value.

Currency: In Adaptiv Analytics the `Currency` property on dividend rates should be the same as the currency of the equity that is associated with, with both simulated in this currency. Adaptiv Analytics does not support dividend payment in a different currency.

7.1.4 Assumptions

7.1.4.1 Dividend Rates and Equity Price Factors

Missing dividend rates for an existing equity price factor will generate warnings in Adaptiv Analytics. Proxy rules can be used to update several price factors simultaneously, see Proxying Rules Guide [6].

7.1.4.2 Modelling Discrete Dividend Payments

See Theory Guide [7, § [1.3.2.1 Interpolation of Dividend Rates](#)] for an explanation of how to convert discrete dividend payments to the continuous format of Adaptiv Analytics.

It is possible to combine both discrete and continuous rates on the same curve, but since the rates are spot rather than forward, this may require many curve points.

7.1.4.3 Dividend Rates and Equity Indexes

For an equity index, composed of dozens, hundreds or even thousands of individual equities, it is theoretically possible to represent the discrete dividends of an index, but in Adaptiv Analytics these are expected to be approximated by a continuous yield. The temporal irregularity of index dividends due to seasons or day of week can be incorporated in the dividend curve term structure.

7.2 Convenience Yield

7.2.1 Overview

Convenience Yields in Adaptiv Analytics are specified as interest rate curves.

Theory Guide [1.3.2](#)

Dividend rate and convenience yield price factors are similar to interest rate price factors. The asset's dividend rate/convenience yield price factor has the same name as the asset. Any of the price factor models of Section 1.6 can be used for dividend rate/convenience yield price factors. Dividend rate price factors have an optional floor rate, which is applied in the same way as Section 1.6.4. Convenience yields are net of storage costs; convenience yields are not floored.

If no price factor model is specified for a dividend rate/convenience yield price factor then the discount factors are given by $Q(t, T) = Q(0, T - t) = e^{-q(T-t)(T-t)}$, where $q(t)$ is the initial dividend rate/convenience yield curve.

Interest rate curves are specified in time relative to the base calculation date, not absolute calendar time.

Convenience Yield inherits from the interest rate price factor, and as such shares the same representation as a continuously compounded zero coupon yield.

Theory Guide 1.3.2.2

The default interpolation method for the initial convenience yield curve is linear with flat extrapolation (see Section A.2.2.2); the default interpolation method can be overridden in the market data file (see Section A.1).

For the representation of convenience yields in Adaptiv Analytics see the ConvenienceYield price factor section of the Interfacing Guide [5, § A.4.1.7 ConvenienceYield].

7.2.2 Price Factor Dependency

No price factor dependencies.

7.2.3 Properties

The properties of Convenience Yield price factors are as follows:

Curve: A list of pairs of convenience yields and tenors (in fractions of 365 days).

Currency: The Currency property on the convenience yield should be the same as the currency of the commodity that it is associated with, with both simulated in this currency.

7.2.4 Assumptions

7.2.4.1 Convenience Yield and Commodity Price Factors

Missing convenience yields for an existing commodity price will generate warnings in Adaptiv Analytics.

7.2.4.2 Net convenience yield

The Convenience Yield price factor holds the a value that is net of the convenience yield and storage costs. Essentially it is the component of the cost of carry that allows spot-forward parity. This is demonstrated in the description of the convenience yield bootstrapper.

Theory Guide ??

A convenience yield price factor (Convenience Yield) is bootstrapped from a market price (Commodity Forward Prices) containing a set of forward price quotes. The price factor surface is the convenience yield curve, which is piecewise linear curve with flat extrapolation (see Section 1.3.2).

The forward price quotes are specified by a list of term and forward price pairs:

$$(\tau_1, F_1), \dots, (\tau_n, F_n) \quad (7.2.1)$$

entered in the Curve property of the market price. The forward delivery date corresponding to term τ_i is given by $T_i = (0 + \tau_i)(\text{mfol})$. The convenience yield curve $y(t)$ is constructed with time points T_1, \dots, T_n and corresponding values

$$y(T_i) = \frac{1}{T_i} \log \left(\frac{S(0)}{F_i D(0, T_i)} \right), \quad (7.2.2)$$

where $S(0)$ is the commodity spot price and $D(0, T_i)$ is the discount factor from interest rate price factor specified by the Discount Rate property of the market price.

7.2.5 Limitations

There is no facility to model seasonal variation in convenience yields. This is because all times in the convenience yield curve are relative to the calculation base date.

Chapter 8

Mortgage Price Factors

8.1 Prepayment Rate

8.1.1 Overview

The representation of prepayment rate in Adaptiv Analytics.

Payments on a mortgage may be made voluntarily before they are contractually required; this is called prepayment. These payments, net of any penalties levied, are applied to reduce the mortgage principal outstanding.

The distinction between liquidation and prepayment is ignored in certain mortgage-back securities and only a total constant prepayment rate is modelled. This combines the liquidation rate and the partial prepayment rate and is applied as if it were simply a liquidation rate.

Prepayment rate inherits from the Interest Rate Price Factor, and as such shares the same representation as a continuously compounded zero coupon yield.

For a representation of this price factor in Adaptiv Analytics see the PrepaymentRate price factor section of the Interfacing Guide [5, § [A.4.1.49 PrepaymentRate](#)].

8.1.2 Price Factor Dependency

No price factor dependencies.

8.1.3 Properties

The properties of Prepayment Rate Price Factors are as follows:

Accrual Calendar An optional accrual calendar to use to convert simulation time to curve time.

Curve: A list of prepayment rates for a discrete set of tenors (in fractions of 365 days).

Currency: The domestic currency, used by Adaptiv Analytics for simulation of the price factor.

Day Count: An optional day count to use to convert simulation time to curve time. Only used if a valid accrual calendar is specified.

Liquidation Rate: The fixed liquidation rate used in certain mortgage backed securities. Values are entered as a decimal or as a percentage. For example, enter 5% or 0.05 for 5%.

Liquidation Vector: The Canadian Liquidation Vector used to calculate liquidation rates in fixed mortgage-back securities in the Canadian market, entered as a list of rates for a discrete set of tenors (in number of months).

Chapter 9

Credit Price Factors

9.1 Survival Probability

9.1.1 Overview

In Adaptiv Analytics, the survival probability is a log survival probability curve with the tenors in fractions of 365 days. It is floored at 0 and capped at 1.

The survival probability price factor is described in detail in the Theory Guide [7, § 1.10. Survival Probabilities]. For the representation in Adaptiv Analytics see the `SurvivalProb` price factor section of the Interfacing Guide [5, § A.4.1.71 [SurvivalProb](#)].

9.1.2 Price Factor Dependency

Survival Probability
└ Credit Rating (§ 9.2)

9.1.3 Properties

The properties of Survival Probability Price Factors are as follows:

Curve: A list of log survival probabilities for a discrete set of tenors (in fractions of 365 days).

Issuer: If the issuer's credit rating is being simulated and Force Default is set then deals referencing this survival probability may respect default.

Minimum Recovery Rate: Optional minimum recovery rate for CDO pricing which must be in the range $[0, 1]$.

Recovery Rate: Recovery rate used to bootstrap the survival probability curve which must be in the range $[0, 1]$.

9.1.4 Assumptions

9.1.4.1 Hazard Rates

In Adaptiv Analytics, the initial representation of survival probabilities is expressed in terms of the initial log survival probability curve, which is in turn defined in terms of hazard rates. The choice of survival probabilities is driven by performance concerns.

Given that the Survival Probability Price factor is defined by the survival probability curve, it is non-trivial to configure consistent shifts in this price factor for sensitivity / stress calculations. This arises because uniform bump survival probability will correspond to different shifts in each hazard rate at each tenor point. Since the bumps should be defined in terms of hazard rates, some upstream work is necessary to convert a parallel shift in hazard rate into a shift in the survival probability curve.

9.1.4.2 Recovery Rate Attribute

The `Recovery Rate` attribute represents the rate determined by market convention for pricing a CDS as opposed to a real world estimate of the recovery rate determined from the historical data on other issuers in the same credit rating category. The `Recovery Rate` attribute is used in valuation of credit derivatives and bootstrapping of the survival probability curve. The default value of the recovery rate is 0.4, however this isn't a universal convention for all issuers therefore it might differ from current market convention.

9.1.4.3 Interpolation Methods

Survival probability supports several interpolation methods out of the box, documented in the Theory Guide [7, § [A.2 Curve Interpolation Methods](#)].

9.2 Credit Rating

9.2.1 Overview

Credit rating price factors hold the initial rating of an entity; the rating is an integer where 0 corresponds to default, and progressively higher integers correspond to progressively higher ratings. The credit rating price factor is described in the Theory Guide [7, § 1.14. Credit Ratings]. For the representation in Adaptiv Analytics see the `CreditRating` price factor section of the Interfacing Guide [5, § [A.4.1.10 CreditRating](#)].

9.2.2 Price Factor Dependency

No price factor dependencies.

9.2.3 Properties

The properties of Credit Rating Price Factors are as follows:

Default Date: If Force Default is set then force the obligor's credit rating to zero (default) on this date.

Force Default: Force the credit rating of the obligor into default. If a value is present for the Default Date then the default is assumed to occur on that date, otherwise the base date is used.

Rating: The rating is represented by an integer. Default has the value zero and progressively higher numbers correspond to progressively higher ratings. The ratings scale is open-ended so that the highest rating is defined implicitly by the market data.

9.3 Recovery Rate

9.3.1 Overview

`Recovery Rate` price factor corresponds to the real world recovery value and is used to value a deal in a market scenario where default has occurred. In Adaptiv Analytics, `Recovery Rate` has its default value set to 0.4, but this is not a universal convention for all issuers and the market might assign a different value. For the definition of recovery rate see Recovery Rates section of the Theory Guide [7, § [1.15 Recovery Rates](#)]. For the representation in Adaptiv Analytics see the `RecoveryRate` price factor section of the Interfacing Guide [5, § [A.4.1.54 RecoveryRate](#)].

9.3.2 Price Factor Dependency

No price factor dependencies.

9.3.3 Properties

The properties of Recovery Rate Price Factors are as follows:

Rate: Recovery rate which must be in the range $[0, 1]$.

9.4 Spreads & Spread Ratios

Spread price factors are defined relative to a parent price factor; for example, see the Theory Guide [1.6.5](#).

In Adaptiv Analytics, spread ratios hold a set of ratio curves indexed by credit rating; one curve for each non-default rating, in order of increasing rating.

9.4.1 Benchmark Spread

The benchmark spread price factor supports issuer specific CDS spread simulation. It is not referenced directly by any financial products.

9.4.2 Generic Spread

Generic Spread price factors has an underlying Benchmark Spread and uses Spot Spread Ratio and Long Term Spread Ratio to calculate the ratio for the generic spreads.

9.4.3 Long Term Spread Ratio

Long term spread ratio is just a named type of spread ratio.

9.4.4 Spot Spread Ratio

Spot spread ratio is just a named type of spread ratio.

Chapter 10

Energy Price Factors

10.1 Interpretation of Energy Price Factors

10.1.1 Common Properties

Currency: The currency of the forward price, e.g. USD.

Curve: A list of forward prices for a discrete set of delivery dates entered in Excel format (number of days since 30 December 1899). The delivery dates are expected to be the last day of each delivery month.

Fixings: A list of fixings. Each fixing triplet contains a start and an end date, representing a sample period, and the associated forward contract delivery date. This property is used in the conversion of terms to absolute dates, as described in the Calculations - Market VaR document.

10.2 Forward Price

10.2.1 Overview

Energy derivatives are generally written on underlying forward prices rather than underlying spot prices.

Theory Guide [4.2.1](#)

Owing to the physical difficulties of storage and the lack of speculators holding the commodity as an investment asset, the arbitrage relationship between spot prices and forward prices of different tenors is weak. Unlike equities and FX rates therefore, the forward price cannot be treated as a deterministic function of the spot price and a cost of carry function. Instead, Analytics directly simulates the underlying forward prices.

For the representation of forward price price factors in Adaptiv Analytics see the `ForwardPrice` price factor section of the Interfacing Guide [5, § [A.4.1.24 ForwardPrice](#)].

Forward prices are stored in Adaptiv Analytics as curves.

Theory Guide [4.2.1](#)

The forward price as of time t for delivery at time T is denoted $F(t, T)$, and the initial forward price curve $F(0, T)$ is entered in the market data file. If the futures prices observed in the market are

for continuous delivery over an interval $[T_1, T_2]$ rather than for delivery concentrated on a single day, then the price should be entered in the forward price curve at T_2 .

Theory Guide [4.2.1](#)

Contracts however which depend on the spot price, $S(t) = F(t, t)$, use the closest delivery futures price as a proxy for the spot. This is achieved by placing the price in the curve at the end of the delivery period and using flat left interpolation on the curve (see Section [A.2.2.4](#)), such that $F(t, T) = F(t, T')$ where T' is the delivery date of the first point in the forward curve for which $T' \geq T$. This approach captures the price risk inherent in continuous physical delivery up to the end of the delivery period.

10.2.2 Price Factor Dependency

Forward Price

- └ FX Rate (§ [4.2](#))
- └ Interest Rate (§ [6.1](#))

10.2.3 Properties

Properties common to Energy Price Factors can be found in section [10.1.1](#). There are no unique properties for the Forward Price Price Factor.

10.2.4 Assumptions

10.2.4.1 No Interpolation of the forward price curve:

Adaptiv Analytics defines the prices of market products relative to observation date, whereas fixing periods are defined in absolute terms. Energy contracts identify the underlying by specifying the name of a reference type; the forward price curve is thus indirectly specified.

The core purpose of a reference type is to determine which date on the forward curve should be sampled for a given sampling date. In Adaptiv Analytics, if a sample date which falls between two point on the forward curve, the latter point (i.e., that to the right of the sample date) will be chosen.

This means that, if the absolute market product (future) rolls over to the next absolute product during the fixing period, the system uses the price of this next absolute product which is not interpolated. Furthermore, the system will take the next available product even if the this price is missing, with no interpolation performed.

10.2.4.2 Assumption on the relative vs. absolute reference to a forward curve:

Adaptiv Analytics views the forward prices not in absolute terms (JAN19, FEB19, ...) but relative to observation date (i.e. month + 1, month + 2, quarter + 1, ...), where month and quarter refer to the calendar month and quarter rather than 1- and 3- month periods.

This means that, once a month, the “front” month is changed from one calendar month to the next, which may occur at any point of the month (e.g., it is permissible for this to happen in the middle of the month).

In general, contracts on energy markets are traded in both as relative terms (in term of front month, month + 1, etc.) and in absolute terms (JAN19, FEB19, etc.). Therefore, traded prices can also be quoted in absolute terms, and the deal fixing can be defined based on these absolute products.

It is usually possible to translate the deal fixings given in absolute terms into relative terms by putting correct sampling methods and using offset to front periods. Adaptiv Analytics employs a workaround by breaking the contract into three monthly observation legs, each with a different offset to refer to the same forward price interval. However, this process is intricate and such translation is not always possible (see section [48.2.4.7](#), below).

10.2.4.3 Granularity

Available time granularities in Adaptiv Analytics are month, quarter, year, week, day. Finer granularities will necessarily result in larger data volumes, which may have an impact on performance (i.e., for trades with daily fixing).

10.2.4.4 Power

Adaptiv Analytics considers base and peak power as different commodities, and hence requires separate forward price curves for each price factor. However, Adaptiv Analytics is able to value power contracts if the requisite (separate) forward curves are supplied.

10.2.5 Limitations

10.2.6 Flooring

Forward price curves are floored at the same small positive value that is used to floor asset prices. See section [4.1.3](#).

10.2.6.1 London Metals Exchange

The London Metals Exchange quotes a mixture of absolute date and relative date contracts on the same underlying commodity. This forward curve construction is not supported.

10.2.6.2 Unit conversion

No 'Units of Volume' concept exists for energy commodities exists in base Adaptiv Analytics. Accordingly, Adaptiv Analytics is not able to support situations in which the deal and the price forward curve denominate quantities in different units; it is instead implicitly assumed that unit quantities are the same. However, in energy markets there are many examples where the deal units of measure differ from the price forward curve unit of measure. Such deals can therefore only be valued if the conversion is done upstream.

10.2.6.3 Balance of Month

Balance of Month is not supported in Adaptiv Analytics.

10.2.6.4 Off-Peak Power:

Off-Peak prices are generally not directly observed in the market, but are instead deduced from a weighted average of hourly peak and base load prices. This derivation (i.e., taking an average weighted by hourly prices; see section [10.2.4.3](#)) is not supported in Adaptiv Analytics. Consequently, where an off-peak curve is required, this must be constructed upstream and supplied separately.

10.3 Forward Spread

10.3.1 Overview

Forward spreads are supported in Adaptiv Analytics; this is described in the ForwardSpread price factor section of the Interfacing Guide [[5](#), § [A.4.1.28 ForwardSpread](#)].

Theory Guide 1.5.1

Analytics allows energy prices to be represented as the sum of a base commodity forward price and a forward spread (or spreads) specific to that base commodity. For example the price of an oil delivery might be represented as a base oil price plus a spread specific to the pipeline. If $F_{\text{base}}(t, T)$ is the base price and $F_{\text{spread}}(t, T)$ is the spread then the total price $F(t, T)$ is given by:

$$F(t, T) = F_{\text{base}}(t, T) + F_{\text{spread}}(t, T) \quad (10.3.1)$$

10.3.2 Price Factor Dependency

Forward Spread

- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

10.3.3 Properties

Properties common to Energy Price Factors can be found in section 10.1.1. There are no unique properties for the Forward Spread Price Factor.

10.4 Forward Price Sample

10.4.1 Overview

Sample prices represent the set of dates on which the Adaptiv Analytics valuation model has to look up the underlying commodity price. The Sampling Convention and Holiday Calendar are used to generate a set of available sampling dates, which are used in conjunction with a reference price fixing curve and a forward price curve in the valuation of energy deals.

Theory Guide 4.2.2.4

For instance, for a daily averaging deal S would contain every business day (this might be approximated with less frequent sampling, however, to improve performance.) On the other hand, for a deal that is written on a single futures price at expiry, the sample set would contain just the expiry dates for the relevant series of futures.

Sample date sets are generated by implementations of the `IForwardPriceSample` interface. Analytics provides four implementations: daily, weekly, monthly samplings and bullet end-of-period sampling. Additional implementations may be supplied by plug-in

For the representation of forward price sample price factors in Adaptiv Analytics see the `ForwardPriceSample` price factor section of the Interfacing Guide [5, § A.4.1.26 [ForwardPriceSample](#)].

10.4.2 Price Factor Dependency

No price factor dependencies.

10.4.3 Properties

Properties common to Energy Price Factors can be found in section 10.1.1. Additional properties of Forward Price Sample Price Factors are as follows:

Holiday Calendar: Name of the holiday calendar for this sampling convention.

Offset: In addition generating observation dates, the `Forward Price Sample` may also specify an `Offset` to observation date. If the `Offset` is K , then on the observation date the forward price will be sampled for $\text{next} + K$ period of the curve.

A common use of this feature is when the `Reference Price` x -coordinates match the calendar structure of a series of futures contracts; the `Offset` can then be used to specify nearby, next-nearby, and so on.

Theory Guide [4.2.2.2](#)

In general the expectation of a fixing price with K samples in the past with respect to t and M samples in the future is:

$$F^f(t, T^f) = \frac{1}{K + M} \left(M F(t, T^f) + \sum_{i=1}^K F(t_i^s, T^f) \right). \quad (10.4.1)$$

Sampling Convention: Name of a forward sample interface that supports the desired convention.

10.5 Reference Price

10.5.1 Overview

Fixing in `Adaptiv Analytics` is controlled by a mechanism called the `Reference Price`.

The set of observation dates within a period is controlled by the `Forward Price Sample` rule described above.

Theory Guide [4.2.2](#)

A reference price is a deterministic function of a forward price curve $F(t, T)$, a sampling period notionally delimited by start and end dates t_s^s and t_e^s , and a set of available sampling dates \mathcal{S} . In practice, reference sampling periods are assumed to be contiguous, so that each period except the first begins on the day after the preceding period ends.

The interpretation of `Reference Price` is described in the Theory Guide.

Theory Guide [4.2.2.1](#)

Reference prices are represented by a fixing curve; the x -axis of the curve specifies the end dates of fixing periods and the y -axis specifies underlying forward price dates corresponding to the sampling period ending at the same ordinal position. The first sampling period extends back to the beginning of time. On each sampling date t^s that falls on or before the end date of the i^{th} fixing period but after the end date of the $i - 1^{\text{th}}$ fixing period, the energy price is sampled at the i^{th} underlying forward price date.

Further details around the representation of the `Reference Price` can be found in the Interfacing Guide [\[5, § A.4.1.55 ReferencePrice\]](#).

10.5.2 Price Factor Dependency

Reference Price

└ Forward Price (§ [10.2](#))

10.5.3 Properties

Properties common to Energy Price Factors can be found in section 10.1.1. Additional properties of Forward Price Sample Price Factors are as follows:

Fixing Curve: Reference prices are represented by a fixing curve; the x-axis of the curve specifies the end dates of fixing periods and the y-axis specifies underlying forward price dates corresponding to the sampling period ending at the same ordinal position. The first sampling period extends back to the beginning of time. On each sampling date t^s that falls on or before the end date of the i^{th} fixing period but after the end date of the $(i - 1)^{\text{th}}$ fixing period, the energy price is sampled at the i^{th} underlying forward price date. For example, a fixing curve intended to represent a series of futures contracts might terminate the first fixing period on September 28 and the second on October 27, with the first fixing period referring to the underlying delivery month end October 31 and the second fixing period referring to the underlying delivery month end November 30. Any sample date from September 29 to October 27 would refer to the November 30 forward price.

Forward Price: ID of the forward price to which the fixing curve applies.

10.5.4 Limitations

10.5.4.1 Single Mapping of Reference Price to Forward Price:

Adaptiv Analytics imposes a one-to-one correspondence between the Reference Price price factor and forward price curve it belongs to. Hence it is not possible to share one Reference Price between multiple commodity contracts, even if they share the same expiry calendar. This correspondence is also imposed between the reference price and the reference volatility.

10.5.4.2 Single Observation of Reference Price:

On a single observation date only a single Reference Price value can be observed.

Chapter 11

Volatility

11.1 Interpretation of Volatility Price Factors

Volatility price factors are mainly used as parameters in option valuation models. They are also used to calculate changes of measure for quanto and compo payoffs. Most option valuation models in Adaptiv Analytics assume geometric Brownian motion dynamics with a constant volatility parameter. It is necessary to provide different constant volatilities in order to reproduce market prices for options on the same underlying but with different strikes and expiries. Volatility price factors represent volatilities for multiple strikes and expiries in order to allow volatilities for unquoted strikes or expiries to be estimated by interpolation. Interest rate and yield volatility price factors represent multiple underlying tenors in order to allow interpolation by tenor as well.

11.1.1 Sticky Delta

The Adaptiv Analytics volatility surfaces are defined in terms of moneyness (as opposed to strike or delta); and the volatility smile follows a sticky moneyness rule.

11.2 Asset Price Volatility

11.2.1 Volatility Representations

The volatility of an asset price is specified by a volatility price factor, described in the Theory Guide [7, § 1.8.1 Asset Price Volatility].

11.2.2 Common Properties

11.2.2.1 Surface

The usual representation of this price is a surface 3.1.4.2 [7, § 1.8.1.1 Surface].

Theory Guide 1.8.1.1

The surface $v(m, \tau)$ has dimensions moneyness m and time-to-expiry τ . Moneyness is measured by the ratio of asset price to strike price.

If $t = 0$ or no price factor model is selected then the implied volatility at time t for expiry time T , forward price F and strike price K is

$$v(F/K, T - t). \quad (11.2.1)$$

11.2.2.2 ATM Vol, Smile

For backwards compatibility, an asset volatility price factor may alternatively be configured to represent volatility a pair of curves [3.1.4.1](#), [7, § [1.8.1.2 ATM and Smile Curve](#)], one of which, the `ATM Vol`, represents at-the-money (ATM) volatility and the other of which, the `Smile`, represents the ratio of implied volatility to ATM implied volatility as a function of option moneyness. Each curve is interpolated or extrapolated independently as required.

Theory Guide [1.8.1.2](#)

The ATM volatility curve $v(\tau)$ specifies volatility for at-the-money options as a function of time-to-expiry τ . The smile curve $\omega(m)$ specifies the ratio of implied volatility to ATM implied volatility as a function of the moneyness of the option m . The moneyness of an option is measured by the time-normalized log moneyness $\log(F/K)/\sqrt{\tau}$, under which moneyness curves are largely independent of time to expiry.

If $t = 0$ or no price factor model is selected then the implied volatility at time t for expiry date T , forward price F and strike price K is

$$\omega\left(\frac{\log(F/K)}{\sqrt{T-t}}\right)v(T-t). \quad (11.2.2)$$

11.2.3 Assumptions

11.2.3.1 Volatility Currency Matches Asset Currency:

The valuation models of Adaptiv Analytics assume that asset volatilities are measured in the correct currency with respect to the deal for which they are specified. Volatilities are not adjusted for currency.

11.2.3.2 Moneyness:

In the latest version of Adaptiv Analytics moneyness is defined as F/K , where F is forward asset price and K is the strike price. However, there is a configuration setting which allows the use of moneyness as S/K , where S is the spot price. This is done to ensure backwards compatibility and for testing purposes.

11.2.4 FX Volatility

11.2.4.1 Overview

FX Volatility price factors are intended to represent the implied volatility of FX options and always apply to a pair of currencies. This is enforced by registering the FX Rate price factor of each currency.

For the representation of the FX Volatility Price Factor in Adaptiv Analytics see the `FXVol` price factor section of the Interfacing Guide [5, § [A.4.1.32 FxVol](#)].

Naming Restrictions: The following describes how price factor IDs must be formed and how this affects the interpretation of moneyness.

Theory Guide [1.8.1.4](#)

The ID of an FX volatility price factor is of the form $A.B$ or $A.B.C$, where A and B are currencies in alphabetical order¹ and C is another ID. For example, `GBP.USD.CALL` and

GBP.USD.PUT.BARRIER. The moneyness values on the volatility surface $v(m, \tau)$ or smile curve $\omega(m)$ are F/K ratios with F and K prices of currency A in currency B . For example, the moneyness values for the JPY.USD volatility price factor are ratios of a JPY/USD forward price to a JPY/USD strike price.

If a valuation model requests the volatility of the B/A rate for strike K then the volatility is calculated for moneyness point K/F , where F is the forward price of currency B in currency A .

FX Volatility Attribute: FX option deals have an FX Volatility attribute and this can be used to specify IDs as described above. However, if unspecified then the behaviour is as follows.

Theory Guide [4.1.1](#)

The ID of the volatility price factor can be specified using either the Equity Volatility, Commodity Volatility or FX Volatility property of the deal. If the volatility price factor ID is not specified on the deal then valuation model uses a default ID. For equity and commodity deals, the default ID is of the form $A.B$, where A is the equity or commodity price factor ID and B is the asset currency. For FX deals, the default ID is of the form $A.B$, where A and B are the currencies (Underlying Currency and Currency) in alphabetical order. For quanto and compo deals, the default ID is used for the FX volatility price factor for the price of asset currency in payoff currency.

11.2.4.2 Price Factor Dependency

FX Volatility

- └ FX Rate (§ [4.2](#))
- └ Interest Rate (§ [6.1](#))
- └ Parent FX Rate (§ [6.1](#))

Interest Rate: Note that FX volatility inherits a dependency to the interest rate associated with each currency of the FX rate to which it refers.

11.2.4.3 Properties

Properties common to Asset Price Volatility Price Factors can be found in section [11.2.2](#). There are no unique properties on the FX Volatility Price Factor.

11.2.4.4 Limitations

No Volatility Triangulation: Adaptiv Analytics does not support triangulation of volatility surfaces to calculate the volatility of FX cross rates. The volatility of every FX pair required must be provided explicitly.

11.2.5 Equity Price Volatility

11.2.5.1 Overview

Equity Price Volatility price factors are intended to represent the implied volatility of equity options and always apply to an Equity Price. This is enforced by registering the Equity Price associated with the volatility price factor.

For the representation in Adaptiv Analytics see the `EquityPriceVol` price factor section of the Interfacing Guide [[5](#), § [A.4.1.20 EquityPriceVol](#)].

11.2.5.1.1 Naming Restrictions

The following describes permissible price factor IDs:

Theory Guide [1.8.1.3](#)

An equity or commodity volatility price factor provides volatilities for an underlying asset price in the price factor currency.

The Currency property is used to set the price factor currency. If the Currency is not specified then the price factor ID must be of the form $A.B$, where B is the price factor currency and A is another ID. For example, IBM.USD and IBM.CALL.USD.

The Equity (or Commodity) property is used to set the ID of the underlying asset price factor. If the Equity (or Commodity) is not specified then the underlying asset price factor ID is the price factor ID excluding any last part. For example, the underlying ID of IBM and IBM.USD is IBM, and the underlying ID of IBM.ADJ.CALL is IBM.ADJ.

11.2.5.1.2 Behaviour Upon Default of Issuer

An equity price volatility can be affected by the default of the issuer of the associated equity. See [4.3.3.5](#) for details.

11.2.5.1.3 Equity Volatility Attribute

Valuation models for equity option deals have an Equity Volatility attribute which can be used to specify IDs as described above. If left unspecified then the behaviour is as follows.

Theory Guide [4.1.1](#)

The ID of the volatility price factor can be specified using either the Equity Volatility, Commodity Volatility or FX Volatility property of the deal. If the volatility price factor ID is not specified on the deal then valuation model uses a default ID. For equity and commodity deals, the default ID is of the form $A.B$, where A is the equity or commodity price factor ID and B is the asset currency. For FX deals, the default ID is of the form $A.B$, where A and B are the currencies (Underlying Currency and Currency) in alphabetical order. For quanto and compo deals, the default ID is used for the FX volatility price factor for the price of asset currency in payoff currency.

Specifying an ID with a third component to allows different volatilities to be used for different markets or option types. A common use for this is to allow for the fact that put-call parity does not hold for American options on dividend-paying equities because it may be optimal to exercise calls early. This can be accommodated by using different volatility price factors for puts and calls.

11.2.5.2 Price Factor Dependency

Equity Price Volatility

- └ Credit Rating (§ [9.2](#))
- └ Dividend Rate (§ [7.1](#))
- └ Equity Price (§ [4.3](#))
- └ Interest Rate (§ [6.1](#))

Credit Rating: Equity price factors depend on the credit rating of the issuer of the associated equity price factor when that price factor is set to respect default. There is no dependency otherwise.

Equity Price: Equity price volatilities depend on the associated equity price factor in order to determine whether to respect issuer default.

11.2.5.3 Properties

Properties common to Asset Price Volatility Price Factors can be found in section 11.2.2. The properties specific to Equity Price Volatility are as follows:

Equity: When populated, the `Equity` property identifies the equity price factor to which the volatility applies. When not populated, see section 11.2.5.1.1 for a description of the behaviour. This equity price must exist because the equity price volatility factor depends on the equity price factor.

Currency: When populated, the `Currency` property indicates the currency of denomination for the implied volatility. When not populated, see section 11.2.5.1.1 for a description of the behaviour.

11.2.6 Commodity Price Volatility

11.2.6.1 Overview

Commodity Price Volatility price factors are intended to represent the implied volatility of commodity options and always apply to a Commodity Price. This is enforced by registering the Commodity Price associated with the volatility price factor.

For the representation in Adaptiv Analytics see the `CommodityPriceVol` price factor section of the Interfacing Guide [5, § A.4.1.6 [CommodityPriceVol](#)].

11.2.6.1.1 Naming Restrictions

The following describes the permissible price factor IDs:

Theory Guide [1.8.1.3](#)

An equity or commodity volatility price factor provides volatilities for an underlying asset price in the price factor currency.

The `Currency` property is used to set the price factor currency. If the `Currency` is not specified then the price factor ID must be of the form $A.B$, where B is the price factor currency and A is another ID. For example, `IBM.USD` and `IBM.CALL.USD`.

The `Equity` (or `Commodity`) property is used to set the ID of the underlying asset price factor. If the `Equity` (or `Commodity`) is not specified then the underlying asset price factor ID is the price factor ID excluding any last part. For example, the underlying ID of `IBM` and `IBM.USD` is `IBM`, and the underlying ID of `IBM.ADJ.CALL` is `IBM.ADJ`.

11.2.6.1.2 Commodity Volatility Attribute

Valuation models for commodity option deals have a Commodity Volatility attribute which can be used to specify IDs as described above. If left unspecified then the behaviour is as follows.

Theory Guide [4.1.1](#)

The ID of the volatility price factor can be specified using either the `Equity Volatility`, `Commodity Volatility` or `FX Volatility` property of the deal. If the volatility price factor ID is not specified on the deal then valuation model uses a default ID. For equity and commodity deals, the default ID is of the form $A.B$, where A is the equity or commodity price factor ID and B is the asset currency. For FX deals, the default ID is of the form $A.B$, where A and B are the currencies (Underlying Currency and Currency) in alphabetical order. For quanto and compo deals, the default ID is used for the FX volatility price factor for the price of asset currency in payoff currency.

Specifying an ID with a third component allows different volatilities to be used for different markets or option types. A common use for this is to allow for the fact that put-call parity does not hold for Amer-

ican options on commodities with a convenience yield because it may be optimal to exercise calls early. This can be accommodated by using different volatility price factors for puts and calls.

11.2.6.2 Price Factor Dependency

No price factor dependencies.

11.2.6.3 Properties

Properties common to Asset Price Volatility Price Factors can be found in section 11.2.2. The properties specific to Commodity Price Volatility are as follows:

Commodity: When populated, the `Commodity` property identifies the commodity price factor to which the volatility applies. When not populated, see section 11.2.6.1.1 for a description of the behaviour.

Currency: When populated, the `Currency` property indicates the currency of denomination for the implied volatility. When not populated, see section 11.2.6.1.1 for a description of the behaviour.

11.3 Interest Rate and Interest Yield Volatility

11.3.1 Volatility Representations

The volatility of an interest rate or interest yield is specified by an interest rate volatility or interest yield price factor, respectively, described in the Theory Guide [7, § 1.8.2 Interest Rate and Interest Yield Volatilities].

Interest rate volatility refers to the implied volatility used for pricing options on simple interest rates, such as caps and floors. Interest yield volatility refers to the implied volatility used for pricing options on a par yield such as swaptions or bond options. For historical reasons, Adaptiv Analytics provides separate price factors for these usages in order to allow them to be distinguished even when the same ID is used for both. However, these two price factors have identical representations and are based on a common underlying implementation. Each interest volatility price factor defines a set of volatilities indexed by option moneyness, option time to expiry, and tenor of the underlying interest rate or yield. Implied interest volatilities that vary depending on some other property of the underlying rate or the option model for which they are intended to be used must be distinguished by ID.

11.3.1.1 Normal and Lognormal Rate Volatilities

Most interest rate option valuation models in Adaptiv Analytics can be priced under either lognormal and normally distributed rates. The `Distribution Type` property of an interest rate volatility or interest yield volatility price factor should be set to `Lognormal` or `Normal` according to the intended usage.

11.3.2 Common Properties

Surface: The usual representation of the interest rate and interest yield price factors is a surface

Theory Guide 1.8.2

The initial implied volatilities are represented by a surface $v(m, \tau, \delta)$ with dimensions moneyness m , time-to-expiry τ , and tenor δ .

Distribution Type: The distribution assumption of the underlying swap rate.

11.3.3 Assumptions

11.3.3.1 Identification:

By default, the ID of an interest volatility price factor is assumed to be the same as that of the underlying interest rate price factor. However, most deals allow interest volatility IDs to be specified explicitly.

11.3.3.2 Moneyiness:

In the latest version of Adaptiv Analytics moneyiness is defined as $F - K$, where F is forward rate or yield and K is the strike rate or yield. However, there is a configuration setting which allows the use of moneyiness as R/K , where R is the spot rate or yield. This is done to ensure backwards compatibility and for testing purposes.

11.3.4 Interest Rate Volatility

11.3.4.1 Overview

The Interest Rate Volatility Price Factor is used by valuation models in Adaptiv Analytics when the volatility of a simple interest rate is required (for instance, caplet volatility).

For the representation in Adaptiv Analytics see the `InterestRateVol` price factor section of the Interfacing Guide [5, § [A.4.1.44 InterestRateVol](#)].

11.3.4.2 Price Factor Dependency

No price factor dependencies.

11.3.4.3 Properties

Properties common to Interest Rate and Interest Rate Volatility Price Factors can be found in section [11.3.2](#).

Shift: Shift must be zero when the Distribution Type is Normal. If the Distribution Type is Lognormal and the Shift is not zero then the valuation models assume that rates have a shifted lognormal distribution.

11.3.5 Interest Yield Volatility

11.3.5.1 Overview

The Interest Yield Volatility Price Factor is used by valuation models in Adaptiv Analytics when the volatility of a par yield is required (for instance, swaption volatility).

For the representation of interest yield volatility price factors in Adaptiv Analytics see the `InterestYieldVol` price factor section of the Interfacing Guide [5, § [A.4.1.45 InterestYieldVol](#)].

11.3.5.2 Price Factor Dependency

No price factor dependencies.

11.3.5.3 Properties

Properties common to Interest Rate and Interest Yield Volatility Price Factors can be found in section [11.3.2](#). There are no additional properties for the Interest Yield Volatility Price Factor.

11.4 Energy Volatility

11.4.1 Forward Price Volatility

11.4.1.1 Overview

Forward price volatility price factor. This is used by some energy deals.

The ID of this price factor consists of two parts separated by the '.' character. The first part represents the ID of the underlying forward price price factor and the second part represents the ID of the currency in which that forward price is quoted.

For the representation of forward price volatility price factors in Adaptiv Analytics see the `ForwardPriceVol` price factor section of the Interfacing Guide [5, § A.4.1.27 [ForwardPriceVol](#)].

11.4.1.2 Price Factor Dependency

No price factor dependencies.

11.4.1.3 Properties

The properties of the Forward Price Volatility Price Factor are as follows:

Surface: A 3 dimensional surface with coordinates of moneyness and time-to-expiry. The format of the Surface property is 'Dimensions, Extrapolation method, List of surface points'. Dimensions displays the dimensionality of the surface (which in this case must be 3). Extrapolation method determines the method used to extrapolate on the surface and may be either `Flat` for flat extrapolation or `Linear` for linear extrapolation (with a default value of `Flat`). The list of surface points is a list of points that define the volatility surface. Each entry in this list must be separated by the comma (',') character. The format for each entry of this list is '(time-to-delivery, time-to-expiry, moneyness, value)', where time-to-delivery, time-to-expiry and moneyness represent time-to-delivery (in fractions of 365 days), time-to-expiry (in fractions of 365 days) and moneyness (as forward price/strike) that define that point in the volatility surface and value represents the value of the volatility at that point.

This volatility surface, by default, uses the `Flat Left` interpolation method for the time-to-delivery dimension, and `Linear` for the time-to-expiry and moneyness dimensions. The `Linear` interpolation method for the time-to-delivery coordinate can be explicitly specified, as described in the Interfacing Guide.

11.4.2 Reference Volatility

11.4.2.1 Overview

Reference Volatility is used by some energy deals to associate the volatility surface with its underlying forward price curve

The ID of this price factor is used as the default value for the Forward Price Volatility and Reference Price Volatility properties but is otherwise not used and has no other constraints.

For the representation of reference volatility price factors in Adaptiv Analytics see the `ReferenceVol` price factor section of the Interfacing Guide [5, § A.4.1.56 [ReferenceVol](#)].

11.4.2.2 Price Factor Dependency

Reference Volatility

- └ Forward Price (§ 10.2)
- └ Forward Price Volatility (§ 11.4.1)

└ Reference Price (§ 10.5)

11.4.2.3 Properties

The properties of Reference Volatility Price Factors are as follows:

Forward Price Volatility: In Adaptiv Analytics it is assumed that the Forward Price Volatility property will use the name as the forward price volatility price factor. If it therefore not possible to specify more than one Forward Price Volatility on a single trade.

Reference Price: ID of the dependant forward price or forward spread price factor used to specify the forward price required to calculate the reference price volatility.

Chapter 12

Implied Correlations

12.1 Interpretation of Implied Correlations

12.1.1 Overview

The `Correlation` price factor ([7, § 1.9.1 Correlation Price Factors]) is used to represent implied correlations between asset prices, between an asset price and an interest rate, or between interest rates in different currencies. These price factors are used when correlations are required to price a deal, such as a quanto or compo payoff for example.

For the representation of `Correlation` price factors in `Adaptiv Analytics` see the `Correlation` price factor section of the `Interfacing Guide` [5, § A.7 Correlations].

12.1.2 Common Properties

Surface: Two-dimensional surface with two date axes. The tenors are in fractions of 365 days.

12.2 Correlation

12.2.1 Price Factor Dependency

No price factor dependencies.

12.2.2 Properties

Properties common to `Correlation Price Factors` can be found in section 12.1.2. Additional properties of `Correlation Price Factors` are as follows:

Value: The `Value` property of a correlation price factor specifies the correlation between the price factors identified by the correlation price factor ID.

12.2.3 Assumptions

12.2.3.1 Correlation Naming Conventions

Correlations are named by the IDs of the two price factors to which they refer, in alphabetical order. For example, `Correlation.EquityPrice.IBM.USD/FxRate.EUR.GBP` refers to the implied correlation between `EquityPrice.IBM.USD` and `FxRate.EUR.GBP`.

Correlation Sets: A correlation ID may be prefixed by a `Correlation Set` ID. This allows different implied correlations between the same price factors to be used in different contexts.

Theory Guide 1.9.1

A correlation price factor ID can also include a correlation set ID. A correlation set ID defines a group of related correlation price factors. For example, the correlation price factor SP500/EquityPrice.IBM.USD/EquityPrice.MSFT.USD belongs to the correlation set SP500.

FX Rate Correlation Names: The FX rate component of a correlation ID must be specified in alphabetical order, even when that does not agree with the quoting convention for the currency. Adaptiv Analytics will invert correlations as required.

Theory Guide 1.9.1

For a correlation price factor where one or both of the factors is an FX rate, each FX rate ID is of form FxRate.A.B, where A and B are currencies in alphabetical order. The initial correlation value is with respect to the A/B rates.

Correlations are assumed to be derived from log changes in asset prices. Therefore, the correlation between a B/A rate and another factor has the opposite sign to the correlation between the A/B rate and the other factor. For example, if the correlation between the IBM price and the JPY/USD rate is 0.5 then the correlation between the IBM price and the USD/JPY rate is -0.5 . Similarly, if the correlation between the EUR/GBP rate and the JPY/USD rate is 0.7 then the correlation between the EUR/GBP rate and the USD/JPY rate is -0.7 , and the correlation between the GBP/EUR rate and the USD/JPY rate is 0.7.

12.2.3.2 Correlation Bounds

Theory Guide 1.9.1

If $t = 0$ or no price factor model is selected then the correlation value at time t is ρ , where $\rho \in [-1, 1]$ is the initial correlation value (Value). Simulated correlation values are floored at -1 and capped at 1.

12.2.4 Limitations

12.2.4.1 Correlations are Flat for All Tenors

Correlations are represented as scalars, even when the correlation is between non-scalar price factors. For example, the correlation between a EUR interest rate curve and a USD interest rate curve is a scalar, the same for all tenors.

12.3 CMS Rate Correlation

12.3.1 Overview

This price factor provides correlations between interest rates in the same currency but with different tenors.

Theory Guide 1.9.1

The initial price factor values are given by a three-dimensional surface $\rho(\delta_1, \delta_2, \tau)$, where δ_1 and δ_2 are rate tenors and τ is a time to expiry. If $t = 0$ or no price factor model is selected then

the CMS rate correlation at valuation date t for rate tenors δ_1 and δ_2 and time to expiry τ is $\rho(\delta_1, \delta_2, \tau)$.

The surface can be defined on any set of points \mathcal{P} , but the surface values must satisfy: $-1 \leq \rho(\delta_1, \delta_2, \tau) \leq 1$ for all $(\delta_1, \delta_2, \tau) \in \mathcal{P}$; $\rho(\delta, \delta, \tau) = 1$ when $(\delta, \delta, \tau) \in \mathcal{P}$; and $\rho(\delta_1, \delta_2, \tau) = \rho(\delta_2, \delta_1, \tau)$ when $(\delta_1, \delta_2, \tau) \in \mathcal{P}$ and $(\delta_2, \delta_1, \tau) \in \mathcal{P}$.

For the representation of CMS Rate Correlation price factors in Adaptiv Analytics see the Correlation price factor section of the Interfacing Guide [5, § A.7 Correlations].

12.3.2 Price Factor Dependency

No price factor dependencies.

12.3.3 Properties

Properties common to CMS Rate Correlation Price Factors can be found in section 12.1.2. There are no additional properties for the CMS Rate Correlation price factor.

12.4 Forward Price Correlation

12.4.1 Overview

This price factor provides correlations between forward prices of the same underlying commodity but with different maturity dates. The initial representation of the price factor is a two-dimensional surface with two date axes. The surface can be defined on any set of date pairs.

For the representation of Forward Price Correlation price factors in Adaptiv Analytics see the Correlation price factor section of the Interfacing Guide [5, § A.7 Correlations].

12.4.2 Price Factor Dependency

No price factor dependencies.

12.4.3 Properties

Properties common to Forward Price Correlation Price Factors can be found in section 12.1.2. There are no additional properties for the Forward Price Correlation price factor.

Part III

Stochastic Models

Chapter 13

Stochastic Simulation

13.1 Overview

The valuation of deals and portfolios of deals in Adaptiv Analytics depend on a number of market variables or *price factors*, which can be defined as follows.

Theory Guide [1.1](#)

A financial product, or portfolio of products, derives its future value from one or more inherently random market variables, such as equity, commodity and FX prices, interest rate curves, survival probability curves and implied volatility surfaces. These market rate variables will be referred to as the *price factors*.

It follows that when calculations need to calculate the price of deals at future times (for example, PFE or Monte Carlo Market Risk calculations), the deal valuation models will require values for the price factors at these times. Adaptiv Analytics uses simulation to estimate the values for price factors at future times, with price factors evolved using stochastic factor models. Calculations such as Base valuation or Market Sensitivities at the system date require only the current value of price factors for their outer scenarios, and consequently do not require or invoke the stochastic price factor models discussed in this section.

In turn, price factor models are driven by sources of randomness called *risk factors*.

Theory Guide [1.1](#)

A *price factor model* calculates the future state of a price factor under Monte Carlo simulation. A price factor model for price factor P has a vector of *risk factor* processes $R_1(t), \dots, R_l(t)$, which are the underlying source of the randomness in the model.

Risk factors are derived from random draws from the standard normal distribution called “correlated normals” in Adaptiv Analytics. For a path-dependent simulation, a risk factor is constructed from a sequence of normal draws at each scenario time step. For a stratified simulation, a risk factor, the value at all time steps is constructed from a single draw or set of draws.

There are two types of these random draws, correlated normals and idiosyncratic normals.

Correlated normal A random standard normal draw which can be correlated with other correlated normals by the copula (see Section [13.2.2](#)).

Idiosyncratic normal An independent random draw. This may be correlated with another correlated normal within a factor model by the model itself, but it cannot be directly correlated with correlated normals by the copula. Indirect correlation of this type can be useful when the ran-

dom factor to be correlated is abstract and its correlation to other factors is difficult to define or measure. Indirect correlation also reduces the size of the copula.

13.1.1 Simulation of Price Factors

13.1.1.1 Initial Price Factor State

Price factors values at the base valuation date ($t = 0$) have their initial state set by a property (scalar, curve, or surface) on the price factor. These values may be a non-market standard representation of the value of the price factor.

13.1.1.2 No model evolution

The absence of a choice of stochastic model is interpreted by Adaptiv Analytics as an instruction not to evolve a price factor. Thus, the no model evolution method is called.

Theory Guide 1.1.3

When no price factor model is selected, the price factor values $P(t; p)$ for $t > 0$ are calculated by the price factor's *no-model evolution method*. Under the no-model evolution method, the price factor values are determined by the initial state of the price factor (see Section 1.1.1) and do not vary under Monte Carlo simulation.

13.1.1.3 Single-Step Scenarios

Single-step scenario generation is a technique used in multiple contexts, such as Monte Carlo market VaR and Value Map calculations.

In Adaptiv Analytics, single-step scenarios are used to generate Monte Carlo scenarios for PFE simulations under Latin hypercube sampling (referred to in Adaptiv Analytics as stratified sampling). This is because stratified sampling is incompatible with full path-dependent scenarios.

Single-step scenarios are not suitable for cases where path-dependence is important.

13.1.1.4 Factor Cones

A factor cone is calculated by Monte Carlo simulation of price factor values up to a horizon time. Such price factors can then be transformed (e.g., interest rate to discount rate), as required for simulation.

Adaptiv Analytics uses the Harrell-Davis [25] estimate of q -quantiles for factor cones, with values calculated for the 0.5%, 2.5%, 5%, 50%, 95%, 97.5% and 99.5% percentiles.

13.2 Common Assumptions and Limitations

13.2.1 Discrete Realisations

The Scenario Time Grid property defines a series of time points which extend to the maximum maturity date of the deals in the portfolio. Discrete realisations of the price factors are calculated at these points, based on the state variables for time $t - 1$ (i.e., the preceding point).

Where prices are required for points which have not already been simulated as part of the time grid, these are by default calculated from interpolated risk factor paths (i.e., not from the prices on the time grid). This offers advantages for prices which are not scalar, for which interpolation becomes complex.

The default interpolation method used by Adaptiv Analytics for this purpose is linear.

13.2.2 Copulas

The joint dependency of a vector correlated normals representing all risk factors in a particular portfolio calculation is calculated by Adaptiv Analytics using a copula model. By default, this is a Gaussian copula, although an alternative, the t -Copula, is also supported.

For the Gaussian copula, Adaptiv Analytics draws a vector of correlated normals by sampling from a uniform distribution and applying a Box-Muller transformation. These are then combined with a decomposition of the correlation matrix to ensure appropriate correlation.

For the t -Copula, a vector of correlated normals is obtained via the same method as the Gaussian copula, followed by transformation to a t -variable using a chi-squared variable; see the Theory Guide, Section 1.2.2.

Note that in either case, the copula used is stationary; that is, the same copula is used at all simulation times.

13.2.3 Variance Reduction

Adaptiv Analytics supports two approaches for variance reduction; stratified sampling and antithetic sampling. Stratified sampling in Adaptiv Analytics uses the Latin hypercube sampling method of Stein [45], while for antithetic a random sample is selected alongside a corresponding mirror-image sample. Note however that the variance of the antithetic estimate will only be reduced if the vector sample and the mirror vector are negatively correlated.

13.2.4 Shared State Variables

Each correlated normal (component of a vector of state variables) has with it an associated ID, which defaults to the ID of the underlying price factor.

Randomness can however be shared between factor models through two mechanisms in Adaptiv Analytics.

- Entire risk factor processes can be shared by registering a risk factor of the same type and ID in two different models. This is useful when using the default system management of correlated normals.
- It is also possible to do a more fine-grained sharing of the correlated normals themselves, by registering the correlated normals directly and building the risk factor paths in the factor model instead of relying on the automatic system generation. This allows two models to share some random drivers but not others.

For some models, the correlated normals ID can be specified using the `Correlated Normals` property of the model.

Chapter 14

Asset Price Models

14.1 Overview

Asset price factors represent the spot prices of equities, cash-and-carry commodities and foreign exchange (FX); they are described in more detail in Section 4, and in the Theory Guide Section 1.3. The common features of the stochastic simulation of each type asset price in Adaptiv Analytics are described below.

14.1.1 Classes of Asset Price Models

14.1.1.1 FX Models

In Adaptiv Analytics, it is possible to specify the counter-currency on any FX price such that the definition of FX rate for any currency is not limited to being against base currency. FX models simulate FX rates in the same terms in which they are specified on the price factor.

14.1.1.2 Equity Models

Equity spot prices and equity dividends are modelled independently in Adaptiv Analytics; the forward price is calculated as the spot equity price plus dividends. The payment of dividends has no effect on the spot price even when the continuous dividend yield curve is configured to mimic discrete payments as described in Section 7.1. The forward price would jump discontinuously in this case, however. Because dividends are represented as yields rather than cash amounts, they rise and fall with the equity price. However, when dividends are modelled stochastically, it is possible to negatively correlate changes in dividend yields with changes in equity prices.

14.1.1.3 Commodity Models

When considering commodities, it is useful to distinguish between precious metals and bulk (or industrial) commodities.

Precious metals trade like currencies, as opposed to trading at industrial value (i.e. the value of use as a raw material in manufacturing) as their market value is often higher due to limited supply and (ultimately) the metallist value associated with possession. The same stochastic models that are used for currencies are often suitable choices for precious metals.

The spot prices of base metals or industrial materials tend to be mean reverting because higher prices induce higher supply, and vice versa. Because of this mean-reversion feature, the Geometric Ornstein-Uhlenbeck model (Section 14.5) model is often the preferred model for industrial commodities when they are modelled as spot prices.

Only the energy price framework supports explicit forward price curves, so if it is desired to model a commodity using a forward price curve, it must be represented as an “energy”.

14.1.2 Common Properties

14.1.2.1 Correlated Normals

This property is used to expose the ID of the correlated normals that drive the risk factor processes of a model. Controlling this ID allows models to share the same correlated normal, which is the simplest and most efficient way to ensure that two models are perfectly correlated. A less efficient alternative is to use separate correlated normals but correlate them with 1 and use identical correlations against the correlated normals of other models.

14.1.2.2 Quanto FX Correlation / Volatility

These properties are used in order to apply a quanto correction described in Theory Guide [7, § 1.3.7.1 [Risk Neutral](#)]. This transforms the evolution of the asset price under the asset currency to an evolution under the base currency risk-neutral measure.

14.1.2.3 Risk Premium

This optional scalar parameter represents the extra return above the risk-free rate that an investor needs in order to be compensated for the risk of a certain investment. It represents the difference between the risk-neutral and real-world expectation of forward prices.

14.1.3 Common Assumptions and Limitations

14.1.3.1 No model evolution

When no model is attached to an asset price, it is fixed at its initial spot value on all scenarios.

Theory Guide [1.3.3](#)

If no price factor model is selected then the asset price is held constant:

$$S(t) = S(0). \quad (14.1.1)$$

14.1.3.2 Correlation between volatility and asset price

The majority of asset price models in Adaptiv Analytics specify volatility parameters that are fixed or are fixed functions of time. These models cannot reproduce the relationship of volatility to asset price that may be found in some markets. The Heston models, which support stochastic volatility, are exceptions to this.

14.1.3.3 FX Assumptions and Limitations

Managed Currencies: Adaptiv Analytics does not supply an asset price model suitable for managed currencies, such as the Hong Kong Dollar, which are characterized by relatively long periods of stability punctuated by large and sudden breaks in both the FX rate and its volatility.

Policy driven volatility skew: The implied market expectation may be a skewed distribution depending on market beliefs about Central Bank policy; however this skew is not factored into any of the stochastic volatility models.

14.1.3.4 Equity Assumptions and Limitations

Long term behaviour of equity prices: In the very long run, all companies are expected to fail, and their equity prices converge to zero. This behaviour is not modelled by the asset price mod-

els in Adaptiv Analytics. However, it can be modelled by simulating the credit rating of the equity issuer.

Relationship to Dividend price factor: Equity prices are not linked to the dividend rate price factor except by the risk factor correlation matrix,

14.1.3.5 Commodity Assumptions and Limitations

Convenience Yields: In Adaptiv Analytics, convenience yields are defined net of storage costs and may be negative. The default interpolation of convenience yields in AA is linear, with flat extrapolation. However, these settings may be overridden in the market data file.

14.2 Drift To Forward Asset Price Model

14.2.1 Overview

This is a non-stochastic risk-neutral model. The model evolves to the initial forward price on all scenarios.

Theory Guide [1.3.4](#)

Under the model, the asset price is evolved to initial forward asset prices:

$$S(t) = F(0, t). \quad (14.2.1)$$

For details about the valuation for this model, see the Theory Guide [[7](#), § [1.3.4 Drift To Forward Model](#)].

14.2.2 Properties

The model has no adjustable properties.

14.2.3 Assumptions and Limitations

14.2.3.1 No Arbitrage

The implicit assumption of this model is that the forward price of the asset is arbitrage-free.

14.3 GBM Asset Price Model

14.3.1 Overview

The GBM (Geometric Brownian Motion) model treats the underlying behaviour of a spot asset price as a Brownian path with a drift (μ) and a volatility (σ). For the basic GBM model, both of these terms are scalars. The asset price (S) is governed by the stochastic differential equation:

Theory Guide [1.3.5](#)

$$\frac{dS(t)}{S(t)} = \mu dt + \sigma dW(t) \quad (14.3.1)$$

where

- μ is the drift of the asset price
- σ is the volatility of the asset price
- $W(t)$ is a standard Wiener process.

This equation may be solved into a lognormal diffusion process. For details about the valuation for this model, see the Theory Guide [7, § [1.3.5 GBM Model](#)].

14.3.2 Properties

Correlated Normals

Component standard normal variables used to update the model's state variables at each time point.

Drift

Drift of the asset. Scalar.

Vol Volatility of the asset. Scalar.

14.3.3 Assumptions and Limitations

14.3.3.1 Postive Prices

Under this model, asset prices are always positive.

14.3.3.2 Unbounded Diffusion

This model has no term structure associated with it and no mean reversion. Hence, paths simulated by this model will diffuse without limit, leading to an expanding factor cone that may be larger than considered realistic in the market. Conversely, note that if the volatility is large relative to the drift, the asset price will converge pathwise to zero almost surely even though the ensemble expectation may diverge.

14.4 GBM Asset Price Term Structure Model

14.4.1 Overview

The Geometric Brownian Motion Term Structure (GBM)-TS model extends the simple GBM Asset Price Model described in Section 14.3 to allow the volatility and drift parameters to be deterministic functions of simulation time. The motivation behind this extension is to reduce the dispersion of simulated prices over long horizons. This is often a concern with FX rates, as economic theory suggests that the dispersion of FX rates should be somewhat constrained by purchasing power parity between the two currencies.

Theory Guide 1.3.7

Alternatively, it is possible to generalize the GBM model so that the volatility parameter $\sigma(t)$ and drift parameter $\mu(t)$ are deterministic functions of time. Typically, $\sigma(t)$ is a decreasing function of t .

When Risk Neutral Drift is No, the model is governed by the SDE:

$$\frac{dS(t)}{S(t)} = \mu(t) dt + \sigma(t) dW(t). \quad (14.4.1)$$

14.4.1.1 Risk Neutrality

When the Risk Neutral Drift property is set to Yes, the model evolves the asset price in the base currency risk-neutral measure.

Theory Guide 1.3.7.1

When Risk Neutral Drift is Yes, the governing SDE is

$$\frac{dS(t)}{S(t)} = (r(t) - q(t) - \nu(t)\sigma(t)\rho + \lambda(t)\sigma(t)) dt + \sigma(t) dW(t), \quad (14.4.2)$$

where:

- q is the yield on the asset. In the case that S is a foreign exchange rate, q is the foreign interest rate.
- r is the interest rate in the asset currency.
- $\nu(t)$ is the Quanto FX Volatility and ρ is the Quanto FX Correlation. If the asset currency is the same as the base currency then $\nu(t) = 0$ and $\rho = 0$. Otherwise, the price of the asset is in a foreign currency, $\nu(t)$ is the volatility of the FX rate (the price of the asset currency in base currency) and ρ is the correlation between the FX rate and the asset price.
- $\lambda(t)$ is the risk premium curve, assumed to be a deterministic function of time.

14.4.2 Properties

The curve drift and volatility properties may be specified in either instantaneous or integrated form. It is often convenient to specify volatility in integrated form because this is how it can be observed in the market as the Black volatility of options.

Drift

Drift of the asset. Term structure.

Quanto FX Correlation

Correlation between the FX rate and the asset price. Used to support risk-neutral drift. Scalar. This parameter, along with the Quanto FX Volatility below, may be ignored for the special case when the foreign currency is the base currency and the domestic currency the factor currency. For this case, the Quanto FX parameters are not used as the quanto FX Correlation $\rho \stackrel{\text{def}}{=} -1$, and $\nu(t) \stackrel{\text{def}}{=} \sigma(t)$.

Quanto FX Volatility

Volatility of the price of the FX rate (the asset currency in base currency). Term structure. Used to support risk-neutral drift; see comment for Quanto FX Correlation above. May be specified either as an instantaneous curve or an integrated curve.

Risk Neutral Drift

Boolean Yes or No to toggle whether to invoke risk-neutral or real-world drift in the simulation. See section [14.4.1.1](#).

Risk Premium

This curve represents the extra return above the risk-free rate that an investor needs in order to be compensated for the risk of a certain investment. Only required if Risk Neutral Drift is Yes. The risk premium curve, if specified, determines the nature of the Wiener measure driving the risk-neutral GBM measure. May be specified either as an instantaneous curve or an integrated curve.

Theory Guide [1.3.7.1](#)

If a risk premium curve is specified then $W(t)$ is a standard Wiener process under the real-world measure, otherwise $W(t)$ is a standard Wiener process under the base currency risk-neutral measure.

Vol Volatility of the asset. Term structure. May be specified either as an instantaneous curve or an integrated curve.

14.4.3 Assumptions and Limitations

14.4.3.1 Conversion Between Instantaneous and Integrated Curves

Curve calculation is described in Theory Guide [1.3.7.3](#). Note that integrated curves must be calculated internally to support the risk-neutral discretization of the model. These calculations require instantaneous drift and volatility curves, which will be calculated from the integrated curves if that is how they are supplied to the model. The calculation of an integrated curve may require extrapolation of the instantaneous curve to be integrated.

14.4.3.2 Interpolation and Extrapolation of Curves

All curves used by the model are interpolated linearly and extrapolated flat.

14.4.3.3 Mean reversion

The cross-sectional distribution of rates produced by reducing volatility in the GBM Term Structure Model can be similar, in appearance, to the distribution of rates produced by a mean-reverting process. However, there is no pathwise mean reversion; the volatility on each scenario eventually becomes stuck in a small region around some value reached earlier in the path.

14.4.3.4 Non-negative Variance

The discrete realization of price changes under the real-world measure calculated Adaptiv Analytics uses a variance curve calculated from the integrated volatility curve. The variance curve is calculated

as integrated variance, and is therefore non-decreasing. If the integrated volatility curve implies decreasing variance over an interval, then the change in variance over that interval is coerced to zero.

Theory Guide [1.3.7.3](#)

The variance curve $V(t)$ is a separate curve with linear interpolation that is defined by $V(0) = 0$, $V(t_i) = \bar{\sigma}(t_i)^2 t_i$, and $V(t) = \bar{\sigma}(t_n)^2 t$ for $t > t_n$, where t_1, \dots, t_n are the discrete time points on the Vol curve. If the integrated curve $\bar{\sigma}(t)$ is specified but implies a decrease in variance then for the first point t_i for which $V(t_i) < V(t_{i-1})$, the variance and integrated curve values at t_i are redefined by $V(t_i) = \bar{\sigma}(t_i)^2 t_i = V(t_{i-1})$. Any subsequent points with a decrease in variance are fixed in the same way.

14.4.3.5 Shocks

The GBM Asset Price Term Structure model generates a continuous diffusion of FX rates, which is representative of a free-floating currency regime under normal economic conditions. It does not account for the possibility of macroeconomic shocks causing a discrete jump in the FX rate.

14.5 GOU Asset Price Model

14.5.1 Overview

The geometric Ornstein-Uhlenbeck (GOU) Asset Price model is similar to the GBM Model (Section 14.3), with the addition of a mean reversion term. Mean reversion constrains the dispersion of asset prices without requiring volatility to shrink along each scenario.

The governing SDE for this model can be constructed from an Ornstein-Uhlenbeck process as follows:

Theory Guide 1.3.9

Then $\log S(t) - \mu t$ is an Ornstein-Uhlenbeck process with mean-reversion speed α , long run mean θ and volatility σ , and the asset price satisfies the SDE

$$d \log S(t) = [\mu + \alpha(\theta + \mu t - \log S(t))] dt + \sigma dW(t). \quad (14.5.1)$$

When $\mu = 0$, the expectation of $S(t)$ tends to the long run mean $e^{\theta + \sigma^2/4\alpha}$ as $t \rightarrow \infty$.

For details about the valuation for this model, see the Theory Guide [7, § 1.3.9 GOU Asset Price Model].

14.5.2 Properties

Alpha

The model mean-reversion speed parameter. Scalar.

Mu Constant drift. Scalar.

Sigma

Volatility of the asset. Scalar.

Theta

Constant long run mean of the asset process. Scalar.

Use Absolute Theta

Specified whether the model should use either absolute (Yes) or relative (No) mean reversion levels. The effect of the Use Absolute Theta setting is to replace the θ parameter in the asset price evolution with $\theta + \log S(0)$, such that the long run mean may be relative to the current asset price.

14.5.3 Assumptions and Limitations

14.5.3.1 Scalar Parameters

The parameters of the GOU Asset Price model have no term structure. The cross-sectional distribution of simulated asset values as viewed from time zero will converge to a stable distribution around the long-run mean.

14.6 GOU Asset Price Term Structure Model

14.6.1 Overview

The term structure version of the GOU asset price model replaces the scalar long run mean (θ) with a term structure ($\theta(t)$) derived from the forward price curve. This model is analogous to the Black-Karasinski interest rate model. The model is suitable for the long term evolution of spot asset prices, in particular FX rates, and can be solved from it's governing equation for asset price $S(t)$.

Theory Guide [1.3.10](#)

For a given deterministic function $\theta(t)$, the solution of the SDE

$$d \log S(t) = \alpha (\theta(t) - \log S(t)) dt + \sigma dW(t) \quad (14.6.1)$$

is $\log S(t) = \log S(0)e^{-\alpha t} + g(t) + \sigma Y(t)$, where

$$g(t) = \alpha \int_0^t e^{-\alpha(t-s)} \theta(s) ds. \quad (14.6.2)$$

(see Section [B.2](#)).

For details about the valuation for this model, see the Theory Guide [[7](#), § [1.3.10 GOU Asset Price Term Structure Model](#)].

14.6.2 Properties

Alpha

The model mean-reversion speed parameter. Scalar.

Forward Price

Forward price curve to which the mean-reversion level is fitted.

Sigma

Volatility of the asset process. Scalar.

Use Forward For Spot

If set to **Yes**, then the expectation of simulated prices is the value of the forward price curve at simulation time t . If set to **No**, then

Theory Guide [1.3.10](#)

The expected asset price is given by

$$\mathbb{E}(S(t)) = F(t) \left(\frac{S(0)}{F(0)} \right)^{\exp(-\alpha t)}. \quad (14.6.3)$$

14.6.3 Assumptions and Limitations

14.6.3.1 Theta Not Specified Directly

The model always fits the theta parameter of the model from the given forward price curve. Theta cannot be specified directly as a model parameter.

14.6.3.2 Risk Neutral Behaviour

The model can be configured to be risk neutral from the static perspective of time zero. It is not dynamically risk neutral in the sense of updating expectations along each scenario path.

14.7 Multi-Factor GBM Asset Price Model

14.7.1 Overview

For details about the valuation for this model, see the Theory Guide [7, § 1.3.6 Multi-Factor GBM Model].

The Multi-Factor GBM Asset Price model overcomes one of the principal disadvantages of the ‘standard’ GBM model for equities. A portfolio may contain many hundreds or thousands of equities; corresponding to many hundreds or thousands of equity drivers inflating the risk factor set required for simulation.

As much of the risk for equities is systemic, an expansive risk factor set is both undesirable and redundant. Much of the variance of an equity portfolio can be captured by a relatively small set of drivers, which may consist of:

- Any number of independent systematic drivers, or;
- Any number of correlated systematic drivers and a single idiosyncratic driver per asset,

The choice of drivers is determined by calibration, and may correspond to actual benchmarks (e.g., regression or beta calibration) or to abstract quantities (e.g., PCA factors). This model shares commonality of behaviour with GBM model (see Section 14.3), with the result that the asset prices are given by a solution to Equation 14.3.1 with suitable variable substitutions.

Theory Guide 1.3.6

The systematic drivers are standard Wiener processes $W_1(t), \dots, W_m(t)$. The idiosyncratic driver is a standard Wiener process $\widetilde{W}(t)$, which is independent of the systematic drivers and independent of all other risk factors. The asset price is given by

$$S(t) = S(0) \exp \left(\left(\mu - \frac{1}{2} \sigma^2 \right) t + \sigma \left(\sum_{k=1}^m a \left(\frac{\hat{\omega}_k}{\hat{\omega}} \right) W_k(t) + b \left(\frac{\hat{\epsilon}}{\hat{\omega}} \right) \widetilde{W}(t) \right) \right) \quad (14.7.1)$$

for $\sigma > 0$, where

- μ is the drift of the asset price
- σ is the volatility of the asset price
- $\hat{\omega}_k$ is the rounded weight of the k^{th} systemic driver
- $\hat{\epsilon}$ is the rounded weight of the idiosyncratic driver
- $\hat{\omega}$ is the normalization factor for the rounded weights
- either $a = 1$ and $b = 1$ when Active Factors is All, $a = 1$ and $b = 0$ when Active Factors is General, $a = 0$ and $b = 1$ when Active Factors is Idiosyncratic, or $a = 0$ and $b = 0$ when Active Factors is None.

14.7.2 Properties

Active Factors

Specifies which risk factors should be taken into account. If set to `Idiosyncratic`, then all systemic factor weights are set to zero. If set to `General`, then all idiosyncratic weights are set to zero. If set to `All`, then no driver weights are changed. If set to `None`, no factors are active, and the model follows the forward price evolution for each asset price.

Drift

Drift of the asset. Scalar.

Idiosyncratic Weight

Weight of the idiosyncratic driver. Scalar.

PCA Factors

Should be set as **Yes** to set correlations between drivers to zero with Adaptiv Analytics calculating normalizing weights to 1; or **No** for correlated drivers with weights assumed to be already normalized.

Significance Threshold

Any driver weights with absolute value less than the threshold are rounded to zero. Scalar.

Vol Volatility of the asset. Scalar.

Weights

List of weights of the assets with respect to the driver. These may however be reduced to zero if they fall below the significance threshold; see Section 14.7.3.1.

14.7.3 Assumptions and Limitations**14.7.3.1 Significance Threshold**

In practise the idiosyncratic weights can be very small, which can inflate the number that need to be simulated and hence compromise performance and stability. To combat this, Adaptiv Analytics applies a threshold Θ against which driver weights are compared and any falling under the threshold rounded down to zero.

Theory Guide [B.1.1](#)

The default value of Θ is 10^{-6} .

14.7.4 Weight Normalisation

When the systemic drivers are correlated, weights must be normalised in advance because the model cannot access the correlations, which would be necessary for the model to do its own normalisation. On the other hand, the model automatically normalises orthogonal drivers (e.g. PCA factors, which are by definition not correlated) because it can.

If the model is parametrised with correlated driver weights below the significance threshold, those weights will be discarded. No re-normalisation will be performed in the non-PCA case because it is impossible due to the model not having knowledge of the correlations between drivers.

Theory Guide [B.1.1](#)

In this case, the model assumes $\omega = 1$, and any reduction in the total weight due to rounding is neglected.

14.7.5 Zero Volatility

When the volatility parameter is zero, the asset price is evolved as follows:

Theory Guide [B.1.1](#)

In the case that $\sigma = 0$, the asset price is given by

$$S(t) = S(0) \exp \left(\left(\mu - \frac{1}{2} \dot{\omega}^2 \right) t + \sum_{k=1}^m a \dot{\omega}_k W_k(t) + b \dot{\epsilon} \widetilde{W}(t) \right). \quad (14.7.2)$$

--

14.8 Multi-Factor GBM Asset Price Term Structure Model

14.8.1 Overview

This model is similar to the ‘standard’ (non-term structure) Multi-Factor GBM Asset Price Model except that, like the GBM Asset Price Term Structure Model (Section 14.4) it uses a term-structure for the drift and volatility. Consequently, both properties become curves.

Theory Guide 1.3.8

The model has systematic drivers $W_1(t), \dots, W_m(t)$ and an idiosyncratic driver $\widetilde{W}(t)$, which is independent of the systematic drivers and independent of all other risk factors. The asset has a time-dependent volatility, a time-dependent drift, and constant weights with respect to the drivers. The asset price is given by

$$S(t) = S(0) \exp \left(\left(\bar{\mu}(t) - \frac{1}{2} \bar{\sigma}(t)^2 \right) t + \sum_{k=1}^m a \left(\frac{\hat{\omega}_k}{\hat{\omega}} \right) \int_0^t \sigma(s) dW_k(s) + b \left(\frac{\hat{\epsilon}}{\hat{\omega}} \right) \int_0^t \sigma(s) d\widetilde{W}(s) \right), \quad (14.8.1)$$

where

- $\mu(t)$ is the drift of the asset price and $\bar{\mu}(t)t = \int_0^t \mu(s) ds$
- $\sigma(t)$ is the volatility of the asset price and $\bar{\sigma}(t)^2 t = \int_0^t \sigma(s)^2 ds$
- $\hat{\omega}_k$ is the rounded weight of the k^{th} systematic driver
- $\hat{\epsilon}$ is the rounded weight of the idiosyncratic driver
- $\hat{\omega}$ is the normalization factor for the rounded weights
- either $a = 1$ and $b = 1$ when Active Factors is All, $a = 1$ and $b = 0$ when Active Factors is General, $a = 0$ and $b = 1$ when Active Factors is Idiosyncratic, or $a = 0$ and $b = 0$ when Active Factors is None.

For details about the valuation for this model, see the Theory Guide [7, § 1.3.8 Multi-Factor GBM Term Structure Model].

14.8.1.1 Risk-Neutrality

The Multi-Factor GBM Asset Price Term Structure Model has both real world and risk neutral formulations, with similar implications as for the GBM Asset Price Term Structure Model (Section 14.4.1.1). The impact of risk-neutral simulation is the introduction of a no-arbitrage relationship, as follows:

Theory Guide 1.3.8.1

When Risk Neutral Drift is Yes, $\mu(t)$ is replaced by

$$r(t) - q(t) - \rho \nu(t) \sigma(t) + \lambda(t) \sigma(t), \quad (14.8.2)$$

where q is the yield on the asset, r is the interest rate in the asset currency, $\nu(t)$ is the quanto FX volatility, ρ is the quanto FX correlation, and λ is the market price of risk.

14.8.2 Properties

Many of the properties for the Multi-Factor GBM Asset Price Term Structure Model are shared with the Multi-Factor GBM Asset Price Model. These properties are outlined in Section 14.7.2. Additional or altered properties for the term structure variant are outlined below.

Drift

Drift of the asset. Term structure.

Quanto FX Correlation

Correlation between the FX rate and the asset price. Used to support risk-neutral drift. Scalar. This parameter, along with the Quanto FX Volatility below, may be ignored for the special case when the foreign currency is the base currency and the domestic currency the factor currency. For this case, the Quanto FX parameters are not used as the quanto FX Correlation $\rho \stackrel{\text{def}}{=} -1$, and $\nu(t) \stackrel{\text{def}}{=} \sigma(t)$.

Quanto FX Volatility

Volatility of the price of the FX rate (the asset currency in base currency). Term structure. Used to support risk-neutral drift; see comment for Quanto FX Correlation above. May be specified either as an instantaneous curve or an integrated curve.

Risk Neutral Drift

Boolean Yes or No to toggle whether to invoke risk-neutral or real-world drift in the simulation. See section 14.4.1.1. May be specified either as an instantaneous curve or an integrated curve.

Risk Premium

This curve represents the extra return above the risk-free rate that an investor needs in order to be compensated for the risk of a certain investment. Only required if Risk Neutral Drift is Yes. The risk premium curve, if specified, determines the nature of the Wiener measure driving the risk-neutral GBM measure.

Vol Volatility of the asset. Term structure. May be specified either as an instantaneous curve or an integrated curve. See Vol definition in Section 14.4.2.

14.8.3 Assumptions and Limitations

The Limitations of this model are similar to those of the Multi-Factor GBM Asset Price Model; see Section 14.7.3.

14.9 Trolle-Schwartz Stochastic Volatility Commodity Spot Model

14.9.1 Overview

The Trolle-Schwartz Commodity Spot Price Model is a triple stochastic volatility model that jointly models the spot price, variance and the effective convenience yield.

In Adaptiv Analytics, a mildly restricted version of the original model presented in [47] is implemented, whereby variance follows a Cox-Ingersoll-Ross (CIR) model.

Theory Guide 1.3.13

The spot price $S(t)$ and the effective convenience yield $y(t, T)$ follow the dynamics:

$$\frac{dS(t)}{S(t)} = (y(t, t) + \lambda_1 \sigma_1 v(t)) dt + \sigma_1 \sqrt{v(t)} dW_1(t) \quad (14.9.1)$$

$$dy(t, T) = (\mu(t, T) + \lambda_2 \sigma_2(t, T) v(t)) dt + \sigma_2(t, T) \sqrt{v(t)} dW_2(t) \quad (14.9.2)$$

$$dv(t) = (\theta - \kappa v(t)) dt + \sigma_3 \sqrt{v(t)} dW_3(t), \quad (14.9.3)$$

where $W_i(t)$ are correlated Wiener processes with $dW_i(t) dW_j(t) = \rho_{ij} dt$ and $\sigma_2(t, T) = \sigma_2 e^{-\gamma(T-t)}$. The model parameters are:

- Spot volatility σ_1 and spot risk premium λ_1 .
- Yield volatility σ_2 , yield risk premium λ_2 and yield reversion speed γ .
- Variance reversion speed κ , variance reversion level θ , variance volatility σ_3 , variance risk premium λ_3 and initial variance $v(0)$.
- spot/yield correlation ρ_{12} , spot/variance correlation ρ_{13} and yield/variance correlation ρ_{23} .

κ is the variance reversion speed under the real world measure and $\kappa^* = \kappa + \lambda_3 \sigma_3$ is the variance reversion speed under the risk neutral measure (as in Section 1.3.11).

Theory Guide 1.3.13

The drift term $\mu(t, T)$ is given by the non-arbitrage constraint:

$$\mu(t, T) = -v(t) \sigma_2(t, T) \left(\sigma_1 \rho_{12} + \int_t^T \sigma_2(t, u) du \right). \quad (14.9.4)$$

When $\sigma_2 = 0$ the model reduces to the Heston model. Alternatively, setting $\sigma_3 = 0$ and $v(0) = 1$, the spot price follows the Black-Scholes model and the effective convenience yield follows the Hull-White model.

This model can account for volatility skew, and can accommodate the seasonality of forward prices in the initial convenience yield.

For details about the valuation for this model, see the Theory Guide [7, § 1.3.13 Trolle-Schwartz Commodity Spot Price Model].

14.9.2 Properties

Initial Variance

Initial state (variance) at $t = 0$ of the CIR variance process. Scalar.

Spot Risk Premium

Represents the extra return above the risk-free rate that an investor needs in order to be compensated for the risk of a certain investment. Scalar value, specifying a spot price.

Spot Variance Correlation

Correlation between the driving Wiener processes for the spot and variance processes. Scalar.

Spot Vol

Instantaneous volatility for the spot process. Scalar.

Spot Yield Correlation

Correlation between the driving Wiener processes for the spot and convenience yield processes. Scalar.

Variance Discretization Scheme

Adaptiv Analytics allows choices of `Zhu` or `Full Truncation`; the discretization scheme for the stochastic volatility CIR process. See Section [18.6.3.1](#)

Variance Reversion Level

Mean reversion level for the CIR variance process. Scalar.

Variance Reversion Speed

Mean reversion speed for CIR variance process. Scalar.

Variance Risk Premium

Represents the extra return above the risk-free rate that an investor needs in order to be compensated for the risk of a certain investment. Scalar value, specifying a variance.

Variance Vol

Instantaneous volatility for the CIR variance process. Scalar.

Yield Reversion Speed

Mean reversion speed for the convenience yield process. Scalar.

Yield Risk Premium

Represents the extra return above the risk-free rate that an investor needs in order to be compensated for the risk of a certain investment. Scalar, specifying a yield.

Yield Variance Correlation

Correlation between the driving Wiener processes for the convenience yield and variance processes. Scalar.

Yield Vol

Instantaneous volatility for the convenience yield process. Scalar.

14.9.3 Assumptions and Limitations**14.9.3.1 Minimum reversion rate**

Small absolute values of the reversion rates are coerced to zero, in order to avoid numerical instability (since reversion rates are used as denominators).

14.9.3.2 FX Rate

The Adaptiv Analytics implementation of the Trolle-Schwartz model may not (necessarily) use the FX rate when calculating forward price; instead, the forward price is calculated directly from the model parameters.

14.9.3.3 No Calibration

Adaptiv Analytics does not support calibration of the Trolle-Schwartz model parameters; instead these must be supplied directly.

14.9.3.4 Stratified Sampling

This model in Adaptiv Analytics cannot fully support stratified sampling. If stratification is requested, one-step simulation from time zero to each horizon is performed, where in such case the stochasticity of the volatility process is lost.

This is permitted as, for extremely short term simulations (e.g., 1d, 2d market simulation), this approach may still have some marginal value.

Chapter 15

Joint Models

15.1 Overview

15.1.1 Heston models

The majority of the asset price models implemented in Adaptiv Analytics have no intrinsic relationship between volatility and asset price, other than the statistical relationship provided by the correlation matrix. They cannot guarantee a skew relationship will hold on each scenario.

“Joint” asset models model both price and volatility jointly within a single model. They therefore support the a relationship such as skew between price and volatility. These models are also referred to as stochastic volatility models.

Adaptiv Analytics includes two joint models; the single factor Heston model of [29], and a generalised two factor variant. The two factor implementation also supports a jump-diffusion process [21]. These are arbitrage-free models which capture the heteroscedasticity of volatility, meaning that some sub-populations of the volatility may attain different distributions from others.

15.1.1.1 FX Volatility Triangulation

Since a Heston model can be defined for each each FX rate price factor, implied volatilities can be calculated for each FX rate price factor. Adaptiv Analytics calculates such volatilities through the triangle rule, whereby:

Theory Guide [1.8.10.2](#)

The triangle rule derived from the decomposition $X_{P/Q} = X_{P/R}X_{R/Q}$ is

$$V_{P/Q}(m)^2 = V_{P/R}(m)^2 + V_{R/Q}(m)^2 + 2\rho V_{P/R}(m)V_{R/Q}(m), \quad (15.1.1)$$

where ρ is the correlation between $X_{P/R}$ and $X_{R/Q}$, which is taken from the correlation price factor.

This feature is discussed in depth in the Theory Guide, Section [1.8.10.2](#).

15.1.2 Common Properties

The following properties are found in both One- and Two- Factor Heston models.

Drift

Drift curve of the asset.

Risk Neutral Drift

Boolean choice, Yes or No; whether to apply risk neutral drift to the simulation.

Risk Premium

This represents the extra return above the risk-free rate that an investor needs in order to be compensated for the risk of a certain investment. Scalar.

15.1.3 Common Assumptions and Limitations

15.1.3.1 Calibration

These models produce realistic behaviour, but are accordingly also more difficult to calibrate.

15.1.3.2 Configuration in Adaptiv Analytics

For a joint model to simultaneously simulate both asset price and volatility, the same model must be chosen for both price factors. Hence, a One- or Two- Factor Asset Price Model must be chosen for the asset price, with a corresponding One- or Two- Factor volatility model assigned to the corresponding volatilities. Note that FX volatility and non-FX volatility are simulated with different models in Adaptiv Analytics, but the underlying asset prices are simulated with the same models whether or not they are FX.

15.1.3.3 Currency of Asset Prices and Volatilities

Adaptiv Analytics does not support Heston models for asset prices and volatilities defined in different currencies. Hence:

Theory Guide [1.8.10.1](#)

In order to have a Heston model of an equity or commodity volatility price factor, the currency of the volatility price factor must be the same as the currency of the underlying equity or commodity price factor.

15.1.3.4 Interest Rates

Adaptiv Analytics does not support any stochastic volatility model for interest rates.

15.2 Heston 1 Factor Model

15.2.1 Overview

The Heston One-Factor Model is a stochastic volatility, arbitrage-free model, which assumes that asset price variance is a random process with a tendency to revert towards a long-term reversion level. It exhibits volatility that is proportional to the square root of its reversion level, and whose source of randomness is correlated with the randomness of the underlying's price processes.

Theory Guide [1.3.11.1](#)

The dynamics of the asset price $S(t)$ and the instantaneous variance $v(t)$ are given by

$$\frac{dS(t)}{S(t)} = \mu(t) dt + \sqrt{v(t)} dZ(t) \quad (15.2.1)$$

$$dv(t) = \kappa(\theta - v(t)) dt + \sigma\sqrt{v(t)} dW(t), \quad (15.2.2)$$

where $\mu(t)$ is the drift of the asset price, κ is the mean reversion speed of the variance, θ is the long run mean of the variance, and σ is the volatility of the variance. Z and W are Wiener processes under the real world measure with correlation ρ :

$$dZ(t) dW(t) = \rho dt. \quad (15.2.3)$$

Adaptiv Analytics also makes provision to calculate prices for European Options analytically under the Heston model. See the Theory Guide, section [1.3.11.7](#). For details about the valuation for this model, see the Theory Guide [[7](#), § [1.3.11 Heston Asset Price Model](#)].

15.2.1.1 Risk-Neutrality

The risk neutral equivalent of the Heston 1 Factor model supplements the underlying Weiner processes with additional risk premiums $\Omega(t)$ and $\Lambda(t)$, such that

$$dZ^*(t) = dZ(t) + \Lambda(t) dt \quad (15.2.4)$$

$$dW^*(t) = dW(t) + \Omega(t) dt \quad (15.2.5)$$

and thence, through appropriate choices for the risk premiums:

Theory Guide [1.3.11.1](#)

Choosing $\Omega(t) = \omega\sqrt{v(t)}$, where ω is constant, the evolution under the risk-neutral measure is given by

$$\frac{dS(t)}{S(t)} = (r(t) - q(t)) dt + \sqrt{v(t)} dZ^*(t) \quad (15.2.6)$$

$$dv(t) = \kappa^*(\theta^* - v(t)) dt + \sigma\sqrt{v(t)} dW^*(t), \quad (15.2.7)$$

where $\kappa^* = \kappa + \omega\sigma$ and $\theta^* = \kappa\theta/\kappa^*$.

Full details of this conversion can be found in the Theory Guide Sections [1.3.11.2](#) and [1.3.11.3](#).

15.2.2 Configuration

Asset Price Model

└ Heston One-Factor Asset Price Model (Theory Guide § [1.3.11](#))

Volatility Model

- └ FX Volatility Heston Model (Theory Guide § 1.8.10)
- └ Asset Price Volatility Heston Model (Theory Guide § 1.8.10)

15.2.3 Properties

See also section 15.1.2 for properties common to One- and Two- Factor Heston Models.

Initial Variance

Initial variance of the variance process at time $t = 0$. Scalar.

Spot Variance Correlation

Correlation between the driving Wiener processes for the spot and variance processes. Scalar.

Variance Reversion Level

Mean reversion level for the variance process. Scalar.

Variance Reversion Speed

Mean reversion speed for instantaneous variance. Scalar.

Variance Risk Premium

Variance This represents the extra return above the risk-free rate that an investor needs in order to be compensated for the risk of a certain investment. Scalar.

Variance Vol

Instantaneous volatility for the variance process. Scalar.

15.2.4 Assumptions and Limitations

15.2.4.1 Limitations on values

Some parameters are limited to positive values (see Theory Guide Section 1.3.11.4).

Theory Guide 1.3.11.4

The initial variance $v(0)$ is a parameter of the model. The model parameters must satisfy $\sigma > 0$, $v(0) > 0$, $-1 \leq \rho \leq 1$ and either $\kappa > 0$ and $\theta > 0$ (Risk Neutral Drift is No), or $\kappa^* > \omega\sigma$ and $\theta^* > 0$ (Risk Neutral Drift is Yes).

A naive discretization of a Heston model can result in negative variances. This is prevented by using =Zhu's approach.

Theory Guide 1.3.11.5

As discussed in Zhu [48], discrete simulation of this process can generate negative variance values, even if the parameters satisfy the Feller condition ($2\kappa\theta \geq \sigma^2$). To avoid these problems, the model follows Zhu's approach of simulating the square root of the variance.

15.2.4.2 Volatility Smile

This model may not be able to replicate a short term volatility smile because it does not incorporate jumps in the asset price.

15.2.4.3 Solving for European Option Volatility

The implied volatility under a Heston model can be calculated by comparing the value of a European option (under the Black formula) with the value of a European option under the Heston formula.

Adaptiv Analytics uses a numerical method for this solution; see Theory Guide Section [1.8.10](#).

Theory Guide [1.8.10](#)

Equation ([1.278](#)) is solved using the false position method to an accuracy of 10^{-5} (see Press et al. [[41](#), Chapter 9.2]).

15.3 Heston 2 Factor Model

15.3.1 Overview

This model is a generalisation of the One-Factor model of Section 15.2, whereby a second variance factor is included.

The Adaptiv Analytics implementation of this model additionally incorporates a normally distributed jump process into the Asset dynamics. Owing to this addition, the Adaptiv Analytics version is the so-called MSVJY model, and allows better approximation of the short term volatility smile.

Theory Guide 1.3.12

The dynamics of the asset price S and instantaneous variance v are given by

$$\frac{dS(t)}{S(t)} = \left(a(t) + \sum_{i=1}^2 b_i(t) \sqrt{v_i(t)} - \lambda \bar{\xi} \right) dt + \sum_{i=1}^2 \sqrt{v_i(t)} dZ_i(t) + dJ(t) \quad (15.3.1)$$

$$dv_i(t) = \kappa_i(\theta_i - v_i(t)) dt + \sigma_i \sqrt{v_i(t)} dW_i(t). \quad (15.3.2)$$

Z_1 and Z_2 are independent Wiener processes, and W_1 and W_2 are independent Wiener processes, with $dZ_i(t) dW_i(t) = \rho_i dt$ and $dZ_i(t) dW_j(t) = 0$ for $i \neq j$.

The jump term, $J(t)$, is a compound Poisson process.

For details about the valuation for this model, see the Theory Guide [7, § 1.3.12 Heston Two Factor Asset Price Model].

15.3.1.1 Risk-Neutrality

The two-factor model also includes options for risk neutral drift, which are outlined in the Theory Guide Section 1.3.12.

15.3.2 Configuration

Asset Price Model

- └ Heston Two-Factor Asset Price Model (Theory Guide § 1.3.12)

Volatility Model

- └ FX Volatility Heston 2 Factor Model (Theory Guide § 1.8.11)
- └ Asset Price Volatility Heston 2 Factor Model (Theory Guide § 1.8.11)

15.3.3 Properties

See also section 15.1.2 for properties common to One- and Two- Factor Heston Models.

Initial Variance1

Initial variance of the CIR variance process for the first factor. Scalar.

Initial Variance2

Initial variance of the CIR variance process for the second factor. Scalar.

Jump Intensity

The jump intensity parameter (defined as the average number of jumps per year). Scalar.

Normal Jump Mean

The mean of the (normally distributed) logarithm of the jump level. Scalar.

Normal Jump Vol

The standard deviation of the (normally distributed) logarithm of the jump level. Scalar.

Variance1 Reversion Level

Mean reversion level for instantaneous variance of the first factor. Scalar.

Variance1 Reversion Speed

Mean reversion speed for instantaneous variance of the first factor. Scalar.

Variance1 Risk Premium

This represents the extra return above the risk-free rate that an investor needs in order to be compensated for the risk of a certain investment of factor 1. Scalar, defined as a variance.

Variance1 Spot Correlation

Correlation between asset price and the variance processes of factor 1. Scalar.

Variance1 Vol

Volatility for instantaneous variance of factor 1. Scalar.

Variance2 Reversion Level

Mean reversion level for instantaneous variance processes of factor 2. Scalar.

Variance2 Reversion Speed

Mean reversion speed for instantaneous variance processes of factor 2. Scalar.

Variance2 Risk Premium

This represents the extra return above the risk-free rate that an investor needs in order to be compensated for the risk of a certain investment of factor 2. Scalar, defined as a variance.

Variance2 Spot Correlation

Correlation between asset price and second factor variance processes of factor 2. Scalar.

Variance2 Vol

Volatility for instantaneous variance of factor 2.

15.3.4 Assumptions and Limitations**15.3.4.1 Alternative Formulations**

There are multiple variants of the two factor Heston model, of which only one, the MSVJY variant, is implemented in Adaptiv Analytics.

15.3.4.2 Solving for European Option Volatility

The limitations for obtaining volatility for the Two-Factor Heston model are similar to those of the One-Factor model (Section [15.2.4.3](#)).

Chapter 16

Energy Price Models

16.1 Overview

In Adaptiv Analytics, the difference between energy and commodity assets is that commodity prices are modelled as spot prices with a continuous convenience yield curve, but energy prices are modelled with an explicit forward price curve specified by calendar date, rather than relative time. Forward price curves intrinsically account for seasonality and mean reversion. Energy price models therefore operate on the entire forward price curve.

Theory Guide [1.4.1](#)

Energy prices do not behave like financial assets. These commodities may exhibit complex forward price curves that incorporate seasonality and mean reversion.

16.1.1 Common Assumptions and Limitations

16.1.1.1 Forward Curve

All energy factor models require the instantiation of an initial forward curve, which is subsequently evolved by the factor model. The curve at $t = 0$ is specified as a discrete set of settlement dates, which are treated as described in the Theory Guide [[7](#), § [1.4.1 Initial Curve](#)].

Theory Guide [1.4.1](#)

Flat left interpolation is used for other settlement dates T , so that

$$F(t, T) = F(t, T_i), \quad (16.1.1)$$

where either i is the least index for which $T_i \geq T$, or $i = m$ if $T > T_m$.

The initial forward price curve $F(0, T)$ is floored at zero.

16.2 Clewlow-Strickland Forward Price Model

16.2.1 Overview

The Clewlow-Strickland model implemented in Adaptiv Analytics is a development of the the Schwartz one-factor model from [[15](#)], and is arbitrage free. The model is defined as follows:

For each settlement date T , the governing SDE for the forward price $F(t, T)$ is

$$dF(t, T) = \mu F(t, T) dt + \sigma e^{-\alpha(T-t)} F(t, T) dW(t), \quad (16.2.1)$$

where

- μ is the drift rate
- σ is the volatility
- α is the mean-reversion speed
- $W(t)$ is a standard Wiener process.

For details about the valuation for this model, see the Theory Guide [7, § 1.4.2 Clewlow-Strickland Model].

16.2.2 Properties

Alpha

The model mean-reversion speed parameter. For the Clewlow-Strickland model, alpha is scalar.

Drift

Drift of the asset. For the Clewlow-Strickland model, drift is a scalar. In the original pricing model of [15], it is assumed that drift is zero and that the Wiener process of the governing SDE is risk-neutral.

Sigma

Volatility of the variance process, which is scalar for Clewlow-Strickland.

16.2.3 Assumptions and Limitations

16.2.3.1 Positive Prices

The mathematical form of the model does not allow negative prices.

16.2.3.2 Volatility Structure

The Clewlow-Strickland model uses constant deterministic volatility parameters which imposes a parametric form on the volatilities of forward prices. This form does not allow for seasonal variations in volatility.

16.3 Multi-Factor Clewlow-Strickland Forward Price Model

16.3.1 Overview

For details about the valuation for this model, see the Theory Guide [7, § 1.4.3 Multi-Factor Clewlow-Strickland Model].

Theory Guide 1.4.3

This model is based on the PCA model of Clewlow and Strickland [17] and [16]. For each settlement date T , the governing SDE for the forward price $F(t, T)$ is

$$\frac{dF(t, T)}{F(t, T)} = \mu(T - t) dt + \sum_{k=1}^m \sigma_k(T - t) dW_k(t), \quad (16.3.1)$$

where $\sigma_k(\tau)$ are instantaneous volatility curves, $\mu(\tau)$ is an instantaneous drift curve, and $W_k(t)$ are independent Wiener processes. Each $\sigma_k(\tau)$ and $\mu(\tau)$ is a flat-left interpolated curve (see Section A.2.2.4).

The multi-factor Clewlow-Strickland model in Adaptiv Analytics has been extended to support any number of factors, represented by separate volatility curves and driven by separate Wiener processes.

16.3.2 Properties

InstantaneousDrift

List of instantaneous drift curves.

InstantaneousVols

List of instantaneous volatility curves.

16.3.3 Assumptions and Limitations

16.3.3.1 No Seasonality

The drift and volatility curves of the model are specified in relative time to delivery and therefore do not support seasonal variations.

16.3.3.2 Positive Prices

The mathematical form of the model does not allow negative prices.

16.4 Andersen Forward Price Model

16.4.1 Overview

The Adaptiv Analytics implementation of the Anderson Forward Price Model (Andersen Markov Model) is a mildly restricted version of the two-factor mean-reverting diffusive model from [9, §7]. The model is governed by an SDE as follows:

Theory Guide [1.4.4](#)

The forward prices are governed by the following governing SDE:

$$dF(t, T) = F(t, T) (\sigma_1(t, T) dW_1(t) + \sigma_2(t, T) dW_2(t)), \quad (16.4.1)$$

where W_1 and W_2 are independent Wiener processes, and the volatility functions σ_1 and σ_2 are deterministic having the following form:

$$\sigma_1(t, T) = e^{\alpha(T)} \eta_1 e^{-\kappa(T-t)} + \eta_\infty e^{\alpha(T)} \quad (16.4.2)$$

$$\sigma_2(t, T) = e^{\alpha(T)} \eta_2 e^{-\kappa(T-t)}. \quad (16.4.3)$$

There is an explicit constant mean reversion term κ , and a deterministic seasonality curve α through which the seasonality of futures price variances across the term-structure can be represented. Three constant volatility terms are included in the model (η_1 and η_2 , and long-term volatility η_∞):

Theory Guide [1.4.4.3](#)

The parameters η_1 and η_2 determine the difference between short-term and long-term volatility, but are difficult to interpret precisely. However, it is possible to use these parameters to specify values for an alternative parameterization with a clearer interpretation.

See the Theory Guide [7, § [1.4.4.3 Parameter Interpretation](#)] for details of this alternative parametrization.

The model is more realistic than the Clewlow-Strickland model (Section [16.2](#)) but is also more difficult to calibrate.

For details about the valuation for this model, see the Theory Guide [7, § [1.4.4 Andersen Markov Model](#)].

16.4.2 Properties

Drift

Drift curve of the asset. This optional setting allows for independent drift adjustment of different delivery times T .

Reversion Speed

Mean reversion speed. Scalar.

Seasonal Adjustment

The seasonal adjustment function is defined by α , where $\exp[\alpha(T)]$ is a seasonal adjustment function and T a relative time. Can be set to a curve with only a zero entry if seasonality is not desired.

Vol 1

Contributes to the short volatility and controls long-short correlation of the first factor. Scalar.

Vol 2

Contributes to the short volatility and controls long-short correlation of the second factor. Scalar.

Vol Long Term

Controls the long volatility. Scalar.

16.4.3 Assumptions and Limitations**16.4.3.1 Change of Measure**

Since the Andersen model was developed as a pricing model, a risk-neutral measure is assumed by default.

Theory Guide [1.4.4.1](#)

For simulation in other measures, Analytics provides a drift parameter $\mu(T)$, which allows for independent drift adjustment of different delivery times T .

Where delivery times are not specified in the drift parameter, adjustments are determined by linear interpolation or flat extrapolation.

16.4.3.2 Volatility skew

This model does not account for volatility skew.

16.4.3.3 Calibration

No calibration method exists in Adaptiv Analytics.

16.5 Andersen Markov Stochastic Volatility Forward Price Model

16.5.1 Overview

This model is a stochastic volatility extension of the Anderson model of section Section 16.4, and is defined in [9, §2]. The governing equation for the model is given by:

Theory Guide 1.4.5

The forward prices are governed by

$$\frac{dF(t, T)}{F(t, T)} = v(t) [\lambda_1 \sigma_1(t, T) + \lambda_2 \sigma_2(t, T)] dt + \sqrt{v(t)} (\sigma_1(t, T) dW_1(t) + \sigma_2(t, T) dW_2(t)), \quad (16.5.1)$$

where $v(t)$ is a variance process and

$$\sigma_1(t, T) = e^{\alpha(T)} \eta_1 \left(\frac{1 + T\delta}{1 + t\delta} \right) e^{-\gamma(T-t)} + \eta_\infty e^{\alpha(T)} \quad (16.5.2)$$

$$\sigma_2(t, T) = e^{\alpha(T)} \eta_2 \left(\frac{1 + T\delta}{1 + t\delta} \right) e^{-\gamma(T-t)}. \quad (16.5.3)$$

The δ parameter above controls the hump shape of forward volatilities, and hence the volatility skew, while γ is the constant mean reversion speed. The remaining terms in this equation take the same meaning as in Section 16.4 except for $v(t)$ which is a variance process governed by:

Theory Guide 1.4.5

The variance process is governed by

$$dv(t) = (\theta - \kappa v(t)) dt + \sigma_3 \sqrt{v(t)} dW_3(t), \quad (16.5.4)$$

where θ is the variance reversion level, κ is the variance reversion speed, σ_3 is the variance volatility.

In the Adaptiv Analytics formulation of this model, the variance reversion speed κ is defined under the real world measure.

Theory Guide 1.4.5

κ is the variance reversion speed under the real world measure and $\kappa^* = \kappa + \lambda_3 \sigma_3$ is the variance reversion speed under the risk neutral measure (as in Section 1.3.11). The value of κ^* is specified by the model parameter Variance Reversion Speed and κ is derived from κ^* , λ_3 and σ_3 .

The stochastic volatility extension provided by this model allows the model to account for the skew of volatility surfaces, resolving the volatility skew limitation in the Anderson Markov model. For details about the valuation for this model, see the Theory Guide [7, § 1.4.5 Andersen Markov Stochastic Volatility Model].

16.5.2 Properties

The Andersen Markov Stochastic Volatility Model shares common properties with the Andersen Forward Price Model. These properties are described in Section 16.4.2. Additional properties for the

Andersen Markov Stochastic Volatility Model are outlined below.

Factor1 Factor2 Correlation

Correlation between the two risk factors. Scalar.

Factor1 Risk Premium

Factor 1 This represents the extra return above the risk-free rate that an investor needs in order to be compensated for the risk of a certain investment. Scalar.

Factor1 Variance Correlation

Correlation between the driving Wiener processes for the spot and variance processes for the first factor. Scalar.

Factor2 Risk Premium

Factor 2 This represents the extra return above the risk-free rate that an investor needs in order to be compensated for the risk of a certain investment. Scalar.

Factor2 Variance Correlation

Correlation between the driving Wiener processes for the spot and variance processes for the second factor. Scalar.

Initial Variance

Initial variance of the CIR variance process. Scalar.

Use Euler Discretization

Yes for using Euler discretization scheme; no for partial integration.

Variance Discretization Scheme

Adaptiv Analytics allows choices of `Zhu` or `Full Truncation`; the discretization scheme for the stochastic volatility CIR process. See Section [18.6.3.1](#)

Variance Reversion Level

Mean reversion level for the CIR variance process. Scalar.

Variance Reversion Speed

Mean reversion speed for instantaneous variance. Scalar.

Variance Risk Premium

Risk premium for variance. This represents the extra return above the risk-free rate that an investor needs in order to be compensated for the risk of a certain investment. Scalar.

Variance Vol

Instantaneous volatility for the CIR variance process. Scalar.

Vol Hump

Controls the hump shape of the volatility profile. Scalar.

16.5.3 Assumptions and Limitations

16.5.3.1 Calibration

No calibration method exists in Adaptiv Analytics.

Chapter 17

Energy Price Spread Models

17.1 Overview

The forward curve of energy commodities can vary based on quality (e.g., grades of oil) or location (e.g., location of a refinery in relation to consumers). Consequently, for such curves, it is common to model the specific grade/delivery of a commodity as a spread on an underlying commodity

Theory Guide [1.5](#)

Analytics allows energy prices to be represented as the sum of a base commodity forward price and a forward spread (or spreads) specific to that base commodity. For example the price of an oil delivery might be represented as a base oil price plus a spread specific to the pipeline. If $F_{\text{base}}(t, T)$ is the base price and $F_{\text{spread}}(t, T)$ is the spread then the total price $F(t, T)$ is given by:

$$F(t, T) = F_{\text{base}}(t, T) + F_{\text{spread}}(t, T) \quad (17.1.1)$$

There is not always sufficient market information to reliably calibrate stochastic models for these spreads.

17.1.1 Common Assumptions and Limitations

Many common assumptions and limitations of the Energy Price Spread stochastic models are inherited from the underlying energy price factors; see [Section 10](#). Additional limits in the stochastic models are outlined below.

17.1.1.1 Correlations

A generic limitation of the spread models in Adaptiv Analytics is that there is no functional relationship between the forward price spread model and the underlying forward price. Instead, the only correlation between these price factors is via the risk factor correlation matrix.

17.1.1.2 Liquidity

Where a energy price spread is used to model a base and spread factor (e.g., the base commodity delivered to a specific location), the spread price factor will often have lower liquidity than the base. It may therefore be impossible to reliably calibrate a spread over the base curve. Consequently, it may be preferable to calibrate the base stochastically, but apply the spread deterministically.

17.1.1.3 Flooring

While spreads can be negative, all-in energy prices (i.e. base + spread price) are floored in the same manner as base forward prices. See section 10.2.6 for details.

17.2 Ornstein-Uhlenbeck Forward Spread Model

17.2.1 Overview

The Ornstein-Uhlenbeck Forward Spread Model simulates spreads using a one-factor mean-reverting process.

Theory Guide 1.5.2

The forward spreads are given by

$$F_{\text{spread}}(t, T) = F_{\text{spread}}(0, T)e^{-\alpha t} + \theta(T) (1 - e^{-\alpha t}) + \int_0^t \sigma(T - s - \delta) dY(s), \quad (17.2.1)$$

where $Y(t)$ is a standard Ornstein-Uhlenbeck process with constant reversion speed α , $\theta(T)$ is a flat-left interpolated reversion level curve, $\sigma(T)$ is a flat-left interpolated volatility curve

Where δ is an offset derived from Last Rollover Date. The arithmetic OU Forward Spread model accepts positive or negative historic spreads from market data, and allows for the forward simulation of positive and negative spreads.

For details about the valuation for this model, see the Theory Guide [7, § 1.5.2 Ornstein-Uhlenbeck Forward Spread Model].

17.2.2 Properties

Last Rollover Date

Last rollover date, used to define an offset δ as follows.

Theory Guide 1.5.2

If a Last Rollover Date is specified and it is before the base valuation date then δ is the time from the Last Rollover Date to the base valuation date; otherwise $\delta = 0$.

Reversion Level

Mean reversion level. Specified in Adaptiv Analytics as a curve, and is flat-left interpolated.

Reversion Speed

Mean reversion speed. Scalar.

Volatility

Volatility curve of the asset. Flat-left interpolated.

17.2.3 Assumptions and Limitations

General assumptions and limitations for the Ornstein-Uhlenbeck Forward Spread Model are covered in the general energy spread model limitations, Section 17.1.1.

17.3 Ornstein-Uhlenbeck Forward Spread TS Model

17.3.1 Overview

This model generalizes the Ornstein-Uhlenbeck Forward Spread model of Section 17.2 to have a term structure of reversion speeds.

Theory Guide 1.5.3

The forward spreads are given by

$$F_{\text{spread}}(t, T) = F_{\text{spread}}(0, T)e^{-A(t, T)} + \theta(T) \left(1 - e^{-A(t, T)}\right) + \int_0^t \sigma(T - s - \delta) dY_T(s), \quad (17.3.1)$$

where $Y_T(t)$ is a generalized Ornstein-Uhlenbeck process given by

$$Y_T(t) = \int_0^t e^{-(A(t, T) - A(s, T))} dW(s) \quad (17.3.2)$$

(see Section B.2), $A(t, T) = \int_0^t \alpha(T - s - \delta) ds$ and $\alpha(T)$ is a flat-left interpolated curve.

Above, $W(s)$ defines the Wiener process from which the Ornstein-Uhlenbeck process is derived, and the remaining terms take the same definition as in Section 17.2.1.

The stochastic model is initialised by curves of $A(t)$, which at $t = 0$ define the instantaneous reversion speed $\alpha(t)$. The terminal date, T , defines the terminal horizon of the dependent process such that the dependent Ornstein-Uhlenbeck process is not evolved beyond this date.

For details about the valuation for this model, see the Theory Guide [7, § 1.5.3 Ornstein-Uhlenbeck Forward Spread Term Structure Model].

17.3.2 Properties

Last Rollover Date

Last rollover date, defining offset δ as described in Section 17.2.2.

Reversion Level

Mean reversion level curve. Flat-left interpolated.

Reversion Speed

Mean reversion speed curve. Term-structure, flat-left interpolated.

Volatility

Volatility curve of the asset. Flat-left interpolated.

17.3.3 Assumptions and Limitations

General Assumptions and Limitations for the Ornstein-Uhlenbeck Forward Spread Term Structure Model are covered in the general energy spread model limitations, Section 17.1.1.

17.3.3.1 Interpolation of mean reversion speeds

For the driving generalised Ornstein-Uhlenbeck process, Adaptiv Analytics linearly interpolates the integrated reversion speed curves. This corresponds to an assumption of piecewise constant mean reversion speeds. A smoothly increasing/decreasing reversion speed can be approximated by entering short period steps in $A(t)$, but at the cost of increasing the computational cost of evolving the risk factor paths.

Chapter 18

Interest Rate Models

18.1 Overview

18.1.1 Spread Curves and All-in Curves

Interest rates in Adaptiv Analytics can be defined either as all-in curves or as a spread on a base curve.

Base and spread curves are simulated independently, even if they use the same type of simulation model. The choice of all-in or base + spread therefore has different implications for simulation

For example, in the market LIBORs are expected to increase in value in order of tenor, but, with an all in curve this cannot be ensured under simulation as such curves are only related by correlation. Thus, simulated curves are not prevented from overlapping or crossing. If instead a choice of 'Base + Spread' curves is made, it is still not possible to ensure this condition is met if every spread curve is configured as a spread on the base curve.

The only way to ensure the condition is met is if compound spreads are iteratively defined on underlying spreads, and a simulation model which ensures positive values is used for all spreads. In this way the interest rate calculated from (for example) a USD.1M.3M price factor will be greater than the interest rate calculated from the USD.1M price factor which will in turn be greater than the interest rate for the USD price factor.

Interest rates and interest rate spreads are implemented with the same underlying price factor. However, if a different stochastic model is desired for the base and spread curves then this can be configured via the Interest Rate sub types price factors, e.g., Interest Rate (Basis Spread).

18.1.1.1 Dividend and Prepayment Rates

Dividend rate and Prepayment rate price factors have the same representation as interest rate price factors and consequently can be simulated with the same models.

18.1.2 Common Properties

18.1.2.1 Interpolation of Initial Curve

The default interpolation method for the initial zero-coupon rate curve is linear with flat, extrapolation, although this can be overridden.

18.1.2.2 Flooring

In Adaptiv Analytics, interest rate flooring is applied under simulation, with floor values defined on the interest rate models.

18.1.3 Common Assumptions and Limitations

18.1.3.1 Shifted Lognormals

Owing to the increasing (current) prevalence of negative interest rates, the use of a shifted lognormal model has recently become popular. This technique allows the flooring of the interest rates at some (typically small) negative value. However, base Adaptiv Analytics does not provide this feature (i.e., application of a shift) to interest models by default.

Instead, the effect can be emulated by using normal model with a (negative) floor value defined on the interest rate price factor.

18.1.3.2 CVA Interest Rate Models

Adaptiv Analytics does not include the classes of interest rate models considered standard for CVA for interest rates; instead, where these are required American Monte Carlo simulation is recommended owing to the smaller number of simulations required by this method.

18.1.3.3 No Model Evolution

When no price factor model is attached, interest rates are evolved by:

Theory Guide [1.6.3](#)

If no price factor model is selected then the zero rates are held constant:

$$D(t, T) = D(0, T - t) = \exp(-r(T - t)(T - t)). \quad (18.1.1)$$

18.2 Drift To Forward Interest Rate Model

18.2.1 Overview

This is a non-stochastic risk-neutral model. The model evolves rates to their initial forward values on all scenarios.

Theory Guide [1.6.9](#)

Under the model, the discount factors are evolved to forward zero-coupon bond prices:

$$D(t, T) = \frac{D(0, T)}{D(0, t)} = \exp(r(t)t - r(T)T). \quad (18.2.1)$$

For details about the valuation for this model, see the Theory Guide [[7](#), § [1.6.9 Drift To Forward Model](#)].

18.2.2 Properties

The model has no adjustable properties.

18.2.3 Assumptions and Limitations

18.2.3.1 No Arbitrage

The implicit assumption of this model is that the forward interest rates are arbitrage-free.

18.3 Gaussian Key Rates Interest Rate Model

18.3.1 Overview

The Gaussian Key Rates Model in Adaptiv Analytics simulates every tenor point as a separate, correlated asset.

The implementation in Adaptiv Analytics supports both normal or lognormal interest rate distributions, driven by a standard Wiener process $W_i(t)$ and with volatility curve $\sigma(\tau)$ at tenor τ :

Theory Guide [1.6.12](#)

Let $r_i(t)$ denote the τ_i -tenor zero rate defined by

$$r_\tau(t) = -\frac{\log D(t, t + \tau)}{\tau}. \quad (18.3.1)$$

The evolved zero rates are given by either

$$r_i(t) = R_i(t) \exp\left(-\frac{1}{2}\sigma(\tau_i)^2 t + \sigma(\tau_i)W_i(t)\right) \quad (18.3.2)$$

if the Distribution Type is set to Lognormal, or

$$r_i(t) = R_i(t) + \sigma(\tau_i)W_i(t) \quad (18.3.3)$$

if the Distribution Type is set to Normal,

Intermediary rates are calculated by linear interpolation or flat extrapolation. For details about the valuation for this model, see the Theory Guide [7, § [1.6.12 Gaussian Key Rates Model](#)].

This model supports a curve of drift rates, and the dimension of the curve is time; however, time here refers to interest rate tenor instead of simulation time. Hence, the model simulates a ‘term-structure’ of interest rates, but the simulation parameters do not vary over time unlike other ‘term-structured’ models (for which the time dimension *is* simulation time). This aligns with the intended use of the model (i.e., for short-term market VaR simulation).

18.3.2 Properties

Distribution Type

Interest Rate Distribution type; either Lognormal or Normal.

Drift

Drift curve of the asset.

Rate Drift Model

Choice of Drift Rate Model; Drift To Forward, Historical, None,

Theory Guide [1.6.12](#)

The model provides three methods for calculating the mean rates, $R_i(t)$.

Drift To Forward: $R_i(t)$ is the initial forward rate for the period t to $t + \tau_i$, so that

$$D(0, t + \tau_i) = D(0, t) \exp(-R_i(t)\tau_i). \quad (18.3.4)$$

Historical: $R_i(t) = r_i(0)e^{\mu(\tau_i)t}$ for Lognormal, or $R_i(t) = r_i(0) + \mu(\tau_i)t$ for Normal, where $\mu(\tau)$ is the drift curve, which is a parameter of the model.

None: $R_i(t) = r_i(0)$.

Risk Factor Tenors

List of zero-rate tenors in the archive.

Vol Choice of *Integrated* or *Instantaneous* volatility curve of the asset. Defines the nature of the volatility curve supplied.

18.3.3 Assumptions and Limitations**18.3.3.1 Arbitrage**

This model is non arbitrage free.

18.3.3.2 Usage for Credit Risk

This model is not recommended for credit risk as it normally generates a highly volatile curve when used in long-horizon simulation. However, it is sometimes preferred over other (term-structured) models for market risk, as the Key-Rates model provides the flexibility to simulate each key rate tenor. Furthermore, for market risk, the reduction in the number of risk factor is undesirable, while the high volatility interest rate curve is not an issue.

18.3.3.3 Price Factor Cone

For the Gaussian Key Rates Model, the price factor cone cannot be calculated exactly as it is not possible to obtain stochastic quantiles between two linearly interpolated Brownian Motions without knowing the correlation between them. Instead, for the factor cone display, Adaptiv Analytics assumes all yield curve points follow a single Brownian motion with parameters obtained using linear interpolation on the parameter curves.

18.4 Hull-White 1 Factor Interest Rate Model

18.4.1 Overview

The One-factor Hull-White model is one of the standard term structure models for interest rates, extending the Vasicek Model and the Cox-Ingersoll-Ross Model. In general it is a risk-neutral arbitrage-free model for which calibration matches the initial term structure of interest rates and cap or swaption volatilities.

In Adaptiv Analytics, the process is driven by a standard Wiener process in the base currency risk-neutral measure that may be converted to a real-world process through a risk premium.

Theory Guide [1.6.13](#)

The SDE governing the behavior of the short rate $r(t)$ is

$$dr(t) = (\theta(t) - \alpha r(t) - \nu(t)\sigma(t)\rho) dt + \sigma(t) dW^*(t), \quad (18.4.1)$$

where:

- $\sigma(t)$ is a deterministic volatility curve
- α is a constant mean reversion speed
- $\theta(t)$ is a deterministic curve derived from $\sigma(t)$ and α , and the initial discount factor curve $D(0, t)$ (see Section [D.1.3.1](#))
- $\nu(t)$ is the quanto FX volatility and ρ is the quanto FX correlation
- $W^*(t)$ is a standard Wiener process under the base-currency risk-neutral measure related to a standard Wiener process $W(t)$ under the real-world measure by $W^*(t) = W(t) + \lambda t$, where λ is a constant market price of risk.

It is assumed that the instantaneous short rate process follows a normal distribution, and hence permits negative interest rate scenarios. Note however that Adaptiv Analytics will later truncate the distribution by flooring the rates. This will result in a deviation of the simulated distribution from the theoretical model.

The Hull-White α parameter is related to the mean reversion process, with the mean reversion half-life λ related to α by $\lambda = \ln(2)/\alpha$. It is possible to use this relationship to check if the value of α obtained by calibration or supplied for the Hull-White Process looks plausible, and thus determine if the mean reversion process will happen on a realistic timescale.

For Hull White One-Factor Models, it can be shown that the discount factor is an Ornstein-Uhlenbeck process, and a known function of the short rate. Such discount factors are calculated on a grid of points spaced at intervals of not greater than 30 days, using numerical integration under the adaptive Simpson rule and linear interpolation, where required. For details on this process, see the Theory Guide [[7](#), § [1.6.13 Hull-White 1-Factor Model](#)].

18.4.2 Properties

Alpha

The model mean-reversion speed parameter. Scalar

Lambda

Constant market price of risk. Scalar.

Quanto FX Correlation

Correlation between the FX rate and the interest rate process. Value will be 0 if the rate currency

is base currency.

Quanto FX Volatility

Volatility of the price of the FX rate (the asset currency in base currency). The curve may be provided as an *Instantaneous* or an *Integrated* curve. Will be 0 if rate currency is base currency.

Sigma

Instantaneous volatility curve of the interest rate process.

18.4.3 Assumptions and Limitations

18.4.3.1 Numerical instability

The calibration of the Hull-White model may be numerically unstable, such that small changes in input prices may result in large changes to the values of α and σ for a best fit calibration.

Typically, the parameter space explored in calibration is complex and replete with widely separated local minima. In calibration, a solution obtained via downhill (e.g., Nelder-Mead) optimisation methods may converge to different local minima on different calibration dates, resulting in a discontinuity in risk results from one date to the next. In practice therefore, it may be advisable to set the mean reversion parameter upfront and calibrate on the volatility parameter only.

18.4.3.2 Rate Tenors

The correlation of key rate tenors on a given interest rate curve is by definition 1. Therefore, the risk of spread products such as CMS spread options is not fully captured under this model; the shape of the curve is deterministic, for a given simulated value of the short rate.

18.4.3.3 Bounds

To avoid numerical errors such as overflows, Adaptiv Analytics imposes various bounds on the initial conditions:

Theory Guide [1.7.1.2](#)

The initial state of the model parameters price factor must satisfy:

- $\sigma(\tau) \geq 0$ for all points τ on which the curve is defined
- $0 \leq \alpha \leq 15$
- $\nu(\tau) \geq 0$ or $\bar{\nu}(\tau) \geq 0$ for all points τ on which the curve is defined
- $-1 \leq \rho \leq 1$.

18.4.3.4 Interpolation Methods

The Hull White volatility curve is interpolated flat-left, unless the model is implied (see Section [26.7](#)). Using other interpolation methods (e.g., linear) can result in unhelpful behaviour (e.g. a saw-tooth curve).

18.5 Hull White 2 Factor Interest Rate Model

18.5.1 Overview

In place of a direct Two-factor Hull White Model, Adaptiv Analytics implements a generalised the G2++ (2 factor additive Gaussian) model of [13, Section 2.9], which has perfect equivalence with the Hull-White 2 factor model of [30]. The model resembles the One-factor Hull White Model described in Section 18.5, but generalised so as to allow a second factor with distinct mean reversion, risk premium, and volatility term-structure curve. The addition of a second factor allows more flexibility for the short curve, which may then evolve with more complex behaviour.

The evolution of the short rate can then be written as:

Theory Guide [D.1.4.1](#)

It follows that

$$dr(t) = \frac{\partial r(0, t)}{\partial T} dt + \sum_{i=1}^2 (\theta_i(t) - \alpha_i(t)x_i(t)) dt + \sigma_i(t) dZ_i(t), \quad (18.5.1)$$

where

$$\theta_i(t) = \alpha_i(t)\mu_i(t) + \mu'_i(t) = \sum_{j=1}^2 \rho_{ij} \int_0^t b_i(s, t)b_j(s, t)\sigma_i(s)\sigma_j(s) ds. \quad (18.5.2)$$

Theory Guide [D.1.4.1](#)

where $\sigma_i(t, T) = \sigma_i(t)b_i(T)/b_i(t)$, $b_i(t) = \exp\left(-\int_0^t \alpha_i(s) ds\right)$, $\sigma_i(t)$ and $\alpha_i(t)$ are deterministic scalar functions with $\sigma_i(t) \geq 0$, and u_1 and u_2 are constant unit vectors with $u_1 \cdot u_2 = \rho$. This model has with two correlated factors; the i^{th} factor has volatility curve $\sigma_i(t)$ and mean reversion speed $\alpha_i(t)$.

Define $Z_i = W \cdot u_i$, so that Z_1 and Z_2 are correlated Wiener processes with correlation ρ .

Similar to the One-Factor Hull White model, the discount factor for the Two-Factor Hull White model is driven by an Ornstein-Uhlenbeck process.

Note that only the instantaneous rate is correlated globally to other risk factors in the simulation. The long term interest rate factor is correlated indirectly to global risk factors via its correlation to the instantaneous rate.

For details about the valuation for this model, see the Theory Guide [7, § 1.6.14 [Hull-White 2-Factor Model](#)].

18.5.2 Properties

Alpha 1

The model mean-reversion speed parameter of the first interest rate process. Scalar.

Alpha 2

The model mean-reversion speed parameter of the second interest rate process. Scalar.

Correlation

Correlation between the risk factors. Scalar.

Lambda 1

Constant market price of risk for first interest rate process. Scalar.

Lambda 2

Constant market price of risk for second interest rate process. Scalar.

Quanto FX Correlation 1

Correlation between the FX rate and the first interest rate process. Scalar. Value will be 0 if the rate currency is base currency.

Quanto FX Correlation 2

Correlation between the FX rate and the second interest rate process. Scalar. Value will be 0 if the rate currency is base currency.

Quanto FX Volatility

Volatility of the price of the FX rate (the asset currency in base currency). The curve may be provided as an *Instantaneous* or an *Integrated* curve. Will be 0 if rate currency is base currency.

Sigma 1

Instantaneous volatility curve of the first interest rate process.

Sigma 2

Instantaneous volatility curve of the second interest rate process.

18.5.3 Assumptions and Limitations**18.5.3.1 Separable Volatilities**

The G2++ model implicitly assumes that the forward rate volatilities are separable.

18.5.3.2 Bounds

Similar to the One-Factor model, Adaptiv Analytics imposes various bounds on the initial conditions:

Theory Guide [1.7.2.2](#)

The initial state of the model parameters price factor must satisfy:

- $\sigma_i(\tau) \geq 0$ for all points τ on which the curve is defined
- $0 \leq \alpha_i \leq 15$
- $-1 \leq \rho \leq 1$
- $\nu(\tau) \geq 0$ or $\bar{\nu}(\tau) \geq 0$ for all points τ on which the curve is defined
- $-1 \leq \tilde{\rho}_i \leq 1$.

18.5.3.3 Interpolation Methods

The same limitations apply for the interpolation methods of the Two-Factor model as apply for the interpolation of the One-Factor model (Section [18.4.3.4](#)).

18.5.3.4 Quanto Parameters not Simulated

The quanto volatility and correlation parameters are not simulated.

Theory Guide [1.7.1.1](#)

The quanto FX volatility curve and quanto FX correlation are not evolved because they are required only for the base valuation date ($t = 0$), by the Hull-White 1-factor interest rate price factor model (see Section 1.6.13).

18.6 Jump Cox-Ingersoll-Ross Interest Rate Model

18.6.1 Overview

Adaptiv Analytics supports a Cox-Ingersoll-Ross (CIR) Interest Rate model, in the form of the CIR++ model of [13, Section 2.9], enhanced by an optional jump feature.

The underlying CIR model is a single factor square root model, with dynamics as follows:

Theory Guide [B.4.1](#)

The dynamics of the short rate are

$$dr(t) = \kappa(\theta - r(t)) dt + \sigma\sqrt{r(t)} dW(t), \quad (18.6.1)$$

where σ is a constant volatility (Vol), κ is a constant mean reversion speed (Reversion Speed), θ is a constant long run mean (Reversion Level), and W is a standard Wiener process under the real world measure. If $r(t) > 0$ and the model parameters satisfy the Feller condition $2\kappa\theta \geq \sigma^2$ then $r(t) > 0$ for all $t \geq 0$.

Accordingly, the CIR model is constrained to non-negative values of interest rates. Adaptiv Analytics implements CIR++ optional adjustment to match the initial term structure which is configured via the `Use Deterministic Shift` option.

Instead of an exact numerical scheme for the CIR process, Adaptiv Analytics provides a choice of discretization scheme; see the Theory Guide, Section [B.4.4](#). This choice is made due to the computational cost of the exact scheme.

For details about the valuation for this model, see the Theory Guide [7, § [1.6.15 Cox-Ingersoll-Ross Model](#)].

18.6.1.1 Jump Feature

The jump feature was introduced to capture discrete events in the short rate dynamics, such as instantaneous interest rate changes due to spontaneous events (for example, a change in credit rating). The jump process can be removed from the model by setting the `Jump Arrival Rate` to zero if this functionality is not desired.

The consequence of the jump rate is to add a further ‘jump’ term, $dJ(t)$ to the dynamics of the model.

Theory Guide [B.4.2](#)

$J(t)$ is compound Poisson process defined as follows.

$$J(t) = \sum_{j=1}^{N(t)} X_j \quad (18.6.2)$$

where $N(t)$ is a standard Poisson process with intensity α (Jump Arrival Rate), and X_j are independent identically distributed exponentially distributed random variables with mean γ (Mean Jump Size), where X_j is independent of $N(t)$ and $W(t)$.

18.6.1.2 Shifted Model

Deterministic shifts are the ‘++’ feature of the CIR++ model in Adaptiv Analytics, based upon the models of [13, Section 3.9]. The shifts can be used to correct the expectations of model values to

match the values implied by the initial curve. Shifts are included as follows.

Theory Guide [B.4.3](#)

If shifts are enabled, then the $r(t) = x(t) + \phi(t)$, where $\phi(t)$ is the shift function, $x(t)$ is a solution of the SDE

$$dx(t) = \kappa^*(\theta^* - x(t)) dt + \sigma \sqrt{x(t)} dW^*(t) + dJ(t), \quad (18.6.3)$$

$$x(0) = x_0.$$

18.6.1.3 Risk-neutrality

The Jump Cox-Ingersoll-Ross Model supports risk-neutral measures. In this case, a risk premium is included such that the dynamics become:

Theory Guide [B.4.2](#)

Under the risk neutral measure

$$dr(t) = \kappa^*(\theta^* - r(t)) dt + \sigma \sqrt{r(t)} dW^*(t) + dJ(t), \quad (18.6.4)$$

where $\kappa^* = \kappa + \sigma\lambda$ and $\theta^* = \kappa\theta/\kappa^*$.

Where the jump process can again be removed by setting the jump arrival rates to zero.

18.6.2 Properties

Discretization Scheme

Adaptiv Analytics allows choices of `Zhu` or `Full Truncation`; the discretization scheme for the CIR process. See Section [18.6.3.1](#)

Initial Process Value

The CIR model initial condition value. Scalar.

Jump Arrival Rate

Jump arrival rate for the compound Poisson process. Scalar.

Mean Jump Size

Mean of jump sizes for the compound Poisson process. Scalar.

Reversion Level

Mean reversion level. Scalar.

Reversion Speed

Mean reversion speed. Scalar.

Risk Premium

This represents the extra return above the risk-free rate that an investor needs in order to be compensated for the risk of a certain investment. Scalar.

Use Deterministic Shift

Yes for making a deterministic shift so the term structure is consistent with current market price;
No otherwise.

Use Dynamic Jump Arrivals

No to assume jumps only occurs at given simulation time grid; Yes to simulate random inter-time-grid jump arrival times.

Vol Volatility of the asset. Scalar.

18.6.3 Assumptions and Limitations

18.6.3.1 Default Discretization

When `Use Deterministic Shift` is 'No', jump arrival will be discretized onto the scenario grid. Jumps are attributed to the first scenario grid date on which they are implied by the discretized Poisson process. This potentially allows several 'accumulated' jumps to occur simultaneously.

When `Use Deterministic Shift` is 'Yes', jumps arrive in a uniform distribution between adjacent time steps. However, this is computationally costly.

18.6.3.2 Flooring

If a negative deterministic shift is used, short rates are no longer constrained to be positive in simulation. When this is used with flooring (i.e., floored at 0), the simulated distribution will be truncated and will not match curve implied values.

18.7 Market Interest Rate Model

18.7.1 Overview

The Adaptiv Analytics Market Interest Rate Model is a LIBOR market model, for which a typical use case would be pricing LIBOR and exotics in front office systems. In theory, the same model should be used for both pricing and risk neutral simulation. The Market Interest Rate Model in Adaptiv Analytics is the version described in [42], and (owing to performance limitations) is intended for validation only.

This is an arbitrage-free model with high dimensionality; a grid of LIBOR rates is used as a list of risk factors and gives a detailed model of the forward LIBOR curve. It is defined for n forward rates as follows:

Theory Guide [1.6.16](#)

After augmenting with the spot rate up to the start of the first forward rate, the rates are defined on a grid of fixed dates $0 = T_0 < T_1 < \dots < T_{n+1}$. The i^{th} LIBOR rate L_i earns interest from T_i to T_{i+1} , pays on T_{i+1} , and has tenor $\tau_i = T_{i+1} - T_i$. L_i expires (ceases to evolve) at T_i ; define $L_i(t) = L_i(T_i)$ for $t > T_i$.

Each forward rate period starts at the end of its variance curve, and has tenor up to the next rate period start, except for the last forward rate which has explicit tenor.

The Market Interest Rates model allows a lot of flexibility in the shape of the simulated curve. It also allows parametrisation of volatility structure and correlation structure. The model behaves as follows, driven by m stochastic factors where $m \leq n$:

Theory Guide [1.6.16](#)

The SDE governing the evolution of rate L_i is:

$$dL_i(t) = L_i(t) \sum_{j=\eta(t)}^i \frac{\sigma_i(t)\sigma_j(t)\rho_{ij}(t)L_j(t)\tau_j}{1 + L_j(t)\tau_j} dt + L_i(t)\sigma_i(t) \sum_{k=1}^m \beta_{ik}(t) dW_k(t) \quad (18.7.1)$$

where the Wiener processes W_k are independent, the factor loadings β_{ik} are deterministic functions of time, and

$$\rho_{ij}(t) = \sum_{k=1}^m \beta_{ik}(t)\beta_{jk}(t). \quad (18.7.2)$$

For details about the valuation for this model, see the Theory Guide [7, § [1.6.16 Market Model](#)].

18.7.1.1 Orthogonality of Weiner Processes

In the Market Interest Rate model, the Wiener process are constructed to be independent from one another, but not from the risk factor processes of other market prices in the simulation, including those driving other interest rates.

18.7.2 Properties

Betas

List of beta curves.

Last Tenor

Upper bound on length of instrument.

Rates

List of LIBOR rates, corresponding to the list of betas

18.7.3 Assumptions and Limitations

18.7.3.1 Lognormal diffusion

Interest rates are modelled as much like lognormal diffusions as possible.

Theory Guide [1.6.16](#)

At most one rate can be a pure lognormal diffusion in a given measure; in general, the drift expressions for the modeled rates depend on the measure chosen for the model. The Analytics implementation of this model uses the rolling spot measure, which can be thought of as pasting together the nearest forward measures as a function of time.

18.7.3.2 Discounting between grid dates

In order to remain arbitrage free, the short bond process must increase monotonically in t , such that its expectation at any given time must equal the implied price at that time.

Theory Guide [1.6.16.1](#)

These constraints are most easily satisfied with a deterministic specification, but that would be unsatisfactory for PFE simulations. Instead the model uses the method of Schlögl [44]

18.7.3.3 Implementation Constraints

The implementation assumptions in Adaptiv Analytics are as follows.

Theory Guide [1.6.16.2](#)

The Analytics implementation supports the rate-specific instantaneous volatility functions $\sigma_i(t)$ as arbitrary functions of simulation time t with piecewise linear interpolation. However, the factor loading functions $\beta_{ik}(t)$ are constrained to be functions of remaining time to expiry, $T_i - t$. This allows the factor loadings and inter-rate correlations of the model to be specified with just m functions $\beta_k(t)$:

$$\beta_{ik}(t) = \beta_k(T_i - t). \quad (18.7.3)$$

The functions $\beta_k(t)$ are arbitrary functions of time to expiry, and are interpolated linearly with a normalization adjustment to recover the model volatility after interpolation:

$$\sum_{k=1}^m \beta_k(T_i - t)^2 = 1. \quad (18.7.4)$$

The inter-rate correlation functions are consequently also constrained to be functions of remaining time to expiry.

18.8 Multi-Factor GOU Interest Rate Model

18.8.1 Overview

This model consists of a Geometric Ornstein-Uhlenbeck process constructed from m systematic factors and an optional idiosyncratic factor, which drive the entire yield curve. Mean reversion is captured, and the model ensures rates are always positive.

The model is particularly appropriate for dividend rates since it reduces the dimensionality of the dividend risk factor space; the systematic drivers can be shared between multiple dividend rate price factors (however, the systematic drivers cannot be shared between dividend rate price factors and equity price factors).

Theory Guide [1.6.11](#)

The simulated zero rates are given by either

$$r_\tau(t) = r_\tau(0)G_\tau(t) \quad (18.8.1)$$

for Drift To Spot, or

$$r_\tau(t) = \frac{r_{t+\tau}(0)(t+\tau) - r_t(0)t}{\tau} G_\tau(t) \quad (18.8.2)$$

for Drift To Forward, where G_τ is the GOU process given by

$$G_\tau(t) = \exp \left(-\frac{1}{2} \sigma(\tau)^2 \left(\frac{1 - e^{-2\alpha t}}{2\alpha} \right) + \sigma(\tau) Y(t) \right), \quad (18.8.3)$$

where

- $\sigma(\tau)$ is the yield volatility for tenor τ
- $Y(t) = \sum_{k=1}^m (\hat{\omega}_k / \hat{\omega}) Y_k(t) + (\hat{\epsilon} / \hat{\omega}) \tilde{Y}(t)$
- $Y_k(t) = \int_0^t e^{-\alpha(t-s)} dW_k(s)$ and $\tilde{Y}(t) = \int_0^t e^{-\alpha(t-s)} d\tilde{W}(s)$ are standard Ornstein-Uhlenbeck processes with reversion speed α
- $\hat{\omega}_k$ is the rounded weight for the k^{th} systematic driver
- $\hat{\epsilon}$ is the rounded weight for the idiosyncratic driver
- $\hat{\omega}$ is the normalization factor for the rounded weights.

This would also be a suitable model for credit rating spreads. For details about the valuation for this model, see the Theory Guide [7, § [1.6.11 Multi-Factor GOU Model](#)].

18.8.2 Properties

Drift Model

Choices of drift methods, which drive the forward rate evolution. Options are Drift To Spot or Drift To Forward; see effects in the rate evolution in Section [18.8.1](#).

Idiosyncratic Weight

Weight of the idiosyncratic driver. Scalar.

Mean Reversion Speed

Mean reversion speed. Scalar.

PCA Factors

Yes to set correlations between drivers to zero with Adaptiv Analytics calculating normalizing

coefficients; No for correlated drivers with weights assumed to be already normalised and normalizing coefficient set to 1.

Significance Threshold

Any driver weights with absolute value less than the threshold are rounded to zero. Scalar.

Vol Choice of Integrated or Instantaneous volatility curve of the asset. Defines the nature of the volatility curve supplied. See Vol definition in Section 14.4.2.

Weights

List of weights of the assets with respect to the driver.

18.8.3 Assumptions and Limitations**18.8.3.1 Significance Threshold**

In common with the GOU Asset Price models, the model applies a significance threshold to the weighting factors. See Section 14.7.3.1.

18.9 PCA Interest Rate Model

18.9.1 Overview

The Adaptiv Analytics PCA Interest Rate Model is an n -factor, real-world model, and consequently not arbitrage free. This model is an appropriate choice for highly correlated systems such as the yield curve.

The principal components are defined as a set of abstract, orthogonal factors which provide the maximum explanatory power of historical changes in interest rates. In practice, three PCA factors are often sufficient to explain around 97% to 99% of observed variation in rates; these factors often happen to coincide to the Level, Slope and Twist (or Curvature) of interest rates (see [30]). However, the calculation of principal components is a purely mathematical process which has no necessary connection to any economic interpretation.

The Adaptiv Analytics implementation supports both lognormal and normal mean reverting processes, in which the normal distribution has the advantage of allowing negative rate scenarios for both risk-free curves and spreads. Eigencurves (eigenvectors for the PCA model that are represented by a function of the zero rate tenor) may be derived from the covariance matrix of the returns on the zero rates, or the correlation matrix of the returns on the zero rates.

Theory Guide 1.6.10

There is one driving factor for each eigencurve supplied to the model. The drivers are independent standard Wiener processes $W_1(t), \dots, W_m(t)$. Define the independent standard Ornstein-Uhlenbeck processes $Y_1(t), \dots, Y_m(t)$ by

$$Y_k(t) = \int_0^t e^{-\alpha(t-s)} dW_k(s) \quad (18.9.1)$$

(see Section B.2). The variance of $Y_k(t)$ is

$$\nu(t) = \int_0^t e^{-2\alpha(t-s)} ds = \begin{cases} \frac{1 - e^{-2\alpha t}}{2\alpha} & \alpha \neq 0 \\ t & \alpha = 0. \end{cases} \quad (18.9.2)$$

The covariance of $Y_k(t)$ and $Y_l(t)$ is $[k = l] \nu(t)$. If $\alpha > 0$ then $\nu(t) \rightarrow 1/2\alpha$ as $t \rightarrow \infty$.

The parameters of the model are as follows.

Theory Guide 1.6.10

- a yield volatility curve $\sigma(\tau)$, giving the volatility of the zero rate r_τ for each tenor τ
- a constant mean-reversion speed α
- an historical yield curve $\Theta(\tau)$ giving the long run mean of r_τ for each tenor τ
- eigenvalues $\lambda_1, \dots, \lambda_m$ and corresponding eigencurves $Q_1(\tau), \dots, Q_m(\tau)$.

The curves $\sigma(\tau)$, $\Theta(\tau)$ and $Q_k(\tau)$ are linearly interpolated with flat extrapolation.

PCA factors of a particular yield curve have zero correlation to one another; however they generally have non-zero correlations other risk factors in the simulation, including the PCA factor of other yield curves.

For details about the valuation for this model, see the Theory Guide [7, § 1.6.10 PCA Model], and the Theory Guide [7, § 3.6.4.1 Principal Components Analysis] for details on the construction of eigen-

curves in Adaptiv Analytics.

18.9.2 Properties

Correlated Normals

Component standard normal variables used to update the model's state variables at each time point.

Distribution Type

Distribution Type. May be Lognormal or Normal.

Eigenvectors

Set of curves represented by a function of the zero-rate tenor.

Historical Yield

Historical yield curve.

Princ Comp Source

Choice for the source of the eigenvectors. Can be Correlation or Covariance.

Rate Drift Model

Drift method, for which three options are provided. Under Drift To Blend, the mean rate is a blend of the initial rate and long run mean, converging to Long Run Mean as $t \rightarrow \infty$. The Log Drift To Blend is similar, although the blend occurs for log rates. For Drift To Forward, the mean rate is the initial rate from t to $t + \tau$.

Reversion Speed

Mean reversion speed. Scalar.

Yield Volatility

Yield volatility curve.

18.9.3 Assumptions and Limitations

18.9.3.1 Arbitrage

The principal components model is a statistical model of interest rates, as opposed to a risk-neutral one. Consequently it follows that interest rate scenarios generated by PCA are not necessarily arbitrage free.

18.9.3.2 Number of Factors Chosen in Advance

Adaptiv Analytics does not provide a mechanism to specify the percentage of variance to be captured in calibration. Instead, the number of factors must be fixed, with the percentage of variance captured consequent upon this choice.

18.9.3.3 Scalar Mean Reversion Speed

Adaptiv Analytics does not provide a term structure for the mean reversion speed.

18.10 Transition Interest Rate Model

18.10.1 Overview

The Transition Interest Rate model is a non-stochastic model which converts credit rating change to switches between interest rate curves. The interest rate is therefore a deterministic function of the credit rating.

For details about the valuation for this model, see the Theory Guide [7, § 1.6.17 [Transition Model](#)].

18.10.2 Properties

Always Generic

If Yes, generic pool interest rates are always used at simulation times after zero. If No, the original price factor interest rate is used until the first transition.

Issuer

Issuer identifies which credit rating to use.

Sub Pool

Subpool price factor to be used.

18.10.3 Assumptions and Limitations

18.10.3.1 Credit Rating Model

As the rate is driven by the credit rating, it is necessary to assign a simulation model to the `CreditRating` price factor to create interest rate risk.

Chapter 19

Volatility Models

19.1 Overview

19.1.1 Classes of Volatility Model

In Adaptiv Analytics, three classes of volatility model exist; simple volatility models, PCA volatility models, and stochastic volatility models. The first two of these are described below, while the stochastic models are associated with the underlying asset prices and are discussed in the joint models section (Section 15).

19.1.2 Common Assumptions and Limitations

19.1.2.1 CVA

A general limitation of Adaptiv Analytics is that it does not currently have the class of models considered to be market standard for CVA. Banks often use American Monte Carlo for stochastic volatility simulation.

19.1.2.2 Inverse relationship between volatility and equity prices

Simple Volatility Models and PCA Volatility Models have no intrinsic relationship between volatility and asset price, other than the statistical relationship provided by the correlation matrix. They cannot guarantee a skew relationship will hold on each scenario.

The skew relationship is however supported by the stochastic volatility models discussed in Section 15.

19.1.2.3 Bounds

Volatilities are floored at 0.01% and capped at 10000%.

Theory Guide 1.8.6

19.2 Simple volatility models

19.2.1 Overview

These are one factor models with simulated ATM volatilities. The wings of the volatility surface move in parallel with ATM volatility. The model is based on a GOU process, which is positive and mean reverting.

Theory Guide [1.8.7](#)

Let p denote a point on the surface. For example, for asset prices, $p = (m, \tau)$ or $p = (K, \tau)$; and for interest rates, $p = (m, \tau, \delta)$. The evolved implied volatility for point p at time t is given by

$$v(t; p) = u(t; p) \exp \left(-\frac{\sigma^2}{2} \left(\frac{1 - e^{-2\alpha t}}{2\alpha} \right) + \sigma Y(t) \right), \quad (19.2.1)$$

where:

- σ is a volatility of implied volatility;
- α is a mean-reversion speed;
- $Y(t)$ is a standard Ornstein-Uhlenbeck process with mean-reversion speed α , as defined in Section [B.2](#).

19.2.1.1 Common Properties

The following properties are often found on simple volatility models.

Blend Method

Blend Method, with two options Drift To Blend Or Log Drift To Blend:

Theory Guide [1.8.7](#)

Drift To Blend. The mean implied volatility is given by

$$u(t; p) = v(p)e^{-\alpha t} + (1 - e^{-\alpha t})\Theta(p). \quad (19.2.2)$$

Log Drift To Blend. The mean implied volatility is given by

$$u(t; p) = \exp \left(\log v(p)e^{-\alpha t} + \theta(p)(1 - e^{-\alpha t}) + \frac{\sigma^2(1 - e^{-2\alpha t})}{4\alpha} \right) \quad (19.2.3)$$

where $\theta(p) = \log \Theta(p) - \sigma^2/4\alpha$, so that $X(t) = \log v(t; p)$ is an Ornstein-Uhlenbeck process with long run mean $\theta(p)$:

$$\log v(t; p) = \log v(p)e^{-\alpha t} + \theta(p)(1 - e^{-\alpha t}) + \sigma Y(t). \quad (19.2.4)$$

Vol of Vol

Volatility of the volatility. Scalar.

Reversion Speed

Mean reversion speed. Scalar.

19.2.1.2 Common Assumptions and Limitations

See Section [19.1.2](#) for common limitations of simple volatility models.

19.2.2 Forward Price Volatility Model

19.2.2.1 Overview

The Forward Price Volatility Model is a simple volatility model for Energy Forward Prices, including validation to ensure the required vols are physical (i.e., delivered after settlement).

For details about the valuation for this model, see the Theory Guide [7, § 1.8.7 Simple (One-Factor) Volatility Model].

19.2.2.2 Properties

See Section 19.2.1.1 for common properties for simple volatility models. Unique properties for the Forward Price Volatility Model are shown below.

Mean Surface

Surface containing the mean volatility against time to delivery, time to Expiry, and moneyness (defined as ratio of forward price to strike price).

19.2.2.3 Assumptions and Limitations

Interpolation Default interpolation method is flat left, but can be made linear by selecting Linear-SurfaceInterpolation for this price factor in the market data file.

19.2.3 Price Index Volatility Model

19.2.3.1 Overview

This is a simple volatility model for Price Indices. Price index values for a given period become available on the first publication date following the end of period; Adaptiv Analytics estimates publication dates after the front date using the publication period. For details about the valuation for this model, see the Theory Guide [7, § 1.8.4 Price Index Volatility].

19.2.3.2 Properties

See Section 19.2.1.1 for common properties for simple volatility models. Unique properties for the Price Index Volatility Model are shown below.

Historical Surface

Surface containing volatility against moneyness (defined as ratio of growth to strike price) time to expiry and tenor.

19.2.3.3 Assumptions and Limitations

Inflation Rates Although inflation options are written in terms of rates, it is convenient to model them in terms of price index levels instead, because inflation rates can be negative. However, price indexes are strictly positive and are plausibly modelled as growing lognormally. Thus, Adaptiv Analytics uses Black's model on index growth.

Volatility Expectations In general, Adaptiv Analytics requires volatility expectations over future periods $[t_1, t_2]$ because the fundamental form of inflation options is forward starting. Hence, it assumes that the actual tenor that should be used to look up the surface can be no greater than $(t_2 - t)$.

We do not assume that volatility expectations for future periods match the variances "implied" by a term-structure of spot integrated Black's volatility because we want the freedom to match market prices.

19.2.4 Beta Asset Price Volatility Model

19.2.4.1 Overview

Theory Guide [1.8.7](#)

The beta asset price volatility model is the same as the simple asset price volatility model except that the single Ornstein-Uhlenbeck process $Y(t)$ in Equation (19.2.1) is replaced by

$$\hat{\omega}Z(t) + \sqrt{1 - \hat{\omega}^2}Y(t), \quad (19.2.5)$$

where $Z(t)$ and $Y(t)$ are Ornstein-Uhlenbeck processes with the same mean reversion speed, and $\hat{\omega}$ is the rounded systemic weight. $Z(t)$ is the systemic driver and can be correlated with other risk factors. $Y(t)$ is the idiosyncratic driver and is independent of all other risk factors.

When pricing equity options it is preferable to specify liquid equity volatilities so that calibration can be done using historical data. Less liquid equity volatilities can be simulated as a volatility ratio between equity and index prices, and can therefore be modelled as a percentage of the index volatility. This is analogous to multi-factor models and provides a way to limit the number of risk factors required.

For details about the valuation for this model, see the Theory Guide [7, § [1.8.9 Beta Asset Price Volatility Model](#)].

19.2.4.2 Properties

See Section [19.2.1.1](#) for common properties for simple volatility models. Unique properties for the Beta Asset Price Volatility Model are shown below.

Historical ATM Vol

Curve containing the historical ATM volatility against time to expiry.

Historical Smile

Curve containing the smile (volatility adjustment) against moneyness (defined as forward asset price/strike price).

Historical Surface

Surface containing volatility against moneyness (defined as forward asset price/strike price) and time to expiry.

Significance Threshold

Any driver weights with absolute value less than the threshold are rounded to zero. Scalar.

Systemic Factor

The driver used to lookup beta values.

Systemic Weight

The weight of the systemic factor. Scalar.

19.2.4.3 Assumptions and Limitations

Correlation with other price factors The idiosyncratic factor is not correlated with any other risk factors.

Significance Threshold The model applies a significance threshold to the driver weights. See Section [14.7.3.1](#) for more details.

19.3 PCA Volatility Models

19.3.1 Overview

These are three-factor models which simulate more complicated perturbations in the volatility surface than can be achieved by the simple volatility models. However, they are not arbitrage free, and they do not support a functional relationship between volatility and underlying asset price.

Theory Guide [1.8.8](#)

Let p denote a point on the volatility surface. The parameters of the model are:

- a mean reversion speed α
- a long run mean surface $\Theta(p)$
- eigenvalues $\sigma_1^2, \dots, \sigma_m^2$, where $\sigma_1 \geq \dots \geq \sigma_m \geq 0$
- eigensurfaces $f_1(p), \dots, f_m(p)$.

There is one driving factor for each eigenvalue. The drivers are independent standard Ornstein-Uhlenbeck processes $Y_1(t), \dots, Y_m(t)$ with the same mean-reversion speed α . These are given by $Y_k(t) = \int_0^t e^{-\alpha(t-s)} dW_k(s)$, where $W_1(t), \dots, W_m(t)$ are independent standard Wiener processes.

For details about the valuation for the PCA Volatility models, see the Theory Guide [[7](#), § [1.8.8 PCA Volatility Models](#)].

19.3.1.1 Common Properties

The following properties are shared between all PCA volatility models.

Eigenvectors

Set of curves represented by a function of the zero-rate tenor.

Historical Surface

Surface containing volatility as a function of moneyness (defined as forward price/strike price, although Adaptiv Analytics may be configured to use the spot price in place of the forward price if the user so desires) and time to expiry.

Reversion Speed

Mean reversion speed. Scalar.

19.3.1.2 Common Limitations and Assumptions

Bisymmetric covariance matrices For the case of a bisymmetric covariance/correlation matrix the structure of eigenvectors is a priori known, and the eigenvectors have the same shape as the empirically observed level, skew, curvature loading vectors. Even if a random system exists, when the covariance matrix is bisymmetric, PCA may indicate the existence of factors which could be interpreted as skew and curvature. This can cause interpretation problems in the analysis of PCA results. Furthermore, when a system exists with level, skew and curvature given, PCA may not correctly recover these effects.

19.3.2 PCA FX Volatility Model

19.3.2.1 Overview

This is an implementation of a PCA Volatility Model for a spot process for FX Volatilities.

19.3.2.2 Properties

All properties are common for PCA models; see Section 19.3.1.1.

19.3.2.3 Assumptions and Limitations

Market Convention In the FX markets, it is usual to publish, for a given currency pair and time to expiry, three implied volatility quotes, namely: an ATM volatility, a risk reversal volatility, and a butterfly volatility. These quotes can be used to extract the entire volatility smile for this given time to expiry. A set of these triplets for different times to expiry yields a full volatility surface.

19.3.3 PCA Asset Price Volatility Model

19.3.3.1 Overview

This is an implementation of a PCA Volatility Model for a spot process for Asset Price Volatilities.

19.3.3.2 Properties

All properties are common for PCA models; see Section 19.3.1.1.

19.3.3.3 Assumptions and Limitations

Currencies An equity or commodity volatility price factor provides volatilities for the asset price in the price factor currency, defined by its Currency property. If the Currency is not specified then the last part of the factor ID is assumed to be the price factor currency (for example, USD when the factor ID is IBM.USD).

If a valuation model requests the volatility of the asset price denominated in another currency then the volatility is calculated for moneyness point $F = K$, where F is the forward asset price in the other currency and K is the requested strike. Note that the volatility values are not adjusted for the FX rate.

19.3.4 PCA Interest Rate Volatility Model

19.3.4.1 Overview

This is an implementation of a PCA Volatility Model for evolution of an interest rate surface.

19.3.4.2 Properties

All properties are common for PCA models; see Section 19.3.1.1.

19.3.4.3 Assumptions and Limitations

19.3.4.4 Common Assumptions and Limitations

See Section 19.1.2 for common limitations of this model.

19.3.5 PCA Interest Yield Volatility Model

19.3.5.1 Overview

This is an implementation of a PCA Volatility Model for evolution of an interest yield surface.

19.3.5.2 Properties

All properties are common for PCA models; see Section 19.3.1.1.

19.3.5.3 Common Assumptions and Limitations

See Section 19.1.2 for common limitations of this model.

Chapter 20

Survival Probability Models

20.1 Overview

20.1.1 Survival Probabilities

The survival probability models in Adaptiv Analytics are real-world models which simulate survival probability independently of interest rates (except through correlation of their risk factors).

The hazard rate curve is related to survival probability as follows.

Theory Guide [1.10](#)

The relationships between hazard rate (or default intensity) $h(t)$, survival probability $S(t, T)$ and forward hazard rate $h(t, T)$ are:

$$\exp \left(- \int_t^T h(t, u) \, du \right) = S(t, T) = \mathbb{E}_t \left(\exp \left(- \int_t^T h(s) \, ds \right) \right), \quad (20.1.1)$$

where \mathbb{E}_t denotes expectation in the risk-neutral measure conditional on the information at time t and $h(t) = h(t, t)$.

20.1.1.1 Analogues

Survival probability is analogous to a discount factor. The integrated hazard rate represented by the survival probability price factor is analogous to the product of a zero coupon interest rate and the maturity of that rate. Discrete tenor hazard rates are analogous to forward interest rates.

20.1.2 Common Assumptions and Limitations

20.1.2.1 No model evolution

Here is the no model evolution of survival probabilities:

Theory Guide [1.10.2](#)

If no price factor model is selected then the evolved survival probabilities are given by

$$S(t, T) = \exp(-I(T - t)). \quad (20.1.2)$$

Where I is the initial curve.

20.1.2.2 Spreads

It is possible to define spreads on survival probabilities. This corresponds to the probability of the survival of one child entity (e.g., an issuer) compared to base survival probability which could represent an abstract quality shared by many issuers (e.g., a credit rating, industry, or geography).

For survival probabilities, such spreads are multiplicative, while the equivalent hazard rate spreads are additive; this is the same as for interest rates.

20.1.2.3 Bounds

Simulated survival probabilities are floored at 0 and capped at 1. Simulated survival probabilities in Adaptiv Analytics never permit a default event to occur. Therefore, while the model can simulate values approaching to zero, survival probability will never actually attain zero.

The same flooring and capping applies to spread survival probabilities.

20.2 Drift To Forward Survival Probability Model

20.2.1 Overview

This is a non-stochastic risk-neutral model. The model evolves to the implied forward survival probability on all scenarios.

Theory Guide [1.10.5](#)

Under the model, the evolved survival probabilities are given by

$$S(t, T) = \frac{S(0, T)}{S(0, t)}. \quad (20.2.1)$$

For details about the valuation for this model, see the Theory Guide [[7](#), § [1.10.5 Drift To Forward Model](#)].

20.2.2 Properties

The model has no adjustable properties.

20.2.3 Assumptions and Limitations

20.2.3.1 No Arbitrage

The implicit assumption of this model is that the forward survival probabilities are arbitrage-free.

20.3 Transition Survival Probability Model

20.3.1 Overview

The Transition Survival Probability model is a non-stochastic model which converts credit rating change to switches between survival probability curves. The survival probability is therefore a deterministic function of the credit rating.

For details about the valuation for this model, see the Theory Guide [7, § 1.10.11 [Transition Model](#)].

20.3.2 Properties

Always Generic

Yes or No. If Yes, generic pool survival probabilities are always used at simulation times after zero. If No, the original price factor survival probability is used until the first transition.

Sub Pool

Sub pool price factor to be used.

20.3.3 Assumptions and Limitations

20.3.3.1 Credit Rating Model

As the survival probability is driven by the credit rating, it is necessary to assign a simulation model to the Credit Rating price factor to create survival probability risk.

20.4 Exponential Vasicek Hazard Rate Model

20.4.1 Overview

In Adaptiv Analytics, the Exponential Vasicek model is a model in which hazard rate is modelled as a log-normal process. More precisely, the log of the hazard rate is mean reverting process, from which survival probability is derived for Adaptiv Analytics. The model is therefore equivalent to the Black-Karasinski model for Interest Rates.

Theory Guide [1.10.8](#)

The logarithm of the hazard rate is modeled as a mean-reverting process satisfying the SDE

$$dx(t) = \alpha (\theta - x(t)) dt + \sigma dW(t), \quad (20.4.1)$$

where $x(t) = \log h(t)$ and the volatility σ , mean-reversion speed α and long run mean θ are constants.

The underlying model is attached to Ornstein-Uhlenbeck process. The process is re-gridded to match integration bounds linear interpolation.

For details about the valuation for this model, see the Theory Guide [\[7, § 1.10.8 Exponential Vasicek Model\]](#).

20.4.2 Properties

Alpha

The model mean-reversion speed parameter. Scalar.

Sigma

Volatility of the variance process. Scalar.

Theta

Constant long run mean of the variance process. Scalar.

20.4.3 Assumptions and Limitations

20.4.3.1 Performance

The model is relatively slow to compute, requiring numerical integration of two conditional moments defined via Fubini's Theorem.

20.4.3.2 CDS Price

As the model is solved via numerical integration, there is no analytic solution for the CDS price in this model.

20.5 Hull-White Hazard Rate Model

20.5.1 Overview

The Hull-White Hazard Rate model applies a mean-reverting Ornstein-Uhlenbeck process to the hazard rate. The driving stochastic process is risk-neutral (denoted below as $W^*(t)$), and related to the real-world measure by a constant risk-premium.

Theory Guide [1.10.6](#)

The Hull-White model for the hazard rate process $h(t)$ is

$$dh(t) = (\theta(t) - \alpha h(t)) dt + \sigma dW^*(t), \quad (20.5.1)$$

where σ is a constant volatility, α is a constant mean-reversion speed, $\theta(t)$ is a deterministic curve.

Survival probabilities may be calculated from this model analytically. For details about the valuation for this model, see the Theory Guide [[7](#), § [1.10.6 Hull-White Model](#)].

20.5.2 Properties

Alpha

The mean-reversion speed parameter. This parameter is scalar for the Hull-White Hazard Rate model.

Lambda

Constant market price of risk. Scalar.

Sigma

Volatility of the variance process. Scalar.

20.5.3 Assumptions and Limitations

20.5.3.1 Scalar Volatility

Whereas the Hull-White interest rate models support term structure volatility, the volatility for the Hull-White Hazard Rate model is a scalar.

20.5.3.2 Calibration

The calibration limitations for this model are similar to those of the One Factor Hull-White Interest Rate Model (Section [18.4.3](#)).

20.6 Jump Cox-Ingersoll-Ross Hazard Rate Model

20.6.1 Overview

Adaptiv Analytics supports a Cox-Ingersoll-Ross Model for Hazard Rates, supplemented by an additional jump feature. On account of the analogue between discount factor and survival probability, the Hazard Rate model functions on the same basis as that of the Jump CIR Interest Rate Model, described in Section 18.6. The same Jump CIR Model, CIR++, is employed by Adaptiv Analytics for Hazard Rates and Interest Rates.

This is the model recommended by [13] as an appropriate model selection for CVA, where the jump component is equivalent to the impact of sudden credit rating changes.

For details about the valuation for this model, see the Theory Guide [7, § B.4 Cox-Ingersoll-Ross Model].

Discretization Scheme

Adaptiv Analytics allows choices of `Zhu` or `Full Truncation`; the discretization scheme for the CIR process. See Section 18.6.3.1

Initial Process Value

The CIR model initial condition value. Scalar.

Jump Arrival Rate

Jump arrival rate for the compound Poisson process. Scalar.

Mean Jump Size

Mean of jump sizes for the compound Poisson process. Scalar.

Reversion Level

Mean reversion level. Scalar.

Reversion Speed

Mean reversion speed. Scalar.

Risk Premium

This represents the extra return above the risk-free rate that an investor needs in order to be compensated for the risk of a certain investment. Scalar.

Use Deterministic Shift

Yes for making a deterministic shift so the term structure is consistent with current market price;
No otherwise.

Use Dynamic Jump Arrivals

No to assume jumps only occurs at given simulation time grid; Yes to simulate random inter-time-grid jump arrival times.

Vol Volatility of the asset. Scalar.

20.6.2 Assumptions and Limitations

20.6.2.1 Calibration

As credit rating changes are discrete (and relatively rare for any given issuer), there is no calibration in Adaptiv Analytics for the jump component corresponding to credit rating changes.

20.7 Multi-Factor GOU Hazard Rate Model

20.7.1 Overview

The Multi-Factor GOU Hazard Rate Model is similar to the multi-factor interest rate GOU model. The model is mean-reverting, and multi-factor, meaning that it is able to simultaneously capture multiple hazard rates at once, making it useful for simulations of large numbers of issuers. As for the interest rate version, the model is driven by an optional idiosyncratic driver and m systematic drivers. While systematic drivers may be shared between multiple survival probability models, the idiosyncratic driver and mean reversion are unique to each model.

The geometric nature of the model ensures that simulated values for survival probability remain positive.

Theory Guide [1.10.10](#)

The simulated survival probabilities are given by

$$S(t, t + \tau) = S(0, \tau)^{G_\tau(t)} \quad (20.7.1)$$

for Drift To Spot, or

$$S(t, t + \tau) = \left(\frac{S(0, t + \tau)}{S(0, t)} \right)^{G_\tau(t)} \quad (20.7.2)$$

for Drift To Forward, where G_τ is the GOU process given by

$$G_\tau(t) = \exp \left(-\frac{1}{2} \sigma(\tau)^2 \left(\frac{1 - e^{-2\alpha t}}{2\alpha} \right) + \sigma(\tau) Y(t) \right), \quad (20.7.3)$$

where

- $\sigma(\tau)$ is the volatility for tenor τ
- $Y(t) = \sum_{k=1}^m (\hat{\omega}_k / \hat{\omega}) Y_k(t) + (\hat{\epsilon} / \hat{\omega}) \tilde{Y}(t)$
- $Y_k(t) = \int_0^t e^{-\alpha(t-s)} dW_k(s)$ and $\tilde{Y}(t) = \int_0^t e^{-\alpha(t-s)} d\tilde{W}(s)$ are standard Ornstein-Uhlenbeck processes with reversion speed α
- $\hat{\omega}_k$ is the rounded weight for the k^{th} systematic driver
- $\hat{\epsilon}$ is the rounded weight for the idiosyncratic driver
- $\hat{\omega}$ is the normalization factor for the rounded weights.

In general, when calibrating this model, owing to illiquidity in the underlying single-name CDS market, sufficient good quality historical data does not exist for rigorous calibrations. It is therefore suggested to calibrate to an Index CDS (i.e., those assets for which there is some liquidity) as a benchmark, and then do a regression calibration against that benchmark

For details about the valuation for this model, see the Theory Guide [[7](#), § [1.10.10 Multi-Factor GOU Model](#)].

20.7.2 Properties

Drift Model

Choices of drift methods, which drive the forward rate evolution. Options are Drift To Spot or Drift To Forward; see effects in the rate evolution in Section [18.8.1](#).

Idiosyncratic Weight

Weight of the idiosyncratic driver. Scalar.

Mean Reversion Speed

Mean reversion speed. Scalar.

PCA Factors

Yes to set correlations between drivers to zero with Adaptiv Analytics calculating normalizing coefficients; No for correlated drivers with weights assumed to be already normalised and normalizing coefficient set to 1.

Significance Threshold

Any driver weights with absolute value less than the threshold are rounded to zero. Scalar.

Vol Choice of *Integrated* or *Instantaneous* volatility curve of the asset. Defines the nature of the volatility curve supplied. See *Vol* definition in Section 14.4.2.

Weights

List of weights of the assets with respect to the driver.

20.7.3 Assumptions and Limitations**20.7.3.1 Credit Rating Changes**

While the model does capture the volatility behaviour that one might expect in survival probabilities, it does not allow any component to represent jumps owing to credit rating changes.

20.7.3.2 Significance Threshold

In common with the multi-factor GBM Asset Price models, the model applies a significance threshold to the weighting factors. See Section 14.7.3.1.

20.8 Multi-Factor GBM Hazard Rate Model

20.8.1 Overview

The Multi-Factor GBM Hazard Rate Model is similar to the Multi-Factor GOU Hazard Rate model of Section 20.7, but without the mean-reverting behaviour. Although the model is multi-factor, it is still single factor in the sense that hazard rates of a name at different tenors have the same volatility and are perfect correlated. Hazard rates are modelled by multi-factor Geometric Browning Motion, with zero drift.

The model allows two options for drift, whereby hazard rates can drift to the spot rate, or the forward rate. Note that because the underlying processes are correlated, the variance of their sum is not the sum of their variances and so the drift adjustment is made in the model rather than using lognormal diffusion processes.

Theory Guide 1.10.9

The simulated forward hazard rate at time t for tenor τ is given by either:

$$h(t, t + \tau) = F(t)h(0, \tau) \quad (20.8.1)$$

for Drift To Spot, or

$$h(t, t + \tau) = F(t)h(0, t + \tau) \quad (20.8.2)$$

for Drift To Forward, where $F(t)$ is the stochastic driver. The stochastic driver is given by

$$F(t) = \exp \left(-\frac{1}{2}\sigma^2 t + \sigma \left(\sum_{k=1}^m \left(\frac{\hat{\omega}_k}{\hat{\omega}} \right) W_k(t) + \left(\frac{\hat{\epsilon}}{\hat{\omega}} \right) \widetilde{W}(t) \right) \right), \quad (20.8.3)$$

where

- σ is the volatility of the hazard rates
- W_k is the Wiener process for the k^{th} driver
- \widetilde{W} is the Wiener process for the idiosyncratic driver
- $\hat{\omega}_k$ is the rounded weight for the k^{th} systemic driver
- $\hat{\epsilon}$ is the rounded weight for the idiosyncratic driver
- $\hat{\omega}$ is the normalization factor for the rounded weights.

For details about the valuation for this model, see the Theory Guide [7, § 1.10.9 Multi-Factor GBM Model].

20.8.2 Properties

Drift Model

Choices of drift methods, which drive the forward rate evolution. Options are Drift To Spot or Drift To Forward; see effects in the rate evolution in Section 18.8.1.

Idiosyncratic Weight

Weight of the idiosyncratic driver. Scalar.

PCA Factors

Yes to set correlations between drivers to zero with Adaptiv Analytics calculating normalizing coefficients; No for correlated drivers with weights assumed to be already normalised and normalizing coefficient set to 1.

Significance Threshold

Any driver weights with absolute value less than the threshold are rounded to zero. Scalar.

Vol Choice of *Integrated* or *Instantaneous* volatility curve of the asset. Defines the nature of the volatility curve supplied. See *Vol* definition in Section 14.4.2.

Weights

List of weights of the assets with respect to the driver.

20.8.3 Assumptions and Limitations**20.8.3.1 Significance Threshold**

In common with the multi-factor GBM Asset Price models, the model applies a significance threshold to the weighting factors. See Section 14.7.3.1.

Chapter 21

Price Index Models

21.1 Overview

In general, it is possible to generate implied forward values of a price index from the inflation rate. However, such price indexes cannot be traded directly - instead, underlying securities, such as bonds, linked to price indexes are traded in the market where they are intended to provide protection against inflation.

In order to price inflation products, such as a bond linked to a particular price index, a forecast of the future value of that price index must be obtained. Thus, for future dates, the price index upon which the bond is valued is the market's expectation of the value of a future price index. This forecast price index will have been evolved forward from a known, published index. However, as the next index publication date approaches, it and the forecast future price index will not in general converge.

In reality, each time a price index is published, expected future values for that price index are predicted by the inflation rate price factor. These expectations will then be revised for each subsequent price index publication.

21.1.1 Common Properties

21.1.1.1 Price Index

A price index is a normalised (typically weighted) average of price for underlying goods or services, within a specified region and over a period of time. Typically, the index is published following the end of the period covered, and potentially following some operational delay.

In Adaptiv Analytics, historical values of price index are mapped into a curve, which is flat right interpolated. The price index is then modelled as a sequence of inflation period start dates commencing at the `Last Period Start Date` (which typically coincides with the last historical value) and falling at monthly or quarterly intervals (controlled by the `Publication Period Period` property). The index is expected to be published at intervals commencing on the `Next Publication Date`.

Historic price index values are calculated by flat-right extrapolation of the historic curve, while future price index forecasts are estimated from the most recent value inflated to the valuation date, with or without a stochastic model.

21.1.1.2 Price Index References

An inflation contract will typically specify that the price index is sampled at a particular 'reference date'. This date is typically a function of one or more previously published price index values.

Where reference dates do not fall in published or forecast index publication dates, Adaptiv Analytics allows several possible means for calculating an appropriate value for the reference price index via

the `Reference Name` property. See the Theory Guide [7, § 1.12.2 Price Index References] for more details.

21.1.2 Common Assumptions and Limitations

21.1.2.1 Inflation

Inflation Rate price factors in Adaptiv Analytics are similar to interest rates, but are not floored, may contain seasonality, and have an associated Price Index price factor. They are defined by a curve of zero-coupon rates with linear interpolation and flat extrapolation.

21.1.2.2 Seasonality

Most inflation price indexes exhibit strong but predictable seasonal variation, which can exceed the annual volatility of the price indexes. These are implemented in Adaptiv Analytics via the `Seasonal Price Index Factor` price factor.

In calculation, since seasonal variation is not visible in quoted (annual) inflation rates, Adaptiv Analytics first linearly interpolates the continuously compounded inflation rates, before applying the seasonal adjustments.

When calculating breakeven future values, Adaptiv Analytics accounts for seasonal variation in the most recently published price index. Consequently, seasonal adjustment will be applied when pricing spot deals.

Adaptiv Analytics includes validation to ensure the monthly seasonal factors multiply to 1 to ensure zero net effect over the year.

21.1.2.3 Breakeven Values

The market quotes price index forecasts as rates and refers to the forecasts implied by these rates breakeven values. In Adaptiv Analytics the quoted rates refer to price index references rather than published price index values.

21.2 Price Index Drift Model

21.2.1 Overview

The Price Index Drift model is important for risk-neutral simulation of inflation, where it is desirable for the price index to converge to the risk-neutral value implied by the inflation rate.

The forward value of the price index is exactly equivalent to the inflation cash account, and is therefore defined by continuous time stochastic factor is $\beta_i(t)$.

Theory Guide [1.12.6.2](#)

The discrete realization of the change in inflation cash account from time t to time $t + \delta$ is approximated by

$$\beta_i(t + \delta) \approx \frac{\beta_i(t)}{D_i(t, t + \delta)}, \quad (21.2.1)$$

where $D_i(t, T)$ is the inflation discount factor. This approximation becomes exact when the inflation rate is deterministic.

For details about the valuation for this model, see the Theory Guide [[7](#), § [1.12.6.3 Price Index Drift Model](#)].

21.2.2 Properties

Inflation Rate

ID of the Inflation Rate price factor that drives the price index evolution

21.2.3 Assumptions and Limitations

21.2.3.1 Real-world usage

This model is risk-neutral, and should not be used for real-world simulations.

21.3 GBM Price Index Model

21.3.1 Overview

The GBM Price Index Model is equivalent to the GBM Asset Price Model, and is a reasonable approach for modelling price indexes, since most (e.g. as CPI) typically creep upward over time.

Theory Guide [1.12.6.1](#)

The continuous-time stochastic factor (see Section [1.12.1](#)) is given by

$$F(t) = \exp \left(\left(\mu - \frac{\sigma^2}{2} \right) t + \sigma W(t) \right), \quad (21.3.1)$$

where σ and μ are the volatility and drift of the price index and $W(t)$ is a standard Wiener process under the real-world measure.

For details about the valuation for this model, see the Theory Guide [\[7, § 1.12.6.1 GBM Model\]](#).

21.3.2 Properties

Drift

Long term drift of the price index.

Seasonal Adjustment

The seasonal adjustment.

Theory Guide [1.12.5](#)

The seasonal adjustment factor between date T_1 and date T_2 is given by

$$A(T_1, T_2) = e^{b(m(T_2)) - b(m(T_1))}, \quad (21.3.2)$$

where $b(i) = \sum_{j=1}^i a_j/12$ and a_i is the annualized seasonal rate of month i , and $b(12) = 0$ (seasonal rates sum to zero).

This property should be set to a curve, and can take zero value if no seasonality is required.

Vol Volatility of the asset. Scalar.

21.3.3 Assumptions and Limitations

The model has no specific limitations or assumptions beyond those common to GBM models. See Section [14.3.3](#).

21.4 GBM Price Index Drift Model

21.4.1 Overview

The GBM Price Index Drift Model is an extension to the GBM Price Index Model in which drift is risk-neutrally implied from the inflation rate. The model behaves as follows:

Theory Guide [1.12.6.2](#)

The continuous-time stochastic factor (see Section [1.12.1](#)) is given by

$$F(t) = \beta_i(t) \exp \left(\left(\lambda - \frac{\sigma^2}{2} \right) t + \sigma W(t) \right), \quad (21.4.1)$$

where σ is the volatility of the price index, λ is the market price of risk, $W(t)$ is a standard Wiener process under the real-world measure, $\beta_i(t) = \exp \left(\int_0^t r_i(s) ds \right)$ is the inflation cash account, and $r_i(t)$ is the spot inflation rate.

Note that the inflation cash account in this model is the same as in the Price Index Drift model. The two models are therefore equivalent when $\sigma = 0$ and $\lambda = 0$.

For details about the valuation for this model, see the Theory Guide [[7](#), § [1.12.6.2 GBM Price Index Drift Model](#)].

21.4.2 Properties

Inflation Rate

ID of the Inflation Rate price factor that evolves the price index.

Lambda

Constant market price of risk. Scalar.

Vol Volatility of the asset. Scalar.

21.4.3 Assumptions and Limitations

The model has no specific limitations or assumptions beyond those common to GBM models. See Section [14.3.3](#).

Chapter 22

Credit Rating Models

22.1 Overview

22.1.0.1 Credit Rating Models

Credit rating models are driven by rating transition matrixes, which specify the probability of transition from each starting rating to any possible rating over some fixed period, such as one year. Adaptiv Analytics does not represent these transition probabilities directly. Instead, it represents transition probabilities as the values of a standard normal variable with cumulative probability equal to the probability represented, as a function of time. These curves are called transition boundary curves.

A simulated creditworthiness process is compared to these boundaries to determine the simulated credit rating of an obligor. Depending on the model, the interpretation of time in the transition boundary curves may be relative to the previous scenario grid date (time homogeneous) or absolute simulation time (time inhomogeneous).

22.1.0.2 Subpools and Transitions

Simulated credit ratings affect valuation through sensitivities to survival probability and interest rate price factors. Adaptiv Analytics represents these sensitivities via the `SubpoolInterestRate` and `SubpoolSurvivalProb` price factors, which represent interest- or hazard- rate curves respectively for each non-default rating, and a subpool represents a class of obligor.

Credit ratings are subsequently linked subpools via Transition Price Factors `TransitionInterestRateModel` and `TransitionSurvivalProbModel`; see the Theory Guide [7, § 1.14.1.2 Subpool Price Factors and § 1.14.1.3 Transition Price Factor Models].

22.1.1 Common Assumptions and Limitations

22.1.1.1 No Recovery from Default

While a transition matrix allows a transition to a default rating, it is not possible to transition from default. Default is assumed to be an absorbing state.

22.1.1.2 Interpolation of Transition Boundary Curves

Transition boundary curves are interpolated linearly when necessary. However, it is best to avoid interpolating these curves by defining them at intervals that match the scenario grid as closely as possible.

22.1.1.3 Significance Threshold

Many of the credit rating models employ a significance threshold, the effect of which is similar to that of the Multi-Factor GBM model. See Section 14.7.3.1.

22.2 Hull-White Credit Rating Model

22.2.1 Overview

The Hull-White Credit Rating model represents creditworthiness via a Wiener process which is constructed from a Gaussian copula. The Adaptiv Analytics implementation is based on the Hull and White default correlation model for valuing credit default swaps, introduced in [31], which has been extended to support permissible credit rating transitions above default.

In operation, the driving process is compared against time-evolving transition probabilities, conditioned on the occurrence of no prior default a given obligor.

Theory Guide [1.14.3.1](#)

Specifically, the obligor rating r_m at boundary time t_n given no prior default by t_{n-1} is

$$r_m(t_n) = \sup_j \frac{W_m(t_n)}{\sqrt{t_n}} > H_{ij}(t_n), \quad (22.2.1)$$

where zero represents default, the case when $W_m(t_n)/\sqrt{t_n} < H_{i,1}(t_n)$.

Where $H_{ij}(t)$ refers to a point on a threshold curve between states (credit ratings) i and j .

For details about the valuation for this model, see the Theory Guide [7, § [1.14.3 Hull-White Credit Rating Model](#)].

22.2.2 Properties

Idiosyncratic Weight

Weight of the idiosyncratic driver. Scalar.

PCA Factors

Yes to set correlations between drivers to zero with Adaptiv Analytics calculating normalizing coefficients; No for correlated drivers with weights assumed to be already normalised and normalizing coefficient set to 1.

Significance Threshold

Any driver weights with absolute value less than the threshold are rounded to zero. Scalar.

Transition Matrix

The identifier of the transition matrix for this model.

Weights

List of weights of the assets with respect to the driver.

22.2.3 Assumptions and Limitations

22.2.3.1 Representations

Theory Guide [1.14.3.2](#)

Because $W_m(t)$ must be transformed to a standard normal variable before it can be compared to $H_{i,j}(t)$, this transformation is made when the process is constructed by Analytics, and the internal representation is in the format $W_m(t)/\sqrt{t}$.

22.2.3.2 Boundaries

The model defines credit rating transitions as the crossings of time-varying boundaries by a multi-factor Wiener process. The underlying transition probabilities are assumed Markov but time-inhomogeneous.

Where the Wiener process extends to dates after the transition boundary curves, flat extrapolation is applied to these curves.

22.2.3.3 Transition Times

For a finite time-grid, the exact time of default between two time-grid points is not well defined. To this end, Adaptiv Analytics uses a continuous-time approximation whereby the boundary curves are interpolated, and the default times are 'smeared' to appear continuous.

Theory Guide [1.14.3.3](#)

This is done by testing for default at t_n when there has been no default by t_{n-1} and then interpolating in the cumulative probabilities of $H_{i,1}(t)$ and $W_m(t)$:

$$t_D = t_n - (t_n - t_{n-1}) \frac{\Phi(H_{i,1}(t_n)) - \Phi(W_m(t_n)/\sqrt{t_n})}{\Phi(H_{i,1}(t_n))}. \quad (22.2.2)$$

Note that $H_{i,1}(t_n)$ is known exactly but $W_m(t_n)$ might be interpolated.

If default has not occurred by t , the values of $W_m(t)$ and $H_{i,j}(t)$ used to determine $r_m(t)$ are calculated by linear interpolation when t is not a time in K or N respectively. The rating calculated by this interpolation is floored at 1, the lowest non-default rating.

22.3 IRC Credit Rating Model

22.3.1 Overview

The IRC Credit Rating model is implemented in Adaptiv Analytics in order to support Incremental Risk Charge (IRC) calculation, and is the only Adaptiv Analytics model able to do so. The model is applied to individual obligors via the following.

Theory Guide [1.14.4](#)

Rating changes for the m^{th} obligor are driven by a discrete time asset process $x_m(t)$ similar to that described by Dunn [22]:

$$x_m(t) = \sqrt{1 - \rho_m^2} \dot{\beta}_m \theta_{m,k}(t) + \sqrt{1 - \dot{\beta}_m^2} \epsilon_m(t), \quad (22.3.1)$$

where $\dot{\beta}_m$ is the rounded systemic weight, $\theta_{m,k}$ is a first-order autoregressive process with autoregressive parameter ρ_m , and ϵ_m is an independent standard normal variable.

For any given obligor, $\beta_{m,k}$ will be non-zero for only one k . Thus, only one systematic factor will affect each obligor.

Theory Guide [1.14.4](#)

The values of a process $x(t)$ have the standard normal distribution by construction. These values imply ratings changes by comparison to a set of ordered thresholds derived from a matrix of transition probabilities, where the transition period of the matrix is chosen to match the intervals between the discrete realizations of the credit process (for regulatory purposes, three months).

For the IRC Credit Rating Model, threshold values may be scalars instead of curves as the time increment is fixed. If the rating is below the lowest increment, the obligor is deemed to be in default. However, since this is not an admissible initial state for the rating transition, the position is reset to the previous credit rating if default occurs within a quarterly period.

For details about the valuation for this model, see the Theory Guide [7, § [1.14.4 IRC Credit Rating Model](#)].

22.3.2 Properties

Autoregression

The autoregression correlation. Scalar.

Sector

The name of the sector to which the obligor associated with the credit rating to be modeled belongs.

Sector Weight

The loading factor on the systemic sector driver. Scalar.

Significance Threshold

Any driver weights with absolute value less than the threshold are rounded to zero. Scalar.

Transition Matrix

The identifier of the transition matrix for this model.

22.3.3 Assumptions and Limitations

22.3.3.1 Transition Probabilities

The model, by implication, requires assumptions as to the nature of credit ratings:

Theory Guide [1.14.4](#)

The IRC credit rating model is implicitly based on a matrix of transition probabilities that are stationary (the same over all time intervals of a given length) and Markov (depending only on the current rating and not on the history of rating changes).

22.3.3.2 Conditional Rating Changes

The IRC credit rating model does not manifest the unconditional obligor default time, since model requires that the rating at time t_i is conditioned on a rating chosen by the calculation at t_{i-1} . Therefore:

Theory Guide [1.14.4.1](#)

Consequently, the simulated history of rating changes of a given obligor on a given scenario is not uniquely defined; it depends on the deal under consideration.

22.3.3.3 Autoregressive Parameter

The autoregressive parameter, ρ_m , is specified per obligor in Adaptiv Analytics. However, it is expected that the same value will be applied to all obligors. Adaptiv Analytics generates values of θ for the autoregressive process at discrete, equally spaced dates, which are serially independent.

22.4 Multi-Factor Diffusion Credit Rating Model

22.4.1 Overview

The Multi-Factor Diffusion Credit Rating Model in Adaptiv Analytics corresponds to the Merton's firm value model. The model is typically used for wrong way risk with exposure conditioned on default.

For a single obligor, the model works by simulating credit quality a GBM stochastic process over discrete intervals (which may be of different durations). These are compared against threshold curves, which correspond to rating transition states and the default state.

Theory Guide [1.14.2.1](#)

The rating at the end of each simulation interval is deemed to be the highest rating such that the probability associated with the Wiener increment over the interval considered as a standard normal variable is above the threshold for the rating.

Accordingly, if the equity value falls beyond a certain level, the counterparty is considered to be in default.

For multiple obligors, a joint event distribution is defined through combination of a set of systematic and (optional idiosyncratic) Wiener processes via a Gaussian copula such that the obligor-specific marginal event distributions can be defined as follows.

Theory Guide [1.14.2.2](#)

$$W_m(t) = \sum_{n=1}^N \frac{\hat{\omega}_{mn}}{\hat{\omega}_m} \widehat{W}_{mn}(t) + \frac{\hat{\epsilon}_m}{\hat{\omega}_m} \widetilde{W}_m(t), \quad (22.4.1)$$

where

- $\hat{\omega}_{mn}$ is the rounded weight for the n^{th} systematic driver
- $\hat{\epsilon}_m$ is the rounded weight for the idiosyncratic driver
- $\hat{\omega}_m$ is the normalization factor for the rounded weights.

For details about the valuation for this model, see the Theory Guide [7, § [1.14.2 Multi-Factor Diffusion Credit Rating Model](#)].

22.4.2 Properties

Idiosyncratic Weight

Weight of the idiosyncratic driver. Scalar.

PCA Factors

Yes to set correlations between drivers to zero with Adaptiv Analytics calculating normalizing coefficients; No for correlated drivers with weights assumed to be already normalised and normalizing coefficient set to 1.

Significance Threshold

Any driver weights with absolute value less than the threshold are rounded to zero. Scalar.

Transition Matrix

The identifier of the credit rating transition matrix to use for this model.

Weights

List of weights of the assets with respect to the driver.

22.4.3 Assumptions and Limitations**22.4.3.1 Transition Probabilities**

The model, by implication, requires assumptions as to the nature of credit ratings:

Theory Guide [1.14.2](#)

The multi-factor diffusion model of credit ratings is implicitly based on a matrix of transition probabilities that are stationary (the same over all time intervals of a given length) and Markov (depending only on the current rating and not on the history of rating changes).

22.4.3.2 Instantaneous Jumps

This is a diffusion model but credit rating behaviour can be jumpy in reality. There is no concept of instantaneous jump to default within this model due to a catastrophic event for example.

22.5 Counterparty Conditioning Credit Rating Model

22.5.1 Overview

This is a reformulation of the Multi-Factor Diffusion Credit Rate Model of Section [22.4](#).

Theory Guide [6.2](#)

The potential exposure to a counterparty at a given future time is defined to be the distribution of possible portfolio values at that time given no prior default by the counterparty. Therefore, it is customary to compute exposure without reference to the credit status of the counterparty. However, exposure is only representative of loss in the event of counterparty default. If the exposure is correlated with the credit status of the counterparty, the exposure conditioned on the assumption of counterparty default is of special interest, as it gives rise to *right-way* and *wrong-way* risk.

For details about the valuation for this model, see the Theory Guide [[7](#), § [1.14.5 Counterparty Default Conditioning Model](#)].

22.5.2 Properties

Curve

Survival Probability Curve of the counterparty.

22.5.3 Assumptions and Limitations

22.5.3.1 Simulation

This model can be considered a model of the creditworthiness process rather than the credit rating, since the point is to coerce transition to default on every scenario. The creditworthiness process is not used to determine the credit rating, but to correlate other prices in the simulation.

Chapter 23

Credit Pool Loss Models

23.1 Overview

Credit Pool Loss models are 'top-down' models which model the aggregate loss of a pool of assets such as a CDO but do not 'look inside' the pool to attribute losses to the individual constituents. Their advantage is that they are computationally very efficient.

When consistency with the simulated behaviour of the constituent assets is required, to reflect hedging for example, a 'bottom-up' model should be used.

23.1.1 Common Properties

23.1.1.1 Loss and Recovery

These models assume fixed recovery rates.

Theory Guide [1.13.1](#)

In the simple case of fixed recovery, the cumulative realized fractional portfolio loss $L(t)$ is given by

$$L(t) = \frac{D(t)}{M}(1 - R), \quad (23.1.1)$$

where $D(t)$ is the number of defaults in the pool, M is the pool size, and R is the recovery rate.

23.1.2 Common Assumptions and Limitations

23.1.2.1 Risk-Neutral vs. Real-World

Credit Pool Loss models do not have a risk-neutral configuration.

23.2 Generalized Poisson Realized Loss Model

23.2.1 Overview

The Generalized Poisson Realized Loss Model is driven by n independent Poisson processes, each of which has a fixed intensity λ_i . From this, Adaptiv Analytics defines the expected losses based on a number of factors

Theory Guide [1.13.1](#)

In the simple case of fixed recovery, the cumulative realized fractional portfolio loss $L(t)$ is given by

$$L(t) = \frac{D(t)}{M}(1 - R), \quad (23.2.1)$$

where $D(t)$ is the number of defaults in the pool, M is the pool size, and R is the recovery rate.

For details about the valuation for this model, see the Theory Guide [[7](#), § [1.13.1 Realized Loss](#)].

23.2.2 Properties

Intensities

Fixed intensities for each of the Poisson processes. Array of scalars.

Recovery

Fixed recovery rate. Percentage.

23.2.3 Assumptions and Limitations

23.2.3.1 Fixed Recovery and Intensity

Adaptiv Analytics assumes that both recovery and intensity are fixed, i.e., they are scalar properties without dependencies on other price factors, which do not evolve in time.

23.3 Geometric Ornstein-Uhlenbeck Expected Loss Model

23.3.1 Overview

An equity tranche is exposed to all pool losses up to its detachment point (B) before maturity time T . In addition, in most cases, a tranche will be protected from early losses by junior tranches, before becoming responsible at attachment point A . The expected loss is therefore defined as a fraction, such that:

Theory Guide [1.13.2](#)

The expectation of loss for a general tranche $\bar{L}_{A,B,T}$ expressed in this way can be calculated from the bounding equity tranches by subtraction:

$$\bar{L}_{A,B,T} = \frac{\bar{L}_{B,T} - \bar{L}_{A,T}}{B - A}. \quad (23.3.1)$$

The Geometric Ornstein-Uhlenbeck Expected Loss Model simulates values of expected losses by defining artificial ‘rates’, $\bar{L} = N(1 - \exp[-r_{B,T}T])$, which express the rate of expected loss. In turn, such rates form a 2-dimensional surface of maturity and detachment point, which can be interpolated bi-linearly, or extrapolated flat to encompass the [maturity, detachment] space.

In simulation, these rates can be driven using an Ornstein-Uhlenbeck process, such that the rates can be modelled as:

Theory Guide [1.13.2](#)

This driver is applied with constant volatility σ to simulate loss rates by

$$r_{B,T}(t) = R_{B,T}(t) \exp \left(-\frac{1}{2} \sigma^2 \left(\frac{1 - e^{-2\alpha t}}{2\alpha} \right) + \sigma Y(t) \right), \quad (23.3.2)$$

where $R_{B,T}(t)$ is a deterministic function, which by this construction is the mean of $r_{B,T}(t)$:

$$\mathbb{E}(r_{B,T}(t)) = R_{B,T}(t). \quad (23.3.3)$$

Owing to the nature of the Ornstein-Uhlenbeck process such rates are always positive, and, on account of a single common factor, ensure arbitrage free conditions in maturity and detachment.

For details about the valuation for this model, see the Theory Guide [[7](#), § [1.13.2 Expected Loss](#)].

23.3.1.1 Bespoke Credit Pools

A bespoke credit pool may be created, and expected loss for such a pool calculated, by reference to a reference pool.

Theory Guide [1.13.2.2](#)

The detachment point of a bespoke equity tranche is mapped to an equivalent reference tranche detachment point according to the following formula:

$$B_{\text{index}} = B_{\text{bespoke}} \left(\frac{\bar{L}_{1,T}^{\text{index}}}{\bar{L}_{1,T}^{\text{bespoke}}} \right)^w, \quad (23.3.4)$$

where w is the Reference Factor on the expected loss price factor.

23.3.2 Properties

Blend Model

In Adaptiv Analytics, drift Models (see below) may be blended with a long term target rate $\theta(B)$. The blending can either be executed via a combination converging to $\theta(B)$ via the `Blend` method, or including the suppression of exponential drift via the `Log Blend` method. See the Theory Guide, Section 1.13.2 or more details.

Drift Model

Adaptiv Analytics offers a choice for the long term behaviour of the mean rate; this can either be a `Drift to Forward` (whereby the model will tend toward the initial forward rate), or `Drift to Spot`, for which the model will drift toward the spot rate at $t = 0$. See the Theory Guide, Section 1.13.2 for more details.

Reversion Level

Mean reversion level curve.

Reversion Speed

Mean reversion speed. Scalar.

Volatility

Volatility of the asset. Scalar.

23.3.3 Assumptions and Limitations

There are no specific assumptions and limitations associated with the Adaptiv Analytics implementation of this model.

Chapter 24

Recovery Rate Models

24.1 Overview

In Adaptiv Analytics, there is a distinction between the recovery rate price factor, and the homonymous attribute on the survival probability price factor.

The `Recovery Rate` attribute on the survival probability price factor may be used in pricing risky credit derivatives and in bootstrapping the CDS curve. Meanwhile, the `Recovery Rate` price factor may be referred to as the realised recovery rate, and is used to value scenarios where a default event has already occurred. The models in this section are used for the `Recovery Rate` price factor.

24.1.1 Common Assumptions and Limitations

In the real-world, recovery rates for multiple defaults in the same sector are not independent. In general, recovery rates are lower for an idiosyncratic default than if there is general pressure on an industry causing multiple defaults. For example, an airline likely secures its loans with its aircraft. But if several airlines default simultaneously, the market would be flooded with used aircraft.

This kind of industry- or sector- wide correlation is not modelled in Adaptiv Analytics.

24.2 IRC Recovery Rate Model

24.2.1 Overview

Unlike most of the stochastic models in Adaptiv Analytics, the IRC Recovery Rate Model has no associated process (therefore, no temporal state) associated with it. Instead, the model samples from a Beta distribution.

Theory Guide [1.15.2](#)

Since the mean of the Beta distribution is

$$\mu = \frac{\alpha}{\alpha + \beta}, \quad (24.2.1)$$

by fixing the mean μ we have constrained β to be:

$$\beta = \alpha \left(\frac{1}{\mu} - 1 \right). \quad (24.2.2)$$

Thus, only the α parameter of the beta model is required.

For details about the valuation for this model, see the Theory Guide [7, § [1.15.2 IRC Recovery Rate Model](#)].

24.2.2 Properties

Alpha

The *alpha* parameter from the beta distribution.

Issuer

Issuer ID, which identifies credit rating to use.

24.2.3 Assumptions and Limitations

24.2.3.1 Subordination

Adaptiv Analytics assumes that recovery rates vary by subordination; thus, different deals against the same obligor may have its own mean and distribution, and may obtain a different recovery rate. However, these instances share a single risk factor and are thus perfectly correlated.

24.3 Multi-Factor Diffusion Recovery Rate Model

24.3.1 Overview

In the Multi-Factor Diffusion Recovery Rate Model, recovery rates are simulated using a set of N correlated systemic Wiener processes, plus an independent idiosyncratic Wiener process that is obligor specific.

Adaptiv Analytics then joins these marginal processes through a weighted N factor Gaussian copula, such that a single Wiener process is produced for each obligor.

Theory Guide [1.15.1](#)

The value of a recovery rate-specific Wiener process at time t , $W_m(t)$, is converted to a standard normal variable Z_t and the cumulative probability of this variable is mapped to the inverse distribution function of the recovery rate:

$$R(t) = \Phi \left(\frac{Z_t + (1 + a^2)^{1/2} \Phi^{-1}(R_0)}{a} \right), \quad (24.3.1)$$

where $Z_t = W_m(t)t^{-1/2}$.

Above, $a > 0$ is the shape parameter for a distribution similar to the beta distribution with mean R_0 . This distribution can be written as follows:

Theory Guide [1.15.1](#)

$$F(R) = \Phi \left(a \Phi^{-1}(R) - (1 + a^2)^{1/2} \Phi^{-1}(R_0) \right), \quad (24.3.2)$$

Recovery Rates generated in this way may be directly related to Credit Rating models.

Theory Guide [1.15.1](#)

The systemic processes driving the recovery rate model may be shared with those driving the credit worthiness model for matrix transitions so as to facilitate the construction of joint distributions of creditworthiness and recovery rate.

For details about the valuation for this model, see the Theory Guide [7, § [1.15.1 Multi-factor Diffusion Recovery Rate Model](#)].

24.3.2 Properties

Idiosyncratic Weight

Weight of the idiosyncratic driver. Scalar.

PCA Factors

Yes to set correlations between drivers to zero with Adaptiv Analytics calculating normalizing coefficients; No for correlated drivers with weights assumed to be already normalised and normalizing coefficient set to 1.

Shape

Recovery rate-specific shape parameter (smaller values for a result in higher variances for the

recovery rate). Scalar.

Significance Threshold

Any driver weights with absolute value less than the threshold are rounded to zero. Scalar.

Weights

List of weights of the assets with respect to the driver.

24.3.3 Assumptions and Limitations**24.3.3.1 Significance Threshold**

This model has a significance threshold, the effect of which is similar to that of the Multi-Factor GBM models. See Section [14.7.3.1](#).

Chapter 25

Exposure at Default Models

25.1 Diffusion Exposure At Default Model

25.1.1 Overview

In a market risk simulation that incorporates default, Exposure at Default (EAD) is the price factor required to price counterparty deals under a default scenario.

In Adaptiv Analytics, EAD is represented as a non-parametric function, which is expressed as a surface dimensioned by time and exposure (quantile). In simulation, exposure values are simulated by interpolating between quantiles with random cumulative probabilities.

Adaptiv Analytics supports only a single Exposure At Default model, the Diffusion Exposure at Default model. The model is driven by a Wiener process, which acts as an abstraction of exposure severity and may be correlated with other models under simulation. From the Wiener process, the model behaves as follows

Theory Guide [1.16.1](#)

The model selects a cumulative probability p with which to select EAD from the marginal cumulative probability of the Wiener process:

$$p(t) = \Phi^{-1} \left(\frac{W(t)}{\sqrt{t}} \right). \quad (25.1.1)$$

For details about the valuation for this model, see the Theory Guide [[7](#), § [1.16.1 Diffusion Exposure at Default Model](#)].

25.1.2 Properties

The model has no adjustable properties (accordingly, there is no calibration method in Adaptiv Analytics).

25.1.3 Assumptions and Limitations

There are no specific assumptions and limitations regarding this model beyond those incorporated into the model definition itself.

Chapter 26

Implied Models

26.1 Overview

For price factor models that can be calibrated to initial price factor values, there is an *implied* version of the model where the model parameters are represented by a price factor (see the Theory Guide [7, § 3.4 Implied Models and Bootstrappers]).

26.2 Clewlow Strickland Implied Forward Price Model (CSImpliedForwardPriceModel)

26.2.1 Properties

na

26.3 GBM Asset Price Term Structure Model (Implied) (GBMAssetPriceTSModelImplied)

26.3.1 Properties

Risk Premium

This represents the extra return above the risk-free rate that an investor needs in order to be compensated for the risk of a certain investment. Scalar.

26.4 Heston 1 Factor Asset Price Model (Implied) (Heston1FactorAssetPriceModelImplied)

26.4.1 Properties

Risk Premium

This represents the extra return above the risk-free rate that an investor needs in order to be compensated for the risk of a certain investment. Scalar.

26.5 Heston 2 Factor Asset Price Model (Implied) (Heston2FactorAssetPriceModelImplied)

26.5.1 Properties

Risk Premium

This represents the extra return above the risk-free rate that an investor needs in order to be

compensated for the risk of a certain investment. Scalar.

26.6 Hull White 1 Factor Implied Inflation Rate Model (HullWhite1FactorImpliedInflationRateModel)

26.6.1 Properties

Lambda

Constant market price of risk. Scalar.

26.7 Hull White 1 Factor Implied Interest Rate Model (HullWhite1FactorImpliedInterestRateModel)

26.7.1 Properties

Lambda

Constant market price of risk.

26.8 Hull White 2 Factor Implied Interest Rate Model (HullWhite2FactorImpliedInterestRateModel)

26.8.1 Properties

Lambda 1

Constant market price of risk of first factor. Scalar.

Lambda 2

Constant market price of risk of second factor. Scalar.

26.9 Multi-Factor GBM Asset Price Term Structure Model (Implied) (MultiGBMAssetPriceTSMModelImplied)

26.9.1 Properties

Active Factors

All, Idiosyncratic, General or None Specifies which risk factors should be taken into account. If set to All or Idiosyncratic then the model has idiosyncratic drivers and the idiosyncratic weights are non-zero. If set to All or General then the model has systematic drivers and the systematic weights are non-zero.

Idiosyncratic Weight

Weight of the idiosyncratic driver.

PCA Factors

Yes or No. Yes to set correlations between drivers to zero with Adaptiv Analytics calculating normalizing coefficients; No for correlated drivers with weights assumed to be already normalised and normalizing coefficient set to 1.

Risk Premium

This represents the extra return above the risk-free rate that an investor needs in order to be compensated for the risk of a certain investment. Scalar.

Significance Threshold

Any driver weights with absolute value less than the threshold are rounded to zero. Scalar.

Weights

List of weights of the assets with respect to the driver.

**26.10 Script Model Hybrid 1-Factor Hull-White Implied
(ScriptModelHybridHullWhiteImplied)****26.10.1 Properties**

na

**26.11 Script Model Interest Rate Hull White Implied
(ScriptModelInterestRateHullWhiteImplied)****26.11.1 Properties**

na

Part IV

Model Calibrations

Chapter 27

Calibration

27.1 Overview

Calibration refers to the calculation of price factor model parameters, either from historical data or from market data. Most calibrations in Adaptiv Analytics are historical, i.e., derive parameters from historical data, supplied to the system via a Market Data Archive file (see Section 27.1.1.3).

The remaining calibrations, which typically using a bootstrap approach to set stochastic model parameters from market data, are discussed in the Risk Neutral Calibration Section.

27.1.1 Common Properties

Adaptiv Analytics allows a choice of historical calibration for most stochastic models: Statistics Set Based Calibration, or Maximum Likelihood estimation (MLE) methods. These two methods produce mathematically similar results, although have different computational cost and sensitivity to data quality and outliers.

27.1.1.1 Statistics Set Calibration

Adaptiv Analytics calculates supports the following statistics from historical data, which may be pre-computed (e.g., saved to file and restored to Adaptiv Analytics), or calculated live during calibration:

Theory Guide 3.3

Statistic	Notation	Description
Drift	$\hat{\mu}$	annualized mean of returns
Volatility	$\hat{\sigma}$	annualized standard deviation of returns
Correlation	$\hat{\rho}$	correlation between returns on two factors
Skewness	$\hat{\kappa}_3$	skewness of returns
Kurtosis	$\hat{\kappa}_4$	kurtosis of returns
Long Run Mean	$\hat{\theta}, \hat{\Theta}$	value to which the factor value reverts
Mean Reversion Speed	$\hat{\alpha}$	annualized mean reversion speed
Reversion Volatility	$\hat{\sigma}$	annualized standard deviation of returns, adjusted for mean reversion
Lambdas	$\lambda_1, \lambda_2, \lambda_3, \lambda_4$	parameters of generalized lambda distribution
Beta	$\hat{\beta}$	linear regression coefficient of returns with respect to returns on another factor

The statistics are computed using time series extracted from the Market Data Archive (Section 27.1.1.3). Within each time series, Adaptiv Analytics defines a return as $r_i = y'_i - y_i$, where y_i and y'_i is defined

from the archive either directly (via the `Diff` setting) or logarithmically (via the `Log` setting). The series are additionally weighted by a decay, such that older returns have less influence than more recent.

Adaptiv Analytics uses analytic formulas, with appropriate `Diff` and `Log` forms, to calculate the statistics above; for details on these formulas, see the Theory Guide [7, § 3.3.1 [Drift, Volatility and Correlation](#) through 3.3.5 [Beta](#)] for more details.

27.1.1.2 Maximum Likelihood Estimation

Maximum likelihood estimation is an alternative method for calibration of price factor model parameters from historical data. The method assumes a form for the distribution or process that best describes the evolution of calibration data in the market data archive, and subsequently uses an unbiased estimator to calculate model parameters that maximise a log likelihood function representing the probability that the model is correct.

The following distributions and processes can be calibrated via maximum likelihood estimation in Adaptiv Analytics:

Normal Distribution Assumes that the historic data are samples from a normal distribution, and defines a likelihood function to estimate mean and variance. See the Theory Guide [7, § 3.2.1 [Normal Distribution](#)].

Ornstein-Uhlenbeck Process Assumes the samples in the historical data are realisations of a single Ornstein-Uhlenbeck process:

Theory Guide [3.2.2](#)

Suppose there are observations y_1, \dots, y_N of $Y(t)$ at times t_1, \dots, t_N , and observations y'_1, \dots, y'_N of $Y(t)$ at times t'_1, \dots, t'_N , where $t'_i = t_i + \delta \leq t_{i+1}$ and $\delta > 0$. Define the increments

$$X_i = Y(t'_i) - e^{-\alpha\delta}Y(t_i) = \theta(1 - e^{-\alpha\delta}) + \sigma \int_{t_i}^{t'_i} e^{-\alpha(t'_i-s)} dW(s). \quad (27.1.1)$$

Then X_1, \dots, X_N are independent identically distributed normal variables with mean $\mu = \theta(1 - e^{-\alpha\delta})$ and variance $\nu^2 = \sigma^2(1 - e^{-2\alpha\delta})/2\alpha$.

Parameters α , θ and σ (mean reversion rate, long run mean and volatility) are estimated. Adaptiv Analytics supports either unconditional estimates α , θ and σ free) or estimates conditioned on α , θ , or α and θ simultaneously. See the Theory Guide [7, § 3.2.2 [Ornstein-Uhlenbeck Process](#)].

Multivariate Normal Distribution Similar to the one-dimensional Normal distribution, Adaptiv Analytics can estimate a vector of means and positive definite covariance matrix using an appropriate log likelihood function. For this purpose Adaptiv Analytics employs the method described by Anderson and Olkin [8], described in the Theory Guide [7, § 3.2.3 [Multivariate Normal Distribution](#)].

Correlated Drifted Brownian Motions Assumes the samples in the historical data are realisations from a correlated vector of Brownian motions:

Theory Guide [3.2.4](#)

Suppose there are observations y_1, \dots, y_N of $Y(t)$ at times t_1, \dots, t_N , and observations y'_1, \dots, y'_N of $Y(t)$ at times t'_1, \dots, t'_N , where $t'_i = t_i + \delta \leq t_{i+1}$ and $\delta > 0$. Define the increments X_1, \dots, X_N

by

$$X_{ik} = Y_k(t'_i) - Y_k(t_i) = \mu_k \delta + \sigma_k (W_k(t'_i) - W_k(t_i)). \quad (27.1.2)$$

Then X_1, \dots, X_N are independent identically distributed multivariate normal variables with mean vector $\delta\mu$ and covariance matrix Σ , where $\Sigma_{kl} = \rho_{kl}\sigma_k\sigma_l\delta$.

Parameters μ (drift), σ (variance) and ρ (correlation between Brownian motions) are estimated simultaneously by maximum likelihood methods, using a log likelihood defined as a combination of the log likelihood function for a single Brownian motion and a correlation factor; see the Theory Guide [7, §3.2.4 Correlated Drifted Brownian Motions].

Correlated Ornstein-Uhlenbeck Processes Assumes the samples in the historical data are realisations from a correlated vector of Ornstein-Uhlenbeck processes:

Theory Guide 3.2.5

Suppose there are observations y_1, \dots, y_N of $Y(t)$ at times t_1, \dots, t_N , and observations y'_1, \dots, y'_N of $Y(t)$ at times t'_1, \dots, t'_N , where $t'_i = t_i + \delta \leq t_{i+1}$ and $\delta > 0$. Define the increments X_1, \dots, X_N by

$$X_{ik} = Y_k(t'_i) - e^{-\alpha_k \delta} Y_k(t_i) = \theta_k (1 - e^{-\alpha_k \delta}) + \sigma_k \int_{t_i}^{t'_i} e^{-\alpha_k (t'_i - s)} dW_k(s). \quad (27.1.3)$$

Then X_1, \dots, X_N are independent identically distributed multivariate normal variables with mean vector μ and covariance matrix Σ , where $\mu_k = \theta_k (1 - e^{-\alpha_k \delta})$, $\Sigma_{kl} = \rho_{kl} \sigma_k \sigma_l (1 - e^{-(\alpha_k + \alpha_l) \delta}) / (\alpha_k + \alpha_l)$.

Parameters α (mean reversion speed) θ (long running mean), σ (variance) and ρ (correlation between Ornstein-Uhlenbeck processes) are estimated simultaneously by maximum likelihood methods, using a log likelihood defined as a combination of the log likelihood function for a single Ornstein-Uhlenbeck process and a correlation factor; see the Theory Guide [7, §3.2.5 Correlated Ornstein-Uhlenbeck Processes].

27.1.1.3 Market Data Archive

For price factor models simulating price factor values at future dates, simulations are performed in the real world measure. Therefore, historical data is an appropriate medium for calculation. In Adaptiv Analytics, the Market Data archive holds such data in the form of time series, which is used for this purpose.

Theory Guide 3.1.1

Data retrieval constructs *time series* from the archive. A time series for a set of factors \mathcal{F} comprises:

- A sequence of historical start dates t_1, \dots, t_N with $t_i < t_{i+1}$.
- For each factor $P \in \mathcal{F}$, a factor value P_i for each start date t_i .
- A sequence of historical end dates t'_1, \dots, t'_N with $t_i < t'_i$.
- For each factor $P \in \mathcal{F}$, a factor value P'_i for each end date t'_i .
- An horizon period $\delta > 0$.

Time series in Adaptiv Analytics are constructed from a set of data retrieval parameters, which include start and end dates, a sample period term (period between start and end dates; can be used to

specify a period after the start date or before the end date, and is ignored if both start and end dates are specified), frequency term (difference between consecutive start dates), horizon term (difference between associated start and end dates), and (optionally) a holiday calendar.

Horizon Period Adaptiv Analytics uses a horizon period (δ defined as follows):

Theory Guide [3.1.1.1](#)

For an horizon term of d days, w weeks, m months and y years:

$$\delta = y + \frac{m}{12} + \frac{7w}{365} + \frac{d}{B}, \quad (27.1.4)$$

where B is the number of business days per year.

Data Cleaning: Adaptiv Analytics supports several data cleaning tools:

- Capping or Flooring - data whose values fall outside specified bounds (e.g., upper or lower limits) are removed or replaced by the upper/lower bounds.
- Outlier removal - data whose Z -score (i.e., error probability) falls outside a specified threshold probability are removed. The z score is defined as

Theory Guide [3.1.2.2](#)

$$z_i = \frac{P_i - \mu_i}{\sigma_i + \gamma}, \quad (27.1.5)$$

where μ_i and σ_i are the local mean and standard deviation calculated from Window Size samples around P_i but excluding P_i , and γ is the Perturbation, which is needed in case rates are close to being constant around P_i .

The default threshold in Adaptiv Analytics is 3.09, corresponding to a 0.1% chance of false positive outlier identification.

Data Filling: Adaptiv Analytics supports a correlated Brownian Bridge method for missing data filling, applied to a multi-dimensional price factor at each missing date or sequence of missing dates. The Brownian Bridge method is described in detail the Theory Guide [[7](#), § [C.1.1 Missing Data Filling](#)].

Theory Guide [3.1.2.3](#)

The parameters of the method are: the Random Seed; the Return Method, which determines whether the factor values are modeled as normal or lognormal; and the Window Size, which determines the number of days of historical data used to calculate the local volatility and drift; Horizon and Business Days In Year, which determine the horizon period δ (Section [3.1.1.1](#)) used to calculate the local volatility and drift.

27.1.2 Common Assumptions and Limitations

27.1.2.1 Market Data Archive Currencies

Asset prices in the market data archive are assumed to be in the asset currency.

27.1.2.2 Market Data Archive Data Requirements

For a time series in the market data archive starting at time S and ending at E , with sample period term τ , the following validation is applied.

Theory Guide [3.1.1](#)

If both S and E are specified then they must satisfy $S < E$. If τ is specified then it must satisfy $\tau > 0$ d.

Furthermore:

Theory Guide [3.1.1](#)

The lower bound L and upper bound U for the time series dates are defined in Table [3.1.1](#) according to which parameters are specified.

If there are no archive dates T for which $L \leq T \leq U$ then no series is generated.

27.1.2.3 Decay Factor

Adaptiv Analytics allows a user defined decay factor, $\lambda \in (0, 1]$, with a default value of $\lambda = 0.97$. The effect of this decay in statistics calculations is to weight each point in the series by λ^n , where n is the index of the data point in reverse order of time.

27.1.2.4 Missing Returns

Missing returns are defined as either:

- For Diff statistics, where price P_i or P'_i is missing
- For Log statistics, where price P_i or P'_i is missing, or either are less than or equal to zero.

The decay factor is incremented only for non-missing returns. In the presence of missing returns, single factor statistics (e.g., drift, volatility) are calculated as follows:

Theory Guide [3.3.6](#)

Considering the returns in reverse order of time (t_N first and t_1 last), define $\omega_i = 1$ for the first non-missing return, $\omega_i = \lambda$ for the second non-missing return, $\omega_i = \lambda^2$ for the third non-missing return, and so on. Define $\omega_i = 0$ if the return at t_i is missing. The average return is the average of the non-missing returns:

$$\bar{r} = \frac{\sum_{i=1}^N [\omega_i > 0] r_i}{\sum_{i=1}^N [\omega_i > 0]}. \quad (27.1.6)$$

Missing returns are also considered in correlations, as follows:

Theory Guide [3.3.6.1](#)

The correlation matrix is positive semidefinite because it has the decomposition $\hat{\rho} = RR^T$, where R is the $n \times N$ matrix

$$R_{ki} = \frac{\sqrt{\omega_{ik}}(r_{ik} - \bar{r}_k)}{V_k} \quad (27.1.7)$$

and n is the number of factor values.

where $\omega_{ik} = \lambda^{h-1}$ when r_{ik} is the h^{th} non-missing return, $\omega_{ik} = 0$ when r_{ik} is missing, and

$$V_k = \left(\sum_{i=1}^N \omega_{ik} (r_{ik} - \bar{r}_k)^2 \right)^{1/2} \quad (27.1.8)$$

$$\bar{r}_k = \frac{\sum_{i=1}^N [\omega_{ik} > 0] r_{ik}}{\sum_{i=1}^N [\omega_{ik} > 0]}. \quad (27.1.9)$$

Note that mean \bar{r}_k is calculated using the sum of all values where $\omega_{ik} > 0$, i.e., Adaptiv Analytics uses equal weighting for the calculation of the mean.

27.1.2.5 Regime changes in historical data archive

When provided with a time series from which to estimate statistics, Adaptiv Analytics will employ all data in the series for calibration notwithstanding decay factor adjustments. Consequently, where a single set of statistics does not provide a good depiction of the underlying time series from which the price factor is calibrated, unrealistic or unphysical statistics may be estimated. Adaptiv Analytics does not provide tools to identify or adapt to such situations.

Chapter 28

Asset Price Model Calibrations

28.1 GBM Asset Price Model

28.1.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.5.1 GBM Model].

28.1.2 Calibration Method

The GBM Asset Price Model can be calibrated using the `GBMAssetPriceCalibration` method in `Adaptiv Analytics`.

Theory Guide [3.5.1](#)

The calibration uses Log statistics of the asset price (Section [3.3](#)). These statistics provide an estimate of σ and $\mu - \sigma^2/2$. The calibration sets $\sigma = \hat{\sigma}$ and $\mu = \hat{\mu} + \hat{\sigma}^2/2$.

28.1.3 Properties

Use Pre Computed Statistics If set to `Yes`, use pre-computed statistics derived from historical market rates; if `No` use archive market data directly.

28.1.4 Assumptions and Limitations

There are no specific assumptions or limitations in the calibration of this model; see general assumptions and limitations, Section [27.1.2](#).

28.2 GBM Asset Price Term Structure Model

28.2.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.5.5 GBM Term Structure Model].

28.2.2 Calibration Method

Adaptiv Analytics has separate variants of the GBM Asset Price Term Structure Model for FX and other Asset Prices. These use the `FXRateTSExtrapolationCalibration` class for FX, or the `GBM-AssetPriceTSCalibration` class otherwise.

28.2.2.1 Standard (Asset Price) Calibration

The Standard GBM Asset Price Term Structure Model Calibration can be used for all asset prices (including FX rates), and can be used under real world or risk neutral measures.

Theory Guide 3.5.5.1

For the drift curve, the calibration uses Log statistics of the asset price (Section 3.3) and sets $\bar{\mu}(t) = \hat{\mu} + \bar{\sigma}(t)^2/2$ so that the evolved price is

$$S(t) = S(0) \exp \left(\bar{\mu}(t)t + \int_0^t \sigma(s) dW(s) \right). \quad (28.2.1)$$

Two variants exist for calibration of the volatility curve, depending on the `Vol Calibration` parameter as follows.

Theory Guide 3.5.5.1

When the calibration parameter `Vol Calibration` is `Historical`, the calibration uses Log statistics of the asset price (Section 3.3) and sets $\bar{\sigma}(t) = \hat{\sigma}$.

When `Vol Calibration` is `Implied` and there are implied volatilities for the asset price S then the calibration sets $\bar{\sigma}(\tau) = \sigma_S(\tau)$ for each time-to-expiry point τ on the implied volatility surface, where σ_S is the ATM implied volatility of S .

28.2.2.2 FX Rate Calibration

The FX Rate TS Calibration can be used only for FX rates, and includes an additional choice of calibration method for the volatility curve calibration and an additional choice of calibration method for drift curve calibration. See Section 28.2.3.3 for details.

The drift curve calibration may use `Historical Calibration` (i.e., the same method as described in Section 28.2.2.1), or `Historical Interest Rate calibration`, defined by the `Drift Calibration` parameter. For `Historical Interest Rate`, the drift curve is implied from forward FX rates, which are in turn calculated from an average of recent historic interest rates.

Theory Guide 3.5.5.2.2

Therefore, the drift implied from forward FX rates is given by

$$\bar{\mu}(t) = r(0, t) - \tilde{r}(0, t). \quad (28.2.2)$$

The calibration calculation sets $\bar{\mu}(t)$ to the average of the difference between historical zero rates over the dates in the Averaging Period.

where $r(0, t)$ and $\bar{r}(0, t)$ are the zero rates in the domestic and foreign currency, respectively.

The volatility curve calibration for the FX Rate GBM Term Structure Model allows both Historical and Implied methods (see Section 28.2.2.1), as well as an additional Implied Extrapolated volatility curve calibration method. This extra method offers calibration of the volatility curve over periods longer than that for which implied FX rate volatilities are commonly available. The method uses iterative optimisation to refine a parametric form for long term volatility, bounded by an iteratively refined long term volatility β .

Theory Guide 3.5.5.2.1

The implied volatility curve is extrapolated using the parametric form

$$\bar{\sigma}(t)^2 = \frac{\beta(1 - e^{-\alpha t})}{t}. \quad (28.2.3)$$

Once optimised, the parametric form for the implied volatility curve is blended with the most recent volatilities available from the market data archive to form a calibrated volatility curve.

28.2.3 Properties

28.2.3.1 Common Properties

The following properties are common to both calibration methods.

Risk Neutral Drift The Risk Neutral Drift flag for the underlying stochastic models; Yes for a Risk Neutral version of the model or No for a Real World version.

Set Risk Neutral Drift Flag to indicate whether the calibration can override the Risk Neutral Drift flag of the model. Yes or No.

Use Pre Computed Statistics If set to Yes, use pre-computed statistics derived from historical market rates; if No use archive market data directly.

28.2.3.2 Standard (Asset Price) Calibration

The following properties are additionally defined for the Asset Price variant of this calibration.

Vol Calibration Option to determine which volatility calibration to use: Implied or Historical. See Section 28.2.2.1.

28.2.3.3 FX Calibration

The following properties are additionally defined for the FX variant of this calibration.

Averaging Period The period over which averaging is to occur. Must be less than the calibration period. Scalar.

Calibration Date The date of the calibration.

Calibration Period The period over which the model is to be calibrated. Scalar.

Convergence Tolerance The maximum tolerance. Model will be incrementally recalculated until the β (long term volatility bound) is less than the convergence tolerance. Scalar.

Drift Calibration Option to determine which drift calibration to use: Historical Drift or Historical Interest Rates. See Section 28.2.2.2.

Vol Calibration Option to determine which volatility calibration to use: Implied, Implied Extrapolated, or Historical. See Section 28.2.2.2.

28.2.4 Assumptions and Limitations

There are no specific assumptions or limitations in the calibration of this model; see general assumptions and limitations, Section 27.1.2.

28.3 GOU Asset Price Model

28.3.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.5.7 GOU Model].

28.3.2 Calibration Method

The GOU Asset Price Model can be calibrated using the `GOUAssetPriceCalibration` method in `Adaptiv Analytics`. The method allows both pre-computed statistics (whereby α and σ are set from the Log statistics of the Asset price) for calibration or maximum likelihood estimation.

28.3.2.1 Maximum Likelihood Estimation

For calibration of the GOU Asset Price Model by Maximum likelihood estimation, `Adaptiv Analytics` constructs two time series of asset price observations at times $t_i \dots t_N$ and $t'_i \dots t'_N$ where $t_i < t'_i \leq t_{i+1}$. Exponential detrending may then (optionally) be applied to both time series if `Detrended Time Series` is Yes.

Theory Guide 3.5.7.2

The detrended values are given by $\tilde{S}_i = S_i e^{-a-bt_i}$ and $\tilde{S}'_i = S'_i e^{-a-bt'_i}$. If `Detrended Time Series` is No then define $\tilde{S}_i = S_i$ and $\tilde{S}'_i = S'_i$.

Finally, parameters are estimated by the maximum likelihood method for an Ornstein-Uhlenbeck process as outlined Section 27.1.1.2, with $y_i = \log(\tilde{S}_i)$ and $y'_i = \log(\tilde{S}'_i)$.

The Maximum Likelihood estimation calibration procedure optionally allows fixed mean reversion and long run mean, via the `Condition on Alpha` and the `Condition on Theta` parameters.

28.3.3 Properties

Calibration Method Choice of calibration method; Pre Computed Statistics or MLE. See Section 27.1.1.

Use Absolute Theta The long running mean (θ) will be calibrated as an absolute quantity if the `Use Absolute Theta` property is Yes. Hence, for statistics set calibrations $\theta = \hat{\theta}$, while for maximum likelihood estimation calibrations θ is estimated from the maximum likelihood method for a Ornstein-Uhlenbeck process (see Section 27.1.1.2). If `Use Absolute Theta` is No, $\log S(0)$ is subtracted.

Use Mu The model can allow or disallow the calibration of μ ; if No, $\mu = 0$. Otherwise, if Yes, $\mu = \hat{\mu}$ (Statistics set calibration) or $\mu = b$ (Maximum Likelihood estimation, when `Detrended Time Series` is also Yes; see Section 28.3.2.1).

28.3.3.1 Maximum Likelihood Estimation

The following properties are additionally defined for the Maximum Likelihood Estimation calibration method.

Detrended Time Series Yes or No. Flag to determine if exponential detrending should be applied to the time series used for calibration.

Condition On Alpha If Yes, value of the mean reversion parameter is fixed to that supplied via parameter Alpha. If No, mean reversion will be found by calibration.

Alpha Fixed Value of mean reversion to apply in calibration; will be used if `Condition On Alpha` is Yes. Scalar.

Condition On Theta If Yes, value of the long run mean property is fixed to that supplied via parameter Theta. If No, long run mean will be found by calibration.

Theta Fixed Value of the long run mean to apply in calibration; will be used if Condition On Theta is Yes. Scalar.

28.3.4 Assumptions and Limitations

There are no specific assumptions or limitations in the calibration of this model; see general assumptions and limitations, Section [27.1.2](#).

28.4 Multi-Factor GBM Asset Price Model

28.4.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.5.2 Multi-Factor GBM Model: PCA Calibration, § 3.5.4 Multi-Factor GBM Model: Beta Calibration and § 3.5.3 Multi-Factor GBM Model: Regression Calibration].

28.4.2 Calibration Method

Adaptiv Analytics includes three variants of the Multi-Factor GBM Asset Price Model calibration; a PCA calibration method, a beta calibration method, and a regression calibration. These use the `MultiGBMAssetPricePCACalibration`, the `MultiGBMAssetPriceBetaCalibration`, or the `MultiGBMAssetPriceRegressionCalibration` classes, respectively.

28.4.2.1 PCA Calibration

Adaptiv Analytics contains a PCA calibration method for the Multi-Factor GBM Asset Price Model. In this method, a small number of independent driving factors are calibrated by application of principal component analysis, with the driving factors together defining a model that encompasses a given fraction of variability in an archive of historical prices.

As per general PCA methods, the components recovered are orthogonal, with the first principal component being the component of the original vector of prices with the greatest variance, the second the component with the second greatest variance, and so on.

For PCA calibration in Adaptiv Analytics, PCA groups must be specified by the grouping file. Each group will be calibrated by a common set of driving factors for which appropriate weights are determined by the calibration. For a vector (group) of n prices, related by $n \times n$ covariance matrix C :

Theory Guide 3.5.2

The calibration uses Log statistics of the underlying prices (Section 3.3), so that the covariance matrix is given by $C_{ij} = \hat{\sigma}_i \hat{\sigma}_j \hat{\rho}_{ij}$. There exists an orthogonal matrix Q such that $C = Q\Lambda Q^T$ where $\Lambda = \text{diag}(\lambda_1, \dots, \lambda_n)$ and $\lambda_1 \geq \dots \geq \lambda_n \geq 0$ are the eigenvalues of C . The columns of Q are the eigenvectors of C and define the principal components. Define the matrix of weights $\Omega = \Sigma^{-1}Q\Lambda^{1/2}$, where $\Sigma = \text{diag}(\hat{\sigma}_1, \dots, \hat{\sigma}_n)$. Then $(\Sigma\Omega)^T(\Sigma\Omega) = \Lambda$ and $\Omega\Omega^T = \hat{\rho}$. The weight of i^{th} price with respect to the k^{th} principal component driver is $\omega_{ik} = Q_{ik}\sqrt{\lambda_k}/\hat{\sigma}_i$. Since $\Omega\Omega^T = \hat{\rho}$, we have $\sum_{k=1}^n \omega_{ik}^2 = 1$.

28.4.2.2 Regression Calibration

Regression Calibration in Adaptiv Analytics takes a list of driving factors, and uses linear regression to determine the weight of each for each price to be simulated.

The calibration can be applied to each underlying asset price S , independently, which will be calibrated using a set of driving factors X_1, \dots, X_m .

Theory Guide 3.5.3

The calibration performs a linear regression of the historical returns of S against the historical returns of the drivers X_k .

Let σ and μ denote the volatility and drift of S , and let σ_k and μ_k denote the volatility and drift of X_k . Define the normalized returns

$$y = \frac{\Delta \log S - \mu}{\sigma} \quad (28.4.1)$$

$$x_k = \frac{\Delta \log X_k - \mu_k}{\sigma_k}. \quad (28.4.2)$$

The calibration seeks coefficients b_1, \dots, b_m that maximize the likelihood that $y = b \cdot x$ given the historical data.

The regression calibration then uses the Log statistics of asset price to calculate weights (systematic and idiosyncratic) which minimise the variance as a function of b , $V(b)$, using single value composition. For full details, refer to the Theory Guide [7, §3.5.3 Multi-Factor GBM Model: Regression Calibration].

28.4.2.3 Beta Calibration

Adaptiv Analytics supports beta calibration for traded and non-traded (insufficient or unavailable history, such that $\hat{\mu}$ and $\hat{\sigma}$ are unavailable and $\hat{\beta}$ must be overridden) assets, using a single systematic driver and optional idiosyncratic driver.

Theory Guide 3.5.4

The model parameters are calculated from statistics according to Table 3.2, where

- $\hat{\beta}$ is the beta of the asset price with respect to the index factor
- $\hat{\sigma}$ and $\hat{\mu}$ are the volatility and drift of the asset price
- $\hat{\sigma}_I$ and $\hat{\mu}_I$ are the volatility and drift of the index factor
- $\hat{\rho} = \hat{\beta}\hat{\sigma}_I/\hat{\sigma}$ is the correlation between the asset price and the index factor
- Θ is the calibration parameter Significance Threshold
- R is the weight rounding function defined in Section B.1.3.

Theory Guide 3.5.4

	Idiosyncratic Factor = Yes and $\hat{\sigma}$ available:	Idiosyncratic Factor = No or $\hat{\sigma}$ not available:
Vol (σ)	$\hat{\sigma}$	$ \hat{\beta} \hat{\sigma}_I$
Weights (ω_1)	$R(\hat{\rho}; \Theta)$	$\hat{\beta}/ \hat{\beta} $
Idiosyncratic Weight (ϵ)	$\sqrt{1 - R(\hat{\rho}; \Theta)^2}$	0
Drift (μ)	$\hat{\sigma}$ and $\hat{\mu}$ available: $\hat{\mu} + \hat{\sigma}^2/2$	$\hat{\sigma}$ or $\hat{\mu}$ not available: $\hat{\mu}_I + \hat{\sigma}_I^2/2$

Similar to the PCA calibration, the grouping of asset prices to systemic drivers is specified in the grouping file.

28.4.3 Properties

The following properties are common for all Multi-Factor GBM Asset Price Model calibrations.

Significance Threshold Any driver weights with absolute value less than the threshold are rounded

to zero. Scalar.

Use Pre Computed Statistics If set to **Yes**, use pre-computed statistics derived from historical market rates; if **No** use archive market data directly.

28.4.3.1 PCA Calibration

The following properties are additionally defined for the PCA calibration.

Idiosyncratic Factor Specifies whether the calibration will allow an idiosyncratic factor. **Yes** or **No**.

Calibrate All In Group If **No**, only primary model parameters are calibrated; otherwise, if **Yes**, calibrate all model parameters.

Explained Variance Target variance that should be accounted for by the PCA calibration. **Adaptiv Analytics** will find the minimum number of factors that explain this level of variance (unless this is greater than the **Number of PCA Factors**). Scalar.

Number of PCA Factors Maximum number of PCA factors to return. **Adaptiv Analytics** will return this number of PCA factors, unless the level of variance specified in **Explained Variance** is achieved by fewer factors. Scalar.

Group By Indication of how to group factors. When **All**, matches everything. Otherwise, will use the **Grouping** file for a matching tag. If blank, uses the **PCA Group** tag.

28.4.3.2 Regression Calibration

The following properties are additionally defined for the price regression calibration.

Drivers List of driving factor (stochastic process) IDs underpinning the model to be calibrated.

Significance Threshold Any driver weights with absolute value less than the threshold are rounded to zero. Scalar.

Use Pre Computed Statistics If set to **Yes**, use pre-computed statistics derived from historical market rates; if **No** use archive market data directly.

28.4.3.3 Beta Calibration

The following properties are additionally defined for the beta calibration.

Idiosyncratic Factor Specifies whether the calibration will allow an idiosyncratic factor. **Yes** or **No**.

Benchmark Identifier for the benchmark (i.e., systematic driver), to be read from the **Grouping** file. String.

28.4.4 Assumptions and Limitations

There are no specific assumptions or limitations in the calibration of this model; see general assumptions and limitations, Section [27.1.2](#).

28.5 Multi-Factor GBM Asset Price Term Structure Model

28.5.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.5.6 Multi-Factor GBM Term Structure Model].

28.5.2 Calibration Method

The Multi-Factor GBM Asset Price Term Structure Model can be calibrated using the `MultiGBMAssetPriceTSRegressionCalibration` method in Adaptiv Analytics.

Adaptiv Analytics calibrates the Multi-Factor GBM Asset Price Term Structure Mode using two independent calculations. First, each underlying asset price is independently calibrated, using the method outlined in Section 28.2. Second, the systematic and idiosyncratic weights of the various factors are calculated using either the PCA or regression calibration methods described in Sections 28.4.2.1 and 28.4.2.2.

28.5.2.1 Regression Calibration

For the regression calibration, curves (both driver and underlying) are synthetically represented as single values, calculated from the statistics of several factor values between the lower and upper tenors. See the Theory Guide [7, § 3.5.3.1 Representation of Underlying and Drivers] for details of how this is performed in Adaptiv Analytics.

28.5.3 Properties

Drivers List of driving factor (stochastic process) IDs underpinning the model to be calibrated.

Risk Neutral Drift The Risk Neutral Drift flag for the underlying stochastic models; `Yes` for a Risk Neutral version of the model or `No` for a Real World version.

Set Risk Neutral Drift Flag to indicate whether the calibration can override the Risk Neutral Drift flag of the model. `Yes` or `No`.

Significance Threshold Any driver weights with absolute value less than the threshold are rounded to zero. Scalar.

Use Pre Computed Statistics If set to `Yes`, use pre-computed statistics derived from historical market rates; if `No` use archive market data directly.

Vol Calibration Option to determine which volatility calibration to use: `Implied` or `Historical`. See Section 28.2.3.2.

28.5.4 Assumptions and Limitations

There are no specific assumptions or limitations in the calibration of this model; see general assumptions and limitations, Section 27.1.2.

28.6 Multi-Factor GBM Asset Price Term Structure Model (Implied)

28.6.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.5.6 Multi-Factor GBM Term Structure Model].

28.6.2 Calibration Method

Adaptiv Analytics includes three variants of the Multi-Factor GBM Asset Price Model (Implied) calibration; two PCA versions (one specific for implied models), and an implied regression calibration. These use the `MultiGBMAssetPriceTSPCACalibration`, the `MultiGBMAssetPriceTSPCACalibrationImplied`, or the `MultiGBMAssetPriceTSRegressionCalibrationImplied` classes, respectively.

The implied methods differ from the non-implied Asset Price Calibrations above by the Volatility Calibrations, which are implied and hence handled by the bootstrapper.

28.6.3 Properties

The following properties are common for all Multi-Factor GBM Asset Price Term Structure Model (Implied) calibrations.

Significance Threshold Any driver weights with absolute value less than the threshold are rounded to zero. Scalar.

Use Pre Computed Statistics If set to `Yes`, use pre-computed statistics derived from historical market rates; if `No` use archive market data directly.

28.6.3.1 PCA Calibration

The following properties are additionally defined for the PCA calibration.

Calibrate All In Group If `No`, only primary model parameters are calibrated; otherwise, if `Yes`, calibrate all parameters.

Group By Indication of how to group factors. When `All`, matches everything. Otherwise, will use the Grouping file for a matching tag. If blank, uses the `PCA Group` tag.

Idiosyncratic Factor Specifies whether the calibration will allow an idiosyncratic factor. `Yes` or `No`.

Explained Variance Target variance that should be accounted for by the PCA calibration. Adaptiv Analytics will find the minimum number of factors that explain this level of variance (unless this is greater than the `Number of PCA Factors`). Scalar.

Number of PCA Factors Maximum number of PCA factors to return. Adaptiv Analytics will return this number of PCA factors, unless the level of variance specified in `Explained Variance` is achieved by fewer factors. Scalar.

Risk Neutral Drift The Risk Neutral Drift flag for the underlying stochastic models; `Yes` for a Risk Neutral version of the model or `No` for a Real World version.

Set Risk Neutral Drift Flag to indicate whether the calibration can override the `Risk Neutral Drift` flag of the model. `Yes` or `No`.

Vol Calibration Options to determine which volatility calibration to use: `Implied` or `Historical`. See Section 28.2.3.2.

28.6.3.2 PCA (Implied) Calibration

The following properties are additionally defined for the PCA (Implied) calibration.

Drivers List of driving factor (stochastic process) IDs underpinning the model to be calibrated.

28.6.3.3 Regression Calibration

The following properties are additionally defined for the Regression calibration.

Calibrate All In Group If No, only primary model parameters are calibrated; otherwise, if Yes, calibrate all parameters.

Explained Variance Target variance that should be accounted for by the PCA calibration. Adaptiv Analytics will find the minimum number of factors that explain this level of variance (unless this is greater than the Number of PCA Factors). Scalar.

Group By Indication of how to group factors. When All, matches everything. Otherwise, will use the Grouping file for a matching tag. If blank, uses the PCA Group tag.

Idiosyncratic Factor Specifies whether the calibration will allow an idiosyncratic factor. Yes or No.

Number Of PCA Factors Maximum number of PCA factors to return. Adaptiv Analytics will return this number of PCA factors, unless the level of variance specified in Explained Variance is achieved by fewer factors. Scalar.

28.6.4 Assumptions and Limitations

See Section 27.1.2 for general assumptions applicable to this calibration.

28.6.4.1 Risk Neutrality

The implied models assume risk neutral drift (i.e, no drift parameter is required. This is equivalent to setting Risk Neutral Drift = Yes for non-implied models.)

Chapter 29

Joint Model Calibrations

29.1 Heston Asset Price Model

29.1.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.5.8 Heston Asset Price Model]. Adaptiv Analytics provides a calibration method only for the Heston 1 Factor Asset Price Model, with no corresponding method for the two factor equivalent.

29.1.2 Calibration Method

The Heston Asset Price Model can be calibrated using the `HestonImpliedVolatilityCalibration` method in Adaptiv Analytics.

Theory Guide 3.5.8

The calibration fits the set of model parameters $\Omega = \{\kappa^*, \theta^*, \sigma, \rho, v(0)\}$ to a given set of implied volatilities:

$$\Sigma = \{(V_1, \tau_1, m_1), \dots, (V_n, \tau_n, m_n)\} \quad (29.1.1)$$

where V_i is the implied volatility for time to expiry τ_i and moneyness factor m_i . The numerical optimization is performed using the downhill simplex method of Nelder and Mead (see Press et al. [41, Chapter 10.4]) on parameter space defined by the calibration parameters.

Parameters are obtained by optimisation which minimise an objective function derived as follows.

Theory Guide 3.5.8.1

Following Cont and Ben Hamida [18], Analytics uses the weights

$$\omega_i = \frac{1}{\max(\mathcal{V}(F_i, K_i, V_i, \tau_i), 0.01)}, \quad (29.1.2)$$

where $\mathcal{V}(F, K, V, \tau) = \partial \mathcal{B}_1(F, K, V\sqrt{\tau}) / \partial V$ is the Black-Scholes vega. Using a first-order Taylor expansion of $\mathcal{B}_\delta(F_i, K_i, V\sqrt{\tau_i})$ about $V = V_i$, the objective function is given approximately by

$$F(\Sigma, \Omega) \approx \sum_{i=1}^n [\omega_i \mathcal{V}(F_i, K_i, V_i, \tau_i) (V_i - V_i^\Omega)]^2 \leq \sum_{i=1}^n (V_i - V_i^\Omega)^2. \quad (29.1.3)$$

The calibration method requires an implied volatility price factor in the same currency as the underlying asset price, from which the set of volatilities Σ are within a given time to expiry and moneyness

window.

29.1.3 Properties

Fix Initial Variance If `Yes`, initial variance $v(0)$ will be fixed at the square of the shortest term ATM implied volatility and long run mean θ^* is allowed to vary. This fixing is required as initial variance and long run mean have similar effect (i.e., parallel shift) on the smile.

Initial Variance Lower Bound Imposes a constraint (lower bound) on the initial variance. Scalar.

Initial Variance Upper Bound Imposes a constraint (upper bound) on the initial variance. Scalar.

Lower Moneyiness Lower moneyiness bound of the volatility set. Scalar. If this is set equal to the upper moneyiness, moneyiness will be fixed during calibration.

Upper Moneyiness Upper moneyiness bound of the volatility set. Scalar. If this is set equal to the lower moneyiness, moneyiness will be fixed during calibration.

Lower Time To Expiry Lower time to expiry bound of the volatility set. Scalar. If this is set equal to the upper time to expiry, time to expiry will be fixed during calibration.

Upper Time To Expiry Upper time to expiry bound of the volatility set. Scalar. If this is set equal to the lower time to expiry, time to expiry will be fixed during calibration.

Optimiser Fractional Tolerance Tolerance for the optimiser, i.e., point at which residual error is sufficiently small that calibration is considered complete and for optimisation to be terminated.

Risk Neutral Drift The Risk Neutral Drift flag for the underlying stochastic models; `Yes` for a Risk Neutral version of the model or `No` for a real world version.

Set Risk Neutral Drift Flag to indicate whether the calibration can override the `Risk Neutral Drift` flag of the model. `Yes` or `No`.

Spot Variance Correlation Lower Bound Imposes a constraint (lower bound) on the spot variance correlation. Scalar. When equal to the upper bound, variance correlation will be fixed.

Spot Variance Correlation Upper Bound Imposes a constraint (upper bound) on the spot variance correlation. Scalar. When equal to the lower bound, variance correlation will be fixed.

Use Penalty Flag for whether the penalty function should be used in order to reduce the likelihood of the downhill simplex used for calibration failing into a local minimum.

Theory Guide [3.5.8.5](#)

Let Ω_0 denote the initial set of model parameters. If `Use Penalty` is `Yes` then (as suggested in Mikhailov and Nögel [40]) the quadratic function $\|\Omega - \Omega_0\|_2^2$ is added to the objective function (3.78).

Use Pre Computed Statistics If set to `Yes`, use pre-computed statistics derived from historical market rates; if `No` use archive market data directly.

Use Last Parameters As Initial Guesses If `Yes`, calibration is run from the last known values, i.e., initial values used are set to the current calibration. Otherwise, Adaptiv Analytics assumes sets all values to the middle of their bounds.

Variance Reversion Level Lower Bound Imposes a constraint (lower bound) on the variance reversion level. Scalar. If this is set equal to the upper bound, the variance reversion level will be fixed during calibration.

Variance Reversion Level Upper Bound Imposes a constraint (upper bound) on the variance reversion level. Scalar. If this is set equal to the lower bound, the variance reversion level will be fixed during calibration.

Variance Reversion Speed Lower Bound Imposes a constraint (lower bound) on the variance reversion speed. Scalar. If this is set equal to the upper bound, the variance reversion speed will be fixed during calibration.

Variance Reversion Speed Upper Bound Imposes a constraint (upper bound) on the variance reversion speed. Scalar. If this is set equal to the lower bound, the variance reversion speed will be fixed during calibration.

Variance Vol Lower Bound Imposes a constraint (lower bound) on the variance volatility. Scalar. If this is set equal to the upper bound, the variance volatility will be fixed during calibration.

Variance Vol Upper Bound Imposes a constraint (upper bound) on the variance volatility. Scalar. If this is set equal to the lower bound, the variance volatility will be fixed during calibration.

29.1.4 Assumptions and Limitations

See Section 27.1.2 for general assumptions applicable to this calibration.

29.1.4.1 Constraints

Owing to the number of free parameters in the model, constraints are set to define the bounds of the parameter space within which the model is to be calibrated.

Theory Guide 3.5.8.2

The model parameters are subject to the linear constraints: $\kappa^* > 0$, $\theta^* > 0$, $\sigma > 0$, $v(0) > 0$ and $\rho \in [-1, 1]$.

These bounds may be further refined by the ‘upper’ and ‘lower’ bound parameters defined in Section 29.1.3. Adaptiv Analytics imposes these constraints via a transformation once optimisation is complete such that.

Theory Guide 3.5.8.2

If p is a model parameter subject to the constraint $L < p < U$ then the transformed parameter \tilde{p} is given by

$$\tilde{p} = \tan \left(\frac{p - M}{U - L} \pi \right), \quad (29.1.4)$$

where $M = (U + L)/2$. The objective function becomes a function of the transformed parameters $\tilde{\Omega}$, and is minimized without constraints.

Above, the inverse transformation can be applied to restore the parameters for the objective function to the original parameter space.

29.1.4.2 Objective Function

The objective function in Adaptiv Analytics is approximately the sum of squared errors in the implied volatility. However, the form of the function does not require that V_i^Ω be computed, and hence alleviates the numerical error.

Chapter 30

Interest Rate Model Calibrations

30.1 Gaussian Key Rates Interest Rate Model

30.1.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.6.6 Gaussian Key Rates Model]. Adaptiv Analytics offers only statistics based calibrations for the Gaussian Key Rates Interest Rate Model.

30.1.2 Calibration Method

The Gaussian Key Rates Interest Rate Model can be calibrated using the `GaussianKeyRatesInterestRateCalibration` method in Adaptiv Analytics. The calibration requires a specification of the key rate tenors, with a volatility provided for each tenor.

30.1.3 Properties

Distribution Type Defines the probability distribution; may be Normal or Lognormal. If Lognormal, uses the Log statistics of zero rates. Otherwise, uses the Diff statistics of zero rates.

Rate Drift Model Defines the drift curve:

Theory Guide 3.6.6

If Rate Drift Model is Historical then the drift curve is given by $\mu(\tau_k) = \hat{\mu}_k + \hat{\sigma}_k^2/2$ for Lognormal or $\mu(\tau_k) = \hat{\mu}_k$ for Normal, where $\hat{\mu}_k$ is the drift for tenor τ_k .

Use Pre Computed Statistics If set to Yes, use pre-computed statistics derived from historical market rates; if No use archive market data directly.

30.1.4 Assumptions and Limitations

There are no specific assumptions or limitations in the calibration of this model; see general assumptions and limitations, Section 27.1.2.

30.2 Jump Cox-Ingersoll-Ross Interest Rate Model

30.2.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.6.3 Cox-Ingersoll-Ross Model].

30.2.2 Calibration Method

Adaptiv Analytics includes two variants of the Jump Cox-Ingersoll-Ross Interest Rate Model calibration, allowing for or excluding a deterministic shift. These use the `CIRInterestRateCalibration` or the `CIRDeterministicShiftInterestRateCalibration` classes, respectively.

Both methods calibrate the model via statics sets, which may be obtained from a market data archive or the market data file. Parameters κ and θ are obtained from the average statistics of each tenor, while σ is obtained as follows, a series of increasing tenor.

Theory Guide 3.6.3

Under the model, the variance of the short rate is given by

$$\text{var}(r(\tau)) = \frac{\sigma^2}{\kappa} \left(r(0)e^{-\kappa\tau}(1 - e^{-\kappa\tau}) + \frac{1}{2}\theta(1 - e^{-\kappa\tau})^2 \right). \quad (30.2.1)$$

The calibration uses Diff statistics of zero rates (Section 3.3). Let τ_1 denote the smallest zero rate tenor in the archive. The calibration sets $\kappa = \hat{\alpha}_1$ and $\theta = \hat{\theta}_1$, where $\hat{\alpha}_1$ and $\hat{\theta}_1$ are the mean reversion speed and long run mean for tenor τ_1 . Let $\check{\sigma}_1$ denote the reversion volatility for tenor τ_1 . Using the approximation $\text{var}(r(\tau_1)) \approx \check{\sigma}_1^2 \tau_1$, the calibration sets

$$\sigma = \check{\sigma}_1 \left(\frac{\kappa\tau_1}{r(0)e^{-\kappa\tau_1}(1 - e^{-\kappa\tau_1}) + \theta(1 - e^{-\kappa\tau_1})^2/2} \right)^{1/2}, \quad (30.2.2)$$

where $r(0)$ is estimated from the initial discount factor curve as in Section 1.6.15.

30.2.3 Properties

The following properties are common to both calibration methods.

Use Pre Computed Statistics If set to Yes, use pre-computed statistics derived from historical market rates; if No use archive market data directly.

30.2.4 Assumptions and Limitations

See Section 27.1.2 for general assumptions applicable to this calibration.

30.2.4.1 Jump Feature

Adaptiv Analytics does not provide a calibration for the jump feature available in the Jump Cox-Ingersoll-Ross models. Consequently, when calibrated, the Jump Arrival Rate is set to 0 (i.e., no simulated jumps occur).

30.2.4.2 Deterministic Shift

If the `CIRDeterministicShiftInterestRateCalibration` calibration class is selected, Adaptiv Analytics sets the `Use Deterministic Shift` parameter to yes, and assumes the initial process value is $r(0)/2$. See Section 18.6 for details on the deterministic shift.

30.3 Hull-White 1-Factor Interest Rate Model

30.3.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.6.1 One-Factor Hull-White Model and § 3.7.1 One-Factor Hull-White Model].

30.3.2 Calibration Method

Adaptiv Analytics includes two variants of the Hull-White 1-Factor Interest Rate Model calibration; a variant using historical zero rates, or a variant using either pre-computed statistics or a maximum likelihood approach. These use the `HullWhiteZeroRateCalibration` or the `HWInterestRateCalibration` classes, respectively.

30.3.2.1 Historical Zero Rate Calibration

The historical calibration requires a set of zero rates at sequentially increasing tenors. The calibration then attempts to minimise the model error in volatility assuming that there is a model-implied process at each tenor:

Theory Guide [3.6.1.3](#)

The calibration uses Diff statistics of zero rates (Section 3.3). Let τ_1, \dots, τ_n denote the zero rate tenors in the archive. The calibration finds values of the model parameters σ and α that minimize

$$\sum_{k=1}^n (v(\tau_k; \sigma, \alpha) - \hat{\sigma}_k)^2, \quad (30.3.1)$$

where $\hat{\sigma}_k$ is the historical volatility of the zero rate with tenor τ_k .

Where $v(\tau; \sigma, \alpha)$ represents volatility (which is assumed to be constant for each mean reverting process) and the minimisation is performed by a Nelder Mead algorithm. Using these statistics, the parameters which define Hull-White 1-Factor Interest Rate Model can be calibrated.

Theory Guide [3.6.1](#)

Historical calibrations calculate the mean reversion rate α and a constant volatility σ ;

30.3.2.2 Interest Rate Calibration

The interest rate calibration can use either pre-computed statistics, or maximum likelihood estimation. For the pre-computed statistics approach:

Theory Guide [3.6.1.1](#)

Let τ_1, \dots, τ_n denote the zero rate tenors for which there are statistics. The calibration sets $\sigma = \sum_{k=1}^n \check{\sigma}_k / n$ and $\alpha = \sum_{k=1}^n \hat{\alpha}_k / n$, where $\check{\sigma}_k$ and $\hat{\alpha}_k$ are the reversion volatility and mean reversion speed for tenor τ_k .

Meanwhile, for the maximum likelihood calibration, Adaptiv Analytics first constructs two time series of zero rates at times $t_1 \dots t_N$ and $t'_1 \dots t'_N$ such that $t'_i = t_i + \delta \leq t_{i+1}$, where δ is the horizon period. Then, starting from initial conditions defined by the pre-computed statistics method above, a log likelihood function $\ell(\sigma, \alpha)$ is minimised as follows:

Define the increments

$$X_i = (r_\tau(t'_i) - \mu(t'_i, \tau; \sigma, \alpha)) - e^{-\alpha\delta} (r_\tau(t_i) - \mu(t_i, \tau; \sigma, \alpha)) \quad (30.3.2)$$

$$= v(\tau; \sigma, \alpha) \int_{t_i}^{t'_i} e^{-\alpha(t'_i - s)} dW(s). \quad (30.3.3)$$

Then X_1, \dots, X_N are independent identically distributed normal variables with mean zero and variance $V(\sigma, \alpha) = v(\tau; \sigma, \alpha)^2 B_{2\alpha}(\delta)$. The log likelihood function for these observations is $N[\ell(\sigma, \alpha) - \log(2\pi)]/2$, where

$$\ell(\sigma, \alpha) = -\log(V(\sigma, \alpha)) - \frac{1}{V(\sigma, \alpha)N} \sum_{i=1}^N x_i^2 \quad (30.3.4)$$

and $x_i = (r'_i - \mu(t'_i, \tau; \sigma, \alpha)) - e^{-\alpha\delta} (r_i - \mu(t_i, \tau; \sigma, \alpha))$.

For full details on the zero rates calibration see the Theory Guide [7, §3.6.1 One-Factor Hull-White Model]

30.3.3 Properties

30.3.3.1 Historical Calibration

The following properties are defined for the historical zero rate variant of this calibration.

Number Of Iterations Number of iterations used by the Nelder Mead simplex algorithm for optimisation. Scalar.

Use Pre Computed Statistics If set to Yes, use pre-computed statistics derived from historical market rates; if No use archive market data directly.

30.3.3.2 Maximum Likelihood Estimation

The following properties are defined for the statistics or maximum likelihood version of this calibration.

Calibration Method Choice of calibration method; Pre Computed Statistics or MLE. See Section 27.1.1.

30.3.4 Assumptions and Limitations

See Section 27.1.2 for general assumptions applicable to this calibration.

30.3.4.1 Calibration Bounds

For simplex optimisation, initial estimates for model parameters (e.g., α and σ) are determined by statistics. Furthermore, parameters may be fixed, and are required to remain within specified bounds if values for these bounds are supplied.

30.3.4.2 Quanto Correction and Market Price of Risk

Historical calibrations in Adaptiv Analytics do not set the quanto correction or market price of risk properties of the Hull-White 1-Factor Interest Rate model.

30.3.4.3 Flatness of the likelihood function

The log likelihood function $\ell(\sigma, \alpha)$ is relatively flat over the $[\sigma, \alpha]$ parameter space explored by a simplex during optimisation. The calibrated values found may therefore be unstable between consecutive calibrations in two dimensional parameter space, if the simplex has converged to different minima in each run.

30.4 Hull-White 2-Factor Interest Rate Model

30.4.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.7.2 Two-Factor Hull-White Model and § 3.6.1 One-Factor Hull-White Model].

30.4.2 Calibration Method

The Hull-White 2-Factor Interest Rate Model can be calibrated using the `HW2FHistoricalVolCalibration` method in `Adaptiv Analytics`. As with the Hull-White 1-Factor Interest Rate Model, `Adaptiv Analytics` calibrates the Hull-White 2-Factor Interest Rate Model using historical zero rates from the market data archive. From these data, values for the two mean reversion rates (α_1 and α_2), two volatilities (σ_1 and σ_2), and the correlation between the two model risk factors (ρ) are found.

The historical calibration operates as follows:

Theory Guide 3.6.2.1

For a given tenor τ , the zero rate $r_\tau(t)$ has constant volatility given by

$$v(\tau; \sigma_1, \alpha_1, \sigma_2, \alpha_2, \rho) = \sqrt{v_1(\tau)^2 + 2\rho v_1(\tau)v_2(\tau) + v_2(\tau)^2}. \quad (30.4.1)$$

The calibration uses Diff statistics of zero rates (Section 3.3). Let τ_1, \dots, τ_n denote the zero rate tenors in the archive. The calibration finds values of the model parameters $\sigma_1, \alpha_1, \sigma_2, \alpha_2$ and ρ that minimize

$$\sum_{k=1}^n \omega_k (v(\tau_k; \sigma_1, \alpha_1, \sigma_2, \alpha_2, \rho) - \hat{\sigma}_k)^2, \quad (30.4.2)$$

where $\hat{\sigma}_k$ is the historical volatility of the zero rate with tenor τ_k , and $\omega_k > 0$ is the corresponding weight. If no weights are specified then the calibration sets $\omega_k = 1$ for $k = 1, \dots, n$. If weights are specified then the number of weights must equal the number of tenors.

Above, $v_i(\tau) = \sigma_i B_i(\tau)/\tau$ and $B_i(\tau) = (1 - e^{-\alpha_i \tau})/\alpha_i$. The calibration process in this case invokes a line-search quasi-Newton optimiser with BFGS update for the Hessian approximation. Since the calibration explores a (generally) non-convex parameter space, three options for avoiding local minima are offered, controlled by the `Method` calibration parameter (see Section 30.4.3).

30.4.3 Properties

Differential Evolution Options A set of further options if the Differential Evolution optimiser method is chosen; includes multiple options - see [46] for details.

Local Optimizer Options Options for the Quasi Newton Optimiser. Includes `Max Major Iterations` (maximum number of iterations within which to expect converge) and `Gradient Tolerance` (the Euclidean normal tolerance for checking whether the gradient is zero).

Method Choice of methods for historical zero rate volatility calibration, with three options:

Theory Guide 3.6.2.1

Multi Start. A population of random initial points is generated and quasi-Newton optimizations are run starting at each of these initial points. The result that has the lowest objective function value is chosen. Larger initial population sizes increase the chances of finding good solutions at the expense of additional computation time.

Stepped Rho. The correlation ρ is held fixed at various points in the interval $[-1, 0]$, and an

optimization is run over the other four variables $\sigma_1, \alpha_1, \sigma_2, \alpha_2$ for each value of ρ . This gives one optimization result for each fixed value of ρ . Then a final optimization is run over all five variables, starting at the best result.

Differential Evolution. The differential evolution method of Storn and Price [46] is used.

Multi Start Options A set of further options if the Multi Start optimiser method is chosen. can be used to specify a random Seed, or the Initial Population Size, i.e., number of points from which optimisation should be started.

Tenor Weights List of weights to apply to the tenors for the historical rates calibration option. List of scalars.

Use Pre Computed Statistics If set to Yes, use pre-computed statistics derived from historical market rates; if No use archive market data directly.

Variables A set of initial values for the variables; can be used to set initial values for $\alpha_1, \alpha_2, \sigma_1, \sigma_2$, and ρ . Values are subsequently optimised by the calibration.

30.4.4 Assumptions and Limitations

See Section 27.1.2 for general assumptions applicable to this calibration.

30.4.4.1 Correlations

The two factor Hull-White Interest Rate model invokes two independent correlated normals, referred to as Z_k and Z_l . Correlation between these factors is determined by ρ , and resides outside the correlation matrix. Hence, correlation to other price factors is established by the one factor method for Z_k (see Section 36.1), while Z_l is only indirectly correlated with global correlated normals through its correlation to Z_k (ρ).

30.5 Market Interest Rate Model

30.5.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.7.4 Market Model].

30.5.2 Calibration Method

The Market Interest Rate Model is calibrated in a two stage process in Adaptiv Analytics. First, the model is calibrated using the `MarketModelCapVolCalibration` method, before a second step is used to calculate the factor loadings (correlations). There are two options available for the factor loadings; a Parametric method and a Statistical method. These use the `MarketModelCorrelationCalibrationParametric` or the `MarketModelCorrelationCalibrationStatistical` classes, respectively.

30.5.2.1 Model Calibration

The Adaptiv Analytics market model is calibrated by first inferring Black's volatility $\sigma_B(T_i)$ for caplets from market quotations of volatility for pricing caplets, and secondly matching these volatilities to a functional form for volatility under the market model suggested by Rebonato [42]:

Theory Guide 3.7.4.1

$$\sigma_i(t) = f(T_i - t)g(t)K_i \quad (30.5.1)$$

where

$$f(T - t) = (a + b(T - t)) \exp(-c(T - t)) + d \quad (30.5.2)$$

$$g(t) = 1 + \left[\sum_{i=1}^k \epsilon_{2i} \sin\left(\frac{t\pi i}{T_n} + \epsilon_{2i-1}\right) \right] \exp(\epsilon_{2k+1}t). \quad (30.5.3)$$

where T_n is the expiry of the most forward rate in the model.

This volatility is matched against $\sigma_B(T_i)$ by

$$\int_0^{T_i} \sigma_i^2(s) ds = \sigma_B^2(T_i)T_i. \quad (30.5.4)$$

The algorithm used by Adaptiv Analytics first finds parameters to define f , then parameters that define g , and finally normalises. For full details on the minimisation performed, refer to the Theory Guide [7, § 3.7.4 Market Model]

30.5.2.2 Statistical Correlation Calibration

The factor loadings (from which correlations are determined) are calibrated after the volatility functions have been determined. They are obtained as a matrix of statistical correlations between log-returns of model forward rates.

Theory Guide 3.7.4.2

Since correlation is assumed to be a function only of time to rate expiry, the correlations between rates of a fixed time to expiry are assumed constant, consistent with the way in which correlations are generally treated in Analytics. The closest matching rates available in the statistics dataset are used as proxies for the model rates with time to expiry as of time zero. Forward rates are defined in the tenor and time to expiry dimension; tenor is considered before time to expiry in searching for matching rates, and only rates of the best matching tenor are used.

Adaptiv Analytics uses the method of Rebonato [42], through which a set of n length m vectors are defined, which are treated as a square root model of correlation matrix ρ^α . Parameters are then found by minimising the (squared) difference between target covariance matrix ρ and model covariance matrix ρ^α . Finally, Adaptiv Analytics performs eigenvalue decomposition and finds the loading functions by scaling the eigenvectors of the correlation matrix by the square root of their associated eigenvalues; full details of this method are provided the Theory Guide [7, § 3.7.4 Market Model].

30.5.2.3 Parametric Correlation Calibration

The parametric correlation calibration is distinct from the statistical method for the following reason.

Theory Guide 3.7.4.3

The parametric intra-model correlation calibration is the same as the statistical calibration except that the target matrix for the calibration is defined by the following function:

$$\rho_{ij} = \rho_\infty + (1 - \rho_\infty) \exp(-\beta |(T_i - t)^\gamma - (T_j - t)^\gamma|). \quad (30.5.5)$$

The parameters of this function, ρ_∞ , β , and γ are specified by the user.

30.5.3 Properties

30.5.3.1 Market Interest Rate Model Calibration

The following properties are set for the Market Interest Rate Model Calibration.

Discretization Discretisation grid for the instantaneous volatility functions, which must be fine enough to match the grid date. Scalar.

Max Horizon Maximum horizon in the calibration set. Scalar

Max Iterations Maximum number of iterations to achieve convergence in for the downhill simplex used for minimisation. Scalar, defaults to 200.

Random Seed Seed for the random number generator used in the basis function. Scalar

Target Tenor Tenor used for all LIBOR rates in the model, with the closest available cap volatilities chosen as the calibration set. Scalar.

Temporal Functions Number of basis functions in the equation for g . Scalar, defaults to 3.

Tolerance Tolerance to be achieved in the function value. Scalar.

30.5.3.2 Market Interest Rate Model Correlations Calibration

The following properties are common for both Market Interest Rate Correlation calibration methods.

Factors Number of model factors to include in calibration. Scalar

Max Iterations Maximum number of iterations to achieve convergence in for the downhill simplex used for minimisation. Scalar, defaults to 200.

Random Seed Seed for the random number generator used in the basis function. Scalar

Tolerance Tolerance to be achieved in the function value. Scalar.

Parametric Calibration: The following properties are additionally defined for parametric calibration.

Beta User specified value of β in equation (30.5.5). Scalar.

Gamma User specified value of γ in equation (30.5.5). Scalar.

Long Correlation User specified value of p_∞ in equation (30.5.5). Scalar.

30.5.4 Assumptions and Limitations

See Section 27.1.2 for general assumptions applicable to this calibration.

30.5.4.1 Dimensionality of Factor Loading Calibrations

While the number of model factors (m) may be specified by the `Factors` parameter, it must not exceed the number of model rates (n).

30.5.4.2 Rate correlation functions

The correlations of the fixed-maturity rates in the model during simulation are determined by their remaining time to maturity. In *Adaptiv Analytics*, the rate correlation functions are required to be completely homogeneous.

30.6 Multi-Factor GOU Interest Rate Model

30.6.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.6.5 Multi-Factor GOU Model].

30.6.2 Calibration Method

The Multi-Factor GOU Interest Rate Model can be calibrated using the `MultiGOUInterestRateRegressionCalibration` method in `Adaptiv Analytics`.

The calibration of the Multi-Factor GOU Interest Rate Model finds weightings for systemic and idiosyncratic drivers by regression, using the same (Regression) method as for the Multi-Factor GBM Asset Price Model described in Section 28.4.2.2.

Theory Guide 3.6.5

The calibration uses Log statistics of zero rates (Section 3.3) for the subset of tenors τ_1, \dots, τ_n in the archive that lie between Lower Tenor and Upper Tenor. The volatility curve is given by $\sigma(\tau_k) = \tilde{\sigma}_k$, where $\tilde{\sigma}_k$ is the reversion volatility for tenor τ_k . The calibration sets $\alpha = \sum_{k=1}^n \hat{\alpha}_k / n$, where $\hat{\alpha}_k$ is the mean reversion speed for tenor τ_k .

30.6.3 Properties

Drivers List of driving factor (stochastic process) IDs underpinning the model for be calibrated.

Idiosyncratic Factor Specifies whether the calibration will allow an idiosyncratic factor. Yes or No.

Lower Tenor Tenor, defining the lower bound of the subset of tenors for zero rates to be used for calibration.

Significance Threshold Any driver weights with absolute value less than the threshold are rounded to zero. Scalar.

Upper Tenor Tenor, defining the upper bound of the subset of tenors for zero rates to be used for calibration.

Use Pre Computed Statistics If set to Yes, use pre-computed statistics derived from historical market rates; if No use archive market data directly.

30.6.4 Assumptions and Limitations

See Section 27.1.2 for general assumptions applicable to this calibration.

30.6.4.1 Dividend Curves

For the calibration of Dividend risk factors, introducing idiosyncratic risk factors may significantly impact performance. For these cases, it is recommended that `Idiosyncratic Factor` is No.

30.7 PCA Interest Rate Model

30.7.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.6.4 PCA Model].

30.7.2 Calibration Method

The PCA Interest Rate Model can be calibrated using the `PCAInterestRateCalibration` method in `Adaptiv Analytics`. `Adaptiv Analytics` can calibrate using either the correlation matrix (ρ_{kl}) or the covariance matrix ($C_{kl} = \sigma_k \sigma_l \rho_{kl}$), from using normal or lognormal rates $r_1 \dots r_N$ for a set of tenors $\tau_1 \dots \tau_N$.

Theory Guide 3.6.4.1

When the calibration parameter `Matrix Type` is `Correlation`, the correlation matrix is diagonalized. In this case, the calibration calculates an orthogonal matrix Q such that $\rho = Q\Lambda Q^T$, where $\Lambda = \text{diag}(\lambda_1, \dots, \lambda_n)$ and $\lambda_1 \geq \dots \geq \lambda_n \geq 0$ are the eigenvalues of ρ . Define the matrix of weights $\Omega = Q\Lambda^{1/2}$. Then $\Omega\Omega^T = \rho$ and $\Omega^T\Omega = \Lambda$.

When `Matrix Type` is `Covariance`, the covariance matrix is diagonalized. In this case, the calibration calculates an orthogonal matrix Q such that $C = Q\Lambda Q^T$, where $\Lambda = \text{diag}(\lambda_1, \dots, \lambda_n)$ and $\lambda_1 \geq \dots \geq \lambda_n \geq 0$ are the eigenvalues of C . Define the matrix of weights $\Omega = \Sigma^{-1}Q\Lambda^{1/2}$, where $\Sigma = \text{diag}(\sigma_1, \dots, \sigma_n)$. Then $\Omega\Omega^T = \rho$ and $(\Sigma\Omega)^T(\Sigma\Omega) = \Lambda$.

The yield volatility curve is defined by $\sigma(\tau_k) = \sigma_k$, and the eigencurves $Q_k(\tau)$ are defined by $Q_k(\tau_i) = Q_{ik}$.

where σ_k is the volatility of the (log) rate r_k .

The PCA interest rate model can be calibrated by pre-computed statistics supplied in a archive data file, or by maximum likelihood. When pre-computed statistics is selected, the supplied statistics for a set of zero rates at tenors $\tau_1 \dots \tau_N$ are used as per the method above. In this case:

Theory Guide 3.6.4.2

The calibration sets $\alpha = \sum_{k=1}^n \hat{\alpha}_k / n$, where $\hat{\alpha}_k$ is the mean reversion speed for the zero rate with tenor τ_k .

For the maximum likelihood calibration, define $y_k(t) = \log r_{\tau_k}(t)$ when the `Distribution Type` is `Lognormal`, or $y_k(t) = r_{\tau_k}(t)$ when the `Distribution Type` is `Normal`. Then:

Theory Guide 3.6.4.3

Under the model, the stochastic part of $y_k(t)$ is a weighted sum of independent Ornstein-Uhlenbeck processes with the same mean reversion speed α . The calibration sets the `Rate Drift Model` to either `Drift To Blend for Normal`, or `Log Drift To Blend for Lognormal`. Then $y_k(t)$ is an Ornstein-Uhlenbeck processes with a constant volatility σ_k , a constant long run mean θ_k , and mean reversion speed α . The processes $y_k(t)$ and $y_l(t)$ have a constant instantaneous correlation ρ_{kl} .

The remaining parameters, α , σ_k , and θ_k are estimated using a maximum likelihood approach for an Ornstein-Uhlenbeck process (see Section 27.1.1.2).

30.7.3 Properties

Calibration Method Choice of calibration method; Pre Computed Statistics or MLE. See Section 27.1.1.

Distribution Type Defines the probability distribution; may be Normal or Lognormal. If Lognormal, uses the Log statistics of zero rates. Otherwise, uses the Diff statistics of zero rates.

Downhill Simplex Scale Optimisation parameter. Scalar, initial scale for the downhill simplex optimiser.

Fractional Tolerance Optimisation parameter. Scalar, tolerance for the downhill simplex optimiser.

Matrix Type Determines whether the Correlation matrix or the Covariance matrix is used for calibration. See Section 30.7.2.

Max Iterations Optimisation parameter. Maximum number of iterations for the downhill simplex optimiser. Scalar.

Number Of PCA Factors Maximum number of PCA factors to return. Adaptiv Analytics will return this number of PCA factors, unless the level of variance specified in Explained Variance is achieved by fewer factors. Scalar.

Rate Drift Model Blend Method, with three options Drift To Blend, Log Drift To Blend, or Drift To Forward. See Drift Blend Method property in Section 18.9 for details.

Reversion Speed Fixed Applicable to Maximum Likelihood Estimation. If a value is specified, then the estimates are conditional on the specified value of α . Scalar.

Reversion Speed Lower Bound Specifies a lower bound for the reversion speed (α) in maximum likelihood estimation, when not fixed. Scalar.

Reversion Speed Upper Bound Specifies an upper bound for the reversion speed (α) in maximum likelihood estimation, when not fixed. Scalar.

Yield Volatility Upper Bound If used, specifies an upper bound for the reversion speed (σ_k) in maximum likelihood estimation. Scalar.

30.7.4 Assumptions and Limitations

See Section 27.1.2 for general assumptions applicable to this calibration.

30.7.4.1 Extrapolation of Parameters

The yield volatility curve (σ), historical yield curve (Θ), and correlation matrix (ρ) are extrapolated backwards in order to be defined at all tenors τ . Adaptiv Analytics performs this extrapolation using a quadratic formula, and minimising. See the Theory Guide [7, § 3.6.4.3.3 Extrapolation of Calibrated Parameters].

Chapter 31

Price Index Calibrations

31.1 GBM Price Index Model

31.1.1 Overview

For details about the calibration of this model, see the Theory Guide [7, §3.5.9 GBM Price Index Model].

31.1.2 Calibration Method

The GBM Price Index Model can be calibrated using the `GBMPriceIndexCalibration` method in Adaptiv Analytics.

The calibration of this model is equivalent to that of the GBM Asset Price Model, described in Section 28.1.

Theory Guide 3.5.9

The calibration uses Log statistics of the price index (Section 3.3) and sets $\sigma = \hat{\sigma}$ and $\mu = \hat{\mu} + \hat{\sigma}^2/2$.

31.1.3 Properties

Use Pre Computed Statistics If set to `Yes`, use pre-computed statistics derived from historical market rates; if `No` use archive market data directly.

31.1.4 Assumptions and Limitations

There are no specific assumptions or limitations in the calibration of this model; see general assumptions and limitations, Section 27.1.2.

31.2 GBM Price Index Drift Model

31.2.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.5.10 GBM Price Index Drift Model].

31.2.2 Calibration Method

The GBM Price Index Drift Model can be calibrated using the `GBMPriceIndexDriftCalibration` method in Adaptiv Analytics.

The calibration of this model is similar to that of the, described in Section 31.1, with the addition of a drift term.

Theory Guide 3.5.10

The calibration uses Log statistics of the price index (Section 3.3) and sets $\sigma = \hat{\sigma}$.

31.2.3 Properties

Use Pre Computed Statistics If set to Yes, use pre-computed statistics derived from historical market rates; if No use archive market data directly.

31.2.4 Assumptions and Limitations

There are no specific assumptions or limitations in the calibration of this model; see general assumptions and limitations, Section 27.1.2.

Chapter 32

Volatility Model Calibrations

32.1 Simple Volatility Models

32.1.1 Overview

For details about the calibration of these models, see the Theory Guide [7, §3.9.1 Simple (One-Factor) Model].

32.1.2 Calibration Method

Adaptiv Analytics includes six variants of Simple Volatility Model calibrations; one for each of FX, Asset Price, Interest Rate, Interest Yield, Forward Price, and Price Index. These use the `SimpleFXVolCalibration`, the `SimpleAssetPriceVolCalibration`, the `SimpleInterestRateVolCalibration`, the `SimpleInterestYieldVolCalibration`, the `SimpleForwardPriceVolCalibration`, and the `SimplePriceIndexVolCalibration`, respectively.

The simple volatility models can be calculated by either pre-computed statistics or by maximum likelihood estimation.

32.1.2.1 Pre-computed statistics

Pre-computed statistics for simple volatility models are computed by the method outlined in Section 27.1.1.1. For these calibrations, Adaptiv Analytics requires a volatility surface from which a set of points \mathcal{P} for which there are statistics are drawn. For these cases:

Theory Guide 3.9.1.1

The calibration sets $\sigma = \sum_{p \in \mathcal{P}} \check{\sigma}(p) / |\mathcal{P}|$ and $\alpha = \sum_{p \in \mathcal{P}} \hat{\alpha}(p) / |\mathcal{P}|$. The historical surface is defined by $\Theta(p) = \hat{\Theta}(p)$ for $p \in \mathcal{P}$, with linear interpolation and flat extrapolation for $p \notin \mathcal{P}$.

32.1.2.2 Maximum Likelihood Estimation

For Maximum Likelihood Estimation, a subset of the volatility surface for which points are provided to Adaptiv Analytics may be defined using upper and lower bounds as described in Section 32.1.3.1.

A pair of time series, $v(p, t)$ and $v'(p, t')$, are then constructed using these points. The time series are ordered such that $t_i < t'_i \leq t_{i+1}$, and may (optionally) be exponentially detrended if `Detrended Time Series` is `Yes` (see Section 28.3.2.1). Adaptiv Analytics finally calibrates the required volatility models using the time series as follows:

Under the model, the average log volatility

$$Y(t) = \frac{1}{|\mathcal{Q}|} \sum_{p \in \mathcal{Q}} \log v(p, t) \quad (32.1.1)$$

is an Ornstein-Uhlenbeck process. The model parameters α and σ are estimated using the maximum likelihood method for an Ornstein-Uhlenbeck process (Section 3.2.2) applied to $Y(t)$ with time series $y_i = \sum_{p \in \mathcal{Q}} y_i(p)/|\mathcal{Q}|$ and $y'_i = \sum_{p \in \mathcal{Q}} y'_i(p)/|\mathcal{Q}|$.

32.1.3 Properties

All six variants of simple volatility model calibrations use the following properties.

Blend Method Blend Method, with two options `Drift To Blend` or `Log Drift To Blend`. See Blend Method property in Section 19.2.1.1 for details.

Calibration Method Choice of calibration method; Pre Computed Statistics or MLE. See Section 27.1.1.

32.1.3.1 Maximum Likelihood Estimation

The following properties are additionally defined for the maximum likelihood variant of this calibration.

Moneyness Lower Bound Lower moneyness bound of the volatility set. Scalar. If this is set equal to the upper moneyness, moneyness will be fixed at the closest supplied point during calibration.

Moneyness Upper Bound Upper moneyness bound of the volatility set. Scalar. If this is set equal to the lower moneyness, moneyness will be fixed at the closest supplied point during calibration.

Expiry Lower Bound Lower time to expiry bound of the volatility set. Scalar. If this is set equal to the upper time to expiry, time to expiry will be fixed at the closest supplied point during calibration.

Expiry Upper Upper time to expiry bound of the volatility set. Scalar. If this is set equal to the lower time to expiry, time to expiry will be fixed at the closest supplied point during calibration.

Detrended Time Series Yes or No. Flag to determine if exponential detrending should be applied to the time series used for calibration.

Condition On Reversion Speed Condition On Reversion Speed is defined as follows:

If Condition On Reversion Speed is Yes then σ is estimated conditional on the value of α specified by Reversion Speed.

Use Current Smile If Yes, the shape of the current volatility surface is applied to the long run mean surface. This is useful where only ATM points are provided from which to calibrate, whereupon:

Θ is defined on the set of points \mathcal{V} on which the initial surface v is defined. For each $p \in \mathcal{V}$, $\Theta(p) = \Theta(p_0)v(p)/v(p_0)$, where p_0 is the ATM point for point p and $\Theta(p_0)$ is the value interpolated from the surface of long run means defined on \mathcal{P} .

Otherwise when Use Current Smile is No:

Theory Guide [3.9.1.2](#)

The model's long run mean surface Θ is then calculated as $\Theta(p) = e^{\theta(p) + \sigma^2/4\alpha}$.

32.1.4 Assumptions and Limitations

See Section [27.1.2](#) for general assumptions applicable to these calibrations.

32.1.4.1 Surfaces of ATM points

For calibrations using pre-computed statistics, if only ATM points are provided, Adaptiv Analytics defines the historical surface on the set of points upon which the initial surface \mathcal{V} is defined.

For Maximum Likelihood estimation where only ATM points are provided, the behaviour of Adaptiv Analytics depends on the setting of Use Current Smile; see Section [32.1.3.1](#).

32.1.4.2 Interpolation and Extrapolation

Adaptiv Analytics extends the volatility surface by linear interpolation and flat extrapolation when a point p_i is required and $p_i \notin \mathcal{P}$.

32.2 Beta Asset Price Volatility Model

32.2.1 Overview

For details about the calibration of this model, see the Theory Guide [7, §3.9.3 Beta Asset Price Volatility Model].

32.2.2 Calibration Method

Adaptiv Analytics includes two variants of the Beta Asset Price Volatility Model calibration; one using betas to benchmark volatility price factor points, and one treating the volatility price factor of the model to be calibrated as the benchmark volatility. These methods use the `BetaAssetPriceVolBetaCalibration` and the `BetaAssetPriceVolSystemicCalibration` classes, respectively.

Both systemic and non-systemic models can be calculated by either pre-computed statistics or by maximum likelihood estimation.

32.2.2.1 Pre-computed statistics

Pre-computed statistics are used to calibrate beta volatility models via the method outlined in Section 27.1.1.1 from the Log statistics of implied volatilities.

Adaptiv Analytics calculates β , σ and σ_I as follows, defining systemic weight $\omega = 1$ if there is no idiosyncratic factor or as $\omega = R(\beta\sigma_I/\sigma; \Theta)$, where Θ is the significance threshold and R is the weight rounding function defined in the Theory Guide [7, §B.1.3 Single Systemic Driver].

Theory Guide 3.9.3.1.1

The volatility σ , mean reversion speed α and beta β are calculated by averaging the reversion volatility $\check{\sigma}(p)$, mean reversion speed $\hat{\alpha}(p)$ and beta $\hat{\beta}(p)$ over all $p \in \mathcal{M}$. The index volatility σ_I is calculated by averaging the reversion volatility $\check{\sigma}(I(p))$ over all index factors $I(p)$ for $p \in \mathcal{M}$.

Above, \mathcal{M} defines the set of points on the volatility surface closest to the ATM values. Finally, long run mean is calculated as:

Theory Guide 3.9.3.1.1

$$\hat{\Theta}(\tau) \frac{v(m, \tau)}{v(1, \tau)}, \quad (32.2.1)$$

where $v(m, \tau)$ is the current volatility, $v(1, \tau)$ is the current ATM volatility, and $\hat{\Theta}(\tau)$ is the long run mean of the ATM volatility.

Adaptiv Analytics can finally calibrate non-traded assets using the Beta Asset Price Volatility Model Calibration,

Theory Guide 3.9.3.1.1

which have $\hat{\beta}(p)$ values in the pre-computed statistics but not $\check{\sigma}(p)$ and $\hat{\alpha}(p)$ values. For non-traded assets, $\sigma = \beta\sigma_I$ and α is set to the average of the $\hat{\alpha}(I(p))$ over all index factors $I(p)$ for $p \in \mathcal{M}$.

Systemic Calibration: The systemic version of this calibration behaves as follows:

Theory Guide 3.9.3.1.2

The systemic calibration sets the Systemic Weight to 1 and the name of the systemic factor to the asset volatility name. The other model parameters are calculated using the calibration of the simple asset price volatility model of Section 3.9.1.1.

32.2.2.2 Maximum Likelihood Estimation

Calibration can be performed using Maximum Likelihood Estimation for beta volatility models via method outlined in Section 27.1.1.2.

Adaptiv Analytics makes use of a Systemic Weight, denoted by ω . When the parameter Idiosyncratic Factor is Yes, the calibration is performed as follows:

Theory Guide 3.9.3.2.1

If Idiosyncratic Factor is Yes then $\omega = R(\rho; \Theta)$, where Θ is the calibration parameter Significance Threshold, R is the weight rounding function defined in Section B.1.3, and ρ is the maximum likelihood estimate of the correlation between two Ornstein-Uhlenbeck processes: the average log asset volatility and the average log systemic factor, where the averages are over sets of points determined by the window parameters, as in Section 3.9.1.2. ρ is calculated from Equation (3.29) using maximum likelihood estimates of α and θ for the average log asset volatility and maximum likelihood estimates of α_I and θ_I for the average log systemic factor.

When Idiosyncratic Factor is No, $\omega = 1$, with other factors calibrated as described above. Adaptiv Analytics allows estimates recovered by calibration to be conditioned on α and/or α_I by calibration parameters.

Systemic Calibration: The systemic version of this calibration behaves as follows:

Theory Guide 3.9.3.2.2

The systemic calibration sets the Systemic Weight to 1 and the name of the systemic factor to the asset volatility name. The other model parameters are calculated using the maximum likelihood calibration of the simple asset price volatility model of Section 3.9.1.2.

32.2.3 Properties

The following properties are defined for both variants of this calibration.

Blend Method Blend Method, with two options Drift To Blend or Log Drift To Blend. See Blend Method property in Section 19.2.1.1 for details.

Calibration Method Choice of calibration method; Pre Computed Statistics or MLE. See Section 27.1.1.

32.2.3.1 Beta Calibration

The following properties are additionally defined for the beta calibration variant.

Idiosyncratic Factor Specifies whether the calibration will allow an idiosyncratic factor. Yes or No.

Significance Threshold Any driver weights with absolute value less than the threshold are rounded to zero. Scalar.

Systemic Factor The Driver used to lookup beta values.

32.2.4 Assumptions and Limitations

There are no specific assumptions or limitations in the calibration of this model; see general assumptions and limitations, Section [27.1.2](#).

32.3 PCA Volatility Model Calibrations

32.3.1 Overview

For details about the calibration of these models, see the Theory Guide [7, § 3.9.2 PCA Model].

32.3.2 Calibration Method

Adaptiv Analytics includes four variants of PCA Volatility Model calibrations; one for each of FX, Asset Price, Interest Rate, Interest Yield. These use the `PCAFXVolCalibration`, the `PCAAssetPriceVolCalibration`, the `PCAIInterestRateVolCalibration`, and the `PCAIInterestYieldVolCalibration`, respectively.

The calibration uses the Log statistics of the implied volatilities to calculate eigenvalues and eigensurfaces. Using a set of points \mathcal{P} defined on the volatility surface with dimensions time to expiry and moneyness, Adaptiv Analytics constructs an $n \times n$ covariance matrix C where C_{ij} the covariance between changes in log volatility at surfaces points p_i and p_j with $p_i, p_j \in \mathcal{P}$.

From this covariance matrix, Adaptiv Analytics calibrates the volatility models as follows.

Theory Guide 1.8.8.1

Diagonalizing the positive semidefinite matrix C , there is an orthogonal matrix F_{ij} and non-negative eigenvalues σ_i^2 such that

$$C_{ij} = \sum_{k=1}^n F_{ik} \sigma_k^2 F_{jk} \quad (32.3.1)$$

and $\sigma_1 \geq \dots \geq \sigma_n \geq 0$. The eigensurfaces are defined by

$$f_k(p_i) = F_{ik}, \quad (32.3.2)$$

and by linear interpolation and flat extrapolation for surface points not in \mathcal{P} .

The model is supplied with the largest m eigenvalues and the corresponding eigensurfaces (where m is a parameter of the calibration calculation).

Finally:

Theory Guide 3.9.2

The calibration sets $\alpha = \sum_{p \in \mathcal{P}} \hat{\alpha}(p) / |\mathcal{P}|$.

32.3.3 Properties

All four variants of PCA volatility model calibrations use the following properties.

Expiry Grid List of expiry dates (periods). Used to define points along the time to expiry dimension of the volatility surface used for calibration. Forms the calibration grid alongside moneyness.

Moneyness Grid List of scalars representing moneyness. Used to define points along the moneyness dimension of the surface volatility surface used for calibration. Forms the calibration grid alongside time to expiry.

Number of PCA Factors Maximum number of PCA factors to return. Adaptiv Analytics will return this number of PCA factors, unless the level of variance specified in `Explained Variance` is achieved by fewer factors. Scalar.

Use Pre Computed Statistics If set to Yes, use pre-computed statistics derived from historical market rates; if No use archive market data directly.

There are no additional properties for any specific PCA volatility calibration.

32.3.4 Assumptions and Limitations

See Section 27.1.2 for general assumptions applicable to this calibration.

32.3.4.1 Interpolation and Extrapolation

Adaptiv Analytics extends the volatility surface by linear interpolation and flat extrapolation when a point p_i is required and $p_i \notin \mathcal{P}$.

32.3.4.2 Equivalence to Simple Volatility Models

Calibrating a beta model to a systemic model is equivalent to a simple volatility Maximum Likelihood Estimation calibration.

Chapter 33

Energy Model Calibrations

33.1 Clewlow-Strickland Forward Price Model

33.1.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.10.1 Clewlow-Strickland Model].

33.1.2 Calibration Method

Adaptiv Analytics includes two variants of the Clewlow-Strickland Forward Price Model calibration; a standard calibration variant, and a full calibration variant. These use the `CSForwardPriceCalibration` or the `CSForwardPriceCalibration.Full` classes, respectively.

The Clewlow-Strickland Forward Price Model can be calibrated either from the historical archive, or from market prices for a set of European energy futures. Where a set of market prices \mathcal{J} are used;

Theory Guide [3.10.1.2](#)

Analytics finds values of the constant model parameters σ and α that minimize

$$\sum_{j \in \mathcal{J}} \omega_j (V_j - V_j^{\text{CS}}(\sigma, \alpha))^2, \quad (33.1.1)$$

where V_j is the market value of instrument j , $V_j^{\text{CS}}(\sigma, \alpha)$ is the value of the instrument under the one-factor Clewlow-Strickland model with constant parameters σ, α , and $\omega_j > 0$ is the weight assigned to the instrument j .

The calculation of values for instruments under the Clewlow-Strickland model are can be found in the Theory Guide [7, § 3.10.1.2 Market Prices].

33.1.2.1 Standard Calibration

Theory Guide [3.10.1.1.1](#)

The calibration uses the Log statistics (Section 3.3) of the lowest tenor forward price and sets $\sigma = \hat{\sigma}$, $\alpha = \hat{\alpha}$ and $\mu = \hat{\mu} + \hat{\sigma}^2/2$.

33.1.2.2 Full Calibration

For the case of Full Calibration, Adaptiv Analytics uses a Nelder Mead downhill simplex algorithm, as follows. Note however that in this case, Adaptiv Analytics does not assign a value to the drift.

Theory Guide [3.10.1.1.2](#)

The calibration uses Log statistics of forward prices (Section [3.3](#)). Let τ_1, \dots, τ_n denote the forward price tenors in the archive. The calibration finds values of the model parameters σ and α that minimize

$$\sum_{k=1}^n (\sigma e^{-\alpha \tau_k} - \hat{\sigma}_k)^2, \quad (33.1.2)$$

where $\hat{\sigma}_k$ is the historical volatility of the forward price with tenor τ_k .

33.1.3 Properties

The following properties are common for all Clewlow-Strickland Forward Price Model calibrations.

Use Pre Computed Statistics If set to Yes, use pre-computed statistics derived from historical market rates; if No use archive market data directly.

33.1.3.1 Full Calibration

The following properties are additionally defined for full calibration.

Number Of Iterations Number of iterations used by the Nelder Mead simplex algorithm for optimisation. Scalar.

33.1.4 Assumptions and Limitations

See Section [27.1.2](#) for general assumptions applicable to this calibration.

33.1.4.1 Price Volatilities

The volatilities and market prices from which the model is calibrated may contain various quanto or compo adjustments. However, since Adaptiv Analytics is calibrating to these overall 'phenomenological' vols, additional quanto/compo adjustments are not made in calibration.

Furthermore, Black volatilities (i.e., log Volatility for this calibration) can be zero. However, since the Clewlow-Strickland model postulates a strictly positive exponential decay form for volatilities problems arise when certain volatilities are non-zero, but certain volatilities are exactly zero. To this end, Adaptiv Analytics floors all volatilities at a small positive value.

33.1.4.2 Reference Price Maturity

Adaptiv Analytics defines the reference price's maturity time as the last of the sample times.

33.2 Multi Factor Clewlow-Strickland Forward Price Model

33.2.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.10.2 Multi-Factor Clewlow-Strickland Model].

33.2.2 Calibration Method

The Multi Factor Clewlow-Strickland Forward Price Model can be calibrated using the `CSMulti-FactorForwardPriceCalibration` method in `Adaptiv Analytics`. The calibration method uses Log statistics of forward prices to calculate instantaneous volatility and drift curve using PCA (see Section 28.4.2.1).

`Adaptiv Analytics` performs this calibration by finding a set of eigenvalues and corresponding eigenvectors that define a defined degree of variance of the covariance matrix $C_{ij} = \hat{\sigma}_i \hat{\sigma}_j \hat{\rho}_{ij}$. From this covariance matrix, `Adaptiv Analytics` recovers the volatility as follows:

Theory Guide 3.10.2

Let λ_k denote the k^{th} eigenvalue and Q_{ik} denote the i^{th} component of the k^{th} eigenvector, where $\lambda_1 \geq \dots \geq \lambda_n$. The curve σ_k is defined by $\sigma_k(\tau_i) = Q_{ik} \sqrt{\lambda_k}$.

Where `Adaptiv Analytics` defines $\hat{\sigma}_j$ and $\hat{\rho}_{ij}$ as follows.

Theory Guide 3.10.2

Let $\hat{\sigma}_i$ and $\hat{\mu}_i$ denote the volatility and drift of the tenor- τ_i forward price, and let $\hat{\rho}_{ij}$ denote the correlation between the tenor- τ_i and the tenor- τ_j forward prices.

33.2.3 Properties

Lower Tenor Bound Tenor, defining the lower bound of the subset of tenors for forward prices to be used for calibration.

Number Of PCA Factors Maximum number of PCA factors to return. `Adaptiv Analytics` will return this number of PCA factors, unless the level of variance specified in `Explained Variance` is achieved by fewer factors. Scalar.

Upper Tenor Bound Tenor, defining the upper bound of the subset of tenors for forward prices to be used for calibration.

Use Drift Options of `Yes` or `No`, which define how the Drift Term μ is determined.

Theory Guide 3.10.2

If `Use Drift` is `Yes` then μ is defined by $\mu(\tau_i) = \hat{\mu}_i + \hat{\sigma}_i^2/2$. If `Use Drift` is `No` then μ is set to zero.

Use Pre Computed Statistics If set to `Yes`, use pre-computed statistics derived from historical market rates; if `No` use archive market data directly.

33.2.4 Assumptions and Limitations

See Section 27.1.2 for general assumptions applicable to this calibration.

33.2.4.1 Excess PCA Factors

If there are more PCA factors than historical variables, Adaptiv Analytics assign the remaining PCA volatilities to zero. In this case, entire volatility is captured, and the calibration is simply analysing the original covariance matrix in an orthogonal space.

33.2.4.2 Sign of First Eigenvector

The first eigenvector is usually interpreted as a parallel shift, for which a positive coefficient is expected. However, due to the Nelder Mede optimisation, a negative value can be found, which is consequently flipped by Adaptiv Analytics.

33.2.4.3 Correlations

The correlations in the Multi Factor Clewlow-Strickland Forward Price Model are set as follows.

Theory Guide [3.13.2.1](#)

The calibration of Section [3.10.2](#) sets $\sigma_k(\tau_i) = Q_{ik}\sqrt{\lambda_k}$ for $k \leq q$, where $q = \min(p, 3)$ and the correlation coefficients are given by $a_{ki} = \sigma_k(\tau_i)\hat{\sigma}_i$.

33.3 Ornstein-Uhlenbeck Forward Spread Model

33.3.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.10.3 Ornstein-Uhlenbeck Forward Spread Model].

33.3.2 Calibration Method

The Ornstein-Uhlenbeck Forward Spread Model can be calibrated using the `OUFowardSpread-Calibration` method in Adaptiv Analytics.

Adaptiv Analytics offers both pre-computed statistics or Maximum Likelihood calibrations for the Ornstein-Uhlenbeck Forward Spread Model.

33.3.2.1 Pre-Computed Statistics

If the pre-computed statistics calibration method is chosen, Adaptiv Analytics calibrates the model using the `Diff` statistics of forward spreads.

Theory Guide [3.10.3.1](#)

Let τ_1, \dots, τ_n denote the tenors of the forward spreads for which there are statistics. The volatility curve is given by $\sigma(t_0 + \tau_k) = \check{\sigma}_k$, where $\check{\sigma}_k$ is reversion volatility for tenor τ_k and t_0 is the Base Date. The calibration sets $\theta(T) = F_{\text{spread}}(0, T)$ and $\alpha = \sum_{k=1}^n \hat{\alpha}_k / n$, where $\hat{\alpha}_k$ is mean reversion speed for tenor τ_k .

33.3.2.2 Maximum Likelihood

The maximum likelihood calibration for the Ornstein-Uhlenbeck Forward Spread Model defines two series of observations at times t_1, \dots, t_N and t'_1, \dots, t'_N , with $t_i < t'_i \leq t_{i+1}$. These time series may (optionally) then be exponentially detrended (see Section [28.3.2.1](#)).

Adaptiv Analytics defines the forward spread the spread between two times separated by tenor τ_k , t and $t + \tau_k$ as $F_k(t) = F_{\text{spread}}(t, t + \tau_k)$. Maximum likelihood estimates for correlated Ornstein-Uhlenbeck processes $F_1(t) \dots F_N(t)$ are then applied to observations at times $t_1 \dots t_N$ and $t'_1 \dots t'_N$, from which Adaptiv Analytics may obtain the following calibrations as follows:

Theory Guide [3.10.3.2](#)

This gives volatility estimates $\sigma_1, \dots, \sigma_n$ and an estimate for the reversion speed α . The estimates are conditional on long run mean values $\theta(t_0 + \tau_k)$, where t_0 is the Base Date. If Condition On Reversion Speed is Yes then then the σ_k are estimated conditional on the value of α specified by Reversion Speed.

Theory Guide [3.10.3.2](#)

The volatility curve is given by $\sigma(t_0 + \tau_k) = \sigma_k$.

In maximum likelihood calibration of a Ornstein-Uhlenbeck Forward Spread Model, long run mean θ is defined as follows.

Theory Guide [3.10.3.2](#)

The calibration sets $\theta(T) = F_{\text{spread}}(0, T)$.

33.3.3 Properties

Calibration Method Choice of calibration method; Pre Computed Statistics or MLE. See Section 27.1.1.

Base Date Base date for the calibration; see Section 33.3.2.2. If not set, Adaptiv Analytics uses the base date provided in the market data.

Last Rollover Date The last rollover date; the most recent rollover date, assumed to be the first point in the supplied curve if not provided.

Condition On Reversion Speed If Yes, output parameters will be conditional on the given Alpha.

Reversion Speed Optional value to use a reversion speed; scalar. Used in combination with Condition On Reversion Speed to fix reversion speed in calibration.

33.3.4 Assumptions and Limitations

There are no specific assumptions or limitations in the calibration of this model; see general assumptions and limitations, Section 27.1.2.

33.4 Ornstein-Uhlenbeck Forward Spread Term Structured Model

33.4.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.10.4 Ornstein-Uhlenbeck Forward Spread Term Structure Model].

33.4.2 Calibration Method

The Ornstein-Uhlenbeck Forward Spread Term Structured Model can be calibrated using the `OU-ForwardSpreadTSCalibration` method in Adaptiv Analytics. As for the non term-structure variant, both pre-computed statistics and maximum likelihood calibrations are supported.

33.4.2.1 Pre-Computed Statistics

The statistical calibration for the Ornstein-Uhlenbeck Forward Spread Term Structured Model is similar to the non term-structure version of the model; see Section 33.3.2.1.

Theory Guide 3.10.4

The calibration is the same as Section 3.10.3.1 except that the reversion speed curve is given by $\alpha(t_0 + \tau_i) = \hat{\alpha}_i$, where $\hat{\alpha}_i$ is reversion speed for tenor τ_i and t_0 is the Base Date.

33.4.2.2 Maximum Likelihood

The maximum likelihood calibration for the Ornstein-Uhlenbeck Forward Spread Term Structured Model is similar to the non term-structure version of the model; see Section 33.3.2.2.

Theory Guide 3.10.4

The calibration is the same as Section 3.10.3.2 except that the mean reversion speeds for different tenors are not constrained to be the same. The reversion speed curve is given by $\alpha(t_0 + \tau_k) = \alpha_k$, where α_k is the estimate of the reversion speed for tenor τ_k and t_0 is the Base Date.

33.4.3 Properties

Calibration Method Choice of calibration method; Pre Computed Statistics or MLE. See Section 27.1.1.

Base Date Base date for the calibration; see Section 33.3.2.2. If not set, Adaptiv Analytics uses the base date provided in the market data.

Last Rollover Date The last rollover date; the most recent rollover date, assumed to be the first point in the supplied curve if not provided.

Condition On Reversion Speed If Yes, output parameters will be conditional on the given Alpha.

Reversion Speed Optional value to use a reversion speed; scalar. Used in combination with `Condition On Reversion Speed` to fix reversion speed in calibration.

Min Reversion Speed If calibrated reversion speed is lower than specified minimum reversion speed, then process will be re-calibrated conditional on given minimum reversion speed. Bounds can be ignored by setting to 0 (`Max Reversion Speed` must also be set to 0). Scalar.

Max Reversion Speed If calibrated reversion speed is higher than specified maximum reversion speed, then process will be re-calibrated conditional on given maximum reversion speed. Bounds can be ignored by setting to 0 (Min Reversion Speed must also be set to 0). Scalar.

33.4.4 Assumptions and Limitations

There are no specific assumptions or limitations in the calibration of this model; see general assumptions and limitations, Section [27.1.2](#).

Chapter 34

Hazard Rate Calibrations

34.1 Jump Cox-Ingersoll-Ross Hazard Rate Model

34.1.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.6.3 Cox-Ingersoll-Ross Model].

34.1.2 Calibration Method

The Jump Cox-Ingersoll-Ross Hazard Rate Model can be calibrated using the `CIRHazardRateCalibration` method in Adaptiv Analytics. The calibration method used by Adaptiv Analytics is similar to that of the Cox-Ingersoll-Ross Interest Rate Model described in Section 18.6, whereby the calibration finds values for κ and θ by the average statistics of each tenor.

The calibration of this model is described in more detail in Section 18.6.

34.1.3 Properties

Use Pre Computed Statistics If set to `Yes`, use pre-computed statistics derived from historical market rates; if `No` use archive market data directly.

34.1.4 Assumptions and Limitations

See Section 27.1.2 for general assumptions applicable to this calibration.

34.1.4.1 Jump Feature

Adaptiv Analytics does not provide a calibration for the jump feature available in the Jump Cox-Ingersoll-Ross models. Consequently, when calibrated, the `Jump Arrival Rate` is set to 0 (i.e., no simulated jumps occur).

34.2 Exponential Vasicek Hazard Rate Model

34.2.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.11.2 Exponential Vasicek Model].

34.2.2 Calibration Method

The Exponential Vasicek Hazard Rate Model can be calibrated using the `ExpVasicekHazardRateCalibration` method in Adaptiv Analytics.

Adaptiv Analytics calibrates the Exponential Vasicek using Log statistics of the log survival probabilities, as follows.

Theory Guide 3.11.2

The log survival probabilities are $I_1(t), \dots, I_n(t)$, where $I_k(t) = -\log S(t, t + \tau_k)$ and τ_1, \dots, τ_n are the tenors in the archive. $I_1(t)/\tau_1$ is an approximation of $h(t)$. The calibration sets $\sigma = \check{\sigma}_1$, $\alpha = \sum_{k=1}^n \hat{\alpha}_k/n$ and $\theta = \hat{\theta}_1 - \log \tau_1$, where $\check{\sigma}_1$ is the reversion volatility of I_1 , $\hat{\alpha}_k$ is the mean reversion speed of I_k , and $\hat{\theta}_1$ is the long run mean of $\log I_1$.

34.2.3 Properties

Use Pre Computed Statistics If set to Yes, use pre-computed statistics derived from historical market rates; if No use archive market data directly.

34.2.4 Assumptions and Limitations

There are no specific assumptions or limitations in the calibration of this model; see general assumptions and limitations, Section 27.1.2.

34.3 Hull-White Hazard Rate Model

34.3.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.11.1 Hull-White Model].

34.3.2 Calibration Method

The Hull-White Hazard Rate Model can be calibrated using the `HwHazardRateCalibration` method in `Adaptiv Analytics`.

`Adaptiv Analytics` calibrates the Hull-White Hazard Rate Model using `Diff` statistics of the log survival probabilities, as follows.

Theory Guide 3.11.1

The log survival probabilities are $I_1(t), \dots, I_n(t)$, where $I_k(t) = -\log S(t, t + \tau_k)$ and τ_1, \dots, τ_n are the tenors in the archive. $I_1(t)/\tau_1$ is an approximation of $h(t)$. The calibration sets $\sigma = \check{\sigma}_1/\tau_1$ and $\alpha = \sum_{k=1}^n \hat{\alpha}_k/n$, where $\check{\sigma}_1$ is the reversion volatility of I_1 and $\hat{\alpha}_k$ is the mean reversion speed of I_k .

34.3.3 Properties

Use Pre Computed Statistics If set to `Yes`, use pre-computed statistics derived from historical market rates; if `No` use archive market data directly.

34.3.4 Assumptions and Limitations

There are no specific assumptions or limitations in the calibration of this model; see general assumptions and limitations, Section 27.1.2.

34.4 Multi-Factor GBM Hazard Rate Model

34.4.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.5.2 Multi-Factor GBM Model: PCA Calibration, § 3.5.4 Multi-Factor GBM Model: Beta Calibration and § 3.5.3 Multi-Factor GBM Model: Regression Calibration].

34.4.2 Calibration Method

Adaptiv Analytics includes two variants of the Multi-Factor GBM Hazard Rate Model calibration; a PCA variant and a regression variant. These use the `MultiGBMHazardRatePCACalibration` or the `MultiGBMHazardRateRegressionCalibration` classes, respectively. The calibration methods in both cases are similar to the Multi-Factor GBM Asset Price Model.

Note however that unlike the Asset price model, Hazard Rate models do not require a drift term. Consequently, drift (μ) is not set during calibration.

34.4.2.1 Regression calibration

The regression calibration for the Multi-Factor GBM Hazard Rate Model is analogous to the Asset Price Model; see Section 28.4.2.2.

34.4.2.2 PCA calibration

The PCA calibration for the Multi-Factor GBM Hazard Rate Model is analogous to the Asset Price Model; see Section 28.4.2.1.

34.4.3 Properties

The following properties are common for all Multi-Factor GBM Hazard Rate Model calibrations.

Significance Threshold Any driver weights with absolute value less than the threshold are rounded to zero. Scalar.

Use Pre Computed Statistics If set to `Yes`, use pre-computed statistics derived from historical market rates; if `No` use archive market data directly.

34.4.3.1 PCA Calibration

The following properties are additionally defined for full calibration.

Calibrate All In Group If `No`, only primary model parameters are calibrated; otherwise, if `Yes`, calibrate all parameters.

Explained Variance Target variance that should be accounted for by the PCA calibration. Adaptiv Analytics will find the minimum number of factors that explain this level of variance (unless this is greater than the `Number of PCA Factors`). Scalar.

Group By Indication of how to group factors. When `All`, matches everything. Otherwise, will use the Grouping file for a matching tag. If blank, uses the `PCA Group` tag.

Idiosyncratic Factor Specifies whether the calibration will allow an idiosyncratic factor. `Yes` or `No`.

Number Of PCA Factors Maximum number of PCA factors to return. Adaptiv Analytics will return this number of PCA factors, unless the level of variance specified in `Explained Variance` is achieved by fewer factors. Scalar.

Tenor The target tenor to be used for calibration. Scalar.

34.4.3.2 Regression Calibration

The following properties are additionally defined for regression calibration.

Drivers List of driving factor (stochastic process) IDs underpinning the model to be calibrated.

Lower Tenor Tenor, defining the lower bound of the subset of tenors for forward prices to be used for calibration.

Upper Tenor Tenor, defining the upper bound of the subset of tenors for forward prices to be used for calibration.

34.4.4 Assumptions and Limitations

There are no specific assumptions or limitations in the calibration of this model; see general assumptions and limitations, Section [27.1.2](#).

34.5 Multi-Factor GOU Hazard Rate Model

34.5.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.11.3 Multi-Factor GOU Model].

34.5.2 Calibration Method

The Multi-Factor GOU Hazard Rate Model can be calibrated using the `MultiGOUHazardRateRegression-Calibration` method in Adaptiv Analytics.

The calibration used for the Multi-Factor GOU Hazard Rate Model is similar to the that of Multi-Factor GBM Asset Price Model, described in Section 28.4. Adaptiv Analytics therefore recovers idiosyncratic and systemic driver weights by regression, using Log log survival probability statistics for a subset of tenors τ_1, \dots, τ_n .

Theory Guide 3.11.3

The volatility curve is given by $\sigma(\tau_k) = \check{\sigma}_k$, where $\check{\sigma}_k$ is the reversion volatility for tenor τ_k . The calibration sets $\alpha = \sum_{k=1}^n \hat{\alpha}_k / n$, where $\hat{\alpha}_k$ is the mean reversion speed for tenor τ_k .

34.5.3 Properties

Drivers List of driving factor (stochastic process) IDs underpinning the model to be calibrated.

Idiosyncratic Factor Specifies whether the calibration will allow an idiosyncratic factor. Yes or No.

Lower Tenor Tenor, defining the lower bound of the subset of tenors for log survival probabilities to be used for calibration.

Significance Threshold Any driver weights with absolute value less than the threshold are rounded to zero. Scalar.

Upper Tenor Tenor, defining the upper bound of the subset of tenors for log survival probabilities to be used for calibration.

Use Pre Computed Statistics If set to Yes, use pre-computed statistics derived from historical market rates; if No use archive market data directly.

34.5.4 Assumptions and Limitations

There are no specific assumptions or limitations in the calibration of this model; see general assumptions and limitations, Section 27.1.2.

Chapter 35

Credit Rating Models

35.1 Hull-White Credit Rating Model

35.1.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § 3.12.1 Multi-Factor Diffusion Credit Rating Models].

35.1.2 Calibration Method

Adaptiv Analytics includes two variants of the Hull-White Credit Rating Model calibration; a PCA, and a regression variant. These use the `HullWhiteCreditRatingPCACalibration` or the `HullWhiteCreditRatingRegressionCalibration` classes, respectively.

Credit rating changes do not occur frequently enough to offer a meaningful time series from which a model could be calibrated (to historic data). Instead, Adaptiv Analytics adopts an analogous approach to Merton's Asset Value Model [12], whereby a creditworthiness process $W_m(t)$ is identified. Transition thresholds in this process are determined, from which an assessment of creditworthiness can be made.

A time series of an entities total asset value would be ideal for this purpose (such that default would occur if debt obligations exceed assets), although is not available in the market. Therefore, equity prices are used for calibration in Adaptiv Analytics.

Theory Guide 3.12.1.1

The key information we require is the correlation between the asset values of the various companies. Often a large component of a company's assets are funded by equity and for this reason it is known that the total asset value of a company usually moves together with its equity price.

35.1.2.1 PCA Calibration

Adaptiv Analytics can perform PCA calibration of the Hull-White Credit Rating Model; the method employed is identical to that of the Multi-Factor GBM Asset Price model described in Section 28.4.2.1.

35.1.2.2 Regression Calibration

For regression calibration, Adaptiv Analytics extracts a time series of equity price data from the historic archive, and performs a regression calibration identical to that from the Multi-Factor GBM Asset Price model described in Section 28.4.2.2.

35.1.3 Properties

The following properties are common for all Hull-White Credit Rating Model calibrations.

Significance Threshold Any driver weights with absolute value less than the threshold are rounded to zero. Scalar.

Use Pre Computed Statistics If set to Yes, use pre-computed statistics derived from historical market rates; if No use archive market data directly.

35.1.3.1 PCA Calibration

The following properties are additionally defined for full calibration.

Calibrate All In Group If No, only primary model parameters are calibrated; otherwise, if Yes, calibrate all parameters.

Explained Variance Target variance that should be accounted for by the PCA calibration. Adaptiv Analytics will find the minimum number of factors that explain this level of variance (unless this is greater than the Number of PCA Factors). Scalar.

Group By Indication of how to group factors. When All, matches everything. Otherwise, will use the Grouping file for a matching tag. If blank, uses the PCA Group tag.

Idiosyncratic Factor Specifies whether the calibration will allow an idiosyncratic factor. Yes or No.

Number Of PCA Factors Maximum number of PCA factors to return. Adaptiv Analytics will return this number of PCA factors, unless the level of variance specified in Explained Variance is achieved by fewer factors. Scalar.

35.1.3.2 Regression Calibration

The following properties are additionally defined for regression calibration.

Drivers List of driving factor (stochastic process) IDs underpinning the model to be calibrated.

35.1.4 Assumptions and Limitations

There are no specific assumptions or limitations in the calibration of this model, beyond the implicit assumption that a method analogous to Merton's Asset Value Model can be applied to credit ratings; see general assumptions and limitations, Section [27.1.2](#).

35.2 Multi-Factor Diffusion Credit Rating Model

35.2.1 Overview

For details about the calibration of this model, see the Theory Guide [7, § [3.12.1 Multi-Factor Diffusion Credit Rating Models](#)].

35.2.2 Calibration Method

Adaptiv Analytics includes two variants of the Multi-Factor Diffusion Credit Rating Model calibration; a PCA, and a regression variant. These use the `DiffusionCreditRatingPCACalibration` or the `DiffusionCreditRatingRegressionCalibration` classes, respectively.

The Multi-Factor Diffusion Credit Rating Model has identical parameters to, and can be calibrated in the same way as, the Hull-White Credit Rating Model.

Theory Guide [3.12.1](#)

These models have different behavior, particularly around the interpretation of their transition boundaries, but they have identical model parameters which can be calibrated in the same way. Therefore these models are considered together here.

It follows that details pertinent to the calibration of the Multi-Factor Diffusion Credit Rating Model in Adaptiv Analytics can be found in [Section 35.1](#).

35.2.3 Properties

Both Regression and PCA variants of the Multi-Factor Diffusion Credit Rating Model calibration use the same properties as those of the Hull-White Credit Rating Model (see [Section 35.1.3](#)).

35.2.4 Assumptions and Limitations

There are no specific assumptions or limitations in the calibration of this model, beyond the implicit assumption that a method analogous to Merton's Asset Value Model can be applied to credit ratings; see general assumptions and limitations, [Section 27.1.2](#).

Chapter 36

Correlations Calibrations

36.1 Correlations Calibration

36.1.1 Overview

Where multiple price factor models are included in a single simulation, correlations between such models must be included. In Adaptiv Analytics, such correlations are encoded as a vector of standard normal variables, which in turn are used to drive updates to the models' state variables.

Theory Guide [3.13](#)

For a given simulation time point, let $Z = (Z_1, \dots, Z_m)^T$ denote the combined vector of normal samples for all price factor models used in the portfolio calculation. The component standard normal variables Z_k are referred to as *correlated normals*.

A *correlations calibration* is a calculation that sets the correlations between the correlated normals.

For details about the correlation calibration, see the Theory Guide [[7](#), §[3.13 Correlations Calibration](#)].

36.1.2 Calibration Method

Correlation Matrices can be calibrated using the `CorrelationsCalibration` method in Adaptiv Analytics. Note that correlations calibration refers to the calibration of risk factors between different price factor models. Some models have additional, internal correlations between their globally correlated risk factors and their internal risk factors. These internal risk factors are indirectly correlated with global risk factors via their coupling to the model's global risk factors, and are described on the individual models to which they apply.

Adaptiv Analytics provides tools for a *correlations calibration* from which correlations between correlated normals are derived. These are usually fewer in number than the factor values, and are derived from pre-computed statistics provided in the `Correlations File`.

Theory Guide [3.13](#)

The standard correlations calibration assumes that the k^{th} correlated normal is a linear combination of returns on factor values P_i :

$$Z_k = \frac{1}{N_k} \sum_i a_{ki} \frac{\Delta y_i - \mu_i}{\sigma_i}, \quad (36.1.1)$$

where the a_{ki} are constant *correlation coefficients*, either $y_i = P_i$ for return method Diff or $y_i = \log P_i$ for return method Log, σ_i and μ_i are the standard deviation and mean of Δy_i ,

$$N_k^2 = \sum_{ij} a_{ki} a_{kj} \rho_{ij} > 0, \quad (36.1.2)$$

and $\rho_{ij} = \text{corr}(\Delta y_i, \Delta y_j)$. The definition of the normalization factors (36.1.2) ensures that $\text{var}(Z_k) = 1$. Then it follows that

$$\text{corr}(Z_k, Z_l) = \sum_{ij} b_{ki} b_{lj} \rho_{ij}, \quad (36.1.3)$$

where $b_{ki} = a_{ki}/N_k$ are the normalized correlation coefficients. The factor correlations ρ_{ij} are taken from the pre-computed statistics.

36.1.3 Properties

The properties set for correlation matrix are as follows.

Use Averaging Determines whether correlated normals should be obtained from a single factor value return (when No), or an average of factor value returns when Yes.

Theory Guide 3.13.1

If Use Averaging is Yes then Z_k is represented by an average of factor value returns:

$$Z_k = \frac{1}{N_k} \sum_{i \in I_k} \frac{\Delta y_i - \mu_i}{\sigma_i}, \quad (36.1.4)$$

where I_k is the set of indexes of points on the price factor curve or surface for which there are pre-computed statistics, and $N_k^2 = \sum_{i,j \in I_k} \rho_{ij}$.

When $N_k = 1$ when No.

36.1.4 Assumptions and Limitations

36.1.4.1 Threshold

In calibration (particularly for PCA factors), very small calibrations may be found by the Correlations-Calibration due to numerical errors. When these fall below a threshold, these are set to 0. Note however that, for (orthogonal) PCA factors, such correlations should in any case be 0.

Part V

OTC Derivatives: Asset Prices

Chapter 37

Asset Price Derivatives

37.1 Overview

Asset price derivatives are derivatives on equities, cash and carry commodities, or foreign exchange. See Section 4 for a description of asset price factors. These deals have similar properties and use similar pricing models for all three types of underlying asset, although some details are asset-specific.

37.2 Common Properties

The properties described below are often found on asset derivative deal types.

37.2.1 Barrier Monitoring Frequency

The barrier monitoring frequency specifies how frequently the barrier is tested for touching. See Section 37.3.7.1 for details about the effect of this property.

37.2.2 Barrier Price

The barrier asset price.

37.2.3 Barrier Type

The barrier may be `Down And In`, `Down And Out`, `Up and In`, or `Up And Out`.

37.2.4 Basket

`Basket` is used instead of an asset price factor ID for forward contracts or options written on a basket of assets rather than a single asset. This property comprises several sub-properties.

Basket Components: A basket component specifies information about one asset in the basket. The details of a basket component depend on the specific type of asset in the basket.

Correlation Set: This is an optional prefix applied to the IDs of correlation price factors needed when pricing a basket. See Section 12.2.3.1.

The following sub-properties are found only on basket options, and used only for baskets of returns, as opposed to baskets of prices. Forward contracts support only baskets of prices.

Basket Multiplier: When the basket type is `Returns`, the basket multiplier is a factor that scales the return.

Basket Return Type: When the basket type is Returns, the basket return type indicates whether the return is Proportional Factor Or Proportional Change.

Basket Type: The basket type indicates whether the basket is a basket of Prices or a basket of Returns.

Reset Date: When the basket type is Returns, the Reset Date is the base date from which returns are measured.

37.2.5 Buy Sell

Buy denotes a bought option or a long forward contract. Sell denotes a sold option or a short forward contract.

37.2.6 Cash Payoff

The amount of the cash payment, if any, in payoff currency.

37.2.7 Cash Rebate

The amount of the rebate, if any, in payoff currency.

37.2.8 Expiry Date

The date on which an option expires and settles.

37.2.9 Forward Price Date

This property is only used when Option on Forward is set to Yes. In this case, it specifies the maturity date of the forward contract underlying the option.

37.2.10 Lower Barrier:

The lower barrier asset price.

37.2.11 Maturity Date

The date on which a forward contract both fixes and is settled in Adaptiv Analytics.

37.2.12 Option on Forward

When set to Yes, the underlying of the option is interpreted as a forward contract.

37.2.13 Option Style

This may be American Or European.

37.2.14 Option Type

This may be Call or Put.

37.2.15 Payment Timing

Payment for one-touch or double one-touch options may be either at Touch or at Expiry.

37.2.16 Payoff Type

This may be Standard, Quanto, or Compo. Standard may only be used when the Currency and the Payoff Currency are identical.

37.2.17 Sampling Data

Each entry in this list represents a weighted price observation in the weighted sum of an explicit averaging forward contract or explicit Asian option. The Date specifies the observation date and the Weight specifies the observation weight. It is an error to attempt to value the deal with an empty sampling data list. It is an error to enter a sampling date after the option expiry. It is an error to enter a duplicate sampling date. It is an error to enter a negative sampling weight. A sampling weight of zero generates a warning message.

The Price property of an entry may be used to specify historical price observations that have been realized on or before the base date of a calculation. If the Price of an entry for a date before the base date is undefined, it will be read from the rate fixings archive (Section 3.1.3), if one is available. If the Price of an entry on the base date is undefined, or if a price for a date before the base date is missing from both the Price property and the rate fixings archive, the price factor value specified in the market data file will be used.

37.2.17.1 Basket Sampling Data

When an option is on a basket instead of a single asset, the Price values in each entry of the sampling data refer to the price or return of the entire basket, and must already incorporate the basket weights. In the case of compo payoffs, these values must also incorporate the conversion of currency. However, these historical values must not incorporate the basket multiplier. Unlike single-asset Asian options, the historical values of baskets cannot be stored in the rate fixings archive; nor does Adaptiv Analytics have the ability to calculate the historical basket value from historical rate fixings for its component assets. The base date price or return of the basket will be substituted for any missing entry.

37.2.18 Settlement Style

This property is only used when Option on Forward is set to Yes. When set to Cash, the value of the forward contract will be settled on the expiry date if the option is exercised. When set to Physical, the option will convert to the underlying forward contract if it is exercised. Note that this feature can be used to work around the limitation that there is no explicit distinction between the option expiry date and the option settlement date.

37.2.19 Strike Price

The strike price of an option denominated in the asset currency except for compo options, when it is denominated in the settlement currency.

37.2.20 Upper Barrier

The upper barrier asset price.

37.3 Assumptions

The assumptions stated below are commonly applicable to asset deal types.

37.3.1 Value of an Underlying Asset

Asset price derivatives require the price of one unit of the underlying asset at future dates. Asset prices are modelled as cash-and-carry spot prices with zero settlement lag (Section 4.1).

This price S is denominated in the asset currency of the asset price factor.

Theory Guide [4.1.1](#)

The *asset currency* is the currency in which the asset price is expressed, defined by the Currency property of the deal. Let $S(t)$ denote the spot price of the asset in asset currency at time t . For FX deal types, $S(t)$ is the spot price of the Underlying Currency in Currency.

If the Currency property is not set, then the asset currency is assumed to be base currency.

Theory Guide [4.1.1](#)

Unless otherwise stated, all valuations are expressed in the payoff currency, and given for deals where the underlying is one unit of the asset. These valuations are then multiplied by the number of Units for equity and commodity deal types, or the Underlying Amount for FX deal types.

37.3.2 No Arbitrage

The valuation of an asset price forward assumes no cash-and-carry arbitrage. When an arbitrage-free expectation of a forward asset price is required, it is calculated from the spot price, the asset price interest rate, and the yield or cost of carry of the asset (Section [4.1.2](#)). This is the dividend for an equity Section [7.1](#)), the foreign currency interest rate for an FX rate, or the convenience yield for a commodity.

37.3.3 Spot Price Dynamics

Unless otherwise stated, all asset derivatives pricing formulas in Adaptiv Analytics that depend on the dynamics of the asset spot price assume that the stochastic process of an asset price is described by geometric Brownian motion (Theory Guide [\[7, § 1.3.5 GBM Model\]](#)), so that the marginal distribution of an asset price at any time is lognormal.

Theory Guide [4.1.1](#)

Asset prices are assumed to be lognormally distributed, and interest rates and asset yields are assumed to be deterministic. Under these assumptions, the prices of forward contracts and European options are given by closed-form formulas.

Option prices and quanto or compo adjustments are examples of formulas that depend on spot price dynamics. A correlation between equity prices or equity and FX prices refers to the correlation between their stochastic processes. The volatility and correlation parameters used for pricing are represented by price factors, see Sections [11.2.1](#) and [12.2](#) respectively.

Formulas for exotic options make the stronger assumption of constant parameters.

Theory Guide [4.1.1](#)

Exotic options are those which do not have a European exercise, or which depend on intermediate values of the underlying asset, or which have non-linear payoffs. Under the additional assumptions that the volatility σ , the carry rate b and the interest rate r are all constant, the prices of many exotic options are given exactly or approximately by a closed-form formula.

The principal source of the formulas used by Adaptiv Analytics is Haug [\[27\]](#).

37.3.4 Valuation of Quanto and Compo Payoffs

Several equity and FX deal types support quanto and compo payoffs. These payoffs are valued using either the risk-neutral forward price of the asset in the payoff currency or the risk-neutral rate of return implied by that forward price. The calculation of these quantities requires a change of measure to the payoff currency, which assumes geometric Brownian motion Section 37.3.3, and which requires volatility parameters for the asset and currency GBM processes and a correlation parameter. See Theory Guide [7, § 4.1.36 Quanto Deals] and Theory Guide [7, § 4.1.37 Compo Deals] for details.

Interpreting the Currencies of Quanto and Compo Deals: Quanto and compo deals must distinguish between the asset and the payoff currencies.

Theory Guide 4.1.1

Equity and commodity deals that have a Payoff Currency also have a Payoff Type. If the Payoff Type is Standard then the payoff currency must be the same as the asset currency. If the Payoff Type is Quanto or Compo then the payoff currency and asset currency must be different. The valuation of quanto and compo deals is described in Sections 4.1.36 and 4.1.37 respectively.

For FX deal types, if the payoff currency is not the asset currency then the payoff is quanto, except for some deal types when the payoff currency is the underlying currency, as explained in Section 4.1.38. The valuation of quanto FX deals is described in Section 4.1.36.1.

Forward ATM Volatility Used for Change of Measure: The volatilities in the change of measure adjustment formulas are forward at-the-money. The volatility used for change of measure may therefore differ from that used in the underlying option formula, which depends on moneyness.

Theory Guide 4.1.36

In practice, σ is set to the implied forward ATM volatility of S for expiry date T , σ_X is set to the implied forward ATM volatility of X for expiry date T , and ρ is taken from the correlation price factor for S and X .

37.3.5 European Option Valuation

European options are valued using the Black formula. See Theory Guide [7, § 4.1.17 European Option] for a description of European option valuation.

37.3.6 American Option Valuation

American options are valued using the Bjerksund and Stensland approximation of 1993, in which exercise is triggered by touching a single flat barrier. See Theory Guide [7, § 4.1.18 American Option] for a description of American option valuation.

Note that physically settled options on forwards are always valued as European options even when the option style is American.

37.3.6.1 Early Exercise Today

Adaptiv Analytics can stop the option from being exercised on the base date of the calculation, via the `Early Exercise Today` parameter of the valuation model. Let the valuation date t correspond to one of the exercise dates, such that t is in the `Exercise Fees` schedule, if one has been specified, or is one of the accrual start dates. The option can be exercised at $t = 0$ only if `Early Exercise Today` is set to `Yes`. Otherwise, if `Early Exercise Today` is `No`, the option can be exercised at t only if $t > 0$.

The default value for `Early Exercise Today` is Yes. The setting of this parameter is important for calculations such as VaR, sensitivities and stress calculations. When `Early Exercise Today` is Yes, an inconsistency can exist where under a subset of scenarios the option will be exercised at $t = 0$, and under the remaining scenarios the option will not be exercised.

37.3.7 Barrier Option Valuation

Single barrier options are valued using the Reiner and Rubinstein formulas derived from the Black-Scholes model. See Theory Guide [7, § 4.1.27 [Barrier Option](#)] for a description of barrier option valuation.

37.3.7.1 Discrete Barrier Options

Barrier option deals have a `Barrier Monitoring Frequency` property which specifies the contractual frequency at which the barrier is tested for touching. For example, barriers are often tested against end-of-day prices, in which case the barrier is only tested daily. The frequency is specified as a term, from which an integer number of days is calculated. Zero means that the barrier is monitored continuously.

Discrete testing reduces the probability of observing a barrier touch. When the barrier monitoring frequency is greater than zero, barriers are adjusted to account for this by increasing barriers in pricing formulas for up options and decreasing them for down options, as described in Theory Guide [7, § 4.1.30 [Discrete Barrier Options](#)].

Theory Guide [4.1.30](#)

Let ϕ denote the Barrier Monitoring Frequency, and define $v = \sigma \sqrt{\ell(\phi)}$, where $\ell(\cdot)$ is the length of a term in years (defined in Section [I.1.3](#)). The adjusted barrier price is given by

$$\tilde{H} = \begin{cases} He^{\beta v} & S(t) < H \text{ (up option or upper barrier)} \\ He^{-\beta v} & S(t) > H \text{ (down option or lower barrier),} \end{cases} \quad (37.3.1)$$

where β is the constant defined by

$$\beta = \frac{-\zeta(1/2)}{\sqrt{2\pi}} \approx 0.5826, \quad (37.3.2)$$

with ζ the Riemann zeta function.

Note that the unadjusted barriers are used to determine whether an option has been knocked in or knocked out in simulation, as described in Section [37.4.14](#).

37.3.7.2 One-Touch and No-Touch Options

The barrier option model in Adaptiv Analytics supports the payment of rebates; that is, the payment of fixed amounts when a knock-out option is knocked out or a knock-in option is never knocked in. The barrier option model is based on the generalized European option that pays

Theory Guide [4.1.27](#)

$$(AS(T) + B) [\delta(S - K) > 0], \quad (37.3.3)$$

where A and B are constants, K is the strike price and $\delta = +1$ for a call option or $\delta = -1$ for a put option. A standard option has $A = \delta$ and $B = -\delta K$; and a binary option has $A = 0$ and B is the payoff amount.

This allows one-touch and no-touch options to be valued with the barrier option model, setting $A = 0$, $B = 1$, and setting the strike K equal to the barrier H to ensure that the option cannot pay without being touched.

Theory Guide [4.1.27.1](#)

For one-touch and no-touch options, σ is the implied volatility at t for expiry date T , forward price $F(t, T)$ and strike H .

One-Touch Options Paying When the Barrier is Touched: Suppose that a one-touch option pays fixed amount C immediately when the barrier is touched. This is valued by Adaptiv Analytics as a knock-out barrier option with rebate C .

One-Touch Options Paying at Expiry: A one-touch option that pays fixed amount C at expiry if the barrier is touched is valued in Adaptiv Analytics from the generalized European option formula.

No-Touch Options: A no-touch option that pays fixed amount C if barrier H is never touched is equivalent to a payment of C at expiry minus a one-touch option with barrier H paying C at expiry. It is valued in Adaptiv Analytics from the generalized European option formula.

37.3.8 Double Barrier Option Valuation

Double barrier options are valued using the infinite series formulas of Douady. See Theory Guide [7, § [4.1.28 Double Barrier Option](#)] for a description of double barrier option valuation.

37.3.8.1 Discrete Double Barrier Options

Double barrier option deals have a `Barrier Monitoring Frequency` property which specifies the contractual frequency at which the barrier is tested for touching. For example, barriers are often tested against end-of-day prices, in which case the barrier is only tested daily.

Discrete testing reduces the probability of observing a barrier touched. When the barrier monitoring frequency is greater than zero, the upper and lower barriers are adjusted to account for this as described in Section [37.3.7.1](#).

37.3.8.2 Double One-Touch and Double No-Touch Options

Adaptiv Analytics supports double one-touch and double no-touch barrier options. One-touch options may have different payoffs for upper and lower barriers, and the payment timing may be either on touching or at expiry. See Theory Guide [7, § [4.1.28.1 One-Touch and No-Touch Options and Rebates](#)] for a description of double one-touch and double no-touch valuation.

37.3.8.3 Max Iterations and Tolerance Parameters

The double barrier option formulas require the evaluation of theoretically infinite series. In practice, these series are approximated by truncation to at most `Max Iterations` terms. Fewer terms are used if the `Tolerance` is achieved before the maximum iterations.

Theory Guide [4.1.28](#)

Each infinite series $\sum_{n=-\infty}^{\infty} Q_n$ is approximated by

$$Q_0 + \sum_{n=1}^M (Q_n + Q_{-n}) [n < m], \quad (37.3.4)$$

where M is the valuation model parameter Max Iterations, and m is the first index for which $|Q_m + Q_{-m}| < \epsilon$, and ϵ is the valuation model parameter Tolerance.

The default value of Max Iterations is 4 because the series usually converge quickly to the option value.

37.3.9 Discrete Asian Option Valuation

Discrete Asian options pay off a function of a weighted arithmetic average of an asset price or a basket of asset prices measured at different times. See Theory Guide [7, § 4.1.33 Discrete (Explicit) Asian Option] for a description of discrete Asian option valuation.

37.3.9.1 Adjusting the Strike for Known Prices

In general, when an Asian option is mid-life, some of the prices in the average are known because they are in the past, and others are in the future and not yet known. These known prices may be specified on the Sampling Data (Section 37.2.17) property of explicit discrete Asian options. Otherwise, they may be stored in the rate fixings archive (Section 3.1.3).

The known contributions to the average are accounted for by reducing the option strike.

Theory Guide 4.1.33

For a given valuation date t , define m to be the least index for which $t_{m+1} > t$ (where $t_{n+1} = \infty$). Then $\bar{S} - K = A - \bar{K}$, where

$$A = \sum_{i=m+1}^n \omega_i S(t_i), \quad (37.3.5)$$

$\omega_i = d_i/D$, and \bar{K} is the adjusted strike defined by

$$\bar{K} = K - \sum_{i=1}^m \omega_i S(t_i). \quad (37.3.6)$$

37.3.9.2 Approximating the Average of Unknown Prices by Moment Matching

The price at each future time is assumed to be lognormally distributed (Section 37.3.3), and prices at different future times are correlated.

Theory Guide 4.1.33

Define $\tau_i = t_i - t$ and let $i \wedge j$ denote $\min(i, j)$. Then $\text{cov}_t(\log S(t_i), \log S(t_j)) = \sigma_{i \wedge j}^2 \tau_{i \wedge j}$, where $\text{var}_t(\log S(t_i)) = \sigma_i^2 \tau_i$.

The weighted average of these correlated lognormal variables A is not itself lognormal; therefore, in order to support option pricing formulas which assume lognormal distributions, the average is approximated by a synthetic asset with lognormal price distribution constructed to match the first two moments of the average.

Theory Guide 4.1.33

Under the moment matching approximation of Section D.4.2, A is lognormal and $\text{var}_t(\log A) = v^2$,

where v is given by

$$F^2 e^{v^2} = \sum_{i,j=m+1}^n \omega_i \omega_j F(t, t_i) F(t, t_j) e^{\sigma_{i \wedge j}^2 \tau_{i \wedge j}}, \quad (37.3.7)$$

and the value of the option is

$$\mathcal{B}_\delta(F, \bar{K}, v) D(t, T). \quad (37.3.8)$$

This construction is described in Theory Guide [7, § D.4.2 Two Moment Matching]. The Asian option is then priced as if it were a single asset option on the synthetic asset.

37.3.9.3 Term Structured

Adaptiv Analytics provides the `Term Structured` valuation option which allows an approximation to be used to accelerate the calculation of the averages of forward prices.

Theory Guide 4.1.33

When the model parameter `Term Structured` is `Yes`, forward prices are calculated for each sampling date t_i , and σ_i is the implied volatility at t for expiry date t_i , forward price $F(t, t_i)$ and strike K' , where K' is the normalized adjusted strike defined by

$$K' = \frac{\bar{K}}{\sum_{i=m+1}^n \omega_i} = \frac{K - \sum_{i=1}^m \omega_i S(t_i)}{\sum_{i=m+1}^n \omega_i}. \quad (37.3.9)$$

When `Term Structured` is `No`, the model provides a faster valuation by assuming a constant carry rate and constant volatility, so that $F(t, t_i) = S(t) e^{b\tau_i}$ and $\sigma_i = \sigma$, where $b = \log(F(t, T)/S(t))/\tau$ and σ is the implied volatility at t for expiry date T , forward price $F(t, T)$ and strike K' .

37.3.10 Discrete Double Asian Option Valuation

Double Asian options pay either the arithmetic or the geometric difference of two weighted averages of FX rate observations. Alternatively, the payoff may be digital, paying a fixed amount if exercised in the money or zero otherwise.

Theory Guide 4.1.34

The payoff of a discrete (explicit) double Asian option is a function of the averages \bar{S}_1 and \bar{S}_2 . The payoff is

$$(\gamma \delta (f(\alpha_1 \bar{S}_1, \alpha_2 \bar{S}_2) - \alpha_0 K) + 1 - \gamma) [\delta (f(\alpha_1 \bar{S}_1, \alpha_2 \bar{S}_2) - \alpha_0 K) > 0] \quad (37.3.10)$$

at the expiry date T , where

- K is the Strike Price
- either $\delta = +1$ for a call, or $\delta = -1$ for a put
- α_1 is the Sampling Multiplier 1 and α_2 is the Sampling Multiplier 2
- α_0 is the Strike Multiplier
- $\gamma = 0$ if `Is Digital` is `Yes`, otherwise $\gamma = 1$
- either $f(x, y) = x - y$ if the Difference Method is Arithmetic, or $f(x, y) = x/y$ if the Difference Method is Geometric.

See Theory Guide [7, § 4.1.34 Discrete (Explicit) Double Asian Option] for a description of discrete double Asian option valuation.

37.3.10.1 Known Prices

In general, when a double Asian option is mid-life, some of the prices in the average are known because they are in the past, and others are in the future and not yet known. These known prices may be specified on the Sampling Data (Section 37.2.17) property of explicit discrete Asian options. Otherwise, they may be stored in the rate fixings archive (Section 3.1.3). The initial price factor value is used when a rate that should be known is missing from both the sampling data and the fixings archive.

37.3.10.2 Approximating the Average of Unknown Prices by Moment Matching

Define the average prices in the payoff function as follows:

Theory Guide 4.1.34

Define the i^{th} average by

$$\bar{S}_i = \frac{1}{D_i} \sum_{j=1}^{n_i} d_{ij} S(t_{ij}), \quad (37.3.11)$$

where $D_i = \sum_{j=1}^{n_i} d_{ij}$ is the total weight.

Each average can be decomposed into the sum of known and unknown averages:

Theory Guide 4.1.34

Define $\omega_{ij} = d_{ij}/D_i$. For a given valuation date t , define m_i to be the least index for which $t_{m_i+1} > t$ (where $t_{n_i+1} = \infty$). Then $\bar{S}_i = R_i + A_i$, where $R_i = \sum_{j=1}^{m_i} \omega_{ij} S(t_{ij})$ and

$$A_i = \sum_{j=m_i+1}^{n_i} \omega_{ij} S(t_{ij}). \quad (37.3.12)$$

The price at each future time is assumed to be lognormally distributed (Section 37.3.3), and prices at different future times are correlated. The weighted average of these correlated lognormal variables A is not itself lognormal; therefore, in order to support option pricing formulas which assume lognormal distributions, the average is approximated by a synthetic asset with lognormal price distribution constructed to match the either first two moments (Theory Guide [7, § D.4.2 Two Moment Matching]) or the first three moments (Theory Guide [7, § D.4.2 Three Moment Matching]) of the average.

Theory Guide 4.1.34

Under the assumption that $S(t_{ij})$ is lognormal, with $\text{cov}_t(\log S(t_{ij}), \log S(t_{i'j'})) = \sigma_{ij}^2(t_{ij} - t)$ for $t_{ij} \leq t_{i'j'}$, the unrealized averages A_i are approximated using either two moment matching (Section D.4.2) or three moment matching (Section D.4.3):

$$A_i \approx F_i - \mu_i + \mu_i \exp(-v_i^2/2 + v_i Z_i), \quad (37.3.13)$$

where

$$F_i = \sum_{j=m_i+1}^{n_i} \omega_{ij} F(t, t_{ij}), \quad (37.3.14)$$

μ_i and v_i are the moment-matched mean and standard deviation, Z_1 and Z_2 are standard normal variables, and ρ is the moment-matched correlation between Z_1 and Z_2 (with $\mu_i = F_i$ for second order moment matching). Defining $X_i = \alpha_i \mu_i \exp(-v_i^2/2 + v_i Z_i)$ and $\lambda_i = \alpha_i(R_i + F_i - \mu_i)$, the moment matching approximation is

$$\alpha_i \bar{S}_i \approx X_i + \lambda_i. \quad (37.3.15)$$

37.3.10.3 Arithmetic Difference Approximation

When the payoff is on the arithmetic difference, the payoff under the moment matching approximation has the following form:

Theory Guide [4.1.34](#)

Under the moment matching approximation, the payoff is approximately

$$(\gamma \delta (X_1 - X_2 - \bar{K}) + 1 - \gamma) [\delta (X_1 - X_2 - \bar{K}) > 0], \quad (37.3.16)$$

where $\bar{K} = \alpha_0 K - \lambda_1 + \lambda_2$.

The expectation of this approximate payoff is itself approximated by the Bjerk Sund and Stenslund formula described in Theory Guide [\[7, § D.3.2 Bjerk Sund and Stensland Spread Option Approximation\]](#).

37.3.10.4 Geometric Difference Approximations

When the payoff is on the geometric difference, the payoff under the moment matching approximation has the following form:

Theory Guide [4.1.34](#)

Under the moment matching approximation, the payoff is approximately

$$\left(\gamma \delta \left(\frac{X_1 + \lambda_1}{X_2 + \lambda_2} - \alpha_0 K \right) + 1 - \gamma \right) \left[\delta \left(\frac{X_1 + \lambda_1}{X_2 + \lambda_2} - \alpha_0 K \right) > 0 \right]. \quad (37.3.17)$$

When λ_1 and λ_2 are both zero, the expectation of this payoff can be calculated analytically:

Theory Guide [4.1.34](#)

Since $X_1/X_2 = X$, where X is lognormal with $\mathbb{E}_t(X) = F$ and $\text{var}_t(\log X) = v^2$, where $F = \exp(v_2^2 - \rho v_1 v_2) \alpha_1 \mu_1 / \alpha_2 \mu_2$ and $v^2 = v_1^2 + v_2^2 - 2\rho v_1 v_2$, the approximate value of the option at time t is

$$\mathcal{B}_\delta(\gamma \delta, -\gamma \delta \alpha_0 K + 1 - \gamma, F, \alpha_0 K, v) D(t, T), \quad (37.3.18)$$

where $\mathcal{B}_\delta(A, B, F, K, v)$ is the generalized Black formula defined in Section [D.3.1](#).

Otherwise, the expectation must be calculated by numerical integration.

Theory Guide [4.1.34](#)

The integral is evaluated numerically using Gauss-Hermite quadrature. The number of points

used by the quadrature can be set by the valuation model parameter Number of Integration Points.

37.3.10.5 Term Structured

Adaptiv Analytics provides the Term Structured valuation option which allows an approximation to be used to accelerate the calculation of the averages of forward prices.

Theory Guide [4.1.34](#)

When the model parameter Term Structured is Yes, forward prices $F(t, t_{ij})$ and volatilities σ_{ij} are calculated for each sampling date t_{ij} . When Term Structured is No, the model provides a faster valuation by assuming a constant carry rate and constant volatility, so that $F(t, t_{ij}) = S(t)e^{b(t_{ij}-t)}$ and $\sigma_{ij} = \sigma$, where $b = \log(F(t, T)/S(t))/\tau$ and σ is the implied at-the-money volatility at time t for expiry date T .

When using the term structured method for calculating the forward prices and volatilities for the unknown prices in the averages, there is a choice of method to calculate the strike used to interpolate the volatilities. When set to At The Money, volatilities are interpolated at the money for expiry date equal to the observation date. When set to Conditional Strike, the volatility is interpolated by setting the strike equal to the expectation of the spot price at the observation date conditional on the difference in the weighted averages being equal to the product of the Strike Price and the Strike Multiplier.

Theory Guide [4.1.34](#)

Further, when Term Structured is Yes, the model provides two methods for calculating the strikes used to interpolate the volatility surface. When Strike Mapping Method is At The Money, σ_{ij} is the ATM volatility at time t for expiry date t_{ij} . When Strike Mapping Method is Conditional Strike, σ_{ij} is the volatility at time t for expiry date t_{ij} and strike $K_{ij} = \mathbb{E}_t(S(t_{ij}) | f(\alpha_1 \bar{S}_1, \alpha_2 \bar{S}_2) = \alpha_0 K)$. The conditional strikes K_{ij} are estimated using the method of Section [D.4.4](#), with σ_{ij} set to the ATM volatility for expiry date t_{ij} . For both arithmetic and geometric methods, the condition $f(\alpha_1 \bar{S}_1, \alpha_2 \bar{S}_2) = \alpha_0 K$ is of the form $k_1 \bar{S}_1 - k_2 \bar{S}_2 = k_0$, where k_0, k_1, k_2 are constants and $k_1, k_2 > 0$.

37.3.11 Continuous Asian Option Valuation

Continuous Asian options pay off a function of an arithmetic or geometric average of an asset price or a basket of asset prices measured at different times. The averaging period runs from the effective date t_1 to the expiry date T . See Theory Guide [\[7, § 4.1.31 Continuous Asian Option\]](#) for a description of continuous Asian option valuation.

37.3.11.1 Geometric Average

When the Asian Type property is set to Geometric daily observations of the price are approximated using

Theory Guide [4.1.31.1](#)

$$\bar{S}(t) = \exp \left(\frac{1}{t - t_1} \int_{t_1}^t \log S(u) du \right) \quad (37.3.19)$$

The value of the option is then given by the Kemna and Vorst formula, as described in the Theory Guide [7, § 4.1.31.1 [Geometric Average](#)].

37.3.11.2 Arithmetic Average

When the Asian Type property is set to Arithmetic daily observations of the price are approximated using

Theory Guide [4.1.31.2](#)

$$\bar{S}(t) = \frac{1}{t - t_1} \int_{t_1}^t S(u) \, du. \quad (37.3.20)$$

The value of the option is then given by the Turnbull and Wakeman formula, as described in the Theory Guide [7, § 4.1.31.2 [Arithmetic Average](#)].

37.3.11.3 Negative Adjusted Strike

Both arithmetic and geometric averaging methods involve adjusting the strike based on prices which are known when the option is mid-life. When the remaining averaging period is small, it is possible that the adjusted strike may become negative. This indicates that the accumulated average is so high that a call option will always be exercised (and a put option never exercised). The call option is then valued as a modified forward contract as described in the Theory Guide [7, § 4.1.31.3 [Negative Adjusted Strike](#)].

37.3.12 Baskets of Asset Prices

Several asset deal types support payoffs on baskets of asset prices, rather than a single asset price. The price of a basket of asset prices is a weighted sum of the prices of the individual assets in the basket.

Theory Guide [4.1.39](#)

The basket price is defined by

$$S(t) = \sum_{i=1}^n \omega_i S_i(t), \quad (37.3.21)$$

where $S_1(t), \dots, S_n(t)$ are the individual asset prices and $\omega_i > 0$ is the number of units of the i^{th} asset.

The risk-neutral expectation of the forward basket price is given by the weighted sum of the forward prices of the individual assets.

Theory Guide [4.1.39](#)

The expectation of the basket price $S(T)$ is given by

$$F(t) = \mathbb{E}_t(S(T)) = \sum_{i=1}^n \omega_i F_i(t, T). \quad (37.3.22)$$

37.3.12.1 Quanto and Compo Basket Components

An individual asset within a basket may have an asset currency which differs from the payoff currency of the basket, in which case the price must be defined as either quanto or compo.

Theory Guide [4.1.39.5](#)

The basket price is defined by

$$S(t) = \sum_{i=1}^n \omega_i S_i(t) X_i(t)^{c_i}, \quad (37.3.23)$$

where X_i is the price of the i^{th} asset currency in the payoff currency, $c_i = 1$ if the i^{th} component is compo, and otherwise $c_i = 0$.

When the component price is quanto, its forward price is replaced with the quanto-adjusted forward price. See Section [37.3.4](#).

When the component price is compo, its forward price is replaced with the compo-adjusted forward price. See Section [37.3.4](#). Its covariance with other prices in the basket is adjusted according to whether or not the other price is also compo.

Theory Guide [4.1.39.5](#)

the volatility σ_i is replaced by the compo volatility $\check{\sigma}_i$ and $\text{cov}_t(\log S_i(T), \log S_j(T))$ is replaced by

$$\begin{aligned} \text{cov}_t(\log S_i(T) + c_i \log X_i(T), \log S_j(T) + c_j \log X_j(T)) = \\ (\rho_{ij} \sigma_i(T) \sigma_j(T) + c_j \hat{\rho}_{ij} \sigma_i(T) \nu_j(T) + c_i \hat{\rho}_{ji} \sigma_j(T) \nu_i(T) + c_i c_j \tilde{\rho}_{ij} \nu_i(T) \nu_j(T)) (T - t), \end{aligned} \quad (37.3.24)$$

where $\nu_i(T)^2(T - t)$ is the variance of $\log X_i(T)$, $\hat{\rho}_{ij}$ is the correlation between $\log S_i(T)$ and $\log X_j(T)$ and $\tilde{\rho}_{ij}$ is the correlation between $\log X_i(T)$ and $\log X_j(T)$.

37.3.12.2 Valuation of Options on Baskets

Each individual asset price is assumed to be lognormally distributed (Section [37.3.3](#)), with each pair of prices S_i, S_j having correlation $\rho_{i,j}$. The weighted sum of these correlated lognormal variables $S(t)$ is not itself lognormal; therefore, in order to support option pricing formulas which assume lognormal distributions, the sum is approximated by a synthetic asset with lognormal price distribution constructed to match either the first two moments of the sum (Theory Guide [\[7, § D.4.2 Two Moment Matching\]](#)) or the first three moments (Theory Guide [\[7, § D.4.2 Three Moment Matching\]](#)). The basket option is then priced as if it were a single asset option on the synthetic asset.

The moment matching methods need input volatilities which are looked up from implied volatility surfaces. This requires a strike for each asset in the basket. Adaptiv Analytics provides two methods for deducing the strike of the assets

Theory Guide [4.1.39.4](#)

For the Asian option on a basket of prices (of which the option on a basket of prices is a special case), the volatility $\sigma_i(t_k)$ is set to the implied volatility of S_i at t for expiry date t_k , forward price $F_i(t, t_k)$ and strike K_{ki} , where K_{ki} is calculated by one the following two methods.

Under the Weighted Strike method,

$$K_{ki} = F_i(t, t_k) \frac{K'}{F(t)}, \quad (37.3.25)$$

where $K' = \bar{K} / \sum_{k=l+1}^m \tilde{\omega}_k$ is the normalized adjusted strike.

Under the Conditional Strike method,

$$K_{ki} = \mathbb{E}_t (S_i(t_k) | A = \bar{K}) . \quad (37.3.26)$$

K_{ki} is calculated by applying the approximation of Section D.4.4 to $X_{ki} = S_i(t_k)$ with $x_{ki} = F_i(t, t_k)$ and σ_{ki} set to the ATM volatility of S_i at time t for expiry date t_k .

37.3.13 Chooser Option Valuation

The valuation method is described below.

Theory Guide 4.1.24

Let t_1 denote the Chooser Date, which must be before the expiry date T . The holder of a chooser option chooses at t_1 to enter into either a call option or a put option with expiry date T and strike K . Let $c(t)$ ($p(t)$) denote the value of the call (put) option at valuation date t . Using put-call parity, the value of the chooser option at t_1 is

$$\max(c(t_1), p(t_1)) = c(t_1) + \max(p(t_1) - c(t_1), 0) \quad (37.3.27)$$

$$= c(t_1) + \max(K - F(t_1, T), 0) D(t_1, T). \quad (37.3.28)$$

Under the Black-Scholes model with constant volatility and deterministic interest rates and asset yields, the value of the chooser option at $t \leq t_1$ is

$$(\mathcal{B}(F(t, T), K, \sigma\sqrt{\tau}) + \mathcal{B}(K, F(t, T), \sigma\sqrt{\tau_1})) D(t, T), \quad (37.3.29)$$

where $\tau_1 = t_1 - t$ and \mathcal{B} is the Black formula defined in Section D.3.1. This formula is given in Rubinstein [43].

37.3.14 Cliquet Option Valuation

The payoff of a cliquet option is described below.

Theory Guide 4.1.23

A cliquet (or ratchet) option is a strip of forward start options.

Let t_0, t_1, \dots, t_n denote the accrual dates generated from the deal's effective date, maturity date, frequency and holiday calendar, as described in Section I.3.2.

Define $\delta = +1$ for a call option, or $\delta = -1$ for a put option. For variable principal options (Principal Fixed Variable is Variable), let N denote either the number of units of the underlying asset (Units) or the amount of underlying currency (Underlying Amount). For fixed principal options (Principal Fixed Variable is Fixed), let P denote the principal amount (Principal).

The i^{th} forward start option expires at t_i and has its strike fixed at t_{i-1} to $\alpha S(t_{i-1})$, where $\alpha > 0$ is the moneyness factor (Moneyness).

For variable-principal options, the i^{th} forward start option pays

$$N \max(\delta(S(t_i) - \alpha S(t_{i-1})), 0) \quad (37.3.30)$$

at t_i . For fixed-principal options, the i^{th} forward start option pays

$$P \max \left(\delta \left(\frac{S(t_i)}{S(t_{i-1})} - \alpha \right), 0 \right) \quad (37.3.31)$$

at t_i .

For $t_i \leq 0$: $S(t_i)$ is the price from the Known Prices list, if one is assigned to t_i under the method of Section 1.6.1; otherwise $S(t_i)$ is the fixing for S at t_i , if one is available (see Section 1.7); otherwise $S(t_i)$ is the initial price factor value.

Valuation uses the generalised Black-Scholes model and results for the expectations of intervals (eg Margrabe formula) and quotients of lognormal variables. For the details of this valuation see Theory Guide [7, § 4.1.23 Cliquet Option].

37.3.15 Compound Option Valuation

The valuation method is described below.

Theory Guide ??

A compound option is a European option on a European option. The underlying option has strike K and expiry date T , and the compound option has strike K_1 and expiry date t_1 , where $t_1 < T$. There are four option types: call-on-call, put-on-call, call-on-put, and put-on-put.

Define $\tau_1 = t_1 - t$ and $\rho = \sqrt{\tau_1/\tau}$. Compound options are valued using the following formulas due to Geske [23]:

call-on-call

$$S(t)e^{(b-r)\tau}\Phi(d_1, y_1, \rho) - Ke^{-r\tau}\Phi(d_2, y_2, \rho) - K_1e^{-r\tau_1}\Phi(y_2) \quad (37.3.32)$$

put-on-call

$$Ke^{-r\tau}\Phi(d_2, -y_2, -\rho) - S(t)e^{(b-r)\tau}\Phi(d_1, -y_1, -\rho) + K_1e^{-r\tau_1}\Phi(-y_2) \quad (37.3.33)$$

call-on-put

$$Ke^{-r\tau}\Phi(-d_2, -y_2, \rho) - S(t)e^{(b-r)\tau}\Phi(-d_1, -y_1, \rho) - K_1e^{-r\tau_1}\Phi(-y_2) \quad (37.3.34)$$

put-on-put

$$S(t)e^{(b-r)\tau}\Phi(-d_1, y_1, -\rho) - Ke^{-r\tau}\Phi(-d_2, y_2, -\rho) + K_1e^{-r\tau_1}\Phi(y_2), \quad (37.3.35)$$

where

$$y_1 = \frac{1}{\sigma\sqrt{\tau_1}} \left(\log \left(\frac{S(t)}{I} \right) + \left(b + \frac{\sigma^2}{2} \right) \tau_1 \right) \quad y_2 = y_1 - \sigma\sqrt{\tau_1} \quad (37.3.36)$$

$$d_1 = \frac{1}{\sigma\sqrt{\tau}} \left(\log \left(\frac{S(t)}{K} \right) + \left(b + \frac{\sigma^2}{2} \right) \tau \right) \quad d_2 = d_1 - \sigma\sqrt{\tau} \quad (37.3.37)$$

and I is the solution of $U(I, K, \tau - \tau_1, \sigma, r, b) = K_1$, where $U(S, K, \tau, \sigma, r, b)$ is the value of the underlying option as a function of asset price S , strike K , time to expiry τ , volatility σ , interest rate r and carry rate b .

37.3.16 Lookback Option Valuation

The valuation method is described below.

Theory Guide 4.1.26

For the valuation of lookback options, define

$$a_1 = \frac{1}{\sigma\sqrt{\tau}} \left(\log \left(\frac{S(t)}{S_{\min}(t)} \right) + \left(b + \frac{\sigma^2}{2} \right) \tau \right) \quad a_2 = a_1 - \sigma\sqrt{\tau} \quad (37.3.38)$$

$$b_1 = \frac{1}{\sigma\sqrt{\tau}} \left(\log \left(\frac{S(t)}{S_{\max}(t)} \right) + \left(b + \frac{\sigma^2}{2} \right) \tau \right) \quad b_2 = b_1 - \sigma\sqrt{\tau} \quad (37.3.39)$$

$$d_1 = \frac{1}{\sigma\sqrt{\tau}} \left(\log \left(\frac{S(t)}{K} \right) + \left(b + \frac{\sigma^2}{2} \right) \tau \right) \quad d_2 = d_1 - \sigma\sqrt{\tau}. \quad (37.3.40)$$

Floating strike lookback options are valued using the following formulas, due to Goldman, Sosin, and Gatto [24].

Theory Guide 4.1.26

The value of the call option is

$$S(t)e^{(b-r)\tau}\Phi(a_1) - S_{\min}(t)e^{-r\tau}\Phi(a_2) + S(t)e^{-r\tau}\frac{\sigma^2}{2b} \left(\left(\frac{S(t)}{S_{\min}(t)} \right)^{-2b/\sigma^2} \Phi \left(-a_1 + \frac{2b}{\sigma}\sqrt{\tau} \right) - e^{b\tau}\Phi(-a_1) \right) \quad (37.3.41)$$

for $b \neq 0$, or

$$S(t)e^{-r\tau}\Phi(a_1) - S_{\min}(t)e^{-r\tau}\Phi(a_2) + S(t)e^{-r\tau}\sigma\sqrt{\tau} \left(\frac{e^{-a_1^2/2}}{\sqrt{2\pi}} + a_1(\Phi(a_1) - 1) \right) \quad (37.3.42)$$

for $b = 0$. The value of the put option is

$$S_{\max}(t)e^{-r\tau}\Phi(-b_2) - S(t)e^{(b-r)\tau}\Phi(-b_1) + S(t)e^{-r\tau}\frac{\sigma^2}{2b} \left(- \left(\frac{S(t)}{S_{\max}(t)} \right)^{-2b/\sigma^2} \Phi \left(b_1 - \frac{2b}{\sigma}\sqrt{\tau} \right) + e^{b\tau}\Phi(b_1) \right) \quad (37.3.43)$$

for $b \neq 0$, or

$$S_{\max}(t)e^{-r\tau}\Phi(-b_2) - S(t)e^{-r\tau}\Phi(-b_1) + S(t)e^{-r\tau}\sigma\sqrt{\tau} \left(\frac{e^{-b_1^2/2}}{\sqrt{2\pi}} + b_1\Phi(b_1) \right) \quad (37.3.44)$$

for $b = 0$.

Fixed strike lookback options are valued using the following formulas due to Conze and Viswanathan [19].

Theory Guide 4.1.26

The value of the call option is

$$S(t)e^{(b-r)\tau}\Phi(d_1) - Ke^{-r\tau}\Phi(d_2) + S(t)e^{-r\tau}\frac{\sigma^2}{2b} \left(- \left(\frac{S(t)}{K} \right)^{-2b/\sigma^2} \Phi \left(d_1 - \frac{2b}{\sigma}\sqrt{\tau} \right) + e^{b\tau}\Phi(d_1) \right) \quad (37.3.45)$$

when $K > S_{\max}(t)$, or

$$(S_{\max}(t) - K)e^{-r\tau} + S(t)e^{(b-r)\tau}\Phi(b_1) - S_{\max}(t)e^{-r\tau}\Phi(b_2) + S(t)e^{-r\tau}\frac{\sigma^2}{2b}\left(-\left(\frac{S(t)}{S_{\max}(t)}\right)^{-2b/\sigma^2}\Phi\left(b_1 - \frac{2b}{\sigma}\sqrt{\tau}\right) + e^{b\tau}\Phi(b_1)\right) \quad (37.3.46)$$

when $K \leq S_{\max}(t)$. The value of the put option is

$$Ke^{-r\tau}\Phi(-d_2) - S(t)e^{(b-r)\tau}\Phi(-d_1) + S(t)e^{-r\tau}\frac{\sigma^2}{2b}\left(\left(\frac{S(t)}{K}\right)^{-2b/\sigma^2}\Phi\left(-d_1 + \frac{2b}{\sigma}\sqrt{\tau}\right) - e^{b\tau}\Phi(-d_1)\right) \quad (37.3.47)$$

when $K < S_{\min}(t)$, or

$$(K - S_{\min}(t))e^{-r\tau} - S(t)e^{(b-r)\tau}\Phi(-a_1) + S_{\min}(t)e^{-r\tau}\Phi(-a_2) + S(t)e^{-r\tau}\frac{\sigma^2}{2b}\left(\left(\frac{S(t)}{S_{\min}(t)}\right)^{-2b/\sigma^2}\Phi\left(-a_1 + \frac{2b}{\sigma}\sqrt{\tau}\right) - e^{b\tau}\Phi(-a_1)\right) \quad (37.3.48)$$

when $K \geq S_{\min}(t)$.

37.3.17 Gap Option Valuation

The valuation method is described below.

Theory Guide [4.1.21](#)

A gap option is a European option a strike K and barrier H . The barrier is used to trigger the payoff and the strike is used to compute the value of the payoff. There are two types of payoff: *barrier* and *reverse barrier*.

The barrier payoff is

$$\delta(S(T) - K) [\delta(S(T) - H) > 0], \quad (37.3.49)$$

where $\delta = +1$ for a call or $\delta = -1$ for a put. The value of the option is

$$\mathcal{B}_{\delta}(\delta, -\delta K, F(t, T), H, \sigma\sqrt{\tau}) D(t, T). \quad (37.3.50)$$

where $\mathcal{B}_{\delta}(A, B, F, K, v)$ is the generalized Black formula defined in Section [D.3.1](#), and σ is the implied volatility at t for expiry date T , forward price $F(t, T)$ and strike H . The option payoff can be negative when $\delta(H - K) < 0$.

For $\delta K < \delta H$, the reverse barrier payoff is

$$\delta(S(T) - K) [\delta K < \delta S(T) < \delta H]. \quad (37.3.51)$$

This payoff is equal to the difference between a standard option payoff and a gap option barrier payoff, because

$$[L < S < U] = [L < S] - [U \leq S]. \quad (37.3.52)$$

The reverse barrier payoff is defined to be zero when $\delta H \leq \delta K$.

37.3.18 Forward Strip Option Valuation

The valuation method is described below.

Theory Guide [4.1.22](#)

The value of the underlying forward strip is given by

$$U(t) = \sum_i (A_i F(t, t_i) - B_i) D(t, t_i). \quad (37.3.53)$$

The underlying settlement dates are on or after the expiry date: $T \leq t_i$. Under the assumption of deterministic interest rates, the value of the underlying at the expiry date is given by

$$U(T) = A(S(T) - K), \quad (37.3.54)$$

where A and K are known at the valuation date and given by

$$A = \sum_i A_i \tilde{D}(T, t_i) = \sum_i A_i \frac{\tilde{D}(t, t_i)}{\tilde{D}(t, T)} \quad (37.3.55)$$

$$AK = \sum_i B_i D(T, t_i) = \sum_i B_i \frac{D(t, t_i)}{D(t, T)}. \quad (37.3.56)$$

Therefore, $\max(\delta U(T), 0)$ is the payoff of a standard European option, and the value of the option at time $t < T$ is

$$AB_\delta (F(t, T), K, \sigma\sqrt{\tau}) D(t, T). \quad (37.3.57)$$

where $\delta = +1$ for a call option or $\delta = -1$ for a put option.

37.3.19 Partial-Time Barrier Option Valuation

The valuation for Type A knock-out call options is described below:

Theory Guide [4.1.29](#)

The value of a down-and-out or up-and-out call option is

$$S(t)e^{(b-r)\tau} \left(\Phi(d_1, \eta e_1, \eta\rho) - \left(\frac{H}{S(t)} \right)^{2(\mu+1)} \Phi(f_1, \eta e_3, \eta\rho) \right) - Ke^{-r\tau} \left(\Phi(d_2, \eta e_2, \eta\rho) - \left(\frac{H}{S(t)} \right)^{2\mu} \Phi(f_2, \eta e_4, \eta\rho) \right), \quad (37.3.58)$$

where $\mu = (b - \sigma^2/2)/\sigma^2$, $\rho = \sqrt{\tau_1}/\tau$, $\tau_1 = t_1 - t$, $\eta = +1$ for down options or $\eta = -1$ for up options,

$$d_1 = \frac{\log(S(t)/K) + (b + \sigma^2/2)\tau}{\sigma\sqrt{\tau}} \quad d_2 = d_1 - \sigma\sqrt{\tau} \quad (37.3.59)$$

$$f_1 = \frac{\log(S(t)/K) + 2\log(H/S(t)) + (b + \sigma^2/2)\tau}{\sigma\sqrt{\tau}} \quad f_2 = f_1 - \sigma\sqrt{\tau} \quad (37.3.60)$$

$$e_1 = \frac{\log(S(t)/H) + (b + \sigma^2/2)\tau_1}{\sigma\sqrt{\tau_1}} \quad e_2 = e_1 - \sigma\sqrt{\tau_1} \quad (37.3.61)$$

$$e_3 = e_1 + \frac{2\log(H/S(t))}{\sigma\sqrt{\tau_1}} \quad e_4 = e_3 - \sigma\sqrt{\tau_1}. \quad (37.3.62)$$

The valuation for Type B1 knock-out call options is described below:

Theory Guide 4.1.29

For $K > H$, the value of a type B1 knock-out call is

$$S(t)e^{(b-r)\tau} \left(\Phi(d_1, e_1, \rho) - \left(\frac{H}{S(t)} \right)^{2(\mu+1)} \Phi(f_1, -e_3, -\rho) \right) - Ke^{-r\tau} \left(\Phi(d_2, e_2, \rho) - \left(\frac{H}{S(t)} \right)^{2\mu} \Phi(f_2, -e_4, -\rho) \right). \quad (37.3.63)$$

For $K < H$, the value of a type B1 knock-out call is

$$\begin{aligned} & S(t)e^{(b-r)\tau} \left(\Phi(-g_1, -e_1, \rho) - \left(\frac{H}{S(t)} \right)^{2(\mu+1)} \Phi(-g_3, e_3, -\rho) \right) \\ & - Ke^{-r\tau} \left(\Phi(-g_2, -e_2, \rho) - \left(\frac{H}{S(t)} \right)^{2\mu} \Phi(-g_4, e_4, -\rho) \right) \\ & - S(t)e^{(b-r)\tau} \left(\Phi(-d_1, -e_1, \rho) - \left(\frac{H}{S(t)} \right)^{2(\mu+1)} \Phi(-f_1, e_3, -\rho) \right) \\ & + Ke^{-r\tau} \left(\Phi(-d_2, -e_2, \rho) - \left(\frac{H}{S(t)} \right)^{2\mu} \Phi(-f_2, e_4, -\rho) \right) \\ & + S(t)e^{(b-r)\tau} \left(\Phi(g_1, e_1, \rho) - \left(\frac{H}{S(t)} \right)^{2(\mu+1)} \Phi(g_3, -e_3, -\rho) \right) \\ & - Ke^{-r\tau} \left(\Phi(g_2, e_2, \rho) - \left(\frac{H}{S(t)} \right)^{2\mu} \Phi(g_4, -e_4, -\rho) \right), \end{aligned} \quad (37.3.64)$$

where

$$g_1 = \frac{\log(S(t)/H) + (b + \sigma^2/2)\tau}{\sigma\sqrt{\tau}} \quad g_2 = g_1 - \sigma\sqrt{\tau} \quad (37.3.65)$$

$$g_3 = g_1 + \frac{2 \log(H/S(t))}{\sigma\sqrt{\tau}} \quad g_4 = g_3 - \sigma\sqrt{\tau}. \quad (37.3.66)$$

The valuation for Type B2 knock-out call options is described below:

Theory Guide 4.1.29

For $H \leq K$, the value of a type B2 down-and-out call is the same as the value of a type B1 down-and-out call. For $K < H$, the value of a type B2 down-and-out call is

$$S(t)e^{(b-r)\tau} \left(\Phi(g_1, e_1, \rho) - \left(\frac{H}{S(t)} \right)^{2(\mu+1)} \Phi(g_3, -e_3, -\rho) \right) - Ke^{-r\tau} \left(\Phi(g_2, e_2, \rho) - \left(\frac{H}{S(t)} \right)^{2\mu} \Phi(g_4, -e_4, -\rho) \right). \quad (37.3.67)$$

The value of a type B2 up-and-out call is zero when $H \leq K$. For $K < H$, the value of a type B2

up-and-out call is

$$\begin{aligned}
 & S(S)e^{(b-r)\tau} \left(\Phi(-g_1, -e_1, \rho) - \left(\frac{H}{S(t)} \right)^{2(\mu+1)} \Phi(-g_3, e_3, -\rho) \right) \\
 & - Ke^{-r\tau} \left(\Phi(-g_2, -e_2, \rho) - \left(\frac{H}{S(t)} \right)^{2\mu} \Phi(-g_4, e_4, -\rho) \right) \\
 & - S(t)e^{(b-r)\tau} \left(\Phi(-d_1, -e_1, \rho) - \left(\frac{H}{S(t)} \right)^{2(\mu+1)} \Phi(e_3, -f_1, -\rho) \right) \\
 & + Ke^{-r\tau} \left(\Phi(-d_2, -e_2, \rho) - \left(\frac{H}{S(t)} \right)^{2\mu} \Phi(e_4, -f_2, -\rho) \right).
 \end{aligned} \tag{37.3.68}$$

The valuation for knock-in options is described below:

Theory Guide [4.1.29](#)

The value of a knock-in option is equal to the value of the underlying option minus the value of the corresponding knock-out option:

$$C = C_{\text{in}} + C_{\text{out}} \tag{37.3.69}$$

$$P = P_{\text{in}} + P_{\text{out}}. \tag{37.3.70}$$

Puts are valued using the put-call transformation of [\[26\]](#).

Theory Guide [4.1.29](#)

$$P_{\text{up}}(S, K, H, r, b) = C_{\text{down}}(K, S, SK/H, r - b, -b) \tag{37.3.71}$$

$$P_{\text{down}}(S, K, H, r, b) = C_{\text{up}}(K, S, SK/H, r - b, -b). \tag{37.3.72}$$

37.4 Limitations

The limitations stated below are commonly applicable to asset deal types.

37.4.1 Interpretation of an Asset Price Factor

The interpretation of an asset price factor in Adaptiv Analytics is not usually identical to a quoted market price. See Section [4.1](#) for details.

37.4.2 Minimum Price

All asset prices are floored at the minimum asset price. See Section [4.1.3](#).

37.4.3 No Settlement Lags

Asset price deals in Adaptiv Analytics usually do not distinguish between the fixing date of a forward contract or the expiry date of an option and the settlement date. FX Option and Equity Option are exceptions to this, see Section [37.2.18](#).

37.4.4 Cash Settled

Unless otherwise noted, asset deals are cash settled in the payoff currency for the net contract value on the maturity date or expiry date, with no provision to exchange payment for the underlying. Several FX deals are exceptions to this; the two underlying currencies are settled gross in these cases. Also, FX Option and Equity Option settle as forward contracts when exercised, see Section 37.2.18.

37.4.5 Approximation for American Options

The Bjerksund and Stenslund formula used to price American options analytically is an approximation. Note that this implementation uses the 1993 version of Bjerksund and Stenslund [10] with a single barrier, not the 2002 version [11] with the barrier split into two pieces.

In the plain Bjerksund and Stenslund formula (Theory Guide Eq. 4.32), it is possible for the difference between the value of American and European exercise to be negative; even so negative that the entire option price is negative. This implementation of the model prevents these anomalies by flooring the value of American options at their European values.

37.4.6 Exercise of American Options

In ageing simulations, the model must decide whether and when to exercise cash-settled American options. Cash-settled options pay out their value when exercised and are then terminated. Physically settled American options are never exercised early because they are valued as European options.

American options are exercised on the first date on which the Bjerksund and Stenslund barrier I (Theory Guide [7, § 4.1.18 American Option]) is observed to be touched. Note that the dates on which the barrier is tested for touching are in part a function of the Monitoring Period model parameter. A period longer than daily is less computationally costly, but may delay exercise. When the monitoring period is longer than daily, the exercise date may depend on the choice of valuation grid because exercise is tested on all valuation dates in addition to the monitoring dates.

37.4.7 Early Call Exercise

The rule of exercising an American option as soon as the Bjerksund and Stenslund barrier (Theory Guide [7, § 4.1.18 American Option]) is touched will usually exercise an American equity call earlier than the classical case of waiting until just before an ex-dividend date.

37.4.8 Lifetime Management of American Options

Adaptiv Analytics assumes that American options have not been exercised before the base calculation date; there is no way to mark an American option as having been previously exercised. American options that have previously been exercised must not be mapped to an Adaptiv Analytics portfolio as American options; cash settled American options should be removed from the portfolio after exercise, and physically settled American options should be mapped to the underlying forward contract.

37.4.9 No American Exercise for Baskets of Returns

American exercise is supported for options on baskets of prices but not for options on baskets of returns.

37.4.10 Volatility for Barrier Options

The generalized Black-Scholes model used to price barrier options has a single scalar volatility parameter. This parameter is interpolated from the volatility surface using the option strike, just as for regular options. The formulas used to value barrier options would be correct if the Black-Scholes model were also correct in the sense that options having different strikes and maturities could be

valued with a single implied volatility. But the reason for representing implied volatility as a surface is that this is not true; options with different terms must be valued with different implied volatilities when using the Black-Scholes model. In particular, market prices for at any given maturity usually imply a marginal distribution of returns on the underlying asset that has excess kurtosis and skew compared to the normal distribution assumed by the Black-Scholes model.

The skew is often negative, meaning that higher volatilities are needed to reproduce option prices at lower strikes. In this case, if a volatility surface that accurately prices European options is also used to price barrier options, the probability of touching a barrier far below the spot will be underestimated, so that down-and out options are overpriced and down-and-in options underpriced. Conversely, the probability of touching a barrier far above the spot price is often overestimated, so that up-and-out options are underpriced and up-and-in options overpriced. Generally, the farther the barrier is from the spot, the greater the degree of mispricing.

When the skew is not significant, there is usually still excess kurtosis. In this case, the probability of touching any barrier far from the spot will be underestimated, causing undervaluation of in options and overvaluation of out options.

It is possible to work around this limitation by using different volatility surfaces to price barrier options. However, several different surfaces, corresponding to several different bands of barrier levels, may be required.

37.4.11 Symmetric Double Barrier Types

The double barriers for all double barrier option types in Adaptiv Analytics must be of the same type, both either knocked-in or both knocked-out.

37.4.12 No Explicit Barrier Monitoring Schedules

It is not currently possible to specify an explicit schedule for the barrier monitoring dates.

37.4.13 No Partial-day Barrier Monitoring

Barrier touching is modeled as occurring at valuation time, and valuations occur at daily increments in Adaptiv Analytics. Suppose that a calculation is done with market data as it was at the start of day, but contractually the barrier is monitored daily at noon. If the initial market data does not imply a barrier touch, then touching cannot occur on the base calculation date because the initial market data will be used to test for touching. In real life the market might have moved sufficiently between start of day and noon to cause touching.

Conversely, there is no way to prevent barrier touching on the base calculation date in Adaptiv Analytics. If the initial market data implies a barrier touch, then touching will be assumed to occur even if the market price might have moved away from the barrier by the observation time.

37.4.14 Barrier Touching

In ageing simulations, the model must decide whether and when to check whether the barriers have been touched, and the action to be taken upon touching. Knock-out options are terminated and the rebate, if any, is paid out upon touching. Knock-in options are converted to plain European options upon touching.

Note that the dates on which the barrier is tested for touching are in part a function of the Monitoring Period model parameter. A period longer than daily is less computationally costly, but may delay exercise. When the monitoring period is longer than daily, the exercise date may depend on the choice of valuation grid because exercise is tested on all valuation dates in addition to the monitoring dates.

Theory Guide 4.1.30

The valuation model generates a set of monitoring dates on which the asset price is compared to the barrier, or barriers. If the asset price on a monitoring date triggers the option then it remains in the triggered state for all valuation dates on the simulation path subsequent to the monitoring date. The monitoring dates are the union of the valuation dates and a set of regular dates. The regular dates are generated from 0 to T at frequency $\max(\phi, \theta)$ using the method of Section 1.3.4, where ϕ is the deal's Barrier Monitoring Frequency and θ is the valuation model parameter Monitoring Period.

37.4.15 Lifetime Management of Barrier Options

Adaptiv Analytics assumes that barriers have not previously been touched before the base calculation date; there is no way to mark a barrier option as having been previously touched. Barrier options that have previously been knocked in or out must not be mapped to an Adaptiv Analytics portfolio as barrier options; they should be mapped as European options, or else removed, respectively. One-touch options paying at expiry should be mapped to cashflows after touching.

Chapter 38

FX

38.1 FX Valuation Models

38.1.1 Common Properties

The properties described below are often found on FX deal types.

38.1.1.1 FX Properties Common to Asset Price Derivatives

See Section [37.2](#).

38.1.1.2 Buy Amount

The amount of the Buy Currency that is bought in an exchange of currencies.

38.1.1.3 Buy Currency

The ID of the FX Rate price factor of the currency that is bought in an exchange of currencies.

38.1.1.4 Buy Discount Rate

The ID of the interest rate price factor that is used to discount the Buy Currency cashflow in an exchange of currencies. When not populated, the ID of the Buy Currency is used instead.

38.1.1.5 Currency

The ID of the domestic currency FX Rate price factor for an FX option or an averaging FX forward contract. Deals that specify Currency and Underlying Currency rather than buy and sell currencies are always settled net in domestic currency, and the quote direction of the strike or forward price is always in the amount of domestic currency required to buy one unit of foreign currency.

38.1.1.6 Discount Rate

The ID of the interest rate price factor that is used to discount the settlement cashflow of deals that settle net. This cashflow is denominated in the Payment Currency. When not populated, the ID of the payoff or settlement currency is used instead.

38.1.1.7 FX Volatility

The ID of an FX volatility price factor used when pricing the deal. If this ID is not specified and an FX volatility price factor is required, then it will be assumed to have the same ID as the corresponding FX price factor. See Section [11.2.4](#) for rules about the ID of this price factor.

38.1.1.8 Payoff Currency

This indicates the settlement currency of a deal which settles net with a single cashflow. If this does not match either the domestic or the foreign currency, then the payoff is quanto and induces a dependency on the volatility price factor for the FX rate between the domestic and payoff currencies and on the correlation price factor between the domestic-payoff FX rate and the domestic-foreign FX rate.

38.1.1.9 Sell Amount

The amount of the `Sell Currency` that is sold in an exchange of currencies.

38.1.1.10 Sell Currency

The ID of the FX Rate price factor of the currency that is sold in an exchange of currencies.

38.1.1.11 Sell Discount Rate

The ID of the interest rate price factor that is used to discount the `Sell Currency` cashflow in an exchange of currencies. When not populated, the ID of the `Sell Currency` is used instead.

38.1.1.12 Settlement Date

The date on which a contract to exchange currencies is settled.

38.1.1.13 Underlying Amount

The amount of foreign currency underlying an FX option or averaging FX forward contract.

The domestic currency amount of an option is the product of the `Strike Price` and the `Underlying Amount`.

38.1.1.14 Underlying Currency

The ID of the foreign currency FX Rate price factor for an FX option or averaging forward contract. Deals that specify `Currency` and `Underlying Currency` rather than buy and sell currencies are always settled net in domestic currency, and the quote direction of the strike or forward price is always in the amount of domestic currency required to buy one unit of foreign currency.

38.1.2 Assumptions

The assumptions stated below are commonly applicable to FX deal types.

38.1.2.1 FX Assumptions Common to Asset Price Derivatives

See Section [37.3](#).

38.1.3 Limitations

The limitations stated below are commonly applicable to FX deal types.

38.1.3.1 FX Limitations Common to Asset Price Derivatives

See Section [37.4](#).

38.1.3.2 No Herstatt (Settlement) Risk

As noted in Section 37.4.4, several FX deals settle gross in the two underlying currencies. However, there is no provision to allow for different settlement times for the two legs; thus they do not model gross settlement risk.

38.2 FX Forward Deal Types

38.2.1 FX Spot

38.2.1.1 Overview

This deal type is for contracts to exchange a pair of cashflows in different currencies with the conventional spot settlement delay. There is nothing in Adaptiv Analytics to distinguish such a deal from any other settlement; consequently, it is implemented with the same deal class as FX Forward but with a different name.

38.2.1.2 Price Factor Dependency

FX Spot

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

38.2.1.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

38.2.1.4 Deal Representation

FX Spot is a deal skin that builds into two fixed cashflow deals. See the Deal Skins Guide [2, [FX Forward](#)].

38.2.1.5 Valuation

In Adaptiv Analytics an FX Spot deal can be valued using the `FXForwardValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.1.5 [FX Forward](#)].

38.2.1.6 Assumptions

See Section 38.1.2 for descriptions of the general FX derivative assumptions of this deal.

38.2.1.7 Limitations

See Section 38.1.3 for descriptions of the general FX derivative limitations of this deal.

38.2.2 FX Forward

38.2.2.1 Overview

This deal type is for contracts to exchange a pair of cashflows in different currencies at a forward settlement date. There is nothing in Adaptiv Analytics to distinguish such a deal from spot settlement; consequently, it is implemented with the same deal class as FX Spot but with a different name.

38.2.2.2 Price Factor Dependency

FX Forward

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

38.2.2.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

38.2.2.4 Deal Representation

FX Forward is a deal skin that builds into two fixed cashflow deals. See the Deal Skins Guide [2, [FX Spot](#)].

38.2.2.5 Valuation

In Adaptiv Analytics an FX Forward deal can be valued using the `FXForwardValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.1.5 [FX Forward](#)].

38.2.2.6 Assumptions

See Section 38.1.2 for descriptions of the general FX derivative assumptions of this deal.

38.2.2.7 Limitations

See Section 38.1.3 for descriptions of the general FX derivative limitations of this deal.

38.2.3 FX Forward Strip

38.2.3.1 Overview

This deal type is for a series of FX forward contracts with the same buy and sell currencies but with different settlement dates.

38.2.3.2 Price Factor Dependency

FX Forward Strip

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

38.2.3.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

Payments: This property is a list of forward contracts. Each item in the list has a `Buy Amount`, a `Sell Amount`, and a `Date`. The `Date` is the settlement date of the contract.

38.2.3.4 Deal Representation

FX Forward Strip is an atomic deal. Although it is logically the same as a Structured Deal containing a set of FX forward contracts on the same currencies, it does not share the same deal representation or valuation model as FX Forward.

38.2.3.5 Valuation

In Adaptiv Analytics an FX Forward Strip deal can be valued using the `FXForwardStripValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.1.8 FX Forward Strip].

38.2.3.6 Assumptions

See Section 38.1.2 for descriptions of the general FX derivative assumptions of this deal.

38.2.3.7 Limitations

See Section 38.1.3 for descriptions of the general FX derivative limitations of this deal.

38.2.4 FX Non-Deliverable Forward

38.2.4.1 Overview

This deal type is for contracts to net the value of a pair of cashflows in different currencies at a forward settlement date with a single currency cashflow. The settlement cashflow may be denominated in a third currency.

38.2.4.2 Price Factor Dependency

FX Non-Deliverable Forward

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

38.2.4.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

Settlement Currency: The currency of the settlement cashflow. Note that this currency must match the currency of the `Discount Rate`.

38.2.4.4 Deal Representation

FX Non-Deliverable Forward is a deal skin that builds into two fixed cashflow deals. See the Deal Skins Guide [2, [FX Non-Deliverable Forward](#)].

38.2.4.5 Valuation

In Adaptiv Analytics an FX Non-Deliverable Forward deal can be valued using the `FXNonDeliverableForwardValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.1.6 [FX Non-Deliverable Forward](#)].

38.2.4.6 Assumptions

See Section 38.1.2 for descriptions of the general FX derivative assumptions of this deal.

38.2.4.7 Limitations

See Section 38.1.3 for descriptions of the general FX derivative limitations of this deal.

38.2.5 FX Time Option

38.2.5.1 Overview

This deal type is for FX forward contracts in which one party is able to choose the settlement date within a time window.

38.2.5.2 Price Factor Dependency

FX Time Option

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

38.2.5.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

First Settlement Date: The first date eligible for settlement.

Last Settlement Date: The last date eligible for settlement.

Option Buy Sell: This indicates which party to the contract has the right to choose the settlement date. `Buy` means that the bank has the right to choose, and `Sell` means that the counterparty has the right to choose.

38.2.5.4 Deal Representation

The FX Time Option is an atomic deal. See the Theory Guide [7, § 4.1.9 FX Time Option].

38.2.5.5 Valuation

In Adaptiv Analytics an FX Time Option deal can be valued using the `FXTimeOptionValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.1.9 FX Time Option].

38.2.5.6 Assumptions

See Section 38.1.2 for descriptions of the general FX derivative assumptions of this deal.

Economically Optimal Exercise: The model calculates value under the assumption that the settlement date will be chosen to maximize the risk-neutral expectation of economic value of the contract to the party that holds the right to choose the settlement date.

In aging simulations, the model must decide whether to exercise on each valuation date. Exercised deals pay out their buy and sell cashflows and are then terminated. Adaptiv Analytics will exercise an FX time option on the first valuation date for which there remain no settlement dates with higher expected value than the valuation date.

38.2.5.7 Limitations

See Section 38.1.3 for descriptions of the general FX derivative limitations of this deal.

Exercised Only on Valuation Dates: Exercise and termination of an FX time option during an aging simulation occurs only on valuation dates. This is opposed to valuation; whenever valuation occurs, it always considers all potential future settlement dates, regardless of whether they are also valuation dates. The base calculation date is always a valuation date. If dynamic dates are in use, the deal's last settlement date will also be a valuation date. Otherwise, only dates in the base valuation grid are valuation dates.

No Delivery Calendar: All calendar dates between the first and last delivery dates, inclusive, are treated as eligible settlement dates. There is no delivery calendar and no exclusion of weekends or holidays.

No Partial Delivery: There is no provision to specify that exercise should occur over multiple days.

38.2.6 FX Average Rate Forward Strip

38.2.6.1 Overview

This deal represents a series of forward contracts where there is one FX Average Rate Forward (Explicit) deal for each item in the `Payments` property. The underlying FX rate, tenor and strike is the same for each deal in the strip.

This deal deduces the sampling dates from the sampling frequency and a first and last sample date in each payment item.

38.2.6.2 Price Factor Dependency

FX Average Rate Forward Strip

- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

38.2.6.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

Forward Price: The strike equity price denominated in `Currency`.

Payments List of average rate FX forward contract details.

Average Average of known prices or rates up to and including `Average Date`. Must be in settlement currency for compo deals.

Average Date Last price or rate observation date for the known average.

First Sample Date First rate observation date.

Last Sample Date Last rate observation date.

Payment Date Settlement date of forward contract.

Sampling Frequency: Period between sample dates. If set to 0d then the `First Sample Date` and the `Last Sample Date` are the only two sample dates of the deal.

Tenor: The tenor over which to calculate each forward equity price included in the average. The tenor should be set to the conventional spot settlement lag if the intent is to average spot rates. When the tenor is specified in days, it will be interpreted as business days if a holiday calendar is available for the deal.

Weighted Average: If Yes and the sampling frequency is in days then each sample is weighted by the number of days from the sample date to the next sample date. Otherwise the sample weights are 1.

38.2.6.4 Deal Representation

The FX Average Rate Forward Strip is a deal skin that builds into a series of FX Average Rate Forward (Explicit) deals. See section 38.2.7 and the Deal Skins Guide [2, [FX Average Rate Forward Strip](#)]. The building process is for the overall deal is:

Theory Guide 4.1.10.1

An FX average rate forward strip deals builds into FX average rate forward (explicit) deals corresponding to the entries in the Payments list.

For each individual deal in the strip the building process is:

Theory Guide 4.1.10

An average rate or average strike forward deal builds into a corresponding average rate or average strike forward (explicit) deal, with the Sampling Data list constructed as follows.

Let $(t_1, \omega_1, F_1), \dots, (t_n, \omega_n, F_n)$ denote the date, weight and (known) price entries in the sampling data list. Let ϕ denote the sampling frequency and \mathcal{H} denote the deal's holiday calendar. The sample dates t_1, \dots, t_n are generated from the first sample date, last sample date, ϕ and \mathcal{H} using the method of Section 1.3.4.

If Weighted Average is Yes, $\phi = fd$ and \mathcal{H} is not empty then ω_i is the number of days from t_i to t_{i+1} , with $t_{n+1} = t_n + fb$. Otherwise $\omega_i = 1$.

Let A and T denote the Average and Average Date. A is the average of the known prices for sample dates up to and including T . If $t_i \leq T$ then $F_i = A$. Otherwise F_i is not specified.

38.2.6.5 Valuation

FX Average Rate Forward Strip deals are valued using the DealSkinValuation model. For details about the valuation for this deal, see the section on the FX Average Rate Forward (Explicit) (section 38.2.7).

38.2.6.6 Assumptions

See Section 38.1.2 for descriptions of the general equity derivative assumptions of this deal.

38.2.6.7 Limitations

See Section 38.1.3 for descriptions of the general equity derivative limitations of this deal.

38.2.7 FX Average Rate Forward (Explicit)

38.2.7.1 Overview

This deal type is a forward contract where the asset effectively being purchased is the arithmetic average of FX rate forward prices (or spot prices). Each forward price in the average is for the same FX rate and tenor. This payoff is settled net on the deal maturity date.

This deal has an explicit list of sampling dates. This means that each forward price can be weighted individually.

38.2.7.2 Price Factor Dependency

FX Average Rate Forward (Explicit)

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

38.2.7.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

Forward Price: The strike FX rate in units of Currency (domestic currency) per Underlying Currency (foreign currency.)

Tenor: The tenor over which to calculate each FX rate in the average. The tenor should be set to the conventional spot settlement lag if the intent is to average spot rates. When the tenor is specified in days, it will be interpreted as business days if a holiday calendar is available for the deal.

38.2.7.4 Deal Representation

The FX Average Rate Forward (Explicit) is an atomic deal. See the Theory Guide [7, § 4.1.11 [Average Rate and Average Strike Forward \(Explicit\)](#)].

38.2.7.5 Valuation

In Adaptiv Analytics an FX Average Rate Forward (Explicit) deal can be valued using the `FXAverageRateForwardValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.1.11 [Average Rate and Average Strike Forward \(Explicit\)](#)].

The valuation relies on the absence of arbitrage argument that the expectation of the forward price is at some future fixing date is equal to the forward price now. Additionally it relies on the distributive property between means and expectations, which allows their order to be exchanged.

38.2.7.6 Assumptions

See Section 38.1.2 for descriptions of the general FX derivative assumptions of this deal.

38.2.7.7 Limitations

See Section 38.1.3 for descriptions of the general FX derivative limitations of this deal.

38.2.8 FX Average Strike Forward

38.2.8.1 Overview

This deal type is a forward contract where the strike is the arithmetic average of FX rate forward prices (or spot prices). Each forward price in the average is for the same FX rate and tenor. Additionally a spread is applied to the strike. This payoff is settled net on the deal maturity date.

This deal deduces the sampling dates from a sampling frequency and a first and last sample date.

38.2.8.2 Price Factor Dependency

FX Average Strike Forward

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

38.2.8.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

Average: Average of known prices or rates up to and including Average Date.

Average Date: Last price or rate observation date for the known average.

First Sample Date: First price observation date.

Last Sample Date: Last price observation date.

Sampling Frequency: Period between sample dates. If set to 0d then the First Sample Date and the Last Sample Date are the only two sample dates of the deal.

Spread: The fixed spread added to the strike price, denominated in Currency.

Tenor: The tenor over which to calculate each forward equity price included in the average. The tenor should be set to the conventional spot settlement lag if the intent is to average spot rates. When the tenor is specified in days, it will be interpreted as business days if a holiday calendar is available for the deal.

Weighted Average: If Yes and the sampling frequency is in days then each sample is weighted by the number of days from the sample date to the next sample date. Otherwise the sample weights are 1.

38.2.8.4 Deal Representation

The FX Average Strike Forward is a deal skin that builds into a FX Average Strike Forward (Explicit) deal. See section 38.2.9 and the Deal Skins Guide [2, FX Average Strike Forward]. The building process is described below.

Theory Guide 4.1.10

An average rate or average strike forward deal builds into a corresponding average rate or average strike forward (explicit) deal, with the Sampling Data list constructed as follows.

Let $(t_1, \omega_1, F_1), \dots, (t_n, \omega_n, F_n)$ denote the date, weight and (known) price entries in the sampling data list. Let ϕ denote the sampling frequency and \mathcal{H} denote the deal's holiday calendar. The sample dates t_1, \dots, t_n are generated from the first sample date, last sample date, ϕ and \mathcal{H} using the method of Section 1.3.4.

If Weighted Average is Yes, $\phi = fd$ and \mathcal{H} is not empty then ω_i is the number of days from t_i to t_{i+1} , with $t_{n+1} = t_n + fb$. Otherwise $\omega_i = 1$.

Let A and T denote the Average and Average Date. A is the average of the known prices for sample dates up to and including T . If $t_i \leq T$ then $F_i = A$. Otherwise F_i is not specified.

38.2.8.5 Valuation

FX Average Strike Forward deals are valued using the DealSkinValuation model. For details about the valuation for this deal, see the section on the FX Average Strike Forward (Explicit) (section 38.2.9).

38.2.8.6 Assumptions

See Section 38.1.2 for descriptions of the general equity derivative assumptions of this deal.

38.2.8.7 Limitations

See Section 38.1.3 for descriptions of the general equity derivative limitations of this deal.

38.2.9 FX Average Strike Forward (Explicit)

38.2.9.1 Overview

This deal type is a forward contract where the strike is the arithmetic average of FX rate forward prices (or spot prices). Each forward price in the average is for the same FX rate and tenor. Additionally a spread is applied to the strike. This payoff is settled net on the deal maturity date.

This deal has an explicit list of sampling dates. This means that each forward price can be weighted individually.

38.2.9.2 Price Factor Dependency

FX Average Strike Forward (Explicit)

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

38.2.9.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

Spread: The fixed spread added to the calculated strike price.

Tenor: The tenor over which to calculate each forward equity price included in the average. The tenor should be set to the conventional spot settlement lag if the intent is to average spot rates. When the tenor is specified in days, it will be interpreted as business days if a holiday calendar is available for the deal.

38.2.9.4 Deal Representation

The FX Average Strike Forward (Explicit) is an atomic deal. See the Theory Guide [7, § 4.1.11 [Average Rate and Average Strike Forward \(Explicit\)](#)].

38.2.9.5 Valuation

In Adaptiv Analytics an FX Average Strike Forward (Explicit) deal can be valued using the `FXAverageStrikeForwardValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.1.11 [Average Rate and Average Strike Forward \(Explicit\)](#)].

The valuation relies on the absence of arbitrage argument that the expectation of the forward price is at some future fixing date is equal to the forward price now. Additionally it relies on the distributive property between means and expectations, which allows their order to be exchanged.

38.2.9.6 Assumptions

See Section 38.1.2 for descriptions of the general equity derivative assumptions of this deal.

38.2.9.7 Limitations

See Section 38.1.3 for descriptions of the general equity derivative limitations of this deal.

38.2.10 FX Swap

38.2.10.1 Overview

This deal type is for deals that match two exchanges of cashflows denominated in different currencies. One currency is bought at a near date and sold at a far date, and the other is sold at the near date and bought at the far date. The amounts of all cashflows are fixed at deal inception. It is logically the same as a structured deal containing two matched FX forward contracts.

38.2.10.2 Price Factor Dependency

FX Swap

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

38.2.10.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

Far Buy Amount: The amount of currency bought at the far settlement date.

Far Sell Amount: The amount of currency sold at the far settlement date.

Far Settlement Date: The later of the two dates at which cashflows are exchanged.

Near Buy Amount: The amount of currency bought at the near settlement date.

Near Buy Far Sell Ccy: The currency that is bought at the near date and sold at the far date.

Near Buy Far Sell Discount Rate: The ID of the interest rate price factor that is used to discount the near buy and far sell cashflows. When not populated, the ID of the Near Buy Far Sell Ccy is used.

Near Sell Amount: The amount of currency that is sold at the near date.

Near Sell Far Buy Ccy: The currency that is sold at the near date and bought at the far date.

Near Sell Far Buy Discount Rate: The ID of the interest rate price factor that is used to discount the near sell and far buy cashflows. When not populated, the ID of the Near Sell Far Buy Ccy is used.

Near Settlement Date: The earlier of the two dates at which cashflows are exchanged.

38.2.10.4 Deal Representation

The FX Swap is a deal skin that builds into four fixed cashflow deals. See the Deal Skins Guide [2, [FX Swap](#)].

38.2.10.5 Valuation

In Adaptiv Analytics an FX Swap deal can be valued using the `FXSwapValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.1.7 [FX Swap](#)].

38.2.10.6 Assumptions

See Section 38.1.2 for descriptions of the general FX derivative assumptions of this deal.

38.2.10.7 Limitations

See Section 38.1.3 for descriptions of the general FX derivative limitations of this deal.

38.3 FX Option Deal Types

38.3.1 FX Option

38.3.1.1 Overview

This deal type is for options on an immediate or forward FX rate, with either European or American exercise, and their quanto variants. The deal is always settled for net value, even when configured to be a physically settled option on a forward rate.

38.3.1.2 Price Factor Dependency

FX Option

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Rate / FX Rate Correlation (§ 12.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

38.3.1.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

38.3.1.4 Deal Representation

The FX Option is an atomic deal.

38.3.1.5 Valuation

In Adaptiv Analytics an FX Option deal can be valued using the `FXOptionDealValuation` model.

This deal can be configured to have either European (Section 37.3.5) or American (Section 37.3.6) exercise.

See Section 37.3.4 for the valuation of quanto payoffs.

This deal can be configured so that the asset underlying the option is a forward contract on an FX rate. In this case, the option may be either cash-settled or physically settled. See Theory Guide [7, § 4.1.19 Options on Forwards] for a description of options on forwards. Note that the only way to specify a spot settlement lag is to configure the deal to be an option on a forward, with the forward period equal to the settlement lag. See [14] for methods to handle settlement adjustments.

38.3.1.6 Tuning Parameters and Valuation Settings

Early Exercise Today: American options are exercised only at times after the base calculation date unless this parameter is Yes. See Section 37.3.6.1.

Monitoring Period: The model exercises American options on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Theory Guide [7, § 4.1.18.4 Monitoring Dates] for details on the use of this parameter.

38.3.1.7 Assumptions

See Section 38.1.2 for descriptions of the general FX derivative assumptions of this deal.

38.3.1.8 Limitations

See Section 38.1.3 for descriptions of the general FX derivative limitations of this deal.

38.3.2 FX Binary Option

38.3.2.1 Overview

This deal type supports two types of fixed payoff, namely cash-or-nothing and call-put spread. Cash-or-nothing pays the `Cash Payoff` if the option is in the money at exercise, or zero if out of the money.

Theory Guide [4.1.20](#)

The option pays

$$C [\delta(S(T) - K) > 0] \quad (38.3.1)$$

at the settlement date t_1 , where C is the Cash Payoff and either $\delta = +1$ for a call option or $\delta = -1$ for a put option.

The call-put spread scales the cash payoff by the ratio between two vanilla calls or puts and the `Call Put Spread` between them:

Theory Guide [4.1.20](#)

Let ϵ denote the Call Put Spread of the deal.

Theory Guide [4.1.20](#)

When $\epsilon \neq 0$, the option pays

$$C \frac{\max(\delta(S(T) - K + \epsilon/2), 0) - \max(\delta(S(T) - K - \epsilon/2), 0)}{\delta\epsilon} \quad (38.3.2)$$

at the settlement date.

This method can be used to take volatility skew into account for binary option pricing. The call-put spread payoff converges to the fixed cash payoff as the spread approaches zero. Consequently, the spread is the only parameter used to decide whether to pay cash-or-nothing or call-put spread.

Only European exercise is supported.

The payoff may be in a third currency (quanto).

38.3.2.2 Price Factor Dependency

FX Binary Option

- └ Discount Rate (§ [6.2](#))
- └ FX Rate (§ [4.2](#))
- └ FX Rate / FX Rate Correlation (§ [12.2](#))
- └ FX Volatility (§ [11.2.4](#))
- └ Interest Rate (§ [6.1](#))

38.3.2.3 Properties

See Section [38.1.1](#) for descriptions of the common properties of this deal.

Cash Payoff: The size of the fixed payoff, scaled by the call spread or put spread when the spread is not zero.

Call Put Spread: The size of the call spread or put spread used to calculate the fixed payoff.

38.3.2.4 Deal Representation

The FX Binary Option is an atomic deal.

38.3.2.5 Valuation

In Adaptiv Analytics an FX Option deal can be valued using the `FXBinaryOptionValuation` model. For details about the valuation for this deal, see Theory Guide [7, § 4.1.20 Binary Option].

See Section 37.3.5 for the valuation of European options.

See Section 37.3.4 for the valuation of quanto payoffs.

38.3.2.6 Tuning Parameters and Valuation Settings

This valuation model has no tuning parameters or valuation settings.

38.3.2.7 Assumptions

See Section 38.1.2 for descriptions of the general FX derivative assumptions of this deal.

38.3.2.8 Limitations

See 38.1.3 for descriptions of the general FX derivative limitations of this deal.

38.3.3 FX Basket Option

38.3.3.1 Overview

This deal type is for options on an underlying basket of FX rates or a basket of FX rate returns, with either European or American exercise, and their quanto or compo variants.

38.3.3.2 Price Factor Dependency

Equity Basket Option

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Rate / FX Rate Correlation (§ 12.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

38.3.3.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

38.3.3.4 Deal Representation

The FX Basket Option is an atomic deal.

38.3.3.5 Valuation

In Adaptiv Analytics a FX Basket Option deal can be valued using the `FXBasketOptionValuation` model. See Section 37.3.4 for the valuation of quanto and compo payoffs. See Section 37.3.12 for the valuation of baskets of prices. See Section 37.3.12.1 for the valuation of basket quanto and compo payoffs.

This deal can be configured to have either European (Section 37.3.5) or American (Section 37.3.6) exercise.

38.3.3.6 Tuning Parameters and Valuation Settings

Approximation Method: Basket options are priced using a moment matching approximation, as described in Section 37.3.12.2. The approximation method may be either `Two Moment Log Normal` for the two moment method or `Three Moment Shifted Log Normal` for the three moment method.

Implied Volatility Method: When an option is on a basket of returns rather than a basket of prices, the choice of volatility method may be either `Weighted Strike` or `Conditional Strike`. See Theory Guide [7, § 4.1.40 [Basket of Returns](#)] for details.

Early Exercise Today: American options are exercised only at times after the base calculation date unless this parameter is `Yes`. See Section 37.3.6.1.

Monitoring Period: The model exercises American options on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the `Monitoring Period` parameter. See Theory Guide [7, § 4.1.18.4 [Monitoring Dates](#)] for details on the use of this parameter.

38.3.3.7 Assumptions

See Section 38.1.2 for descriptions of the general FX rate derivative assumptions of this deal.

38.3.3.8 Limitations

See Section 38.1.3 for descriptions of the general FX rate derivative limitations of this deal.

38.3.4 FX Chooser Option

38.3.4.1 Overview

This deal type is for chooser options on an underlying FX rate. Chooser options are where the holder can decide on the chooser date whether the option should be a call or a put. The chooser date is often prior to option expiry. Quanto variants are also supported.

38.3.4.2 Price Factor Dependency

FX Chooser Option

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Rate / FX Rate Correlation (§ 12.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

38.3.4.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

Chooser Date: Date on which the decision is made to enter into a call option or a put option. Must be on or before the expiry date.

38.3.4.4 Deal Representation

The FX Chooser Option is an atomic deal.

38.3.4.5 Valuation

In Adaptiv Analytics an FX Chooser Option deal can be valued using the `FXChooserOptionValuation` model. See Section 37.3.4 for the valuation of quanto and compo payoffs.

Valuation of this deal is described in Section 37.3.13.

38.3.4.6 Tuning Parameters and Valuation Settings

This deal type has no valuation configuration settings.

38.3.4.7 Assumptions

See Section 38.1.2 for descriptions of the general FX rate derivative assumptions of this deal.

38.3.4.8 Limitations

See Section 39.1.3 for descriptions of the general FX rate derivative limitations of this deal.

38.3.5 FX Cliquet Option

38.3.5.1 Overview

This deal type is for cliquet options on an underlying FX rate. Cliquet options are a strip of forward start options. The notional can be fixed or variable. Quanto variants are also supported.

38.3.5.2 Price Factor Dependency

Equity Cliquet Option

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Rate / FX Rate Correlation (§ 12.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

38.3.5.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

Effective Date: Unadjusted deal start date.

Frequency: Frequency of the option payments.

Moneyness: Moneyness factor.

Principal Fixed Variable: Determines whether the deal has a fixed or variable principal amount.

Principal: The fixed principal amount of the option. Used when Principal Fixed Variable is Fixed and ignored otherwise.

Known Prices: List of reset dates and corresponding known FX rates, entered in the form of number of units of domestic currency per unit of foreign currency. (List (Date, Value)).

38.3.5.4 Deal Representation

The FX Cliquet Option is an atomic deal.

38.3.5.5 Valuation

In Adaptiv Analytics an FX Cliquet Option deal can be valued using the FXCliquetOptionValuation model. See Section 37.3.4 for the valuation of quanto payoffs.

The valuation of this deal is described in Section 37.3.14.

38.3.5.6 Tuning Parameters and Valuation Settings

This deal type has no valuation configuration settings.

38.3.5.7 Assumptions

See Section 38.1.2 for descriptions of the general FX rate derivative assumptions of this deal.

38.3.5.8 Limitations

See Section 38.1.3 for descriptions of the general FX rate derivative limitations of this deal.

38.3.6 FX Compound Option

38.3.6.1 Overview

This deal type is for compound options on an underlying FX rate. A compound option is a European option on a European option. Quanto variants are also supported.

38.3.6.2 Price Factor Dependency

Equity Compound Option

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Rate / FX Rate Correlation (§ 12.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

38.3.6.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

Option Type: Type of the compound option. For example, Call On Put is a European call option on a European Put option. (Call On Call, Call On Put, Put On Call or Put On Put).

Strike Price: Strike price of the compound option in asset currency (or settlement currency for compo options).

Underlying Strike: Strike price of the underlying European option.

Underlying Maturity: Expiry date of the underlying European option.

38.3.6.4 Deal Representation

The FX Compound Option is an atomic deal.

38.3.6.5 Valuation

In Adaptiv Analytics an FX Compound Option deal can be valued using the `FXCompoundOptionValuation` model. See Section 37.3.4 for the valuation of quanto payoffs.

The valuation of this deal is described in Section 37.3.15.

38.3.6.6 Tuning Parameters and Valuation Settings

This deal type has no valuation configuration settings.

38.3.6.7 Assumptions

See Section 38.1.2 for descriptions of the general FX rate derivative assumptions of this deal.

38.3.6.8 Limitations

See Section 38.1.3 for descriptions of the general FX rate derivative limitations of this deal.

38.3.7 FX Lookback Option

38.3.7.1 Overview

This deal type is for lookback options on an underlying FX rate. The holder of a lookback option may choose the historically realized price over the life of the option that maximizes the option payoff. Adaptiv Analytics supports two types of lookback options:

- Floating Strike Lookback Option

Theory Guide [4.1.26](#)

The payoff of a floating strike lookback call option is $\max(S(T) - S_{\min}(T), 0)$, where $S_{\min}(t)$ is the lowest asset price observed from the trade date up to t . Similarly, the payoff of a floating strike lookback put option is $\max(S_{\max}(T) - S(T), 0)$, where $S_{\max}(t)$ is the highest asset price observed from the trade date up to t .

- Fixed Strike Lookback Option

Theory Guide [4.1.26](#)

The payoff of a fixed strike lookback call option is $\max(S_{\max}(T) - K, 0)$; and the payoff of a fixed strike lookback put option is $\max(K - S_{\min}(T), 0)$.

where

Theory Guide [4.1.26](#)

For a given valuation date t , the minimum and maximum asset price are calculated as follows:

$$S_{\min}(t) = \min\{S_{\min}, S(0), S(t_1), \dots, S(t_m), S(t)\} \quad (38.3.3)$$

$$S_{\max}(t) = \max\{S_{\max}, S(0), S(t_1), \dots, S(t_m), S(t)\}, \quad (38.3.4)$$

where: t_1, \dots, t_m are the valuation dates between 0 and t ; S_{\min} is the Observed Minimum if its value is positive, or otherwise $S_{\min} = \infty$; and S_{\max} is the Observed Maximum.

Quanto variants are also supported.

38.3.7.2 Price Factor Dependency

FX Lookback Option

- └ Discount Rate (§ [6.2](#))
- └ FX Rate (§ [4.2](#))
- └ FX Rate / FX Rate Correlation (§ [12.2](#))
- └ FX Volatility (§ [11.2.4](#))
- └ Interest Rate (§ [6.1](#))

38.3.7.3 Properties

See Section [38.1.1](#) and Section [37.2](#) for descriptions of the common properties of this deal.

Observed Maximum: Realised observed maximum price

Observed Minimum: Realised observed minimum price if the value is positive, otherwise $S_{\min} = \infty$.

Strike Type: Determines the variant of the Lookback option. `Fixed` is a Fixed Strike Lookback option and `Floating` refers to a Floating Strike Lookback option.

38.3.7.4 Deal Representation

The FX Lookback Option is an atomic deal.

38.3.7.5 Valuation

In Adaptiv Analytics an FX Lookback Option deal can be valued using the `FXLookbackOptionValuation` model. See Section 37.3.4 for the valuation of quanto payoffs.

The valuation of this deal is described in Section 37.3.16.

38.3.7.6 Tuning Parameters and Valuation Settings

This deal type has no valuation configuration settings.

38.3.7.7 Assumptions

See Section 38.1.2 for descriptions of the general FX rate derivative assumptions of this deal.

38.3.7.8 Limitations

See Section 38.1.3 for descriptions of the general FX rate derivative limitations of this deal.

Observed Minimum and Maximum The "observed" minimum and maximum (before the base valuation date) must be populated on the deal when the deal is valued mid-life. The valuation model will not check the rate fixing file to find the historical values.

38.3.8 FX Gap Option

38.3.8.1 Overview

This deal type is for gap options on an underlying FX rate. A gap option has a strike and a barrier. The barrier triggers the payoff and the magnitude of the payoff is determined by the strike. Barrier and reverse barrier variants are supported, as are quanto variants.

38.3.8.2 Price Factor Dependency

FX Gap Option

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Rate / FX Rate Correlation (§ 12.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

38.3.8.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

Barrier Price: Barrier price in asset currency.

Gap Type: Gap option type: Barrier Or Reverse Barrier.

38.3.8.4 Deal Representation

The FX Gap Option is an atomic deal.

38.3.8.5 Valuation

In Adaptiv Analytics an FX Gap Option deal can be valued using the `FXGapOptionValuation` model. See Section 37.3.4 for the valuation of quanto and compo payoffs.

The valuation of this deal is described in Section 37.3.17.

38.3.8.6 Tuning Parameters and Valuation Settings

This deal type has no valuation configuration settings.

38.3.8.7 Assumptions

See Section 38.1.2 for descriptions of the general FX rate derivative assumptions of this deal.

38.3.8.8 Limitations

See Section 38.1.3 for descriptions of the general FX rate derivative limitations of this deal.

38.3.9 FX Forward Strip Option

38.3.9.1 Overview

This deal type is for an option on a series of FX Forward contracts with the same buy and sell currency but different settlement dates as detailed in Section 38.2.3. Quanto variants are also supported.

Theory Guide 4.1.22

The option payoff is $\max(\delta U(T), 0)$, where $U(t)$ is the value of the underlying forward strip, T is the option expiry date, and $\delta = +1$ for a call option or $\delta = -1$ for a put option.

38.3.9.2 Price Factor Dependency

FX Forward Strip Option

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Rate / FX Rate Correlation (§ 12.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

38.3.9.3 Properties

See Section 38.1.1 and Section 37.2 for descriptions of the common properties of this deal.

Payments: This property is a list of forward contracts. Each item in the list has a Buy Amount, a Sell Amount, and a Date. The Date is the settlement date of the contract.

38.3.9.4 Deal Representation

The FX Forward Strip Option is an atomic deal.

38.3.9.5 Valuation

In Adaptiv Analytics an FX Forward Strip Option deal can be valued using the `FXForwardStripOptionValuation` model. See Section 37.3.4 for the valuation of quanto and compo payoffs

The valuation of this deal is described in Section 37.3.18.

38.3.9.6 Tuning Parameters and Valuation Settings

This deal type has no valuation configuration settings.

38.3.9.7 Assumptions

See Section 38.1.2 for descriptions of the general FX rate derivative assumptions of this deal.

38.3.9.8 Limitations

See Section 38.1.3 for descriptions of the general FX rate derivative limitations of this deal.

38.4 FX Asian Option Deal Types

38.4.1 FX Discrete (Explicit) Asian Option

38.4.1.1 Overview

This deal type is for Asian options on an underlying FX rate. They are called discrete Asian options in Adaptiv Analytics because they are fully modelled as a finite weighted sum of observations, and not approximated with a continuous average. They are called explicit because the set of observation dates must be explicitly enumerated in a deal property, rather than calculated from a formula. This explicit representation also allows each observation to be individually weighted.

The deal is always settled for net value with a single domestic currency cashflow.

38.4.1.2 Price Factor Dependency

FX Discrete (Explicit) Asian Option

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

38.4.1.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

38.4.1.4 Deal Representation

The FX Discrete (Explicit) Asian Option is an atomic deal.

38.4.1.5 Valuation:

In Adaptiv Analytics an FX Discrete (Explicit) Asian Option deal can be valued using the `FXDiscrete-AsianOptionValuation` model. See Section 37.3.9 for discrete Asian option valuation.

38.4.1.6 Tuning Parameters and Valuation Settings

Term Structured: See Section 37.3.9.3 for a description of this setting.

38.4.1.7 Assumptions

See Section 38.1.2 for descriptions of the general FX derivative assumptions of this deal.

38.4.1.8 Limitations

See Section 38.1.3 for descriptions of the general FX derivative limitations of this deal.

38.4.2 FX Discrete Asian Option

38.4.2.1 Overview

This deal type is for Asian options on an underlying FX rate. They are called discrete Asian options in Adaptiv Analytics because they are fully modelled as a finite weighted sum of observations, and not approximated with a continuous average. They use provided first and last sample dates, along with the sample frequency, to determine the sampling schedule.

The deal is always settled for net value with a single domestic currency cashflow.

38.4.2.2 Price Factor Dependency

FX Discrete Asian Option

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

38.4.2.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

Calendars: The list of holiday calendars used when calculating sampling dates. The union of all holidays in each calendar are treated as non-business days.

First Sample Date: The first price or rate observation date.

Last Sample Date: The last price or rate observation date.

Sampling Frequency: Period between sample dates. If set to 0M then the First Sample Date and the Last Sample Date are the only two sample dates of the deal.

Average: Average of known prices or rates up to and including Average Date. Must be in settlement currency for compo deals.

Average Date: Last price or rate observation date for the known average.

Weighted Average: If Yes and the sampling frequency is in days then each sample is weighted by the number of days from the sample date to the next sample date. Otherwise the sample weights are 1.

38.4.2.4 Deal Representation

FX Discrete Asian Option is a deal skin that builds into an FX Discrete (Explicit) Asian Option deal. See section 38.4.1 and the Deal Skins Guide [2, FX Discrete Asian Option]. The building process is described below.

Theory Guide 4.1.32

A discrete Asian option builds into a corresponding discrete (explicit) Asian option, with the Sampling Data list constructed as follows.

Let $(t_1, d_1, S_1), \dots, (t_n, d_n, S_n)$ denote the date, weight and (known) price entries in the sampling data list. Let ϕ denote the sampling frequency and \mathcal{H} denote the deal's holiday calendar. The sample dates t_1, \dots, t_n are generated from the first sample date, last sample date, ϕ and \mathcal{H} using the method of Section 1.3.4.

If Weighted Average is Yes, $\phi = fd$ and \mathcal{H} is not empty then d_i is the number of days from t_i to t_{i+1} , with $t_{n+1} = t_n + fb$. Otherwise $d_i = 1$.

Let A and T denote the Average and Average Date. A is the average of the known prices for sample dates up to and including T . If $t_i \leq T$ then $S_i = A$. Otherwise S_i is not specified.

38.4.2.5 Valuation:

FX Discrete Asian Option deals are valued using the DealSkinValuation model. For details about the valuation for this deal, see the section on the FX Discrete (Explicit) Asian Option (section 38.4.1).

38.4.2.6 Tuning Parameters and Valuation Settings

This valuation model has no tuning parameters or valuation settings.

38.4.2.7 Assumptions

See Section 38.1.2 for descriptions of the general FX derivative assumptions of this deal.

38.4.2.8 Limitations

See Section 38.1.3 for descriptions of the general FX derivative limitations of this deal.

38.4.3 FX Discrete (Explicit) Double Asian Option

38.4.3.1 Overview

This deal type is for double Asian options on an underlying FX rate. They are called discrete Asian options in Adaptiv Analytics because they are fully modelled with finite weighted sums of observations, and not approximated with a continuous average. They are called explicit because the sets of observation dates must be explicitly enumerated in deal properties, rather than calculated from a formula. This explicit representation also allows each observation to be individually weighted.

The deal is always settled for net value with a single domestic currency cashflow.

38.4.3.2 Price Factor Dependency

FX Discrete (Explicit) Double Asian Option

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

38.4.3.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

Difference Method: *Arithmetic* indicates that the option is on the arithmetic difference between the two weighted sums of observations; *Geometric* indicates that the option is on their ratio.

Is Digital: If *Yes*, the option pays a fixed amount determined by the two sampling multipliers.

Sampling Data 1: The sampling data for the first weighted sum in the difference term.

Sampling Data 2: The sampling data for the second weighted sum in the difference term.

Sampling Multiplier 1: The multiplier for the first weighted sum in the difference term.

Sampling Multiplier 2: The multiplier for the second weighted sum in the difference term.

Strike Multiplier: The strike is scaled by this multiplier before it is subtracted from the difference in weighted sums when calculating the option payoff.

38.4.3.4 Deal Representation

The FX Discrete (Explicit) Double Asian Option is an atomic deal.

38.4.3.5 Valuation:

In Adaptiv Analytics an FX Discrete (Explicit) Double Asian Option deal can be valued using the `FXDiscreteExplicitDoubleAsianOptionValuation` model. For details about the valuation for this deal, see Theory Guide [7, § 4.1.34 [Discrete \(Explicit\) Double Asian Option](#)].

See Section 37.3.9 for discrete Asian option valuation.

38.4.3.6 Tuning Parameters and Valuation Settings

Moment Matching Method: Double asian options are priced using a moment matching approximation, as described in Section 37.3.10.1. The approximation method may be either Two Moment Log Normal for the two moment method or Three Moment Shifted Log Normal for the three moment method.

Number of Integration Points: When the difference method is Geometric, the option must be valued with a numerical integration except in special cases, as described in Section 37.3.10.4. The number of points in the integration is specified with this parameter.

Strike Mapping Method: See Section 37.3.10.5 for a description of this setting.

Term Structured: See Section 37.3.10.5 for a description of this setting.

38.4.3.7 Assumptions

See Section 38.1.2 for descriptions of the general FX derivative assumptions of this deal.

38.4.3.8 Limitations

See Section 38.1.3 for descriptions of the general FX derivative limitations of this deal.

No Quanto Payoffs: Quanto payoffs are not supported for double asian options.

38.4.4 FX Basket Discrete (Explicit) Asian Option

38.4.4.1 Overview

This deal type is for Asian options on an underlying basket of either FX rate prices or returns, and their quanto or compo variants. They are called discrete Asian options in Adaptiv Analytics because they are fully modelled as a finite weighted sum of basket observations, and not approximated with a continuous average. They are called explicit because the set of observation dates must be explicitly enumerated in a deal property, rather than calculated from a formula. This explicit representation also allows each observation to be individually weighted.

38.4.4.2 Price Factor Dependency

FX Basket Discrete (Explicit) Asian Option

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Rate Correlation (§ 12.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

38.4.4.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

38.4.4.4 Deal Representation

The FX Basket Discrete (Explicit) Asian Option is an atomic deal.

38.4.4.5 Valuation

In Adaptiv Analytics an FX Basket Discrete (Explicit) Asian Option deal can be valued using the `EquityBasketDiscreteAsianOptionValuation` model. See Section 37.3.9 for discrete Asian option valuation.

This deal can be configured to support standard payoffs in the equity currency, quanto payoffs, and compo payoffs. See Section 37.3.4 for the valuation of quanto and compo payoffs.

38.4.4.6 Tuning Parameters and Valuation Settings

Term Structured: See Section 37.3.9.3 for a description of this setting.

Approximation Method: See Section 37.3.12.2 for a description of this setting.

Implied Volatility Method: See Section 37.3.12.2 for a description of this setting.

38.4.4.7 Assumptions

See Section 38.1.2 for descriptions of the general FX derivative assumptions of this deal.

38.4.4.8 Limitations

See Section 38.1.3 for descriptions of the general FX derivative limitations of this deal.

38.4.5 FX Basket Discrete Asian Option

38.4.5.1 Overview

This deal type is for Asian options on an underlying basket of either FX rate prices or returns, and their quanto or compo variants. They are called discrete Asian options in Adaptiv Analytics because they are fully modelled as a finite weighted sum of basket observations, and not approximated with a continuous average. They use provided first and last sample dates, along with the sample frequency, to determine the sampling schedule.

38.4.5.2 Price Factor Dependency

FX Basket Discrete Asian Option

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Rate Correlation (§ 12.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

38.4.5.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

Calendars: The list of holiday calendars used when calculating sampling dates. The union of all holidays in each calendar are treated as non-business days.

First Sample Date: The first price or rate observation date.

Last Sample Date: The last price or rate observation date.

Sampling Frequency: Period between sample dates. If set to 0M then the First Sample Date and the Last Sample Date are the only two sample dates of the deal.

Average: Average of known prices or rates up to and including Average Date. Must be in settlement currency for compo deals.

Average Date: Last price or rate observation date for the known average.

Weighted Average: If Yes and the sampling frequency is in days then each sample is weighted by the number of days from the sample date to the next sample date. Otherwise the sample weights are 1.

38.4.5.4 Deal Representation

FX Discrete Asian Option is a deal skin that builds into an FX Basket Discrete (Explicit) Asian Option deal. See section 38.4.4 and the Deal Skins Guide [2, [FX Basket Discrete Asian Option](#)]. The building process is the same as that described in section 38.4.2

38.4.5.5 Valuation:

FX Basket Discrete Asian Option deals are valued using the DealSkinValuation model. For details about the valuation for this deal, see the section on the FX Basket Discrete (Explicit) Asian Option (section 38.4.4).

38.4.5.6 Tuning Parameters and Valuation Settings

This valuation model has no tuning parameters or valuation settings.

38.4.5.7 Assumptions

See Section 38.1.2 for descriptions of the general FX derivative assumptions of this deal.

38.4.5.8 Limitations

See Section 38.1.3 for descriptions of the general FX derivative limitations of this deal.

38.4.6 FX Continuous Asian Option

38.4.6.1 Overview

This deal type is for Asian options on an underlying FX rate. They are called continuous because they use a continuous average to approximate daily observations of the underlying FX rate. Both geometric and arithmetic averaging are available.

38.4.6.2 Price Factor Dependency

FX Continuous Asian Option

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

38.4.6.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

Asian Type: Asian option type: Geometric or Arithmetic.

Average: Average of known prices or rates up to the base valuation date.

38.4.6.4 Deal Representation

The FX Continuous Asian Option is an atomic deal.

38.4.6.5 Valuation:

FX Continuous Asian Option deals are valued using the `FXAsianOptionValuation` model. See Section 37.3.11 for continuous Asian option valuation.

38.4.6.6 Tuning Parameters and Valuation Settings

This valuation model has no tuning parameters or valuation settings.

38.4.6.7 Assumptions

See Section 38.1.2 for descriptions of the general FX derivative assumptions of this deal.

38.4.6.8 Limitations

See Section 38.1.3 for descriptions of the general FX derivative limitations of this deal.

38.4.7 FX Basket Continuous Asian Option

38.4.7.1 Overview

This deal type is for Asian options on an underlying basket of FX rate prices. They are called continuous because they use a continuous average to approximate daily observations of the underlying FX rate. Both geometric and arithmetic averaging are available.

38.4.7.2 Price Factor Dependency

FX Basket Continuous Asian Option

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Rate Correlation (§ 12.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

38.4.7.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

Asian Type: Asian option type: Geometric or Arithmetic.

Average: Average of known prices or rates up to the base valuation date.

Correlation Set: ID of the group of correlation price factors used to calculate the basket price volatility.

Basket Components: List of basket components.

38.4.7.4 Deal Representation

The FX Basket Continuous Asian Option is an atomic deal.

38.4.7.5 Valuation:

FX Basket Continuous Asian Option deals are valued using the `FXAsianOptionValuation` model. See Section 37.3.11 for continuous Asian option valuation.

38.4.7.6 Tuning Parameters and Valuation Settings

This valuation model has no tuning parameters or valuation settings.

38.4.7.7 Assumptions

See Section 38.1.2 for descriptions of the general FX derivative assumptions of this deal.

38.4.7.8 Limitations

See Section 38.1.3 for descriptions of the general FX derivative limitations of this deal.

38.5 FX Barrier Option Deal Types

38.5.1 FX Barrier Option

38.5.1.1 Overview

This deal type is for single barrier options on an underlying FX rate. The barrier monitoring frequency may be specified. The option may pay a rebate. An out rebate is paid when the option is knocked out. An in rebate is paid at option expiry if the option is never knocked in.

The deal is always settled for net value with a single currency cashflow in the payoff currency.

38.5.1.2 Price Factor Dependency

FX Barrier Option

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Rate / FX Rate Correlation (§ 12.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

38.5.1.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

38.5.1.4 Deal Representation

The FX Barrier Option is an atomic deal.

38.5.1.5 Valuation:

In Adaptiv Analytics an FX Barrier Option deal can be valued using the `FXBarrierOptionValuation` model. For details about the valuation for this deal, see Theory Guide [7, § 4.1.27 [Barrier Option](#)].

38.5.1.6 Tuning Parameters and Valuation Settings

Monitoring Period: The model exercises knock-in or knock-out on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Section 37.4.14 and the Theory Guide [7, § 4.1.30.1 [Monitoring Dates](#)].

38.5.1.7 Assumptions

See Section 38.1.2 for descriptions of the general FX derivative assumptions of this deal.

38.5.1.8 Limitations

See Section 38.1.3 for descriptions of the general FX derivative limitations of this deal.

38.5.2 FX Barrier Binary Option

38.5.2.1 Overview

This deal type is for single barrier binary options on an underlying FX rate. An FX barrier binary option pays the Cash Payoff if the option is in the money at exercise and the barrier has been touched (knock-in) or never touched (knock-out). The barrier monitoring frequency may be specified.

The deal is always settled for net value with a single currency cashflow in the payoff currency.

38.5.2.2 Price Factor Dependency

FX Barrier Binary Option

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Rate / FX Rate Correlation (§ 12.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

38.5.2.3 Properties

See Section 38.1.1 and Section 37.2 for descriptions of the common properties of this deal.

38.5.2.4 Deal Representation

The FX Barrier Binary Option is an atomic deal.

38.5.2.5 Valuation:

In Adaptiv Analytics an FX Barrier Binary Option deal can be valued using the `FXBarrierBinaryOptionValuation` model. For details about the valuation for this deal, see Section 37.3.7

38.5.2.6 Tuning Parameters and Valuation Settings

Monitoring Period: The model exercises knock-in or knock-out on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Section 37.4.14 and the Theory Guide [7, § 4.1.30.1 Monitoring Dates].

38.5.2.7 Assumptions

See Section 38.1.2 for descriptions of the general FX derivative assumptions of this deal.

38.5.2.8 Limitations

See Section 38.1.3 for descriptions of the general FX derivative limitations of this deal.

38.5.3 FX Double Barrier Option

38.5.3.1 Overview

This deal type is for double barrier options on an underlying FX rate. The barrier monitoring frequency may be specified. The option may pay a rebate. An out rebate is paid when the option is knocked out. An in rebate is paid at option expiry if the option is never knocked in.

The deal is always settled for net value with a single currency cashflow in the payoff currency.

38.5.3.2 Price Factor Dependency

FX Double Barrier Option

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Rate / FX Rate Correlation (§ 12.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

38.5.3.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

38.5.3.4 Deal Representation

The FX Double Barrier Option is an atomic deal.

38.5.3.5 Valuation:

In Adaptiv Analytics an FX Double Barrier Option deal can be valued using the `FXDoubleBarrierOptionValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.1.28 Double Barrier Option].

38.5.3.6 Tuning Parameters and Valuation Settings

Max Iterations: The maximum number of terms in the truncation of infinite series used to value the option. See Section 37.3.8.3 for details.

Monitoring Period: The model exercises knock-in or knock-out on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Section 37.4.14 and the Theory Guide [7, § 4.1.30.1 Monitoring Dates].

Tolerance: The tolerance at which to truncate the infinite series used to value the option. See Section 37.3.8.3 for details.

38.5.3.7 Assumptions

See Section 38.1.2 for descriptions of the general FX derivative assumptions of this deal.

38.5.3.8 Limitations

See Section 38.1.3 for descriptions of the general FX derivative limitations of this deal.

38.5.4 FX One Touch Option

38.5.4.1 Overview

This deal type is for one-touch options on an underlying FX rate. The barrier monitoring frequency may be specified. The option pays a fixed amount conditional on barrier touching; the payment timing may be either upon touching or at expiry.

The deal is always settled for net value with a single currency cashflow in the payoff currency.

38.5.4.2 Price Factor Dependency

FX One Touch Option

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Rate / FX Rate Correlation (§ 12.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

38.5.4.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

38.5.4.4 Deal Representation

The FX One Touch Option is an atomic deal.

38.5.4.5 Valuation

In Adaptiv Analytics an FX One Touch Option deal can be valued using the `FXTouchOptionValuation` model. For details about the valuation for this deal, see Theory Guide [7, § 4.1.27.1 [One-Touch and No-Touch Options and Rebates](#)].

38.5.4.6 Tuning Parameters and Valuation Settings

Monitoring Period: The model exercises knock-in or knock-out on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Section 37.4.14 and the Theory Guide [7, § 4.1.30.1 [Monitoring Dates](#)].

38.5.4.7 Assumptions

See Section 38.1.2 for descriptions of the general FX derivative assumptions of this deal.

38.5.4.8 Limitations

See Section 38.1.3 for descriptions of the general FX derivative limitations of this deal.

38.5.5 FX No Touch Option

38.5.5.1 Overview

This deal type is for no-touch options on an underlying FX rate. The barrier monitoring frequency may be specified. The option pays a fixed amount at expiry conditional on no barrier touching during the life of the option.

The deal is always settled for net value with a single currency cashflow in the payoff currency.

38.5.5.2 Price Factor Dependency

FX No Touch Option

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Rate / FX Rate Correlation (§ 12.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

38.5.5.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

38.5.5.4 Deal Representation

The FX No Touch Option is an atomic deal.

38.5.5.5 Valuation

In Adaptiv Analytics an FX No Touch Option deal can be valued using the `FXTouchOptionValuation` model. For details about the valuation for this deal, see Theory Guide [7, § 4.1.27.1 [One-Touch and No-Touch Options and Rebates](#)].

38.5.5.6 Tuning Parameters and Valuation Settings

Monitoring Period: The model exercises knock-in or knock-out on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Section 37.4.14 and the Theory Guide [7, § 4.1.30.1 [Monitoring Dates](#)].

38.5.5.7 Assumptions

See Section 38.1.2 for descriptions of the general FX derivative assumptions of this deal.

38.5.5.8 Limitations

See Section 38.1.3 for descriptions of the general FX derivative limitations of this deal.

38.5.6 FX Double One Touch Option

38.5.6.1 Overview

This deal type is for double one-touch options on an underlying FX rate. The barrier monitoring frequency may be specified. The option pays fixed amounts conditional on barrier touching; the payment timing may be either upon touching or at expiry. Different payoffs may be specified for the upper and lower barriers.

The deal is always settled for net value with a single currency cashflow in the payoff currency.

38.5.6.2 Price Factor Dependency

FX Double One Touch Option

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Rate / FX Rate Correlation (§ 12.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

38.5.6.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

38.5.6.4 Deal Representation

The FX Double One Touch Option is an atomic deal.

38.5.6.5 Valuation

In Adaptiv Analytics an FX Double One Touch option deal can be valued using the `FXDoubleTouchOptionValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.1.28.1 One-Touch and No-Touch Options and Rebates].

38.5.6.6 Tuning Parameters and Valuation Settings

Monitoring Period: The model exercises knock-in or knock-out on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Section 37.4.14 and the Theory Guide [7, § 4.1.30.1 Monitoring Dates].

38.5.6.7 Assumptions

See Section 38.1.2 for descriptions of the general FX derivative assumptions of this deal.

38.5.6.8 Limitations

See Section 38.1.3 for descriptions of the general FX derivative limitations of this deal.

38.5.7 FX Double No Touch Option

38.5.7.1 Overview

This deal type is for double no-touch options on an underlying FX rate. The barrier monitoring frequency may be specified. The option pays fixed amounts conditional on neither barrier being touched during the life of the option.

The deal is always settled for net value with a single currency cashflow in the payoff currency.

38.5.7.2 Price Factor Dependency

FX Double No Touch Option

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Rate / FX Rate Correlation (§ 12.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

38.5.7.3 Properties

See Section 38.1.1 and Section 37.2 for descriptions of the common properties of this deal.

38.5.7.4 Deal Representation

The FX Double No Touch Option is an atomic deal.

38.5.7.5 Valuation

In Adaptiv Analytics an FX Double No Touch option deal can be valued using the `FXDoubleTouchOptionValuation` model. For details about the valuation for this deal, see the Section 37.3.8.2.

38.5.7.6 Tuning Parameters and Valuation Settings

Monitoring Period: The model exercises knock-in or knock-out on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Section 37.4.14 and the Theory Guide [7, § 4.1.30.1 [Monitoring Dates](#)].

38.5.7.7 Assumptions

See Section 38.1.2 for descriptions of the general FX derivative assumptions of this deal.

38.5.7.8 Limitations

See Section 38.1.3 for descriptions of the general FX derivative limitations of this deal.

38.5.8 FX Partial-Time Barrier Option

38.5.8.1 Overview

This deal type is for partial-time barrier options on an underlying FX rate. In this type of option, the period over which the barrier is effective is a subset of the lifetime of the option. The barrier monitoring frequency may be specified.

The deal is always settled for net value with a single currency cashflow in the payoff currency.

Theory Guide [4.1.29](#)

Let t_1 denote the Barrier Limit Date, which must be before the option expiry date T . There are three types of partial-time barrier option.

Type A: Barrier At Start is Yes. The barrier period starts at the trade date and ends at t_1 . Up (down) options are knocked out or knocked in at the first date $t \leq t_1$ for which $S(t)$ is above (below) the barrier.

Type B1: Barrier At Start is No and Barrier Type is either In or Out. The barrier period starts at t_1 and ends at T . The option is knocked out or knocked in at the first date $t \geq t_1$ for which $S(t)$ touches the barrier (from either above or below). The asset price at the trade date may be either above or below the barrier.

Type B2: Barrier At Start is No and Barrier Type is either Down And In, Up And In, Down And Out or Up And Out. The barrier period starts at t_1 and ends at T . Up (down) options are knocked out or knocked in at the first date $t \geq t_1$ for which $S(t)$ is above (below) the barrier. Note that an up (down) option is triggered immediately at t_1 if $S(t_1)$ is above (below) the barrier.

38.5.8.2 Price Factor Dependency

FX Partial-Time Barrier Option

- └ Discount Rate (§ [6.2](#))
- └ FX Rate (§ [4.2](#))
- └ FX Rate / FX Rate Correlation (§ [12.2](#))
- └ FX Volatility (§ [11.2.4](#))
- └ Interest Rate (§ [6.1](#))

38.5.8.3 Properties

See Section [38.1.1](#) and Section [37.2](#) for descriptions of the common properties of this deal.

Barrier At Start: This represents whether the period over which the barrier is effective begins at the trade date. If Barrier At Start is set to **Yes** then the barrier is effective between Start Date and Barrier Limit Date. If Barrier At Start is set to **No**, then the barrier is effective from the Barrier Limit Date until the option Maturity date (T)

Barrier Limit Date: This represents the limit date of the barrier (t_1) and must be before the maturity of the option T. This is an input to determine the period over which the barrier is effective.

38.5.8.4 Deal Representation

The FX Partial-Time Barrier Option is an atomic deal.

38.5.8.5 Valuation

In Adaptiv Analytics an FX Partial-Time Barrier Option deal can be valued using the `FXPartialTimeBarrierOptionValuation` model.

The valuation of this deal is described in Section [37.3.19](#).

38.5.8.6 Tuning Parameters and Valuation Settings

Monitoring Period: The model exercises knock-in or knock-out on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Section [37.4.14](#) and the Theory Guide [[7](#), § [4.1.30.1 Monitoring Dates](#)].

38.5.8.7 Assumptions

See Section [38.1.2](#) for descriptions of the general FX derivative assumptions of this deal.

38.5.8.8 Limitations

See Section [38.1.3](#) for descriptions of the general FX derivative limitations of this deal.

38.6 FX Variance Swap Deal Types

38.6.1 FX Variance Swap

38.6.1.1 Overview

This deal type represents swaps on the variance of an FX rate.

38.6.1.2 Price Factor Dependency

FX Variance Swap

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Rate / FX Rate Correlation (§ 12.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

38.6.1.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

Effective Date: The date at which the period of reference variance begins.

Maturity Date: The date at which the period of reference variance ends and the swap is settled.

Notional: The notional principal amount of the swap denominated in the settlement currency.

Number Of Returns: The number of discrete returns used to calculate the final reference variance. If set to zero, then Adaptiv Analytics calculates the number of returns.

Theory Guide 4.1.44

The number of returns n_0 is set to Number Of Returns if it is positive. Otherwise, Analytics calculates n_0 as follows. If the deal has a holiday calendar then $n_0 + 1$ is the number of business dates in the period $[T_0, T]$ (inclusive of T_0 and T). If the deal does not have a holiday calendar then $n_0 = 252(T - T_0)$.

Pay Receive: When set to Pay, the bank pays the fixed strike and receives the realized variance. When set to Receive, the bank receives the fixed strike and pays the realized variance.

Realized Variance: The sum of the squared log price returns up to the base calculation date. If left undefined, Adaptiv Analytics will calculate the realized variance from the rate fixings file.

Strike: The strike variance of the swap.

38.6.1.4 Deal Representation

The FX Variance Swap is an atomic deal.

38.6.1.5 Valuation

In Adaptiv Analytics an FX Variance Swap deal can be valued using the `FXVarianceSwapValuation` model. The pricing approach used that of in Demeterifi et al [20]. For details about the valuation for this deal, see Theory Guide [7, § 4.1.44 Variance and Volatility Swap].

Payoff: The variance swap payoff is given by

Theory Guide 4.1.44

The payoff of a variance swap on an asset price S is $100^2 N (\bar{\sigma}(T_0, T)^2 - K^2)$, where N is the notional amount, $\bar{\sigma}(T_0, T)$ is the realized volatility from the effective date T_0 to the maturity date T , and K is the strike price. For example, if $N = 10$, $K = 0.20$ and $\bar{\sigma} = 0.25$ at maturity then the payoff is $10(25^2 - 20^2) = 2250$.

Calculation of Realized Variance: The calculation of realized variance is given by

Theory Guide 4.1.44

The realized volatility becomes known at the maturity date and is given by

$$\bar{\sigma}(T_0, T)^2 = \frac{252}{n_0} \sum_{i=1}^n (\log S(t_i) - \log S(t_{i-1}))^2, \quad (38.6.1)$$

where t_0, t_1, \dots, t_n are the observation dates for the asset price between the effective date and the maturity date ($T_0 \leq t_0 < t_1 < \dots < t_n \leq T$), and n_0 is the number of returns expected at the effective date (based on the number of scheduled trading dates in the deal period).

Realized and Expected Variance: The reference variance of the swap is decomposed into the sum of realized past variance and expected future variance. Variance which is realized as of the base calculation date may be specified directly on the deal; if it is not, then Adaptiv Analytics will calculate it from the rate fixings file. Realized variance may be further decomposed into variance which is realized as of the base calculation date and variance which is realized during the course of simulation along scenario paths. The total reference variance is therefore the sum of actual historical variance, simulated historical variance, and expected future variance.

38.6.1.6 Tuning Parameters and Valuation Settings

Monitoring Period: The dates upon which the realized variance is calculated are determined from the Effective Date, Maturity Date and this Monitoring Period.

Number Of Strikes: The number of strikes used in the discrete approximation to the integral which gives the continuous time limit of the expectation of future variance. The default is 50. Higher numbers of strikes require more computation time.

38.6.1.7 Assumptions

See Section 38.1.2 for descriptions of the general FX rate derivative assumptions of this deal.

Variances of Disjoint Periods are Independent: The variances of two non-overlapping periods are assumed to be independent, so that the total variance of two disjoint periods can be calculated by adding the variances of each period.

38.6.1.8 Limitations

See Section 38.1.3 for descriptions of the general FX rate derivative limitations of this deal.

Discrete Approximation of the Continuous Time Integral: The valuation of a variance swap requires the calculation of the expectation of future variance. The Demeterifi approach is to express the continuous time limit of this expectation as an integral, and then calculate the integral with a discrete approximation.

No Reference Period Offsets: The period over which the reference variance is calculated runs from the effective date to the maturity date. There is no provision to offset the reference period from these dates.

38.6.2 FX Volatility Swap

38.6.2.1 Overview

This deal type represents swaps on the volatility of an FX rate price.

38.6.2.2 Price Factor Dependency

FX Volatility Swap

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Rate / FX Rate Correlation (§ 12.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

38.6.2.3 Properties

See Section 38.1.1 for descriptions of the common properties of this deal.

Effective Date: The date at which the period of reference volatility begins.

Maturity Date: The date at which the period of reference volatility ends and the swap is settled.

Notional: The notional principal amount of the swap denominated in the settlement currency.

Number Of Returns: The number of discrete returns used to calculate the final reference volatility. If set to zero, then Adaptiv Analytics calculates the number of returns.

Theory Guide 4.1.44

The number of returns n_0 is set to Number Of Returns if it is positive. Otherwise, Analytics calculates n_0 as follows. If the deal has a holiday calendar then $n_0 + 1$ is the number of business dates in the period $[T_0, T]$ (inclusive of T_0 and T). If the deal does not have a holiday calendar then $n_0 = 252(T - T_0)$.

Pay Receive: When set to Pay, the bank pays the fixed strike and receives the realized volatility. When set to Receive, the bank receives the fixed strike and pays the realized volatility.

Realized Variance: The sum of the squared log price returns up to the base calculation date. If left undefined, Adaptiv Analytics will calculate the realized variance from the rate fixings file.

Strike: The strike volatility of the swap.

38.6.2.4 Deal Representation

The FX Volatility Swap is an atomic deal.

38.6.2.5 Valuation

In Adaptiv Analytics an FX Volatility Swap deal can be valued using the `FXVolatilitySwapValuation` model. The pricing approach used that of in Demeterifi et al [20]. For details about the valuation for this deal, see Theory Guide [7, § 4.1.44 Variance and Volatility Swap].

Payoff: The volatility swap payoff is given by

Theory Guide [4.1.44.2](#)

A volatility swap is similar to a variance swap but the payoff is $100N(\bar{\sigma}(T_0, T) - K)$.

Calculation of Realized Volatility: The calculation of realized volatility is given by

Theory Guide [4.1.44](#)

The realized volatility becomes known at the maturity date and is given by

$$\bar{\sigma}(T_0, T)^2 = \frac{252}{n_0} \sum_{i=1}^n (\log S(t_i) - \log S(t_{i-1}))^2, \quad (38.6.2)$$

where t_0, t_1, \dots, t_n are the observation dates for the asset price between the effective date and the maturity date ($T_0 \leq t_0 < t_1 < \dots < t_n \leq T$), and n_0 is the number of returns expected at the effective date (based on the number of scheduled trading dates in the deal period).

Realized and Expected Variance: The reference volatility of the swap is decomposed into the sum of realized past volatility and expected future volatility. Volatility which is realized as of the base calculation date may be specified directly on the deal; if it is not, then Adaptiv Analytics will calculate it from the rate fixings file. Realized volatility may be further decomposed into volatility which is realized as of the base calculation date and variance which is realized during the course of simulation along scenario paths. The total reference volatility is therefore the sum of actual historical volatility, simulated historical volatility, and expected future volatility.

38.6.2.6 Tuning Parameters and Valuation Settings

Monitoring Period: The dates upon which the realized volatility is calculated is determined from the Effective Date, Maturity Date and this Monitoring Period.

Number Of Strikes: The number of strikes used in the discrete approximation to the integral which gives the continuous time limit of the expectation of future volatility. The default is 50. Higher numbers of strikes require more computation time.

38.6.2.7 Assumptions

See Section [38.1.2](#) for descriptions of the general FX rate derivative assumptions of this deal.

Variances of Disjoint Periods are Independent: The variances of two non-overlapping periods are assumed to be independent, so that the total variance of two disjoint periods can be calculated by adding the variances of each period.

38.6.2.8 Limitations

See Section [38.1.3](#) for descriptions of the general FX rate derivative limitations of this deal.

Discrete Approximation of the Continuous Time Integral: The valuation of a volatility swap requires the calculation of the expectation of future volatility. The Demeterifi approach is to express the continuous time limit of this expectation as an integral, and then calculate the integral with a discrete approximation.

No Reference Period Offsets: The period over which the reference volatility is calculated runs from the effective date to the maturity date. There is no provision to offset the reference period from these dates.

Chapter 39

Equity

39.1 Equity Valuation Models

39.1.1 Common Properties

The properties described below are often found on equity deal types.

39.1.1.1 Equity Properties Common to Asset Price Derivatives

See Section 37.2.

39.1.1.2 Basket Components

A list of equities in an equity basket. Each entry specifies an (equity) Asset, Currency, Equity Volatility, Payoff Type, and Units. Note that the Currency property of a basket derivative specifies the payoff currency of the derivative; the Currency property of each basket component specifies the currency of the component equity, needed when the payoff type is quanto or compo.

39.1.1.3 Currency

The ID of the FX price factor for the currency in which deal cashflows are denominated when the Payoff Type is Standard, or the currency in which the asset price is assumed to be denominated when the Payoff Type is Quanto or Compo.

39.1.1.4 Discount Rate

The ID of the interest rate price factor used to discount deal cashflows. If this ID is not specified, then the Currency will be used as the discount interest rate ID.

39.1.1.5 Equity

The ID of the equity price factor which represents the equity underlying an equity deal.

39.1.1.6 Equity Volatility

The ID of an equity volatility price factor used when pricing the deal. If this ID is not specified and an equity volatility price factor is required, then it will be assumed to have the same ID as the corresponding equity price factor. See Section 11.2.5.1 for situations in which this property might be used.

39.1.1.7 Payoff Currency

The ID of the FX price factor of the currency in which deal cashflows are denominated. This property may be left empty when the Payoff Type is Standard.

39.1.1.8 Units

Underlying equity prices are per "unit". The number of Units in a deal specifies the size of the deal in units of the equity price.

39.1.2 Assumptions

The assumptions stated below are commonly applicable to equity deal types.

39.1.2.1 Equity Assumptions Common to Asset Price Derivatives

See Section 37.3.

39.1.2.2 Default of Issuer

Equity valuation models do not have any explicit provision to account for the simulated default of the issuer. However, equity price and volatility factors can be configured to jump to special values upon default. The value of equity derivatives will reflect these special values.

Theory Guide 1.3.1

Equity price factors have an optional Issuer property and a Respect Default property. Suppose the price factor has an issuer, Respect Default is Yes and the issuer's credit rating is being simulated. If the issuer reaches default at time τ on a given scenario then the equity price is set to $\max(S(t)\alpha, S_{\min})$ for $t \geq \tau$, where α is the Jump Level ($0 \leq \alpha \leq 1$), and the equity price volatility is set to $\sigma_{\min} = 10^{-4}$.

39.1.3 Limitations

The limitations stated below are commonly applicable to equity deal types.

39.1.3.1 Equity Limitations Common to Asset Price Derivatives

See Section 37.4.

39.1.3.2 Dividends

See Section 7.1 for details about the representation of dividends as continuous rates in Adaptiv Analytics, and some of the limitations of this representation. Note that Adaptiv Analytics does not record cum- or ex-dividend dates; dividends accrue to the holder of an equity when they are paid.

39.2 Equity Position Deal Types

39.2.1 Equity

39.2.1.1 Overview

This deal type represents the value of a position in a single equity.

39.2.1.2 Price Factor Dependency

Equity

- └ Credit Rating (§ 9.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

39.2.1.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

Investment Horizon: Date when position will be liquidated. Essentially the end date for the deal's exposure profile.

39.2.1.4 Deal Representation

Equity is an atomic deal.

39.2.1.5 Valuation

In Adaptiv Analytics an Equity deal can be valued using the EquityValuation model. For details about the valuation for this deal, see Theory Guide [7, § 4.1.2 Equity].

The value is simply the current value of the equity, as shown below.

Theory Guide 4.1.2

The value at valuation date t of one unit of an equity deal is $S(t)$ [$t \leq T$], where T is the investment horizon date.

The Investment Horizon simply defines the end date of the deal. It doesn't imply a liquidation cash flow, it primarily defines the end date of the exposure profile. For this reason this deal is most appropriate for use in market risk calculations.

39.2.1.6 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

It is assumed that it is known how long the position will be held for in advance so that the Investment Horizon is known.

39.2.1.7 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

39.2.2 Equity Basket

39.2.2.1 Overview

This deal type represents the value of a position in a basket of equities.

39.2.2.2 Price Factor Dependency

Equity Basket

- └ Credit Rating (§ 9.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

39.2.2.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

Investment Horizon: Date when position will be liquidated. Essentially the end date for the deal's exposure profile.

39.2.2.4 Deal Representation

Equity Basket is an atomic deal.

39.2.2.5 Valuation

In Adaptiv Analytics an Equity Basket deal can be valued using the EquityBasketValuation model. For details about the valuation for this deal, see Theory Guide [7, § 4.1.2 Equity].

The value is simply the current value of the equity basket, as shown below.

Theory Guide 4.1.2

The value at valuation date t of one unit of an equity deal is $S(t)$ [$t \leq T$], where T is the investment horizon date.

The price of the basket is calculated as below.

Theory Guide 4.1.39

The basket price is defined by

$$S(t) = \sum_{i=1}^n \omega_i S_i(t), \quad (39.2.1)$$

where $S_1(t), \dots, S_n(t)$ are the individual asset prices and $\omega_i > 0$ is the number of units of the i^{th} asset.

The Investment Horizon simply defines the end date of the deal. It doesn't imply a liquidation cash flow, it primarily defines the end date of the exposure profile. For this reason this deal is most appropriate for use in market risk calculations.

39.2.2.6 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

It is assumed that it is known how long the position will be held for in advance so that the Investment Horizon is known.

39.2.2.7 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

39.2.3 Equity Position

39.2.3.1 Overview

This deal type represents the value of a position in a single equity. The details of the equity position are defined in issue static data.

39.2.3.2 Price Factor Dependency

Equity Position

- └ Credit Rating (§ 9.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

39.2.3.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

Issue Identifier: Identifies the issue deal. The issue identifier has two string fields, Series and Contract, by which an issue deal is referenced in issue static data.

39.2.3.4 Deal Representation

The `Equity Position` is a deal skin that builds into a `Equity` deal. See section 39.2.1 and the Deal Skins Guide [2, [Equity Position](#)].

The details of the `Equity` deal that is built are looked up from issue static data (see section 3.3.7).

39.2.3.5 Valuation

`Equity Position` deals are valued using the `GenericPositionValuation` model, which is closely related to the `DealSkinValuation` model. The only additional thing it does is apply the number units held in the position. For details about the valuation for this deal, see the section on the `Equity` deal (section 39.2.1).

39.2.3.6 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.2.3.7 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

39.2.4 ETF

39.2.4.1 Overview

This deal type represents the value of a position in a single exchange traded fund (ETF).

Theory Guide [4.1.3](#)

An exchange-traded fund (ETF) deal is the same as an equity deal, except that the underlying price is an ETF price rather than an equity price. An ETF price behaves like an equity price without any dividends, and has a property `Underlying Type`, which can be used to put ETF price factors into appropriate factor groups in market VaR calculations.

39.2.4.2 Price Factor Dependency

ETF

- └ ETF Price (§ [4.5](#))
- └ FX Rate (§ [4.2](#))
- └ Interest Rate (§ [6.1](#))

39.2.4.3 Properties

See Section [39.1.1](#) for descriptions of the common properties of this deal.

ETF: ID of the underlying exchange-traded fund. For example, SPDR.

Investment Horizon: Date when position will be liquidated. Essentially the end date for the deal's exposure profile.

39.2.4.4 Deal Representation

ETF is an atomic deal.

39.2.4.5 Valuation

In Adaptiv Analytics an ETF deal can be valued using the `ETFValuation` model. The details of the valuation are the same as the `Equity` deal (section [39.2.1](#)), and can be found in the Theory Guide [[7](#), § [4.1.2Equity](#)].

39.2.4.6 Assumptions

See Section [39.1.2](#) for descriptions of the general equity derivative assumptions of this deal.

It is assumed that it is known how long the position will be held for in advance so that the `Investment Horizon` is known.

39.2.4.7 Limitations

See Section [39.1.3](#) for descriptions of the general equity derivative limitations of this deal.

39.3 Equity Forward Deal Types

39.3.1 Equity Forward

39.3.1.1 Overview

This deal type is for equity forward contracts, and their quanto or compo variants.

39.3.1.2 Price Factor Dependency

Equity Forward

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Rate (§ 4.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

39.3.1.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

39.3.1.4 Deal Representation

The Equity Forward is an atomic deal.

39.3.1.5 Valuation

In Adaptiv Analytics an Equity Forward deal can be valued using the `EquityForwardValuation` model. For details about the valuation for this deal, see Theory Guide [7, § 4.1.4 [Equity and Commodity Forward](#)]. See Section 37.3.4 for the valuation of quanto and compo payoffs.

39.3.1.6 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.3.1.7 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

39.3.2 Equity Basket Forward

39.3.2.1 Overview

This deal type is for forward contracts on an underlying basket of equity prices, and their quanto or compo variants. It is equivalent to a Structured Deal containing a portfolio of Equity Forward deals. See Section 39.1.1 for descriptions of the properties of this deal.

39.3.2.2 Price Factor Dependency

Equity Basket Forward

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

39.3.2.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

39.3.2.4 Deal Representation

The Equity Basket Forward is an atomic deal.

39.3.2.5 Valuation

In Adaptiv Analytics an Equity Basket Forward deal can be valued using the `EquityForwardValuation` model. For details about the valuation for this deal, see Theory Guide [7, § 4.1.39 Basket of Prices]. See Section 37.3.12 for the valuation of baskets of prices. See Section 37.3.12.1 for the valuation of basket quanto and compo payoffs.

39.3.2.6 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.3.2.7 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

39.3.3 Equity Average Rate Forward

39.3.3.1 Overview

This deal type is a forward contract where the asset effectively being purchased is the arithmetic average of equity forward prices (or spot prices). Each forward price in the average is for the same asset and has the same currency and tenor. This payoff is settled net on the deal maturity date.

This deal deduces the sampling dates from a sampling frequency and a first and last sample date.

39.3.3.2 Price Factor Dependency

Equity Average Rate Forward (Explicit)

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

39.3.3.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

Average: Average of known prices or rates up to and including Average Date. Must be in settlement currency for compo deals.

Average Date: Last price or rate observation date for the known average.

First Sample Date: First price observation date.

Forward Price: The strike equity price denominated in Currency.

Last Sample Date: Last price observation date.

Sampling Frequency: Period between sample dates. If set to 0d then the First Sample Date and the Last Sample Date are the only two sample dates of the deal.

Tenor: The tenor over which to calculate each forward equity price included in the average. The tenor should be set to the conventional spot settlement lag if the intent is to average spot rates. When the tenor is specified in days, it will be interpreted as business days if a holiday calendar is available for the deal.

Weighted Average: If Yes and the sampling frequency is in days then each sample is weighted by the number of days from the sample date to the next sample date. Otherwise the sample weights are 1.

39.3.3.4 Deal Representation

The Equity Average Rate Forward is a deal skin that builds into a Equity Average Rate Forward (Explicit) deal. See section 39.3.4 and the Deal Skins Guide [2, [Equity Average Rate Forward](#)]. The building process is described below.

Theory Guide 4.1.10

An average rate or average strike forward deal builds into a corresponding average rate or average strike forward (explicit) deal, with the Sampling Data list constructed as follows.

Let $(t_1, \omega_1, F_1), \dots, (t_n, \omega_n, F_n)$ denote the date, weight and (known) price entries in the sampling data list. Let ϕ denote the sampling frequency and \mathcal{H} denote the deal's holiday calendar. The sample dates t_1, \dots, t_n are generated from the first sample date, last sample date, ϕ and \mathcal{H} using the method of Section 1.3.4.

If Weighted Average is Yes, $\phi = fd$ and \mathcal{H} is not empty then ω_i is the number of days from t_i to t_{i+1} , with $t_{n+1} = t_n + fb$. Otherwise $\omega_i = 1$.

Let A and T denote the Average and Average Date. A is the average of the known prices for sample dates up to and including T . If $t_i \leq T$ then $F_i = A$. Otherwise F_i is not specified.

39.3.3.5 Valuation

Equity Average Rate Forward deals are valued using the DealSkinValuation model. For details about the valuation for this deal, see the section on the Equity Average Rate Forward (Explicit) (section 39.3.4).

39.3.3.6 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.3.3.7 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

39.3.4 Equity Average Rate Forward (Explicit)

39.3.4.1 Overview

This deal type is a forward contract where the asset effectively being purchased is the arithmetic average of equity forward prices (or spot prices). Each forward price in the average is for the same asset and has the same currency and tenor. This payoff is settled net on the deal maturity date.

This deal has an explicit list of sampling dates. This means that each forward price can be weighted individually.

39.3.4.2 Price Factor Dependency

Equity Average Rate Forward (Explicit)

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

39.3.4.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

Forward Price: The strike equity price denominated in Currency.

Tenor: The tenor over which to calculate each forward equity price included in the average. The tenor should be set to the conventional spot settlement lag if the intent is to average spot rates. When the tenor is specified in days, it will be interpreted as business days if a holiday calendar is available for the deal.

39.3.4.4 Deal Representation

The Equity Average Rate Forward (Explicit) is an atomic deal. See the Theory Guide [7, § 4.1.11 [Average Rate and Average Strike Forward \(Explicit\)](#)].

39.3.4.5 Valuation

In Adaptiv Analytics an Equity Average Rate Forward (Explicit) deal can be valued using the `Equity-AverageRateForwardValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.1.11 [Average Rate and Average Strike Forward \(Explicit\)](#)].

The valuation relies on the absence of arbitrage argument that the expectation of the forward price is at some future fixing date is equal to the forward price now. Additionally it relies on the distributive property between means and expectations, which allows their order to be exchanged.

39.3.4.6 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.3.4.7 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

39.3.5 Equity Average Strike Forward

39.3.5.1 Overview

This deal type is a forward contract where the strike is the arithmetic average of equity forward prices (or spot prices). Each forward price in the average is for the same asset and has the same currency and tenor. Additionally a spread is applied to the strike. This payoff is settled net on the deal maturity date.

This deal deduces the sampling dates from a sampling frequency and a first and last sample date.

39.3.5.2 Price Factor Dependency

Equity Average Strike Forward

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

39.3.5.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

Average: Average of known prices or rates up to and including Average Date. Must be in settlement currency for compo deals.

Average Date: Last price or rate observation date for the known average.

First Sample Date: First price observation date.

Last Sample Date: Last price observation date.

Sampling Frequency: Period between sample dates. If set to 0d then the First Sample Date and the Last Sample Date are the only two sample dates of the deal.

Spread: The fixed spread added to the strike price, denominated in Currency.

Tenor: The tenor over which to calculate each forward equity price included in the average. The tenor should be set to the conventional spot settlement lag if the intent is to average spot rates. When the tenor is specified in days, it will be interpreted as business days if a holiday calendar is available for the deal.

Weighted Average: If Yes and the sampling frequency is in days then each sample is weighted by the number of days from the sample date to the next sample date. Otherwise the sample weights are 1.

39.3.5.4 Deal Representation

The Equity Average Strike Forward is a deal skin that builds into a Equity Average Strike Forward (Explicit) deal. See section 39.3.6 and the Deal Skins Guide [2, [Equity Average Strike Forward](#)]. The building process is described below.

Theory Guide 4.1.10

An average rate or average strike forward deal builds into a corresponding average rate or average strike forward (explicit) deal, with the Sampling Data list constructed as follows.

Let $(t_1, \omega_1, F_1), \dots, (t_n, \omega_n, F_n)$ denote the date, weight and (known) price entries in the sampling data list. Let ϕ denote the sampling frequency and \mathcal{H} denote the deal's holiday calendar. The sample dates t_1, \dots, t_n are generated from the first sample date, last sample date, ϕ and \mathcal{H} using the method of Section 1.3.4.

If Weighted Average is Yes, $\phi = fd$ and \mathcal{H} is not empty then ω_i is the number of days from t_i to t_{i+1} , with $t_{n+1} = t_n + fb$. Otherwise $\omega_i = 1$.

Let A and T denote the Average and Average Date. A is the average of the known prices for sample dates up to and including T . If $t_i \leq T$ then $F_i = A$. Otherwise F_i is not specified.

39.3.5.5 Valuation

Equity Average Strike Forward deals are valued using the DealSkinValuation model. For details about the valuation for this deal, see the section on the Equity Average Strike Forward (Explicit) (section 39.3.6).

39.3.5.6 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.3.5.7 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

39.3.6 Equity Average Strike Forward (Explicit)

39.3.6.1 Overview

This deal type is a forward contract where the strike is the arithmetic average of equity forward prices (or spot prices). Each forward price in the average is for the same asset and has the same currency and tenor. Additionally a spread is applied to the strike. This payoff is settled net on the deal maturity date.

This deal has an explicit list of sampling dates. This means that each forward price can be weighted individually.

39.3.6.2 Price Factor Dependency

Equity Average Strike Forward (Explicit)

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

39.3.6.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

Spread: The fixed spread added to the strike price, denominated in Currency.

Tenor: The tenor over which to calculate each forward equity price included in the average. The tenor should be set to the conventional spot settlement lag if the intent is to average spot rates. When the tenor is specified in days, it will be interpreted as business days if a holiday calendar is available for the deal.

39.3.6.4 Deal Representation

The Equity Average Strike Forward (Explicit) is an atomic deal. See the Theory Guide [7, § 4.1.11 [Average Rate and Average Strike Forward \(Explicit\)](#)].

39.3.6.5 Valuation

In Adaptiv Analytics an Equity Average Strike Forward (Explicit) deal can be valued using the `EquityAverageStrikeForwardValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.1.11 [Average Rate and Average Strike Forward \(Explicit\)](#)].

The valuation relies on the absence of arbitrage argument that the expectation of the forward price is at some future fixing date is equal to the forward price now. Additionally it relies on the distributive property between means and expectations, which allows their order to be exchanged.

39.3.6.6 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.3.6.7 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

39.4 Equity Swap Deal Types

39.4.1 Overview

An equity swap exchanges the return on an equity portfolio for interest rate payments. The equity return may either include or exclude dividend payments. The interest rate payments may be either at a fixed rate or a floating rate of the notional principal. The principal may be either a fixed value or a fixed number of shares; the these cases are referred to as fixed and variable principal respectively. The equity return and the interest rate payments may be made in different currencies. Quanto and compo equity return payoffs are supported.

Adaptiv Analytics supports two types of equity swap: Equity Swap and Equity Basket Swap. The former swaps the return on a single equity or an equity index treated as a single asset whereas the latter swaps the return on an explicitly specified weighted basket of equities, but the two deal types are otherwise similar. Both equity swap types are deal skins building into a set of swap legs drawn from a set of shared swap leg types.

39.4.2 Properties

See Section 39.1.1 for descriptions of the common properties of equity deals.

39.4.2.1 Accrual Adjustment Method

The date adjustment method for accrual dates. See Section 3.3.5 for details on date adjustment.

39.4.2.2 Accrual Calendars

The list of holiday calendars used when calculating accrual start and end dates and accrual year fractions. The union of all holidays in each calendar are treated as non-business days. If no holiday calendars are provided, then all calendar days are treated as business days and dates are not adjusted.

39.4.2.3 Dividend Timing

If the dividend timing is `Terminal`, dividend payments are accrued until each payment date for settlement. If the dividend timing is `Continuous`, then dividend cashflows are settled immediately. Ignored if include dividends is `No`.

39.4.2.4 Effective Date

The unadjusted start date of the swap. The start of the first accrual period is calculated by adjusting this date.

39.4.2.5 Equity Discount Rate

The ID of the interest rate price factor used to discount the cashflows of equity swap legs. If not specified, the ID of the equity payoff currency is used.

39.4.2.6 Equity Payment Frequency

The period between the regular payments on the equity legs. If set to `0d`, there is a single payment at maturity.

39.4.2.7 Equity Payoff Currency

The ID of the FX rate price factor for the currency in which equity leg cashflows are denominated. This is required basket swaps and for single equity swaps with quanto or compo payoffs. May be

left unspecified for single equity swaps with standard payoffs, but if it is specified, it must match the equity currency.

39.4.2.8 Equity PV Accrued

A list of `Date-Amount` pairs. Each amount represents a gain or loss to the equity receiver on the given date. The swap builds the PV accrued amounts into a fixed cashflow list. See Theory Guide [7, § 4.1.41.3.1 PV Accrued] for details.

39.4.2.9 Equity Principal

This specifies the principal of the equity swap legs when the principal is `Fixed`. It has no effect when the principal is `Variable`.

39.4.2.10 Equity Reset Calendars

The list of holiday calendars used when calculating equity reset dates. The union of all holidays in each calendar are treated as non-business days. If no holiday calendars are provided, then all calendar days are treated as business days and equity reset dates are set one equity reset offset after the unadjusted accrual end dates.

39.4.2.11 Equity Reset Offset

The number of business days between an accrual end date and the associated equity reset date.

39.4.2.12 First Coupon Date

The unadjusted payment date of the first coupon. Used when there is an odd first coupon.

39.4.2.13 Include Dividends

`Yes` indicates that the returns paid by equity legs include dividends. `No` indicates that they do not.

39.4.2.14 Interest Accrual Day Count

The day count convention used to calculate the interest accrual year fractions (the period over which a rate earns interest.) See Section 3.3.4 for more information about day counts in *Adaptiv Analytics*.

39.4.2.15 Interest Currency

The ID of the FX rate price factor for the settlement currency of the interest leg.

39.4.2.16 Interest Discount Rate

The ID of the interest rate price factor used to discount the cashflows of interest swap legs. If not specified, the ID of the interest currency is used.

39.4.2.17 Interest Fixed Rate

The fixed rate of the interest legs to use when the interest rate type is `Fixed`. Ignored when the interest rate type is `Floating`.

39.4.2.18 Interest Fixed Rate Schedule

The interest fixed rate schedule accommodates step-up or step-down coupons during the life of the swap. It is a list of Date-Value pairs. The date indicates the nominal date on which a change in the fixed rate takes effect, and the value indicates the new fixed rate. Accrual periods are always associated with a single fixed rate. The new fixed rate is applied to the accrual period with start date closest to the new rate date, unless that accrual period has already been allocated a fixed rate with an even closer date. Ignored when the interest rate type is *Floating*.

39.4.2.19 Interest Forecast Rate

The ID of the interest rate price factor used to calculate reference interest rates when the interest rate type is *Floating*. If not specified, the interest discount rate is used. Ignored when the interest rate type is *Fixed*.

39.4.2.20 Interest Index Adjustment Method

The date adjustment method for reference floating rate end dates. See Section 3.3.5 for details on date adjustment. Ignored when the interest rate type is *Fixed*.

39.4.2.21 Interest Index Calendars

The list of holiday calendars used when calculating the reference floating rate start and end dates and the year fraction of the reference floating rate. The union of all holidays in each calendar are treated as non-business days. If no holiday calendars are provided, then all calendar days are treated as business days and dates are not adjusted. Ignored when the interest rate type is *Fixed*.

39.4.2.22 Interest Index Day Count

The day count convention used to calculate the year fractions of reference floating rates. Ignored when the interest rate type is *Fixed*. See Section 3.3.4 for more information about day counts in Adaptiv Analytics.

39.4.2.23 Interest Index Publication Calendars

The list of holiday calendars used when calculating the reset dates for floating interest cashflow legs. The union of all holidays in each calendar are treated as non-business days. If no holiday calendars are provided, then all calendar days are treated as business days and dates are not adjusted. Ignored when the interest rate type is *Fixed*.

39.4.2.24 Interest Index Offset

The number of business days between a rate reset date and the start of the associated reference rate period. Ignored when the interest rate type is *Fixed*.

39.4.2.25 Interest Index Tenor

The reference tenor for floating interest legs. When set to 0d, the payment frequency is used. Ignored when the interest rate type is *Fixed*.

39.4.2.26 Interest Known Rates

A list of Date - Value pairs. The dates denote reset dates and the values denote reset rates. Ignored when the interest rate type is *Fixed*.

39.4.2.27 Interest Margin

A fixed margin rate added to floating interest legs. Ignored when the interest rate type is *Fixed*.

39.4.2.28 Interest Margin Schedule

The interest fixed rate schedule accommodates step-up or step-down floating rate margins during the life of the swap. It is a list of `Date-Value` pairs. The date indicates the nominal date on which a change in the margin takes effect, and the value indicates the new margin. Accrual periods are always associated with a single margin value. The new margin is applied to the accrual period with start date closest to the new rate date, unless that accrual period has already been allocated a margin with an even closer date. Ignored when the interest rate type is `Fixed`.

39.4.2.29 Interest Payment Frequency

The period between the regular payments on the interest legs. If set to `0d`, there is a single payment at maturity.

39.4.2.30 Interest Principal

The notional principal amount of the interest legs when the principal is `Fixed`. Ignored when the principal is `Variable`.

39.4.2.31 Interest Rate Constant

A fixed rate added to interest rate of floating legs. Ignored when the interest rate type is `Fixed`.

39.4.2.32 Interest Rate Fixing

The interest rate fixing ID used when the interest legs are floating. If not specified, the ID will be formed from the interest forecast rate and interest index tenor. The interest rate fixing ID is used to find known rate fixing values. Ignored when the interest rate type is `Fixed`.

39.4.2.33 Interest Rate Multiplier

A multiplier for the interest legs when the interest rate type is `Floating`. Ignored when the interest rate type is `Fixed`.

39.4.2.34 Interest Rate Type

When `Fixed`, the swap builds a fixed interest cashflow list for each equity leg. When `Floating`, the swap builds a floating interest cashflow list for each equity leg.

39.4.2.35 Known FX Rates

A list of FX rates that can be used to override the rate fixings file. It is a list of `Date-Value` pairs. Each date represents a fixing date and each value represents the historical FX rate on that date. If a required historical rate is missing from this list, then the rate fixings file is used instead.

39.4.2.36 Maturity Date

The unadjusted end date of the swap.

39.4.2.37 Pay Receive Equity

`Pay` indicates that the bank pays the equity leg payments and receives the interest leg payments. `Receive` indicates that the bank receives the equity leg payments and pays the interest leg payments.

39.4.2.38 Payment Adjustment Method

The date adjustment method for payment dates. See Section [3.3.5](#) for details on date adjustment.

39.4.2.39 Payment Calendars

The list of holiday calendars used when calculating payment dates. The union of all holidays in each calendar are treated as non-business days. If no holiday calendars are provided, then all calendar days are treated as business days and payment dates are not adjusted.

39.4.2.40 Payment Offset

The number of business days between accrual an end date and the associated payment date.

39.4.2.41 Penultimate Coupon Date

The unadjusted payment date of the penultimate coupon. Used when there is an odd last coupon.

39.4.2.42 Principal Fixed Variable

`Fixed` denotes a fixed notional amount and `Variable` denotes a fixed number of units, so that the notional principal varies according to the market value of a unit.

39.4.2.43 Roll Direction

Specifies whether dates roll `Forward` or `Backward` when adjusting dates. See Theory Guide [[7](#), § [1.1.6 Date Adjustment](#)] for details.

39.4.2.44 Units

The number of shares of the underlying equity or, for a basket equity swap, a multiplier applied to the number of shares of each equity in the basket. This property is used to determine the notional principal when principal is variable and has no effect when principal is fixed.

39.4.3 Assumptions

See Section [39.1.2](#) for descriptions of the general equity derivative assumptions of equity swap deal types.

39.4.4 Limitations

See Section [39.1.3](#) for descriptions of the general equity derivative limitations of equity swap deal types.

39.4.5 Equity Swap

39.4.5.1 Overview

This deal type is for swaps on the return of a single equity or on the return of an index treated as a single asset.

39.4.5.2 Price Factor Dependency

Equity Swap

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

39.4.5.3 Properties

See Section 39.4.2 for descriptions of the common properties of equity swaps.

Equity Known Prices: A list of equity prices and FX rates that can be used to override the rate fixings file. It is a list of `Date-Asset Price-FX Rate` triplets. Each date represents a fixing date and each asset price represents the historical equity price on that date. The FX rate is used if the payoff type is `Compo`, and ignored otherwise. If a required historical price is missing from this list, then the rate fixings file is used instead.

Equity Payoff Currency: The settlement currency of the equity leg. See Section 39.1.1.7.

Equity Payoff Type: The payoff type of the equity leg. See Section 37.2.16.

Equity Quanto FX Rate: If the payoff type is `Quanto`, then each cashflow on the equity leg is multiplied by the equity quanto FX rate. Ignored otherwise.

Known Dividends: A list of historical dividend payments on the equity. It is a list of `Date-Value` pairs. Each date represents ex-dividend date and each value represents the historical dividend payment per `Unit` on that date.

39.4.5.4 Deal Representation

The Equity Swap is a deal skin the builds into one equity swaplet list and one interest rate cashflow list, which may be either fixed interest or floating interest. When the swap principal is variable, the interest rate cashflow list is equity-linked. When there is equity PV accrued, it is represented by a fixed cashflow list paid to the same party that receives the equity swaplet leg.

See the Deal Skins Guide [2, [Equity Swap](#)].

39.4.5.5 Valuation

In Adaptiv Analytics an Equity Swap deal can be valued using the `DealSkinValuation` model. For details about the valuation for this deal, see Theory Guide [7, § 4.1.41.3 [Equity Swap](#)].

39.4.5.6 Tuning Parameters and Valuation Settings

The deal skin valuation model does not have any tuning parameters or valuation settings.

39.4.5.7 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.4.5.8 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

39.4.6 Equity Basket Swap

39.4.6.1 Overview

This deal type is for swaps on the return of a weighted portfolio of equities.

39.4.6.2 Price Factor Dependency

Equity Basket Swap

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

39.4.6.3 Properties

See Section 39.4.2 for descriptions of the common properties of equity swaps.

Basket: The basket is a list of entries; there is one entry for each equity in the basket. Each entry has the following properties:

- └ *Asset:* The ID of the equity price factor for this entry.
- └ *Currency:* The ID of the FX rate price factor for the currency of this equity entry.
- └ *Equity Volatility:* The ID of an equity volatility price factor associated with this equity entry. If this ID is not specified and an equity volatility price factor is required, then it will be assumed to have the same ID as the corresponding equity price factor. See Section 11.2.5.1 for situations in which this property might be used.
- └ *Known Dividends:* The known dividends of this equity entry. See Section 39.4.5.3 for details.
- └ *Known Prices:* The known historical prices of this equity entry. See Section 39.4.5.3 for details.
- └ *Payoff Type:* The payoff type for this equity entry. See Section 39.4.5.3 for details.
- └ *Quanto FX Rate:* The quanto FX rate for this equity entry. See Section 39.4.5.3 for details.
- └ *Units:* The number of shares of this equity in the basket.

39.4.6.4 Deal Representation

The Equity Basket Swap is a deal skin the builds into one equity swaplet list and one interest rate cashflow list for each equity in the basket. The interest rate cashflow lists may be either fixed interest or floating interest. When the swap principal is variable, the interest rate cashflow lists are equity-linked. When there is equity PV accrued, it is represented by a fixed cashflow list paid to the same party that receives the equity swaplet lists.

See the Deal Skins Guide [2, [Equity Swap](#)].

39.4.6.5 Valuation

In Adaptiv Analytics an Equity Basket Swap deal can be valued using the `DealSkinValuation` model. For details about the valuation for this deal, see Theory Guide [7, § [4.1.41.3 Equity Swap](#)].

39.4.6.6 Tuning Parameters and Valuation Settings

The deal skin valuation model does not have any tuning parameters or valuation settings.

39.4.6.7 Assumptions

See Section [39.1.2](#) for descriptions of the general equity derivative assumptions of this deal.

39.4.6.8 Limitations

See Section [39.1.3](#) for descriptions of the general equity derivative limitations of this deal.

39.4.7 Equity Swap Leg

39.4.7.1 Overview

This deal type is for the equity legs of equity swaps and equity basket swaps. It is used internally by the equity swap deal skins to create equity swaplet lists. An alternative representation of an equity swap is to place a interest rate swap leg and an equity swap leg inside a structured deal.

39.4.7.2 Price Factor Dependency

Equity Swap Leg

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

39.4.7.3 Properties

The properties of the equity swap leg are found on the single equity swap and described in Section 39.4.5.3, or else are common properties of equity deals described in Section 39.1.1.

39.4.7.4 Deal Representation

The Equity Swap Leg is a deal skin that builds into an equity swaplet list. See the Deal Skins Guide [2, [Equity Swap Leg](#)].

39.4.7.5 Valuation

In Adaptiv Analytics an Equity Swap Leg deal can be valued using the `DealSkinValuation` model. For details about the valuation for this deal, see Theory Guide [7, § 4.1.41.1 [Equity Swap Leg](#)].

39.4.7.6 Tuning Parameters and Valuation Settings

The deal skin valuation model does not have any tuning parameters or valuation settings.

39.4.7.7 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.4.7.8 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

39.4.8 Equity Swaplet List

39.4.8.1 Overview

This deal type represents payments on the returns on an equity price, or on equity price dividends, or both. It is possible to populate and use this deal type directly, but it is usually built automatically from equity swap or equity swap leg deal skins.

39.4.8.2 Price Factor Dependency

Equity Swaplet List

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

39.4.8.3 Properties

Most of the properties of the equity swaplet list are found on the single equity swap and described in Section 39.4.5.3, or else are common properties of equity deals described in Section 39.1.1.

Cashflows: This is a list of cashflows paying returns on an equity. Each cashflow has the following properties:

- └ *Amount:* The notional principal amount when the principal type is `Fixed`, or the number of units when the principal type is `Variable`.
- └ *Dividend Multiplier:* This is set to 1 when dividends are included or 0 when they are not included.
- └ *End Date:* The end of the equity return period for this cashflow.
- └ *End Multiplier:* The share price of the equity at the end date is multiplied by this value; it is used to support dividend-only swaps by setting it to zero. It is set to 1 for regular equity swaps.
- └ *Known End FX Rate:* The historical FX rate at the end date used to convert the equity currency to the payoff currency. Only used when the payoff type is `Compo`.
- └ *Known End Price:* The historical equity price at the end date.
- └ *Known Start FX Rate:* The historical FX rate at the start date used to convert the equity currency to the payoff currency when the payoff type is `Compo`.
- └ *Known Start Price:* The historical equity price at the start date.
- └ *Payment Date:* The cashflow payment date.
- └ *Quanto FX Rate:* A fixed FX rate applied to the cashflow when the payoff type is `Quanto`.
- └ *Start Date:* The start of the equity return period for this cashflow.
- └ *Start Multiplier:* The share price of the equity at the start date is multiplied by this value; it is used to support dividend-only swaps by setting it to zero. It is set to 1 for regular equity swaps.

39.4.8.4 Deal Representation

The Equity Swaplet List is an atomic deal.

39.4.8.5 Valuation

In Adaptiv Analytics an Equity Swaplet List deal can be valued using the `EquitySwapletList-Valuation` model. For details about the valuation for this deal, see Theory Guide [7, § 4.1.41.1 [Equity Swap Leg](#)].

39.4.8.6 Tuning Parameters and Valuation Settings

Cashflow Rounding: This controls whether cashflow rounding is applied to each amount. It may be set to `None`, `Nearest`, or `Next Lower`.

Theory Guide [4.3.17.2](#)

If the valuation model parameter `Cashflow Rounding` is `Nearest` or `Next Lower` then rounding is applied to each cashflow amount.

Settlement Offset: The settlement offset is used to to exclude cashflows paid within one settlement period of the base calculation date.

Theory Guide [4.3.17.1](#)

If the valuation model parameter `Use Settlement Offset` is `Yes` then the valuation model ignores cashflows with payment date before the settlement date t_s , where s is the `Settlement Offset`, t_s is calculated by adding $s + 1$ business days to the base valuation date, and addition of business days is with respect to the holiday calendar defined by `Settlement Offset Calendars`.

The settlement offset s is usually either 0, 1 or 2 and cannot be negative. In the case $s = 0$, the settlement date is the business day following the base valuation date, and hence cashflows on the base valuation date are ignored.

Settlement Offset Calendars: This is a list of calendars. The settlement offset is calculated in business days, where non-business days are taken from the union of all holiday calendars in the list. If the list is empty, then all calendar days are treated as business days.

Use Settlement Offset: If set to `Yes`, then cashflows within one settlement offset of the base calculation date will be excluded.

39.4.8.7 Assumptions

See Section [39.1.2](#) for descriptions of the general equity derivative assumptions of this deal.

39.4.8.8 Limitations

See Section [39.1.3](#) for descriptions of the general equity derivative limitations of this deal.

39.4.9 Equity-Linked Fixed Interest Cashflow List

39.4.9.1 Overview

This deal type represents fixed interest payments on a notional principal linked to an equity price. It is possible to populate and use this deal type directly, but it is usually built automatically from equity swap deal skins.

39.4.9.2 Price Factor Dependency

Equity-Linked Floating Interest Cashflow List

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

39.4.9.3 Properties

See Section 39.1.1 for descriptions of the common properties equity deals. See Section 39.4.5.3 for common single equity swap properties.

Accrual Day Count: The day count convention used to calculate the interest accrual year fractions (the period over which a rate earns interest.) See Section 3.3.4 for more information about day counts in Adaptiv Analytics.

Cashflows: This is a list of cashflows with notional principal amounts linked to an equity price. Each cashflow has the following properties:

- └ *Accrual End Date:* The end of the period over which interest is accrued.
- └ *Accrual Start Date:* The start of the period over which interest is accrued.
- └ *Accrual Year Fraction:* The year fraction from the accrual start date to the accrual end date.
- └ *Equity End Date:* The end of the equity return period.
- └ *Equity Known FX Rate:* The FX rate to convert from the equity currency to the equity payoff currency at the equity start date. Used only when the equity payoff type is *Compo*.
- └ *Equity Known Price:* The historical equity price at the equity start date.
- └ *Equity Quanto FX Rate:* If the payoff type is *Quanto*, then each cashflow on the equity leg is multiplied by the equity quanto FX rate. Ignored otherwise.
- └ *Equity Start Date:* The start of the equity return period.
- └ *Known End FX Rate:* The FX rate to convert from the equity payoff currency to the settlement currency at the equity end date when the equity payoff type is *Quanto*.
- └ *Known Start FX Rate:* The FX rate to convert from the equity payoff currency to the settlement currency at the equity start date when the equity payoff type is *Quanto*.

└ **Payment Date:** The cashflow payment date.

39.4.9.4 Deal Representation

The Equity-Linked Fixed Interest Cashflow List is an atomic deal.

39.4.9.5 Valuation

In Adaptiv Analytics an Equity-Linked Fixed Interest Cashflow List deal can be valued using the `CFEquityFixedInterestListValuation` model. For details about the valuation for this deal, see Theory Guide [7, § 4.1.41.8 [Equity-Linked Fixed Interest Cashflow](#)].

39.4.9.6 Tuning Parameters and Valuation Settings

Cashflow Rounding: This controls whether cashflow rounding is applied to each amount. It may be set to `None`, `Nearest`, or `Next Lower`.

Theory Guide [4.3.17.2](#)

If the valuation model parameter Cashflow Rounding is `Nearest` or `Next Lower` then rounding is applied to each cashflow amount.

Settlement Offset: The settlement offset is used to to exclude cashflows paid within one settlement period of the base calculation date.

Theory Guide [4.3.17.1](#)

If the valuation model parameter Use Settlement Offset is `Yes` then the valuation model ignores cashflows with payment date before the settlement date t_s , where s is the Settlement Offset, t_s is calculated by adding $s + 1$ business days to the base valuation date, and addition of business days is with respect to the holiday calendar defined by Settlement Offset Calendars.

The settlement offset s is usually either 0, 1 or 2 and cannot be negative. In the case $s = 0$, the settlement date is the business day following the base valuation date, and hence cashflows on the base valuation date are ignored.

Settlement Offset Calendars: This is a list of calendars. The settlement offset is calculated in business days, where non-business days are taken from the union of all holiday calendars in the list. If the list is empty, then all calendar days are treated as business days.

Use Settlement Offset: If set to `Yes`, then cashflows within one settlement offset of the base calculation date will be excluded.

39.4.9.7 Assumptions

See Section [39.1.2](#) for descriptions of the general equity derivative assumptions of this deal.

39.4.9.8 Limitations

See Section [39.1.3](#) for descriptions of the general equity derivative limitations of this deal.

39.4.10 Equity-Linked Floating Interest Cashflow List

39.4.10.1 Overview

This deal type represents floating interest payments on a notional principal linked to an equity price. It is possible to populate and use this deal type directly, but it is usually built automatically from equity swap deal skins.

39.4.10.2 Price Factor Dependency

Equity-Linked Floating Interest Cashflow List

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

39.4.10.3 Properties

See Section 39.1.1 for descriptions of the common properties equity deals. See Section 39.4.5.3 for common single equity swap properties.

Accrual Day Count: The day count convention used to calculate the interest accrual year fractions (the period over which a rate earns interest.) See Section 3.3.4 for more information about day counts in Adaptiv Analytics.

Cashflows: This is a list of cashflows with notional principal amounts linked to an equity price. Each cashflow has the following properties:

- └ *Accrual End Date:* The end of the period over which interest is accrued.
- └ *Accrual Start Date:* The start of the period over which interest is accrued.
- └ *Accrual Year Fraction:* The year fraction from the accrual start date to the accrual end date.
- └ *Equity End Date:* The end of the equity return period.
- └ *Equity Known FX Rate:* The FX rate to convert from the equity currency to the equity payoff currency at the equity start date. Used only when the equity payoff type is *Compo*.
- └ *Equity Known Price:* The historical equity price at the equity start date.
- └ *Equity Quanto FX Rate:* If the payoff type is *Quanto*, then each cashflow on the equity leg is multiplied by the equity quanto FX rate. Ignored otherwise.
- └ *Equity Start Date:* The start of the equity return period.
- └ *Known End FX Rate:* The FX rate to convert from the equity payoff currency to the settlement currency at the equity end date when the equity payoff type is *Quanto*.
- └ *Known Rate:* This rate is used to override the historical reference interest rate when *Use Known Rate* is set to *Yes*.

- └ **Known Start FX Rate:** The FX rate to convert from the equity payoff currency to the settlement currency at the equity start date when the equity payoff type is `Quanto`.
- └ **Margin:** A fixed margin rate added to the reference interest rate.
- └ **Payment Date:** The cashflow payment date.
- └ **Rate End Date:** The end of the reference rate period.
- └ **Rate Constant:** A fixed rate added to the reference interest rate.
- └ **Rate Fixing:** The ID used to fetch a historical fixing value.
- └ **Rate Multiplier:** A multiplier applied to the reference rate.
- └ **Rate Reset Date:** The observation date for the reference interest rate.
- └ **Rate Start Date:** The start of the reference rate period.
- └ **Rate Tenor:** The tenor of the reference interest rate.
- └ **Rate Year Fraction:** The year fraction from the rate start date to the rate end date.
- └ **Units:** The number of shares constituting the notional principal.
- └ **Use Known Rate:** The historical rate is taken from the `Known Rate` on the cashflow instead of the rate fixing file when this is set to `Yes`.

Discount Rate Cap Volatility: The ID of the interest rate volatility price factor representing the volatility of the discount rate. If not specified, the ID of the discount interest rate is used.

Forecast Rate Cap Volatility: The ID of the interest rate volatility price factor representing the volatility of the floating reference rate. If not specified, the ID of the forecast interest rate is used.

Rate Adjustment Method: The date adjustment method for the rate end date. See Section 3.3.5 for details on date adjustment.

Rate Calendars: The list of holiday calendars used when calculating start and end dates and accrual year fractions for the reference floating rate. The union of all holidays in each calendar are treated as non-business days. If no holiday calendars are provided, then all calendar days are treated as business days and dates are not adjusted.

Rate Day Count: The day count convention used to calculate the interest accrual year fraction of the reference floating rate. See Section 3.3.4 for more information about day counts in Adaptiv Analytics.

Rate Offset: The number of business days between the rate reset date and the rate start date.

Rate Sticky Month End: Used to calculate missing rate end dates. If set to `Yes`, the rate end date is set to the last business day of the month when the rate start date is the last business day of the month and the rate tenor is a number of months or years.

39.4.10.4 Deal Representation

The Equity-Linked Floating Interest Cashflow List is an atomic deal.

39.4.10.5 Valuation

In Adaptiv Analytics an Equity-Linked Floating Interest Cashflow List deal can be valued using the `CFEquityFloatingInterestListValuation` model. For details about the valuation for this deal, see Theory Guide [7, § 4.1.41.7 [Equity-Linked Fixed and Floating Interest Cashflow List](#)].

39.4.10.6 Tuning Parameters and Valuation Settings

Convexity Correction: When set to `Yes`, a convexity correction is applied as needed to account for the difference between the rate end date and the payment date. Adaptiv Analytics does not apply a convexity correction to calculate the expectation of the product of the equity price and the reference interest rate.

Cashflow Rounding: This controls whether cashflow rounding is applied to each amount. It may be set to `None`, `Nearest`, or `Next Lower`.

Theory Guide [4.3.17.2](#)

If the valuation model parameter Cashflow Rounding is `Nearest` or `Next Lower` then rounding is applied to each cashflow amount.

Quanto Correction: If set to `Yes`, a quanto correction is applied when the reference rate currency is not the same as the settlement currency.

Settlement Offset: The settlement offset is used to to exclude cashflows paid within one settlement period of the base calculation date.

Theory Guide [4.3.17.1](#)

If the valuation model parameter Use Settlement Offset is `Yes` then the valuation model ignores cashflows with payment date before the settlement date t_s , where s is the Settlement Offset, t_s is calculated by adding $s + 1$ business days to the base valuation date, and addition of business days is with respect to the holiday calendar defined by Settlement Offset Calendars.

The settlement offset s is usually either 0, 1 or 2 and cannot be negative. In the case $s = 0$, the settlement date is the business day following the base valuation date, and hence cashflows on the base valuation date are ignored.

Settlement Offset Calendars: This is a list of calendars. The settlement offset is calculated in business days, where non-business days are taken from the union of all holiday calendars in the list. If the list is empty, then all calendar days are treated as business days.

Use Settlement Offset: If set to `Yes`, then cashflows within one settlement offset of the base calculation date will be excluded.

39.4.10.7 Assumptions

See Section [39.1.2](#) for descriptions of the general equity derivative assumptions of this deal.

39.4.10.8 Limitations

See Section [39.1.3](#) for descriptions of the general equity derivative limitations of this deal.

39.5 Equity Option Deal Types

39.5.1 Equity Option

39.5.1.1 Overview

This deal type is for options on an underlying equity for immediate or forward delivery, with either European or American exercise, and their quanto or compo variants.

39.5.1.2 Price Factor Dependency

Equity Option

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Rate (§ 4.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

39.5.1.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

39.5.1.4 Deal Representation

The Equity Option is an atomic deal.

39.5.1.5 Valuation

In Adaptiv Analytics an Equity Option deal can be valued using the `OptionValuation` model. See Section 37.3.4 for the valuation of quanto and compo payoffs.

This deal can be configured to have either European (Section 37.3.5) or American (Section 37.3.6) exercise.

This deal can be configured so that the asset underlying the option is a forward contract on an equity. In this case, the option may be either cash-settled or physically settled. See Theory Guide [7, § 4.1.19 [Options on Forwards](#)] for a description of options on forwards. Note that the only way to specify a spot settlement lag is to configure the deal to be an option on a forward, with the forward period equal to the settlement lag.

39.5.1.6 Tuning Parameters and Valuation Settings

Early Exercise Today: American options are exercised only at times after the base calculation date unless this parameter is Yes. See Section 37.3.6.1.

Monitoring Period: The model exercises American options on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Theory Guide [7, § 4.1.18.4 [Monitoring Dates](#)] for details on the use of this parameter.

39.5.1.7 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.5.1.8 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

Warrants: The difference between a Warrant and an Equity Option is that when a Warrant is exercised, it creates a new equity, therefore dilutes existing shareholders. There is no provision to model dilution in Adaptiv Analytics; Warrants must be approximated as Equity Options.

Equity Rights: Equity Rights are similar to Warrants in that exercise of the Right leads to the creation of new equity and hence dilutes existing shareholders. There is no provision to model dilution in Adaptiv Analytics; Rights must be approximated as Equity Options.

39.5.2 Equity Binary Option

39.5.2.1 Overview

This deal type supports two types of fixed payoff, namely cash-or-nothing and call-put spread. Cash-or-nothing pays the `Cash Payoff` if the option is in the money at exercise, or zero if out of the money.

Theory Guide [4.1.20](#)

The option pays

$$C [\delta(S(T) - K) > 0] \quad (39.5.1)$$

at the settlement date t_1 , where C is the Cash Payoff and either $\delta = +1$ for a call option or $\delta = -1$ for a put option.

The call-put spread scales the cash payoff by the ratio between two vanilla calls or puts and the `Call Put Spread` between them:

Theory Guide [4.1.20](#)

Let ϵ denote the Call Put Spread of the deal.

Theory Guide [4.1.20](#)

When $\epsilon \neq 0$, the option pays

$$C \frac{\max(\delta(S(T) - K + \epsilon/2), 0) - \max(\delta(S(T) - K - \epsilon/2), 0)}{\delta\epsilon} \quad (39.5.2)$$

at the settlement date.

This method can be used to take volatility skew into account for binary option pricing. The call-put spread payoff converges to the fixed cash payoff as the spread approaches zero. Consequently, the spread is the only parameter used to decide whether to pay cash-or-nothing or call-put spread.

Only European exercise is supported.

The payoff may be in a third currency (quanto).

39.5.2.2 Price Factor Dependency

Equity Binary Option

- └ Credit Rating (§ [9.2](#))
- └ Discount Rate (§ [6.2](#))
- └ Dividend Rate (§ [7.1](#))
- └ Equity Price (§ [4.3](#))
- └ Equity Price / FX Rate Correlation (§ [12.2](#))
- └ Equity Price Volatility (§ [11.2.5](#))
- └ FX Rate (§ [4.2](#))
- └ FX Volatility (§ [11.2.4](#))
- └ Interest Rate (§ [6.1](#))

39.5.2.3 Properties

See Section [39.1.1](#) for descriptions of the common properties of this deal.

Cash Payoff: The size of the fixed payoff, scaled by the call spread or put spread when the spread is not zero.

Call Put Spread: The size of the call spread or put spread used to calculate the fixed payoff.

39.5.2.4 Deal Representation

The Equity Binary Option is an atomic deal.

39.5.2.5 Valuation

In Adaptiv Analytics an Equity Binary Option deal can be valued using the `BinaryOptionValuation` model. For details about the valuation for this deal, see Theory Guide [[7](#), § [4.1.20 Binary Option](#)].

See Section [37.3.5](#) for the valuation of European options.

See Section [37.3.4](#) for the valuation of quanto payoffs.

39.5.2.6 Tuning Parameters and Valuation Settings

This valuation model has no tuning parameters or valuation settings.

39.5.2.7 Assumptions

See Section [39.1.2](#) for descriptions of the general equity derivative assumptions of this deal.

39.5.2.8 Limitations

See [39.1.3](#) for descriptions of the general equity derivative limitations of this deal.

39.5.3 Equity Basket Option

39.5.3.1 Overview

This deal type is for options on an underlying basket of equity prices or basket of equity returns, with either European or American exercise, and their quanto or compo variants.

39.5.3.2 Price Factor Dependency

Equity Basket Option

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

39.5.3.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

39.5.3.4 Deal Representation

The Equity Basket Option is an atomic deal.

39.5.3.5 Valuation

In Adaptiv Analytics an Equity Basket Option deal can be valued using the `EquityBasketOptionValuation` model. See Section 37.3.4 for the valuation of quanto and compo payoffs. See Section 37.3.12 for the valuation of baskets of prices. See Section 37.3.12.1 for the valuation of basket quanto and compo payoffs.

This deal can be configured to have either European (Section 37.3.5) or American (Section 37.3.6) exercise.

39.5.3.6 Tuning Parameters and Valuation Settings

Approximation Method: Basket options are priced using a moment matching approximation, as described in Section 37.3.12.2. The approximation method may be either `Two Moment Log Normal` for the two moment method or `Three Moment Shifted Log Normal` for the three moment method.

Implied Volatility Method: When an option is on a basket of returns rather than a basket of prices, the choice of volatility method may be either `Weighted Strike` or `Conditional Strike`. See Theory Guide [7, § 4.1.40 [Basket of Returns](#)] for details.

Early Exercise Today: American options are exercised only at times after the base calculation date unless this parameter is `Yes`. See Section 37.3.6.1.

Monitoring Period: The model exercises American options on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Theory Guide [7, § 4.1.18.4 [Monitoring Dates](#)] for details on the use of this parameter.

39.5.3.7 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.5.3.8 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

39.5.4 Equity Chooser Option

39.5.4.1 Overview

This deal type is for chooser options on an underlying equity. Chooser options are where the holder can decide on the chooser date whether the option should be a call or a put. The chooser date is often prior to option expiry. Quanto or compo variants are also supported.

39.5.4.2 Price Factor Dependency

Equity Chooser Option

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Rate (§ 4.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

39.5.4.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

Chooser Date: Date on which the decision is made to enter into a call option or a put option. Must be on or before the expiry date.

39.5.4.4 Deal Representation

The Equity Chooser Option is an atomic deal.

39.5.4.5 Valuation

In Adaptiv Analytics an Equity Chooser Option deal can be valued using the `ChooserOptionValuation` model. See Section 37.3.4 for the valuation of quanto and compo payoffs.

Valuation of this deal is described in Section 37.3.13.

39.5.4.6 Tuning Parameters and Valuation Settings

This deal type has no valuation configuration settings.

39.5.4.7 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.5.4.8 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

39.5.5 Equity Cliquet Option

39.5.5.1 Overview

This deal type is for cliquet options on an underlying equity. Cliquet options are a strip of forward start options. The notional can be fixed or variable. Quanto or compo variants are also supported.

39.5.5.2 Price Factor Dependency

Equity Cliquet Option

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Rate (§ 4.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

39.5.5.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

Effective Date: Unadjusted deal start date.

Frequency: Frequency of the option payments.

Moneyness: Moneyness factor.

Principal Fixed Variable: Determines whether the deal has a fixed or variable principal amount.

Principal: The fixed principal amount of the option. Used when Principal Fixed Variable is Fixed and ignored otherwise.

Known Prices: List of reset dates and corresponding known equity prices and (for Compo deals) FX rates specified in the form of (Date, Asset price, FX rate) triples. FX Rates are used for deals with Payoff Type = Compo. Each asset price should correspond to the asset value at the beginning of a forward price option. Only one known asset price (corresponding to the asset value at the beginning of the current forward start option) will be used per valuation. All the previous known asset prices will be ignored since the previous forward start options have already been settled. (List (Date; Asset Price; FX Rate)). Any missing known equity prices will be read from the rate fixings (if available) or otherwise the price assumed to be the base date spot prices. Similarly, if the FX rates are missing these are read from the rate fixings file (if available) or assumed to be the spot value if no fixings are available.

39.5.5.4 Deal Representation

The Equity Cliquet Option is an atomic deal.

39.5.5.5 Valuation

In Adaptiv Analytics an Equity Cliquet Option deal can be valued using the `CliquetOptionValuation` model. See Section 37.3.4 for the valuation of quanto and compo payoffs.

The valuation of this deal is described in Section 37.3.14.

39.5.5.6 Tuning Parameters and Valuation Settings

This deal type has no valuation configuration settings.

39.5.5.7 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.5.5.8 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

39.5.6 Equity Compound Option

39.5.6.1 Overview

This deal type is for compound options on an underlying equity. A compound option is a European option on a European option. Quanto or compo variants are also supported.

39.5.6.2 Price Factor Dependency

Equity Compound Option

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Rate (§ 4.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

39.5.6.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

Option Type: Type of the compound option. For example, Call On Put is a European call option on a European Put option. (Call On Call, Call On Put, Put On Call or Put On Put).

Strike Price: Strike price of the compound option in asset currency (or settlement currency for compo options).

Underlying Strike: Strike price of the underlying European option.

Underlying Maturity: Expiry date of the underlying European option.

39.5.6.4 Deal Representation

The Equity Compound Option is an atomic deal.

39.5.6.5 Valuation

In Adaptiv Analytics an Equity Compound Option deal can be valued using the CompoundOptionValuation model. See Section 37.3.4 for the valuation of quanto and compo payoffs.

The valuation of this deal is described in Section 37.3.15.

39.5.6.6 Tuning Parameters and Valuation Settings

This deal type has no valuation configuration settings.

39.5.6.7 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.5.6.8 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

39.5.7 Equity Gap Option

39.5.7.1 Overview

This deal type is for gap options on an underlying equity. A gap option has a strike and a barrier. The barrier triggers the payoff and the magnitude of the payoff is determined by the strike. Barrier and reverse barrier variants are supported, as are quanto or compo variants.

39.5.7.2 Price Factor Dependency

Equity Gap Option

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Rate (§ 4.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

39.5.7.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

Barrier Price: Barrier price in asset currency (or settlement currency for compo options).

Gap Type: Gap option type: Barrier or Reverse Barrier.

39.5.7.4 Deal Representation

The Equity Gap Option is an atomic deal.

39.5.7.5 Valuation

In Adaptiv Analytics an Equity Gap Option deal can be valued using the `GapOptionValuation` model. See Section 37.3.4 for the valuation of quanto and compo payoffs.

The valuation of this deal is described in Section 37.3.17.

39.5.7.6 Tuning Parameters and Valuation Settings

This deal type has no valuation configuration settings.

39.5.7.7 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.5.7.8 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

39.5.8 Equity Lookback Option

39.5.8.1 Overview

This deal type is for lookback options on an underlying equity. The holder of a lookback option may choose the historically realized price over the life of the option that maximizes the option payoff. Adaptiv Analytics supports two types of lookback options:

- Floating Strike Lookback Option

Theory Guide [4.1.26](#)

The payoff of a floating strike lookback call option is $\max(S(T) - S_{\min}(T), 0)$, where $S_{\min}(t)$ is the lowest asset price observed from the trade date up to t . Similarly, the payoff of a floating strike lookback put option is $\max(S_{\max}(T) - S(T), 0)$, where $S_{\max}(t)$ is the highest asset price observed from the trade date up to t .

- Fixed Strike Lookback Option

Theory Guide [4.1.26](#)

The payoff of a fixed strike lookback call option is $\max(S_{\max}(T) - K, 0)$; and the payoff of a fixed strike lookback put option is $\max(K - S_{\min}(T), 0)$.

where

Theory Guide [4.1.26](#)

For a given valuation date t , the minimum and maximum asset price are calculated as follows:

$$S_{\min}(t) = \min\{S_{\min}, S(0), S(t_1), \dots, S(t_m), S(t)\} \quad (39.5.3)$$

$$S_{\max}(t) = \max\{S_{\max}, S(0), S(t_1), \dots, S(t_m), S(t)\}, \quad (39.5.4)$$

where: t_1, \dots, t_m are the valuation dates between 0 and t ; S_{\min} is the Observed Minimum if its value is positive, or otherwise $S_{\min} = \infty$; and S_{\max} is the Observed Maximum.

Quanto and compo variants are also supported.

39.5.8.2 Price Factor Dependency

Equity Lookback Option

- └ Credit Rating (§ [9.2](#))
- └ Discount Rate (§ [6.2](#))
- └ Dividend Rate (§ [7.1](#))
- └ Equity Price (§ [4.3](#))
- └ Equity Price / FX Rate Correlation (§ [12.2](#))
- └ Equity Price Volatility (§ [11.2.5](#))
- └ FX Rate (§ [4.2](#))
- └ FX Volatility (§ [11.2.4](#))
- └ Interest Rate (§ [6.1](#))

39.5.8.3 Properties

See Section 39.1.1 and Section 37.2 for descriptions of the common properties of this deal.

Observed Maximum: Realised observed maximum price

Observed Minimum: Realised observed minimum price if the value is positive, otherwise $S_{\min} = \infty$.

Strike Type: Determines the variant of the Lookback option. `Fixed` is a Fixed Strike Lookback option and `Floating` refers to a Floating Strike Lookback option.

39.5.8.4 Deal Representation

The Equity Lookback Option is an atomic deal.

39.5.8.5 Valuation

In Adaptiv Analytics an Equity Lookback Option deal can be valued using the `LookbackOptionValuation` model. See Section 37.3.4 for the valuation of quanto payoffs and compo payoffs.

The valuation of this deal is described in Section 37.3.16.

39.5.8.6 Tuning Parameters and Valuation Settings

This deal type has no valuation configuration settings.

39.5.8.7 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.5.8.8 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

Observed Minimum and Maximum The "observed" minimum and maximum (before the base valuation date) must be populated on the deal when the deal is valued mid-life. The valuation model will not check the rate fixing file to find the historical values.

39.6 Equity Asian Option Deal Types

39.6.1 Equity Discrete (Explicit) Asian Option

39.6.1.1 Overview

This deal type is for Asian options on an underlying equity, and their quanto or compo variants. They are called discrete Asian options in Adaptiv Analytics because they are fully modelled as a finite weighted sum of observations, and not approximated with a continuous average. They are called explicit because the set of observation dates must be explicitly enumerated in a deal property, rather than calculated from a formula. This explicit representation also allows each observation to be individually weighted.

39.6.1.2 Price Factor Dependency

Equity Discrete (Explicit) Asian Option

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Rate (§ 4.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

39.6.1.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

39.6.1.4 Deal Representation

The Equity Discrete (Explicit) Asian Option is an atomic deal.

39.6.1.5 Valuation:

In Adaptiv Analytics an Equity Discrete (Explicit) Asian Option deal can be valued using the `AssetDiscreteAsianOption` model. See Section 37.3.9 for discrete Asian option valuation.

This deal can be configured to support standard payoffs in the equity currency, quanto payoffs, and compo payoffs. See Section 37.3.4 for the valuation of quanto and compo payoffs.

39.6.1.6 Tuning Parameters and Valuation Settings

Term Structured: See Section 37.3.9.3 for a description of this setting.

39.6.1.7 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.6.1.8 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

39.6.2 Equity Discrete (Explicit) Double Asian Option

39.6.2.1 Overview

This deal type is for double Asian options on an underlying equity price. They are called discrete Asian options in Adaptiv Analytics because they are fully modelled with finite weighted sums of observations, and not approximated with a continuous average. They are called explicit because the sets of observation dates must be explicitly enumerated in deal properties, rather than calculated from a formula. This explicit representation also allows each observation to be individually weighted.

The deal is always settled for net value with a single cashflow.

39.6.2.2 Price Factor Dependency

Equity Discrete (Explicit) Double Asian Option

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

39.6.2.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

Difference Method: *Arithmetic* indicates that the option is on the arithmetic difference between the two weighted sums of observations; *Geometric* indicates that the option is on their ratio.

Is Digital: If *Yes*, the option pays a fixed amount determined by the two sampling multipliers.

Sampling Data 1: The sampling data for the first weighted sum in the difference term.

Sampling Data 2: The sampling data for the second weighted sum in the difference term.

Sampling Multiplier 1: The multiplier for the first weighted sum in the difference term.

Sampling Multiplier 2: The multiplier for the second weighted sum in the difference term.

Strike Multiplier: The strike is scaled by this multiplier before it is subtracted from the difference in weighted sums when calculating the option payoff.

39.6.2.4 Deal Representation

The Equity Discrete (Explicit) Double Asian Option is an atomic deal.

39.6.2.5 Valuation:

In Adaptiv Analytics an Equity Discrete (Explicit) Double Asian Option deal can be valued using the `DiscreteExplicitDoubleAsianOptionValuation` model. For details about the valuation for this deal, see Theory Guide [7, § 4.1.34 [Discrete \(Explicit\) Double Asian Option](#)].

See Section 37.3.9 for discrete Asian option valuation.

39.6.2.6 Tuning Parameters and Valuation Settings

Moment Matching Method: Double asian options are priced using a moment matching approximation, as described in Section 37.3.10.1. The approximation method may be either `Two Moment Log Normal` for the two moment method or `Three Moment Shifted Log Normal` for the three moment method.

Number of Integration Points: When the difference method is `Geometric`, the option must be valued with a numerical integration except in special cases, as described in Section 37.3.10.4. The number of points in the integration is specified with this parameter.

Strike Mapping Method: See Section 37.3.10.5 for a description of this setting.

Term Structured: See Section 37.3.10.5 for a description of this setting.

39.6.2.7 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.6.2.8 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

No Quanto Payoffs: Quanto payoffs are not supported for double asian options.

39.6.3 Equity Basket Discrete (Explicit) Asian Option

39.6.3.1 Overview

This deal type is for Asian options on an underlying basket of either equity prices or returns, and their quanto or compo variants. They are called discrete Asian options in Adaptiv Analytics because they are fully modelled as a finite weighted sum of basket observations, and not approximated with a continuous average. They are called explicit because the set of observation dates must be explicitly enumerated in a deal property, rather than calculated from a formula. This explicit representation also allows each observation to be individually weighted.

39.6.3.2 Price Factor Dependency

Equity Basket Discrete (Explicit) Asian Option

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Rate (§ 4.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

39.6.3.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

39.6.3.4 Deal Representation

The Equity Basket Discrete (Explicit) Asian Option is an atomic deal.

39.6.3.5 Valuation

In Adaptiv Analytics an Equity Basket Discrete (Explicit) Asian Option deal can be valued using the `EquityBasketDiscreteAsianOptionValuation` model. See Section 37.3.9 for discrete Asian option valuation.

This deal can be configured to support standard payoffs in the equity currency, quanto payoffs, and compo payoffs. See Section 37.3.4 for the valuation of quanto and compo payoffs.

39.6.3.6 Tuning Parameters and Valuation Settings

Term Structured: See Section 37.3.9.3 for a description of this setting.

Approximation Method: See Section 37.3.12.2 for a description of this setting.

Implied Volatility Method: See Section 37.3.12.2 for a description of this setting.

39.6.3.7 Assumptions

See Section 39.1.2 for descriptions of the general FX derivative assumptions of this deal.

39.6.3.8 Limitations

See Section 39.1.3 for descriptions of the general FX derivative limitations of this deal.

39.7 Equity Barrier Option Deal Types

39.7.1 Equity Barrier Option

39.7.1.1 Overview

This deal type is for single barrier options on an underlying equity price. The barrier monitoring frequency may be specified. The option may pay a rebate. An out rebate is paid when the option is knocked out. An in rebate is paid at option expiry if the option is never knocked in.

The deal is always settled for net value with a single cashflow in the payoff currency.

39.7.1.2 Price Factor Dependency

Equity Barrier Option

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Rate (§ 4.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

39.7.1.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

39.7.1.4 Deal Representation

The Equity Barrier Option is an atomic deal.

39.7.1.5 Valuation:

In Adaptiv Analytics an Equity Barrier Option deal can be valued using the `BarrierOptionValuation` model. For details about the valuation for this deal, see Theory Guide [7, § 4.1.27 [Barrier Option](#)].

39.7.1.6 Tuning Parameters and Valuation Settings

Monitoring Period: The model exercises knock-in or knock-out on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the `Monitoring Period` parameter. See Section 37.4.14 and the Theory Guide [7, § 4.1.30.1 [Monitoring Dates](#)].

39.7.1.7 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.7.1.8 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

39.7.2 Equity Barrier Binary Option

39.7.2.1 Overview

This deal type is for single barrier binary options on an underlying equity. An equity barrier binary option pays the Cash Payoff if the option is in the money at exercise and the barrier has been touched (knock-in) or never touched (knock-out). The barrier monitoring frequency may be specified.

39.7.2.2 Price Factor Dependency

Equity Barrier Binary Option

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Rate (§ 4.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

39.7.2.3 Properties

See Section 39.1.1 and Section 37.2 for descriptions of the common properties of this deal.

39.7.2.4 Deal Representation

The Equity Barrier Binary Option is an atomic deal.

39.7.2.5 Valuation:

In Adaptiv Analytics an Equity Barrier Binary Option deal can be valued using the `BarrierBinaryOptionValuation` model. For details about the valuation for this deal, see Section 37.3.7.

39.7.2.6 Tuning Parameters and Valuation Settings

Monitoring Period: The model exercises knock-in or knock-out on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Section 37.4.14 and the Theory Guide [7, § 4.1.30.1 [Monitoring Dates](#)].

39.7.2.7 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.7.2.8 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

39.7.3 Equity Double Barrier Option

39.7.3.1 Overview

This deal type is for double barrier options on an underlying equity price. The barrier monitoring frequency may be specified. The option may pay a rebate. An out rebate is paid when the option is knocked out. An in rebate is paid at option expiry if the option is never knocked in.

The deal is always settled for net value with a single cashflow in the payoff currency.

39.7.3.2 Price Factor Dependency

Equity Double Barrier Option

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Rate (§ 4.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

39.7.3.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

39.7.3.4 Deal Representation

The Equity Double Barrier Option is an atomic deal.

39.7.3.5 Valuation:

In Adaptiv Analytics an Equity Double Barrier Option deal can be valued using the `DoubleBarrierOptionValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.1.28 Double Barrier Option].

39.7.3.6 Tuning Parameters and Valuation Settings

Max Iterations: The maximum number of terms in the truncation of infinite series used to value the option. See Section 37.3.8.3 for details.

Monitoring Period: The model exercises knock-in or knock-out on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Section 37.4.14 and the Theory Guide [7, § 4.1.30.1 Monitoring Dates].

Tolerance: The tolerance at which to truncate the infinite series used to value the option. See Section 37.3.8.3 for details.

39.7.3.7 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.7.3.8 Limitations

See Section 38.1.3 for descriptions of the general equity derivative limitations of this deal.

39.7.4 Equity One Touch Option

39.7.4.1 Overview

This deal type is for one-touch options on an underlying equity price. The barrier monitoring frequency may be specified. The option pays a fixed amount conditional on barrier touching; the payment timing may be either upon touching or at expiry.

The deal is always settled for net value with a single cashflow in the payoff currency.

39.7.4.2 Price Factor Dependency

Equity One Touch Option

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Rate (§ 4.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

39.7.4.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

39.7.4.4 Deal Representation

The Equity One Touch Option is an atomic deal.

39.7.4.5 Valuation

In Adaptiv Analytics an Equity One Touch Option deal can be valued using the `TouchOptionValuation` model. For details about the valuation for this deal, see Theory Guide [7, § 4.1.27.1 [One-Touch and No-Touch Options and Rebates](#)].

39.7.4.6 Tuning Parameters and Valuation Settings

Monitoring Period: The model exercises knock-in or knock-out on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Section 37.4.14 and the Theory Guide [7, § 4.1.30.1 [Monitoring Dates](#)].

39.7.4.7 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.7.4.8 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

39.7.5 Equity No Touch Option

39.7.5.1 Overview

This deal type is for no-touch options on an underlying equity price. The barrier monitoring frequency may be specified. The option pays a fixed amount at expiry conditional on no barrier touching during the life of the option.

The deal is always settled for net value with a single cashflow in the payoff currency.

39.7.5.2 Price Factor Dependency

Equity No Touch Option

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Rate (§ 4.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

39.7.5.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

39.7.5.4 Deal Representation

The Equity No Touch Option is an atomic deal.

39.7.5.5 Valuation

In Adaptiv Analytics an Equity No Touch Option deal can be valued using the `TouchOptionValuation` model. For details about the valuation for this deal, see Theory Guide [7, § 4.1.27.1 [One-Touch and No-Touch Options and Rebates](#)].

39.7.5.6 Tuning Parameters and Valuation Settings

Monitoring Period: The model exercises knock-in or knock-out on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Section 37.4.14 and the Theory Guide [7, § 4.1.30.1 [Monitoring Dates](#)].

39.7.5.7 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.7.5.8 Limitations

See Section 38.1.3 for descriptions of the general equity derivative limitations of this deal.

39.7.6 Equity Double One Touch Option

39.7.6.1 Overview

This deal type is for double one-touch options on an underlying equity price. The barrier monitoring frequency may be specified. The option pays fixed amounts conditional on barrier touching; the payment timing may be either upon touching or at expiry. Different payoffs may be specified for the upper and lower barriers.

The deal is always settled for net value with a single cashflow in the payoff currency.

39.7.6.2 Price Factor Dependency

Equity Double One Touch Option

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Rate (§ 4.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

39.7.6.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

39.7.6.4 Deal Representation

The Equity Double One Touch Option is an atomic deal.

39.7.6.5 Valuation

In Adaptiv Analytics an Equity Double One Touch option deal can be valued using the DoubleTouch-OptionValuation model. For details about the valuation for this deal, see the Theory Guide [7, § 4.1.28.1 One-Touch and No-Touch Options and Rebates].

39.7.6.6 Tuning Parameters and Valuation Settings

Monitoring Period: The model exercises knock-in or knock-out on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Section 37.4.14 and the Theory Guide [7, § 4.1.30.1 Monitoring Dates].

39.7.6.7 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.7.6.8 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

39.7.7 Equity Double No Touch Option

39.7.7.1 Overview

This deal type is for double no-touch options on an underlying equity. The barrier monitoring frequency may be specified. The option pays fixed amounts conditional on neither barrier being touched during the life of the option.

39.7.7.2 Price Factor Dependency

Equity Double No Touch Option

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ Dividend Rate (§ 7.1)
- └ Equity Price (§ 4.3)
- └ Equity Price / FX Rate Correlation (§ 12.2)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Rate (§ 4.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

39.7.7.3 Properties

See Section 39.1.1 and Section 37.2 for descriptions of the common properties of this deal.

39.7.7.4 Deal Representation

The Equity Double No Touch Option is an atomic deal.

39.7.7.5 Valuation

In Adaptiv Analytics an Equity Double No Touch option deal can be valued using the `DoubleTouch-OptionValuation` model. For details about the valuation for this deal, see Section 37.3.8.2.

39.7.7.6 Tuning Parameters and Valuation Settings

Monitoring Period: The model exercises knock-in or knock-out on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Section 37.4.14 and the Theory Guide [7, § 4.1.30.1 [Monitoring Dates](#)].

39.7.7.7 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

39.7.7.8 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

39.7.8 Equity Partial-Time Barrier Option

39.7.8.1 Overview

This deal type is for partial-time barrier options on an underlying equity. In this type of option, the period over which the barrier is effective is a subset of the lifetime of the option. The barrier monitoring frequency may be specified.

Theory Guide [4.1.29](#)

Let t_1 denote the Barrier Limit Date, which must be before the option expiry date T . There are three types of partial-time barrier option.

Type A: Barrier At Start is Yes. The barrier period starts at the trade date and ends at t_1 . Up (down) options are knocked out or knocked in at the first date $t \leq t_1$ for which $S(t)$ is above (below) the barrier.

Type B1: Barrier At Start is No and Barrier Type is either In or Out. The barrier period starts at t_1 and ends at T . The option is knocked out or knocked in at the first date $t \geq t_1$ for which $S(t)$ touches the barrier (from either above or below). The asset price at the trade date may be either above or below the barrier.

Type B2: Barrier At Start is No and Barrier Type is either Down And In, Up And In, Down And Out or Up And Out. The barrier period starts at t_1 and ends at T . Up (down) options are knocked out or knocked in at the first date $t \geq t_1$ for which $S(t)$ is above (below) the barrier. Note that an up (down) option is triggered immediately at t_1 if $S(t_1)$ is above (below) the barrier.

39.7.8.2 Price Factor Dependency

Equity Partial-Time Barrier Option

- └ Credit Rating (§ [9.2](#))
- └ Discount Rate (§ [6.2](#))
- └ Dividend Rate (§ [7.1](#))
- └ Equity Price (§ [4.3](#))
- └ Equity Price / FX Rate Correlation (§ [12.2](#))
- └ Equity Price Volatility (§ [11.2.5](#))
- └ FX Rate (§ [4.2](#))
- └ FX Volatility (§ [11.2.4](#))
- └ Interest Rate (§ [6.1](#))

39.7.8.3 Properties

See Section [39.1.1](#) and Section [37.2](#) for descriptions of the common properties of this deal.

Barrier At Start: This represents whether the period over which the barrier is effective begins at the trade date. If Barrier At Start is set to **Yes** then the barrier is effective between Start Date and Barrier Limit Date. If Barrier At Start is set to **No**, then the barrier is effective from the Barrier Limit Date until the option Maturity date (T)

Barrier Limit Date: This represents the limit date of the barrier (t_1) and must be before the maturity of the option T . This is an input to determine the period over which the barrier is effective.

39.7.8.4 Deal Representation

The Equity Partial-Time Barrier Option is an atomic deal.

39.7.8.5 Valuation

In Adaptiv Analytics an Equity Partial-Time Barrier Option deal can be valued using the `Partial-TimeBarrierOptionValuation` model.

The valuation of this deal is described in Section [37.3.19](#).

39.7.8.6 Tuning Parameters and Valuation Settings

Monitoring Period: The model exercises knock-in or knock-out on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Section [37.4.14](#) and the Theory Guide [[7](#), § [4.1.30.1 Monitoring Dates](#)].

39.7.8.7 Assumptions

See Section [39.1.2](#) for descriptions of the general equity derivative assumptions of this deal.

39.7.8.8 Limitations

See Section [39.1.3](#) for descriptions of the general equity derivative limitations of this deal.

39.8 Equity Variance Swap Deal Types

39.8.1 Equity Variance Swap

39.8.1.1 Overview

This deal type represents swaps on the variance of an equity price.

39.8.1.2 Price Factor Dependency

Equity Variance Swap

- └ Dividend Rate (§ 7.1)
- └ Discount Rate (§ 6.2)
- └ Equity Price (§ 4.3)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

39.8.1.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

Effective Date: The date at which the period of reference variance begins.

Maturity Date: The date at which the period of reference variance ends and the swap is settled.

Notional: The notional principal amount of the swap denominated in the settlement currency.

Number Of Returns: The number of discrete returns used to calculate the final reference variance. If set to zero, then Adaptiv Analytics calculates the number of returns.

Theory Guide 4.1.44

The number of returns n_0 is set to Number Of Returns if it is positive. Otherwise, Analytics calculates n_0 as follows. If the deal has a holiday calendar then $n_0 + 1$ is the number of business dates in the period $[T_0, T]$ (inclusive of T_0 and T). If the deal does not have a holiday calendar then $n_0 = 252(T - T_0)$.

Pay Receive: When set to Pay, the bank pays the fixed strike and receives the realized variance. When set to Receive, the bank receives the fixed strike and pays the realized variance.

Realized Variance: The sum of the squared log price returns up to the base calculation date. If left undefined, Adaptiv Analytics will calculate the realized variance from the rate fixings file.

Strike: The strike variance of the swap.

39.8.1.4 Deal Representation

The Equity Variance Swap is an atomic deal.

39.8.1.5 Valuation

In Adaptiv Analytics an Equity Variance Swap deal can be valued using the `EquityVarianceSwapValuation` model. The pricing approach used that of in Demeterifi et al [20]. For details about the valuation for this deal, see Theory Guide [7, § 4.1.44 Variance and Volatility Swap].

Payoff: The variance swap payoff is given by

Theory Guide 4.1.44

The payoff of a variance swap on an asset price S is $100^2 N (\bar{\sigma}(T_0, T)^2 - K^2)$, where N is the notional amount, $\bar{\sigma}(T_0, T)$ is the realized volatility from the effective date T_0 to the maturity date T , and K is the strike price. For example, if $N = 10$, $K = 0.20$ and $\bar{\sigma} = 0.25$ at maturity then the payoff is $10(25^2 - 20^2) = 2250$.

Calculation of Realized Variance: The calculation of realized variance is given by

Theory Guide 4.1.44

The realized volatility becomes known at the maturity date and is given by

$$\bar{\sigma}(T_0, T)^2 = \frac{252}{n_0} \sum_{i=1}^n (\log S(t_i) - \log S(t_{i-1}))^2, \quad (39.8.1)$$

where t_0, t_1, \dots, t_n are the observation dates for the asset price between the effective date and the maturity date ($T_0 \leq t_0 < t_1 < \dots < t_n \leq T$), and n_0 is the number of returns expected at the effective date (based on the number of scheduled trading dates in the deal period).

Realized and Expected Variance: The reference variance of the swap is decomposed into the sum of realized past variance and expected future variance. Variance which is realized as of the base calculation date may be specified directly on the deal; if it is not, then Adaptiv Analytics will calculate it from the rate fixings file. Realized variance may be further decomposed into variance which is realized as of the base calculation date and variance which is realized during the course of simulation along scenario paths. The total reference variance is therefore the sum of actual historical variance, simulated historical variance, and expected future variance.

39.8.1.6 Tuning Parameters and Valuation Settings

Monitoring Period: The dates upon which the realized variance is calculated are determined from the Effective Date, Maturity Date and this Monitoring Period.

Number Of Strikes: The number of strikes used in the discrete approximation to the integral which gives the continuous time limit of the expectation of future variance. The default is 50. Higher numbers of strikes require more computation time.

39.8.1.7 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

Variances of Disjoint Periods are Independent: The variances of two non-overlapping periods are assumed to be independent, so that the total variance of two disjoint periods can be calculated by adding the variances of each period.

39.8.1.8 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

Discrete Approximation of the Continuous Time Integral: The valuation of a variance swap requires the calculation of the expectation of future variance. The Demeterifi approach is to express the continuous time limit of this expectation as an integral, and then calculate the integral with a discrete approximation.

No Reference Period Offsets: The period over which the reference variance is calculated runs from the effective date to the maturity date. There is no provision to offset the reference period from these dates.

39.8.2 Equity Volatility Swap

39.8.2.1 Overview

This deal type represents swaps on the volatility of an equity price.

39.8.2.2 Price Factor Dependency

Equity Volatility Swap

- └ Dividend Rate (§ 7.1)
- └ Discount Rate (§ 6.2)
- └ Equity Price (§ 4.3)
- └ Equity Price Volatility (§ 11.2.5)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

39.8.2.3 Properties

See Section 39.1.1 for descriptions of the common properties of this deal.

Effective Date: The date at which the period of reference volatility begins.

Maturity Date: The date at which the period of reference volatility ends and the swap is settled.

Notional: The notional principal amount of the swap denominated in the settlement currency.

Number Of Returns: The number of discrete returns used to calculate the final reference volatility. If set to zero, then Adaptiv Analytics calculates the number of returns.

Theory Guide 4.1.44

The number of returns n_0 is set to Number Of Returns if it is positive. Otherwise, Analytics calculates n_0 as follows. If the deal has a holiday calendar then $n_0 + 1$ is the number of business dates in the period $[T_0, T]$ (inclusive of T_0 and T). If the deal does not have a holiday calendar then $n_0 = 252(T - T_0)$.

Pay Receive: When set to Pay, the bank pays the fixed strike and receives the realized volatility. When set to Receive, the bank receives the fixed strike and pays the realized volatility.

Realized Variance: The sum of the squared log price returns up to the base calculation date. If left undefined, Adaptiv Analytics will calculate the realized variance from the rate fixings file.

Strike: The strike volatility of the swap.

39.8.2.4 Deal Representation

The Equity Volatility Swap is an atomic deal.

39.8.2.5 Valuation

In Adaptiv Analytics an Equity Volatility Swap deal can be valued using the `EquityVolatilitySwapValuation` model. The pricing approach used that of in Demeterifi et al [20]. For details about the valuation for this deal, see Theory Guide [7, § 4.1.44 Variance and Volatility Swap].

Payoff: The volatility swap payoff is given by

Theory Guide 4.1.44.2

A volatility swap is similar to a variance swap but the payoff is $100N(\bar{\sigma}(T_0, T) - K)$.

Calculation of Realized Volatility: The calculation of realized volatility is given by

Theory Guide 4.1.44

The realized volatility becomes known at the maturity date and is given by

$$\bar{\sigma}(T_0, T)^2 = \frac{252}{n_0} \sum_{i=1}^n (\log S(t_i) - \log S(t_{i-1}))^2, \quad (39.8.2)$$

where t_0, t_1, \dots, t_n are the observation dates for the asset price between the effective date and the maturity date ($T_0 \leq t_0 < t_1 < \dots < t_n \leq T$), and n_0 is the number of returns expected at the effective date (based on the number of scheduled trading dates in the deal period).

Realized and Expected Variance: The reference volatility of the swap is decomposed into the sum of realized past volatility and expected future volatility. Volatility which is realized as of the base calculation date may be specified directly on the deal; if it is not, then Adaptiv Analytics will calculate it from the rate fixings file. Realized volatility may be further decomposed into volatility which is realized as of the base calculation date and variance which is realized during the course of simulation along scenario paths. The total reference volatility is therefore the sum of actual historical volatility, simulated historical volatility, and expected future volatility.

39.8.2.6 Tuning Parameters and Valuation Settings

Monitoring Period: The dates upon which the realized volatility is calculated are determined from the Effective Date, Maturity Date and this Monitoring Period.

Number Of Strikes: The number of strikes used in the discrete approximation to the integral which gives the continuous time limit of the expectation of future volatility. The default is 50. Higher numbers of strikes require more computation time.

39.8.2.7 Assumptions

See Section 39.1.2 for descriptions of the general equity derivative assumptions of this deal.

Variances of Disjoint Periods are Independent: The variances of two non-overlapping periods are assumed to be independent, so that the total variance of two disjoint periods can be calculated by adding the variances of each period.

39.8.2.8 Limitations

See Section 39.1.3 for descriptions of the general equity derivative limitations of this deal.

Discrete Approximation of the Continuous Time Integral: The valuation of a volatility swap requires the calculation of the expectation of future volatility. The Demeterifi approach is to express the continuous time limit of this expectation as an integral, and then calculate the integral with a discrete approximation.

No Reference Period Offsets: The period over which the reference volatility is calculated runs from the effective date to the maturity date. There is no provision to offset the reference period from these dates.

Chapter 40

Commodity

40.1 Commodity Valuation Models

40.1.1 Common Properties

The properties described below are often found on commodity deal types.

40.1.1.1 Commodity Properties Common to Asset Price Derivatives

See Section [37.2](#).

40.1.1.2 Basket Components

A list of commodities in an commodity basket. Each entry specifies an (commodity) Asset, Currency, Commodity Volatility, Payoff Type, and Units. Note that the Currency property of a basket derivative specifies the payoff currency of the derivative; the Currency property of each basket component specifies the currency of the component commodity, needed when the payoff type is quanto or compo.

40.1.1.3 Currency

The ID of the FX price factor for the currency in which deal cashflows are denominated when the Payoff Type is Standard, or the currency in which the asset price is assumed to be denominated when the Payoff Type is Quanto or Compo.

40.1.1.4 Discount Rate

The ID of the interest rate price factor used to discount deal cashflows. If this ID is not specified, then the Currency will be used as the discount interest rate ID.

40.1.1.5 Commodity

ID of the underlying commodity. For example, GOLD.

40.1.1.6 Commodity Volatility

ID of the commodity volatility price factor. For example, GOLD or GOLD.USD or GOLD.AMERICAN.CALL. If left blank, Commodity.Currency is used, where Commodity is the underlying commodity name and Currency is the ID of the currency of the underlying commodity. See Section [11.2.6](#) for more details.

40.1.1.7 Payoff Currency

The ID of the FX price factor of the currency in which deal cashflows are denominated. This property may be left empty when the `Payoff Type` is `Standard`.

40.1.1.8 Units

Number of units of the underlying asset.

40.1.2 Assumptions

The assumptions stated below are commonly applicable to commodity deal types.

40.1.2.1 Commodity Assumptions Common to Asset Price Derivatives

See Section [37.3](#).

40.1.3 Limitations

The limitations stated below are commonly applicable to commodity deal types.

40.1.3.1 Commodity Limitations Common to Asset Price Derivatives

See Section [37.4](#).

40.2 Commodity Forward Deal Types

40.2.1 Commodity Forward

40.2.1.1 Overview

This deal type is for commodity forward contracts, and their quanto or compo variants.

40.2.1.2 Price Factor Dependency

Commodity Forward

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

40.2.1.3 Properties

See Section 40.1.1 for descriptions of the common properties of this deal.

40.2.1.4 Deal Representation

The Commodity Forward is an atomic deal.

40.2.1.5 Valuation

In Adaptiv Analytics a Commodity Forward deal can be valued using the `CommodityForwardValuation` model. For details about the valuation for this deal, see Theory Guide [7, § 4.1.4 [Equity and Commodity Forward](#)]. See Section 37.3.4 for the valuation of quanto and compo payoffs.

40.2.1.6 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.2.1.7 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

40.2.2 Commodity Average Rate Forward

40.2.2.1 Overview

This deal type is a forward contract where the asset effectively being purchased is the arithmetic average of commodity forward prices (or spot prices). Each forward price in the average is for the same asset and has the same currency and tenor. This payoff is settled net on the deal maturity date.

This deal deduces the sampling dates from a sampling frequency and a first and last sample date.

40.2.2.2 Price Factor Dependency

Commodity Average Rate Forward (Explicit)

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.2.2.3 Properties

See Section 40.1.1 for descriptions of the common properties of this deal.

Average: Average of known prices or rates up to and including Average Date. Must be in settlement currency for compo deals.

Average Date: Last price or rate observation date for the known average.

First Sample Date: First price observation date.

Forward Price: The strike commodity price denominated in Currency.

Last Sample Date: Last price observation date.

Sampling Frequency: Period between sample dates. If set to 0d then the First Sample Date and the Last Sample Date are the only two sample dates of the deal.

Tenor: The tenor over which to calculate each forward commodity price included in the average. The tenor should be set to the conventional spot settlement lag if the intent is to average spot rates. When the tenor is specified in days, it will be interpreted as business days if a holiday calendar is available for the deal.

Weighted Average: If Yes and the sampling frequency is in days then each sample is weighted by the number of days from the sample date to the next sample date. Otherwise the sample weights are 1.

40.2.2.4 Deal Representation

The Commodity Average Rate Forward is a deal skin that builds into a Commodity Average Rate Forward (Explicit) deal. See section 40.2.3 and the Deal Skins Guide [2, [Commodity Average Rate Forward](#)]. The building process is described below.

Theory Guide 4.1.10

An average rate or average strike forward deal builds into a corresponding average rate or average strike forward (explicit) deal, with the Sampling Data list constructed as follows.

Let $(t_1, \omega_1, F_1), \dots, (t_n, \omega_n, F_n)$ denote the date, weight and (known) price entries in the sampling data list. Let ϕ denote the sampling frequency and \mathcal{H} denote the deal's holiday calendar. The sample dates t_1, \dots, t_n are generated from the first sample date, last sample date, ϕ and \mathcal{H} using the method of Section 1.3.4.

If Weighted Average is Yes, $\phi = fd$ and \mathcal{H} is not empty then ω_i is the number of days from t_i to t_{i+1} , with $t_{n+1} = t_n + fb$. Otherwise $\omega_i = 1$.

Let A and T denote the Average and Average Date. A is the average of the known prices for sample dates up to and including T . If $t_i \leq T$ then $F_i = A$. Otherwise F_i is not specified.

40.2.2.5 Valuation

Commodity Average Rate Forward deals are valued using the DealSkinValuation model. For details about the valuation for this deal, see the section on the Commodity Average Rate Forward (Explicit) (section 40.2.3).

40.2.2.6 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.2.2.7 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

40.2.3 Commodity Average Rate Forward (Explicit)

40.2.3.1 Overview

This deal type is a forward contract where the asset effectively being purchased is the arithmetic average of commodity forward prices (or spot prices). Each forward price in the average is for the same asset and has the same currency and tenor. This payoff is settled net on the deal maturity date.

This deal has an explicit list of sampling dates. This means that each forward price can be weighted individually.

40.2.3.2 Price Factor Dependency

Commodity Average Rate Forward (Explicit)

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.2.3.3 Properties

See Section 40.1.1 for descriptions of the common properties of this deal.

Forward Price: The strike equity price denominated in `Currency`.

Tenor: The tenor over which to calculate each forward commodity price included in the average. The tenor should be set to the conventional spot settlement lag if the intent is to average spot rates. When the tenor is specified in days, it will be interpreted as business days if a holiday calendar is available for the deal.

40.2.3.4 Deal Representation

The Commodity Average Rate Forward (Explicit) is an atomic deal. See the Theory Guide [7, § 4.1.11 [Average Rate and Average Strike Forward \(Explicit\)](#)].

40.2.3.5 Valuation

In *Adaptiv Analytics* a Commodity Average Rate Forward (Explicit) deal can be valued using the `CommodityAverageRateForwardValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.1.11 [Average Rate and Average Strike Forward \(Explicit\)](#)].

The valuation relies on the absence of arbitrage argument that the expectation of the forward price is at some future fixing date is equal to the forward price now. Additionally it relies on the distributive property between means and expectations, which allows their order to be exchanged.

40.2.3.6 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.2.3.7 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

40.2.4 Commodity Average Strike Forward

40.2.4.1 Overview

This deal type is a forward contract where the strike is the arithmetic average of commodity forward prices (or spot prices). Each forward price in the average is for the same asset and has the same currency and tenor. Additionally a spread is applied to the strike. This payoff is settled net on the deal maturity date.

This deal deduces the sampling dates from a sampling frequency and a first and last sample date.

40.2.4.2 Price Factor Dependency

Commodity Average Strike Forward

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.2.4.3 Properties

See Section 40.1.1 for descriptions of the common properties of this deal.

Average: Average of known prices or rates up to and including Average Date. Must be in settlement currency for compo deals.

Average Date: Last price or rate observation date for the known average.

First Sample Date: First price observation date.

Last Sample Date: Last price observation date.

Sampling Frequency: Period between sample dates. If set to 0d then the First Sample Date and the Last Sample Date are the only two sample dates of the deal.

Spread: The fixed spread added to the strike price, denominated in Currency.

Tenor: The tenor over which to calculate each forward commodity price included in the average. The tenor should be set to the conventional spot settlement lag if the intent is to average spot rates. When the tenor is specified in days, it will be interpreted as business days if a holiday calendar is available for the deal.

Weighted Average: If Yes and the sampling frequency is in days then each sample is weighted by the number of days from the sample date to the next sample date. Otherwise the sample weights are 1.

40.2.4.4 Deal Representation

The Commodity Average Strike Forward is a deal skin that builds into a Commodity Average Strike Forward (Explicit) deal. See section 40.2.5 and the Deal Skins Guide [2, [Commodity Average Strike Forward](#)]. The building process is described below.

Theory Guide 4.1.10

An average rate or average strike forward deal builds into a corresponding average rate or average strike forward (explicit) deal, with the Sampling Data list constructed as follows.

Let $(t_1, \omega_1, F_1), \dots, (t_n, \omega_n, F_n)$ denote the date, weight and (known) price entries in the sampling data list. Let ϕ denote the sampling frequency and \mathcal{H} denote the deal's holiday calendar. The sample dates t_1, \dots, t_n are generated from the first sample date, last sample date, ϕ and \mathcal{H} using the method of Section 1.3.4.

If Weighted Average is Yes, $\phi = fd$ and \mathcal{H} is not empty then ω_i is the number of days from t_i to t_{i+1} , with $t_{n+1} = t_n + fb$. Otherwise $\omega_i = 1$.

Let A and T denote the Average and Average Date. A is the average of the known prices for sample dates up to and including T . If $t_i \leq T$ then $F_i = A$. Otherwise F_i is not specified.

40.2.4.5 Valuation

Commodity Average Strike Forward deals are valued using the DealSkinValuation model. For details about the valuation for this deal, see the section on the Commodity Average Strike Forward (Explicit) (section 40.2.5).

40.2.4.6 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.2.4.7 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

40.2.5 Commodity Average Strike Forward (Explicit)

40.2.5.1 Overview

This deal type is a forward contract where the strike is the arithmetic average of commodity forward prices (or spot prices). Each forward price in the average is for the same asset and has the same currency and tenor. Additionally a spread is applied to the strike. This payoff is settled net on the deal maturity date.

This deal has an explicit list of sampling dates. This means that each forward price can be weighted individually.

40.2.5.2 Price Factor Dependency

Commodity Average Strike Forward (Explicit)

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.2.5.3 Properties

See Section 40.1.1 for descriptions of the common properties of this deal.

Spread: The fixed spread added to the strike price, denominated in Currency.

Tenor: The tenor over which to calculate each forward commodity price included in the average. The tenor should be set to the conventional spot settlement lag if the intent is to average spot rates. When the tenor is specified in days, it will be interpreted as business days if a holiday calendar is available for the deal.

40.2.5.4 Deal Representation

The Commodity Average Strike Forward (Explicit) is an atomic deal. See the Theory Guide [7, § 4.1.11 [Average Rate and Average Strike Forward \(Explicit\)](#)].

40.2.5.5 Valuation

In Adaptiv Analytics an Commodity Average Strike Forward (Explicit) deal can be valued using the `CommodityAverageStrikeForwardValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.1.11 [Average Rate and Average Strike Forward \(Explicit\)](#)].

The valuation relies on the absence of arbitrage argument that the expectation of the forward price is at some future fixing date is equal to the forward price now. Additionally it relies on the distributive property between means and expectations, which allows their order to be exchanged.

40.2.5.6 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.2.5.7 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

40.2.6 Commodity Basket Forward

40.2.6.1 Overview

This deal type is for forward contracts on an underlying basket of commodity prices, and their quanto or compo variants. It is equivalent to a Structured Deal containing a portfolio of Commodity Forward deals. See Section [40.1.1](#) for descriptions of the properties of this deal.

40.2.6.2 Price Factor Dependency

Commodity Basket Forward

- └ Commodity Price (§ [4.4](#))
- └ Commodity Price / FX Rate Correlation (§ [12.2](#))
- └ Commodity Price Volatility (§ [11.2.6](#))
- └ Convenience Yield (§ [7.2](#))
- └ Discount Rate (§ [6.2](#))
- └ FX Volatility (§ [11.2.4](#))
- └ FX Rate (§ [4.2](#))
- └ Interest Rate (§ [6.1](#))

40.2.6.3 Properties

See Section [40.1.1](#) for descriptions of the common properties of this deal.

40.2.6.4 Deal Representation

The Commodity Basket Forward is an atomic deal.

40.2.6.5 Valuation

In Adaptiv Analytics an Commodity Basket Forward deal can be valued using the `CommodityForwardValuation` model. For details about the valuation for this deal, see Theory Guide [\[7, § 4.1.39 Basket of Prices\]](#). See Section [37.3.12](#) for the valuation of baskets of prices. See Section [37.3.12.1](#) for the valuation of basket quanto and compo payoffs.

40.2.6.6 Assumptions

See Section [40.1.2](#) for descriptions of the general commodity derivative assumptions of this deal.

40.2.6.7 Limitations

See Section [40.1.3](#) for descriptions of the general commodity derivative limitations of this deal.

40.2.7 Commodity Basket Average Rate Forward

40.2.7.1 Overview

This deal type is a forward contract where the asset effectively being purchased is the arithmetic average of commodity basket forward prices (or spot prices). Each forward price in the average is for the same basket and has the same currency and tenor. This payoff is settled net on the deal maturity date.

This deal deduces the sampling dates from a sampling frequency and a first and last sample date.

40.2.7.2 Price Factor Dependency

Commodity Basket Average Rate Forward (Explicit)

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.2.7.3 Properties

See Section 40.1.1 for descriptions of the common properties of this deal.

Average: Average of known prices or rates up to and including Average Date. Must be in settlement currency for compo deals.

Average Date: Last price or rate observation date for the known average.

First Sample Date: First price observation date.

Forward Price: The strike commodity price denominated in Currency.

Last Sample Date: Last price observation date.

Sampling Frequency: Period between sample dates. If set to 0d then the First Sample Date and the Last Sample Date are the only two sample dates of the deal.

Tenor: The tenor over which to calculate each forward commodity price included in the average. The tenor should be set to the conventional spot settlement lag if the intent is to average spot rates. When the tenor is specified in days, it will be interpreted as business days if a holiday calendar is available for the deal.

Weighted Average: If Yes and the sampling frequency is in days then each sample is weighted by the number of days from the sample date to the next sample date. Otherwise the sample weights are 1.

40.2.7.4 Deal Representation

The Commodity Basket Average Rate Forward is a deal skin that builds into a Commodity Basket Average Rate Forward (Explicit) deal. See section 40.2.3 and the Deal Skins Guide [2, Commodity Average Rate Forward]. The building process is described below.

Theory Guide 4.1.10

An average rate or average strike forward deal builds into a corresponding average rate or average strike forward (explicit) deal, with the Sampling Data list constructed as follows.

Let $(t_1, \omega_1, F_1), \dots, (t_n, \omega_n, F_n)$ denote the date, weight and (known) price entries in the sampling data list. Let ϕ denote the sampling frequency and \mathcal{H} denote the deal's holiday calendar. The sample dates t_1, \dots, t_n are generated from the first sample date, last sample date, ϕ and \mathcal{H} using the method of Section 1.3.4.

If Weighted Average is Yes, $\phi = fd$ and \mathcal{H} is not empty then ω_i is the number of days from t_i to t_{i+1} , with $t_{n+1} = t_n + fb$. Otherwise $\omega_i = 1$.

Let A and T denote the Average and Average Date. A is the average of the known prices for sample dates up to and including T . If $t_i \leq T$ then $F_i = A$. Otherwise F_i is not specified.

40.2.7.5 Valuation

Commodity Basket Average Rate Forward deals are valued using the DealSkinValuation model. For details about the valuation for this deal, see the section on the Commodity Basket Average Rate Forward (Explicit) (section 40.2.8).

40.2.7.6 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.2.7.7 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

40.2.8 Commodity Basket Average Rate Forward (Explicit)

40.2.8.1 Overview

This deal type is a forward contract where the asset effectively being purchased is the arithmetic average of commodity basket forward prices (or spot prices). Each forward price in the average is for the same basket and has the same currency and tenor. This payoff is settled net on the deal maturity date.

This deal has an explicit list of sampling dates. This means that each forward price can be weighted individually.

40.2.8.2 Price Factor Dependency

Commodity Average Rate Forward (Explicit)

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.2.8.3 Properties

See Section 40.1.1 for descriptions of the common properties of this deal.

Forward Price: The strike equity price denominated in `Currency`.

Tenor: The tenor over which to calculate each forward commodity price included in the average. The tenor should be set to the conventional spot settlement lag if the intent is to average spot rates. When the tenor is specified in days, it will be interpreted as business days if a holiday calendar is available for the deal.

40.2.8.4 Deal Representation

The Commodity Basket Average Rate Forward (Explicit) is an atomic deal. See the Theory Guide [7, § 4.1.11 [Average Rate and Average Strike Forward \(Explicit\)](#)].

40.2.8.5 Valuation

In Adaptiv Analytics an Commodity Basket Average Rate Forward (Explicit) deal can be valued using the `CommodityAverageRateForwardValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.1.11 [Average Rate and Average Strike Forward \(Explicit\)](#)] about the valuation itself and [7, § 4.1.39 [Basket of Prices](#)] about basket forward prices.

The valuation relies on the absence of arbitrage argument that the expectation of the forward price is at some future fixing date is equal to the forward price now. Additionally it relies on the distributive property between means and expectations, which allows their order to be exchanged.

Basket prices are calculated as

Theory Guide [4.1.39](#)

The basket price is defined by

$$S(t) = \sum_{i=1}^n \omega_i S_i(t), \quad (40.2.1)$$

where $S_1(t), \dots, S_n(t)$ are the individual asset prices and $\omega_i > 0$ is the number of units of the i^{th} asset.

forward basket prices are calculated as

Theory Guide [4.1.39](#)

The expectation of the basket price $S(T)$ is given by

$$F(t) = \mathbb{E}_t(S(T)) = \sum_{i=1}^n \omega_i F_i(t, T). \quad (40.2.2)$$

40.2.8.6 Assumptions

See Section [40.1.2](#) for descriptions of the general commodity derivative assumptions of this deal.

40.2.8.7 Limitations

See Section [40.1.3](#) for descriptions of the general commodity derivative limitations of this deal.

40.3 Commodity Swap Deal Types

40.3.1 Overview

A commodity swap exchanges payments based on a floating commodity price for payments based on a fixed commodity price. The floating commodity price can be an average. Quanto and compo variant are also supported.

Adaptiv Analytics supports two types of commodity swap: Commodity Swap and Commodity Basket Swap. The former swaps the price of a single commodity whereas the latter swaps the price of an explicitly specified weighted basket of commodities, but the two deal types are otherwise similar. Both commodity swap types are deal skins building into a set of swap legs drawn from a set of shared swap leg types.

40.3.2 Properties

See Section [40.1.1](#) for descriptions of the common properties of equity deals.

40.3.2.1 Averages

List of realized average asset prices and corresponding dates up to which that average has been calculated. Used for deals that are in progress at the calculation base date. Only one entry in Averages is usually required. However, two entries may be required if two swaplets are simultaneously in progress, which can only happen if the base calculation date falls after the last sample date and before the payment date of one swaplet and after the first sample date of the next swaplet.

40.3.2.2 Fixed Price

Fixed price paid by the fixed leg for a unit of the commodity.

40.3.2.3 Payment Frequency

Period between swaplet payment dates. If this property is set to zero, then the payment periods will be determined by the trade effective and maturity dates.

40.3.2.4 Sample Period

Length of sampling period. Cannot be less than `Sampling Frequency`. If set to 0d then there is only be one sample date, at the beginning of the swaplet.

40.3.2.5 Sampling Frequency

Period between sample dates. If this property is set to zero, each swaplet's first sample date and last sample date will be the only two sample dates in that swaplet.

40.3.3 Assumptions

See Section [40.1.2](#) for descriptions of the general commodity derivative assumptions of commodity swap deal types.

40.3.4 Limitations

See Section [40.1.3](#) for descriptions of the general commodity derivative limitations of commodity swap deal types.

40.3.5 Commodity Swap

40.3.5.1 Overview

A commodity swap exchanges payments based on a floating commodity price for payments based on a fixed commodity price. The floating commodity price can be an average. Quanto and compo variant are also supported.

40.3.5.2 Price Factor Dependency

Commodity Swap

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.3.5.3 Properties

See Section 40.3.2 for descriptions of the common properties of this deal.

40.3.5.4 Deal Representation

The Commodity Swap is a deal skin that builds into a Commodity Swaplet List deal. See section 40.3.8 and the Deal Skins Guide [2, Commodity Swap]. The building process is described below.

Theory Guide 4.1.13

If the configuration setting BUILD DEAL SKINS INTO SEPARATE LEGS is No (see *Configuration Settings* in the Analytics Technical Guide) or the setting is not specified then a commodity swap builds into a commodity swaplet list deal. If BUILD DEAL SKINS INTO SEPARATE LEGS is Yes then a commodity swap builds into a commodity swaplet list deal with Fixed Price equal to zero and a fixed cashflow list deal. For each commodity swaplet, the fixed cashflow list deal has cashflow with same payment date and Fixed Amount equal to NK , where N is the number of units and K is the Fixed Price of the commodity swap.

Accrual start dates, accrual end dates and payment dates are generated from the deal's effective date, maturity date, payment frequency and holiday calendar, as described in Section 1.3.2. Let $T_1^s, \dots, T_n^s, T_1^e, \dots, T_n^e$ and T_1, \dots, T_n denote the accrual start dates, accrual end dates and payment dates, respectively. For each accrual period, resets dates and corresponding weights are generated as described in Section 1.3.3, with the reset frequency set to Sampling Frequency, the averaging term set to Sampling Period and the index calendar and index publication calendar set to the deal's holiday calendar. Let $t_{i,1}, \dots, t_{i,m(i)}$ and $\omega_{i,1}, \dots, \omega_{i,m(i)}$ denote the reset dates and corresponding weights.

The commodity swaplet list deal has n commodity swaplets. The i^{th} swaplet has payment date T_i and its Sampling Data list has dates $t_{i,1}, \dots, t_{i,m(i)}$ and weights $\omega_{i,1}, \dots, \omega_{i,m(i)}$.

Let (t_i, A_i) denote the last entry in the Averages list for which $T_i^s \leq t_i < T_i^e$, if one exists. If (t_i, A_i) exists then all entries in the i^{th} sampling data list with $t_{i,j} \leq t_i$ have known price A_i .

40.3.5.5 Valuation

In Adaptiv Analytics a Commodity Swap deal are valued using the `DealSkinValuation` model. For details about the valuation for this deal, see the section on the Commodity Swaplet List (section 40.3.8).

40.3.5.6 Tuning Parameters and Valuation Settings

The Commodity Swap deal has no valuation settings.

40.3.5.7 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.3.5.8 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

40.3.6 Commodity Basket Swap

40.3.6.1 Overview

A commodity basket swap exchanges payments based on a basket of floating commodity prices for payments based on a fixed commodity price. The floating commodity prices can be an average. Quanto and compo variant are also supported.

40.3.6.2 Price Factor Dependency

Commodity Basket Swap

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.3.6.3 Properties

See Section 40.3.2 for descriptions of the common properties of this deal.

40.3.6.4 Deal Representation

The Commodity Swap is a deal skin that builds into a series of Commodity Basket Average Rate Forward deal. See section 40.2.7 and the Deal Skins Guide [2, Commodity Basket Swap]. The building process is described below.

Theory Guide 4.1.14

A commodity basket swap builds into a sequence of commodity basket average rate forward (explicit) deals.

Accrual start dates, accrual end dates and payment dates are generated as described in Section 4.1.13.

The commodity basket swap builds into n corresponding commodity basket average rate forward (explicit) deals. The i^{th} deal has maturity date T_i , Forward Price set to Fixed Price, and the Sampling Data list has dates $t_{i,1}, \dots, t_{i,m(i)}$ and weights $\omega_{i,1}, \dots, \omega_{i,m(i)}$.

The known prices are generated from the Averages list as described in Section 4.1.13.

40.3.6.5 Valuation

In Adaptiv Analytics a Commodity Basket Swap deal are valued using the DealSkinValuation model. For details about the valuation for this deal, see the section on the Commodity Swaplet List (section 40.2.7).

40.3.6.6 Tuning Parameters and Valuation Settings

The Commodity Basket Swap deal has no valuation settings.

40.3.6.7 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.3.6.8 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

40.3.7 Commodity Swap Leg

40.3.7.1 Overview

A commodity swap leg presents the floating side of a commodity swap. See Section [40.3.5](#). The floating commodity price can be an average. Quanto and compo variant are also supported.

40.3.7.2 Price Factor Dependency

Commodity Swap Leg

- └ Commodity Price (§ [4.4](#))
- └ Commodity Price / FX Rate Correlation (§ [12.2](#))
- └ Commodity Price Volatility (§ [11.2.6](#))
- └ Convenience Yield (§ [7.2](#))
- └ Discount Rate (§ [6.2](#))
- └ FX Volatility (§ [11.2.4](#))
- └ FX Rate (§ [4.2](#))
- └ Interest Rate (§ [6.1](#))

40.3.7.3 Properties

See Section [40.3.2](#) for descriptions of the common properties of this deal.

40.3.7.4 Deal Representation

The Commodity Swap Leg is a deal skin that builds into a Commodity Swaplet List deal. See section [40.3.8](#) and the Deal Skins Guide [[2](#), [Commodity Swap Leg](#)]. The building process is described below as described in Section [40.3.5](#), with this modification:

Theory Guide [4.1.13.1](#)

A commodity swap leg is the same as a commodity swap with Fixed Price equal to zero.

40.3.7.5 Valuation

In Adaptiv Analytics Commodity Swap Leg deals are valued using the `DealSkinValuation` model. For details about the valuation for this deal, see the section on the Commodity Swaplet List (section [40.3.8](#)).

40.3.7.6 Tuning Parameters and Valuation Settings

The Commodity Swap Leg deal has no valuation settings.

40.3.7.7 Assumptions

See Section [40.1.2](#) for descriptions of the general commodity derivative assumptions of this deal.

40.3.7.8 Limitations

See Section [40.1.3](#) for descriptions of the general commodity derivative limitations of this deal.

40.3.8 Commodity Swaplet List

40.3.8.1 Overview

A commodity swaplet list explicitly defines the swaplets that make up a commodity swap (see Section 40.3.5). The floating commodity price can be an average. Quanto and compo variant are also supported.

40.3.8.2 Price Factor Dependency

Commodity Swaplet List

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.3.8.3 Properties

See Section 40.3.2 for descriptions of the common properties of this deal.

Cashflows: A compound property containing the explicit details of the swaplets.

Items: A list of swaplet details with one item per swaplet, each with the following elements:

Payment Date: Payment date of the swaplet.

Sampling Data: A list of explicit sampling information for calculating the average commodity prices. There is one item for each sampling date, each with the following elements:

Price: The known sampled price. Expected to be `undefined` if `Date` is in the future.

Date: Sampling date for the average commodity price.

Weight: Weight used during averaging of the commodity prices. See Theory Guide [7, § 4.1.11 [Average Rate and Average Strike Forward \(Explicit\)](#)]

40.3.8.4 Deal Representation

The Commodity Swaplet List is an atomic deal.

40.3.8.5 Valuation

In Adaptiv Analytics Commodity Swaplet List deals are valued using the `CommoditySwapletListValuation` model.

Theory Guide [4.1.12](#)

A commodity swaplet list deal defines a list of commodity swaplets. The value of each swaplet is the value of a corresponding commodity average rate forward (explicit) deal (see Section 4.1.11)

with maturity date equal to the swaplet payment date, and Forward Price equal to the Fixed Price on the commodity swaplet list deal.

For details on the Commodity Average Rate Forward see Section 40.2.3 and Theory Guide [7, § 4.1.11 [Average Rate and Average Strike Forward \(Explicit\)](#)].

40.3.8.6 Tuning Parameters and Valuation Settings

Cashflow Rounding: This controls whether cashflow rounding is applied to each amount. It may be set to None, Nearest, Or Next Lower.

Theory Guide [4.3.17.2](#)

If the valuation model parameter Cashflow Rounding is Nearest or Next Lower then rounding is applied to each cashflow amount.

Settlement Offset: The settlement offset is used to to exclude cashflows paid within one settlement period of the base calculation date.

Theory Guide [4.3.17.1](#)

If the valuation model parameter Use Settlement Offset is Yes then the valuation model ignores cashflows with payment date before the settlement date t_s , where s is the Settlement Offset, t_s is calculated by adding $s + 1$ business days to the base valuation date, and addition of business days is with respect to the holiday calendar defined by Settlement Offset Calendars.

The settlement offset s is usually either 0, 1 or 2 and cannot be negative. In the case $s = 0$, the settlement date is the business day following the base valuation date, and hence cashflows on the base valuation date are ignored.

Settlement Offset Calendars: This is a list of calendars. The settlement offset is calculated in business days, where non-business days are taken from the union of all holiday calendars in the list. If the list is empty, then all calendar days are treated as business days.

Use Settlement Offset: If set to Yes, then cashflows within one settlement offset of the base calculation date will be excluded.

40.3.8.7 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.3.8.8 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

40.4 Commodity Option Deal Types

40.4.1 Commodity Option

40.4.1.1 Overview

This deal type is for options on an underlying commodity for immediate or forward delivery, with either European or American exercise, and their quanto or compo variants.

40.4.1.2 Price Factor Dependency

Commodity Option

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.4.1.3 Properties

See Section 40.1.1 for descriptions of the common properties of this deal.

40.4.1.4 Deal Representation

The Commodity Option is an atomic deal.

40.4.1.5 Valuation

In Adaptiv Analytics a Commodity Option deal can be valued using the `OptionValuation` model. See Section 37.3.4 for the valuation of quanto and compo payoffs.

This deal can be configured to have either European (Section 37.3.5) or American (Section 37.3.6) exercise.

This deal can be configured so that the asset underlying the option is a forward contract on a commodity. In this case, the option may be either cash-settled or physically settled. See Theory Guide [7, § 4.1.19 Options on Forwards] for a description of options on forwards. Note that the only way to specify a spot settlement lag is to configure the deal to be an option on a forward, with the forward period equal to the settlement lag.

40.4.1.6 Tuning Parameters and Valuation Settings

Early Exercise Today: American options are exercised only at times after the base calculation date unless this parameter is `Yes`. See Section 37.3.6.1.

Monitoring Period: The model exercises American options on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Theory Guide [7, § 4.1.18.4 Monitoring Dates] for details on the use of this parameter.

40.4.1.7 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.4.1.8 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

40.4.2 Commodity Binary Option

40.4.2.1 Overview

This deal type supports two types of fixed payoff, namely cash-or-nothing and call-put spread. Cash-or-nothing pays the `Cash Payoff` if the option is in the money at exercise, or zero if out of the money.

Theory Guide [4.1.20](#)

The option pays

$$C [\delta(S(T) - K) > 0] \quad (40.4.1)$$

at the settlement date t_1 , where C is the Cash Payoff and either $\delta = +1$ for a call option or $\delta = -1$ for a put option.

The call-put spread scales the cash payoff by the ratio between two vanilla calls or puts and the `Call Put Spread` between them:

Theory Guide [4.1.20](#)

Let ϵ denote the Call Put Spread of the deal.

Theory Guide [4.1.20](#)

When $\epsilon \neq 0$, the option pays

$$C \frac{\max(\delta(S(T) - K + \epsilon/2), 0) - \max(\delta(S(T) - K - \epsilon/2), 0)}{\delta\epsilon} \quad (40.4.2)$$

at the settlement date.

This method can be used to take volatility skew into account for binary option pricing. The call-put spread payoff converges to the fixed cash payoff as the spread approaches zero. Consequently, the spread is the only parameter used to decide whether to pay cash-or-nothing or call-put spread.

Only European exercise is supported.

The payoff may be in a third currency (quanto).

40.4.2.2 Price Factor Dependency

Commodity Binary Option

- └ Commodity Price (§ [4.4](#))
- └ Commodity Price / FX Rate Correlation (§ [12.2](#))
- └ Commodity Price Volatility (§ [11.2.6](#))
- └ Convenience Yield (§ [7.2](#))
- └ Discount Rate (§ [6.2](#))
- └ FX Volatility (§ [11.2.4](#))
- └ FX Rate (§ [4.2](#))
- └ Interest Rate (§ [6.1](#))

40.4.2.3 Properties

See Section [40.1.1](#) for descriptions of the common properties of this deal.

Cash Payoff: The size of the fixed payoff, scaled by the call spread or put spread when the spread is not zero.

Call Put Spread: The size of the call spread or put spread used to calculate the fixed payoff.

40.4.2.4 Deal Representation

The Commodity Binary Option is an atomic deal.

40.4.2.5 Valuation

In Adaptiv Analytics a Commodity Binary Option deal can be valued using the `BinaryOptionValuation` model. For details about the valuation for this deal, see Theory Guide [[7](#), § [4.1.20 Binary Option](#)].

See Section [37.3.5](#) for the valuation of European options.

See Section [37.3.4](#) for the valuation of quanto payoffs.

40.4.2.6 Tuning Parameters and Valuation Settings

This valuation model has no tuning parameters or valuation settings.

40.4.2.7 Assumptions

See Section [40.1.2](#) for descriptions of the general commodity derivative assumptions of this deal.

40.4.2.8 Limitations

See [40.1.3](#) for descriptions of the general commodity derivative limitations of this deal.

40.4.3 Commodity Basket Option

40.4.3.1 Overview

This deal type is for options on an underlying basket of commodity prices or basket of commodity returns, with either European or American exercise, and their quanto or compo variants.

40.4.3.2 Price Factor Dependency

Commodity Basket Option

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.4.3.3 Properties

See Section 40.1.1 for descriptions of the common properties of this deal.

40.4.3.4 Deal Representation

The Commodity Basket Option is an atomic deal.

40.4.3.5 Valuation

In Adaptiv Analytics a Commodity Basket Option deal can be valued using the `CommodityBasketOptionValuation` model. See Section 37.3.4 for the valuation of quanto and compo payoffs. See Section 37.3.12 for the valuation of baskets of prices. See Section 37.3.12.1 for the valuation of basket quanto and compo payoffs.

This deal can be configured to have either European (Section 37.3.5) or American (Section 37.3.6) exercise.

40.4.3.6 Tuning Parameters and Valuation Settings

Approximation Method: Basket options are priced using a moment matching approximation, as described in Section 37.3.12.2. The approximation method may be either `Two Moment Log Normal` for the two moment method or `Three Moment Shifted Log Normal` for the three moment method.

Implied Volatility Method: When an option is on a basket of returns rather than a basket of prices, the choice of volatility method may be either `Weighted Strike` or `Conditional Strike`. See Theory Guide [7, § 4.1.40 [Basket of Returns](#)] for details.

Early Exercise Today: American options are exercised only at times after the base calculation date unless this parameter is `Yes`. See Section 37.3.6.1.

Monitoring Period: The model exercises American options on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Theory Guide [7, § 4.1.18.4 [Monitoring Dates](#)] for details on the use of this parameter.

40.4.3.7 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.4.3.8 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

40.4.4 Commodity Chooser Option

40.4.4.1 Overview

This deal type is for chooser options on an underlying commodity. Chooser options are where the holder can decide on the chooser date whether the option should be a call or a put. The chooser date is often prior to option expiry. Quanto or compo variants are also supported.

40.4.4.2 Price Factor Dependency

Commodity Chooser Option

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.4.4.3 Properties

See Section 40.1.1 for descriptions of the common properties of this deal.

Chooser Date: Date on which the decision is made to enter into a call option or a put option. Must be on or before the expiry date.

40.4.4.4 Deal Representation

The Equity Chooser Option is an atomic deal.

40.4.4.5 Valuation

In Adaptiv Analytics an Commodity Chooser Option deal can be valued using the `ChooserOptionValuation` model. See Section 37.3.4 for the valuation of quanto and compo payoffs.

Valuation of this deal is described in Section 37.3.13.

40.4.4.6 Tuning Parameters and Valuation Settings

This deal type has no valuation configuration settings.

40.4.4.7 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.4.4.8 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

40.4.5 Commodity Cliquet Option

40.4.5.1 Overview

This deal type is for cliquet options on an underlying commodity. Cliquet options are a strip of forward start options. The notional can be fixed or variable. Quanto or compo variants are also supported.

40.4.5.2 Price Factor Dependency

Commodity Cliquet Option

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.4.5.3 Properties

See Section 40.1.1 for descriptions of the common properties of this deal.

Effective Date: Unadjusted deal start date.

Frequency: Frequency of the option payments.

Moneyness: Moneyness factor.

Principal Fixed Variable: Determines whether the deal has a fixed or variable principal amount.

Principal: The fixed principal amount of the option. Used when Principal Fixed Variable is Fixed and ignored otherwise.

Known Prices: List of reset dates and corresponding known commodity prices and (for Compo deals) FX rates specified in the form of (Date, Asset price, FX rate) triples. FX Rates are used for deals with Payoff Type = Compo. Each asset price should correspond to the asset value at the beginning of a forward price option. Only one known asset price (corresponding to the asset value at the beginning of the current forward start option) will be used per valuation. All the previous known asset prices will be ignored since the previous forward start options have already been settled. (List (Date; Asset Price; FX Rate)). Any missing known commodity prices will be read from the rate fixings (if available) or otherwise the price assumed to be the base date spot prices. Similarly, if the FX rates are missing these are read from the rate fixings file (if available) or assumed to be the spot value if no fixings are available.

40.4.5.4 Deal Representation

The Commodity Cliquet Option is an atomic deal.

40.4.5.5 Valuation

In Adaptiv Analytics an Commodity Cliquet Option deal can be valued using the `CliquetOptionValuation` model. See Section 37.3.4 for the valuation of quanto and compo payoffs.

The valuation of this deal is described in Section 37.3.14.

40.4.5.6 Tuning Parameters and Valuation Settings

This deal type has no valuation configuration settings.

40.4.5.7 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.4.5.8 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

40.4.6 Commodity Compound Option

40.4.6.1 Overview

This deal type is for compound options on an underlying commodity. A compound option is a European option on a European option. Quanto or compo variants are also supported.

40.4.6.2 Price Factor Dependency

Commodity Compound Option

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.4.6.3 Properties

See Section 40.1.1 for descriptions of the common properties of this deal.

Option Type: Type of the compound option. For example, Call On Put is a European call option on a European Put option. (Call On Call, Call On Put, Put On Call or Put On Put).

Strike Price: Strike price of the compound option in asset currency (or settlement currency for compo options).

Underlying Strike: Strike price of the underlying European option.

Underlying Maturity: Expiry date of the underlying European option.

40.4.6.4 Deal Representation

The Commodity Compound Option is an atomic deal.

40.4.6.5 Valuation

In Adaptiv Analytics an Commodity Compound Option deal can be valued using the CompoundOptionValuation model. See Section 37.3.4 for the valuation of quanto and compo payoffs.

The valuation of this deal is described in Section 37.3.15.

40.4.6.6 Tuning Parameters and Valuation Settings

This deal type has no valuation configuration settings.

40.4.6.7 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.4.6.8 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

40.4.7 Commodity Gap Option

40.4.7.1 Overview

This deal type is for gap options on an underlying commodity. A gap option has a strike and a barrier. The barrier triggers the payoff and the magnitude of the payoff is determined by the strike. Barrier and reverse barrier variants are supported, as are quanto or compo variants.

40.4.7.2 Price Factor Dependency

Commodity Gap Option

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.4.7.3 Properties

See Section 40.1.1 for descriptions of the common properties of this deal.

Barrier Price: Barrier price in asset currency (or settlement currency for compo options).

Gap Type: Gap option type: Barrier or Reverse Barrier.

40.4.7.4 Deal Representation

The Commodity Gap Option is an atomic deal.

40.4.7.5 Valuation

In Adaptiv Analytics an Commodity Gap Option deal can be valued using the GapOptionValuation model. See Section 37.3.4 for the valuation of quanto and compo payoffs.

The valuation of this deal is described in Section 37.3.17.

40.4.7.6 Tuning Parameters and Valuation Settings

This deal type has no valuation configuration settings.

40.4.7.7 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.4.7.8 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

40.4.8 Commodity Lookback Option

40.4.8.1 Overview

This deal type is for lookback options on an underlying commodity. The holder of a lookback option may choose the historically realized price over the life of the option that maximizes the option payoff. Adaptiv Analytics supports two types of lookback options:

- Floating Strike Lookback Option

Theory Guide [4.1.26](#)

The payoff of a floating strike lookback call option is $\max(S(T) - S_{\min}(T), 0)$, where $S_{\min}(t)$ is the lowest asset price observed from the trade date up to t . Similarly, the payoff of a floating strike lookback put option is $\max(S_{\max}(T) - S(T), 0)$, where $S_{\max}(t)$ is the highest asset price observed from the trade date up to t .

- Fixed Strike Lookback Option

Theory Guide [4.1.26](#)

The payoff of a fixed strike lookback call option is $\max(S_{\max}(T) - K, 0)$; and the payoff of a fixed strike lookback put option is $\max(K - S_{\min}(T), 0)$.

where

Theory Guide [4.1.26](#)

For a given valuation date t , the minimum and maximum asset price are calculated as follows:

$$S_{\min}(t) = \min\{S_{\min}, S(0), S(t_1), \dots, S(t_m), S(t)\} \quad (40.4.3)$$

$$S_{\max}(t) = \max\{S_{\max}, S(0), S(t_1), \dots, S(t_m), S(t)\}, \quad (40.4.4)$$

where: t_1, \dots, t_m are the valuation dates between 0 and t ; S_{\min} is the Observed Minimum if its value is positive, or otherwise $S_{\min} = \infty$; and S_{\max} is the Observed Maximum.

Quanto and compo variants are also supported.

40.4.8.2 Price Factor Dependency

Commodity Lookback Option

- └ Commodity Price (§ [4.4](#))
- └ Commodity Price / FX Rate Correlation (§ [12.2](#))
- └ Commodity Price Volatility (§ [11.2.6](#))
- └ Convenience Yield (§ [7.2](#))
- └ Discount Rate (§ [6.2](#))
- └ FX Volatility (§ [11.2.4](#))
- └ FX Rate (§ [4.2](#))
- └ Interest Rate (§ [6.1](#))

40.4.8.3 Properties

See Section 40.1.1 and Section 37.2 for descriptions of the common properties of this deal.

Observed Maximum: Realised observed maximum price

Observed Minimum: Realised observed minimum price if the value is positive, otherwise $S_{\min} = \infty$.

Strike Type: Determines the variant of the Lookback option. `Fixed` is a Fixed Strike Lookback option and `Floating` refers to a Floating Strike Lookback option.

40.4.8.4 Deal Representation

The Commodity Lookback Option is an atomic deal.

40.4.8.5 Valuation

In Adaptiv Analytics a Commodity Lookback Option deal can be valued using the `LookbackOptionValuation` model. See Section 37.3.4 for the valuation of quanto payoffs and compo payoffs.

The valuation of this deal is described in Section 37.3.16.

40.4.8.6 Tuning Parameters and Valuation Settings

This deal type has no valuation configuration settings.

40.4.8.7 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.4.8.8 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

Observed Minimum and Maximum The "observed" minimum and maximum (before the base valuation date) must be populated on the deal when the deal is valued mid-life. The valuation model will not check the rate fixing file to find the historical values.

40.5 Commodity Asian Option Deal Types

40.5.1 Commodity Discrete (Explicit) Asian Option

40.5.1.1 Overview

This deal type is for Asian options on an underlying commodity, and their quanto or compo variants. They are called discrete Asian options in Adaptiv Analytics because they are fully modelled as a finite weighted sum of observations, and not approximated with a continuous average. They are called explicit because the set of observation dates must be explicitly enumerated in a deal property, rather than calculated from a formula. This explicit representation also allows each observation to be individually weighted.

40.5.1.2 Price Factor Dependency

Commodity Discrete (Explicit) Asian Option

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.5.1.3 Properties

See Section 40.1.1 for descriptions of the common properties of this deal.

40.5.1.4 Deal Representation

The Commodity Discrete (Explicit) Asian Option is an atomic deal.

40.5.1.5 Valuation:

In Adaptiv Analytics an Commodity Discrete (Explicit) Asian Option deal can be valued using the `AssetDiscreteAsianOptionValuation` model. See Section 37.3.9 for discrete Asian option valuation.

This deal can be configured to support standard payoffs in the commodity currency, quanto payoffs, and compo payoffs. See Section 37.3.4 for the valuation of quanto and compo payoffs.

40.5.1.6 Tuning Parameters and Valuation Settings

Term Structured: See Section 37.3.9.3 for a description of this setting.

40.5.1.7 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.5.1.8 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

40.5.2 Commodity Discrete (Explicit) Double Asian Option

40.5.2.1 Overview

This deal type is for double Asian options on an underlying commodity price. They are called discrete Asian options in Adaptiv Analytics because they are fully modelled with finite weighted sums of observations, and not approximated with a continuous average. They are called explicit because the sets of observation dates must be explicitly enumerated in deal properties, rather than calculated from a formula. This explicit representation also allows each observation to be individually weighted.

The deal is always settled for net value with a single cashflow.

40.5.2.2 Price Factor Dependency

Commodity Discrete (Explicit) Double Asian Option

- └ Commodity Price (§ 4.4)
- └ Commodity Price Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.5.2.3 Properties

See Section 40.1.1 for descriptions of the common properties of this deal.

Difference Method: *Arithmetic* indicates that the option is on the arithmetic difference between the two weighted sums of observations; *Geometric* indicates that the option is on their ratio.

Is Digital: If *Yes*, the option pays a fixed amount determined by the two sampling multipliers.

Sampling Data 1: The sampling data for the first weighted sum in the difference term.

Sampling Data 2: The sampling data for the second weighted sum in the difference term.

Sampling Multiplier 1: The multiplier for the first weighted sum in the difference term.

Sampling Multiplier 2: The multiplier for the second weighted sum in the difference term.

Strike Multiplier: The strike is scaled by this multiplier before it is subtracted from the difference in weighted sums when calculating the option payoff.

40.5.2.4 Deal Representation

The Commodity Discrete (Explicit) Double Asian Option is an atomic deal.

40.5.2.5 Valuation:

In Adaptiv Analytics an Commodity Discrete (Explicit) Double Asian Option deal can be valued using the `DiscreteExplicitDoubleAsianOptionValuation` model. For details about the valuation for this deal, see Theory Guide [7, § 4.1.34 [Discrete \(Explicit\) Double Asian Option](#)].

See Section 37.3.9 for discrete Asian option valuation.

40.5.2.6 Tuning Parameters and Valuation Settings

Moment Matching Method: Double asian options are priced using a moment matching approximation, as described in Section 37.3.10.1. The approximation method may be either `Two Moment Log Normal` for the two moment method or `Three Moment Shifted Log Normal` for the three moment method.

Number of Integration Points: When the difference method is `Geometric`, the option must be valued with a numerical integration except in special cases, as described in Section 37.3.10.4. The number of points in the integration is specified with this parameter.

Strike Mapping Method: See Section 37.3.10.5 for a description of this setting.

Term Structured: See Section 37.3.10.5 for a description of this setting.

40.5.2.7 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.5.2.8 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

No Quanto Payoffs: Quanto payoffs are not supported for double asian options.

40.5.3 Commodity Basket Discrete (Explicit) Asian Option

40.5.3.1 Overview

This deal type is for Asian options on an underlying basket of either commodity prices or returns, and their quanto or compo variants. They are called discrete Asian options in Adaptiv Analytics because they are fully modelled as a finite weighted sum of basket observations, and not approximated with a continuous average. They are called explicit because the set of observation dates must be explicitly enumerated in a deal property, rather than calculated from a formula. This explicit representation also allows each observation to be individually weighted.

40.5.3.2 Price Factor Dependency

Commodity Basket Discrete (Explicit) Asian Option

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.5.3.3 Properties

See Section 40.1.1 for descriptions of the common properties of this deal.

40.5.3.4 Deal Representation

The Commodity Basket Discrete (Explicit) Asian Option is an atomic deal.

40.5.3.5 Valuation

In Adaptiv Analytics an Commodity Basket Discrete (Explicit) Asian Option deal can be valued using the `CommodityBasketDiscreteAsianOptionValuation` model. See Section 37.3.9 for discrete Asian option valuation.

This deal can be configured to support standard payoffs in the commodity currency, quanto payoffs, and compo payoffs. See Section 37.3.4 for the valuation of quanto and compo payoffs.

40.5.3.6 Tuning Parameters and Valuation Settings

Term Structured: See Section 37.3.9.3 for a description of this setting.

Approximation Method: See Section 37.3.12.2 for a description of this setting.

Implied Volatility Method: See Section 37.3.12.2 for a description of this setting.

40.5.3.7 Assumptions

See Section 40.1.2 for descriptions of the general FX derivative assumptions of this deal.

40.5.3.8 Limitations

See Section 40.1.3 for descriptions of the general FX derivative limitations of this deal.

40.6 Commodity Barrier Option Deal Types

40.6.1 Commodity Barrier Option

40.6.1.1 Overview

This deal type is for single barrier options on an underlying commodity price. The barrier monitoring frequency may be specified. The option may pay a rebate. An out rebate is paid when the option is knocked out. An in rebate is paid at option expiry if the option is never knocked in.

The deal is always settled for net value with a single cashflow in the payoff currency.

40.6.1.2 Price Factor Dependency

Commodity Barrier Option

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.6.1.3 Properties

See Section 40.1.1 for descriptions of the common properties of this deal.

40.6.1.4 Deal Representation

The Commodity Barrier Option is an atomic deal.

40.6.1.5 Valuation:

In Adaptiv Analytics an Commodity Barrier Option deal can be valued using the `BarrierOptionValuation` model. For details about the valuation for this deal, see Theory Guide [7, § 4.1.27 [Barrier Option](#)].

40.6.1.6 Tuning Parameters and Valuation Settings

Monitoring Period: The model exercises knock-in or knock-out on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the `Monitoring Period` parameter. See Section 37.4.14 and the Theory Guide [7, § 4.1.30.1 [Monitoring Dates](#)].

40.6.1.7 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.6.1.8 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

40.6.2 Commodity Barrier Binary Option

40.6.2.1 Overview

This deal type is for single barrier binary options on an underlying commodity. A commodity barrier binary option pays the Cash Payoff if the option is in the money at exercise and the barrier has been touched (knock-in) or never touched (knock-out). The barrier monitoring frequency may be specified.

40.6.2.2 Price Factor Dependency

Commodity Barrier Binary Option

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.6.2.3 Properties

See Section 40.1.1 and Section 37.2 for descriptions of the common properties of this deal.

40.6.2.4 Deal Representation

The Commodity Barrier Binary Option is an atomic deal.

40.6.2.5 Valuation:

In Adaptiv Analytics a Commodity Barrier Binary Option deal can be valued using the `Barrier-BinaryOptionValuation` model. For details about the valuation for this deal, see Section 37.3.7.

40.6.2.6 Tuning Parameters and Valuation Settings

Monitoring Period: The model exercises knock-in or knock-out on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Section 37.4.14 and the Theory Guide [7, § 4.1.30.1 [Monitoring Dates](#)].

40.6.2.7 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.6.2.8 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

40.6.3 Commodity Double Barrier Option

40.6.3.1 Overview

This deal type is for double barrier options on an underlying commodity price. The barrier monitoring frequency may be specified. The option may pay a rebate. An out rebate is paid when the option is knocked out. An in rebate is paid at option expiry if the option is never knocked in.

The deal is always settled for net value with a single cashflow in the payoff currency.

40.6.3.2 Price Factor Dependency

Commodity Double Barrier Option

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.6.3.3 Properties

See Section 40.1.1 for descriptions of the common properties of this deal.

40.6.3.4 Deal Representation

The Commodity Double Barrier Option is an atomic deal.

40.6.3.5 Valuation:

In Adaptiv Analytics an Commodity Double Barrier Option deal can be valued using the `DoubleBarrierOptionValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.1.28 Double Barrier Option].

40.6.3.6 Tuning Parameters and Valuation Settings

Max Iterations: The maximum number of terms in the truncation of infinite series used to value the option. See Section 37.3.8.3 for details.

Monitoring Period: The model exercises knock-in or knock-out on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Section 37.4.14 and the Theory Guide [7, § 4.1.30.1 Monitoring Dates].

Tolerance: The tolerance at which to truncate the infinite series used to value the option. See Section 37.3.8.3 for details.

40.6.3.7 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.6.3.8 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

40.6.4 Commodity One Touch Option

40.6.4.1 Overview

This deal type is for one-touch options on an underlying commodity price. The barrier monitoring frequency may be specified. The option pays a fixed amount conditional on barrier touching; the payment timing may be either upon touching or at expiry.

The deal is always settled for net value with a single cashflow in the payoff currency.

40.6.4.2 Price Factor Dependency

Commodity One Touch Option

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.6.4.3 Properties

See Section 40.1.1 for descriptions of the common properties of this deal.

40.6.4.4 Deal Representation

The Commodity One Touch Option is an atomic deal.

40.6.4.5 Valuation

In Adaptiv Analytics an Commodity One Touch Option deal can be valued using the `TouchOption-Valuation` model. For details about the valuation for this deal, see Theory Guide [7, § 4.1.27.1 [One-Touch and No-Touch Options and Rebates](#)].

40.6.4.6 Tuning Parameters and Valuation Settings

Monitoring Period: The model exercises knock-in or knock-out on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Section 37.4.14 and the Theory Guide [7, § 4.1.30.1 [Monitoring Dates](#)].

40.6.4.7 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.6.4.8 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

40.6.5 Commodity No Touch Option

40.6.5.1 Overview

This deal type is for no-touch options on an underlying commodity price. The barrier monitoring frequency may be specified. The option pays a fixed amount at expiry conditional on no barrier touching during the life of the option.

The deal is always settled for net value with a single cashflow in the payoff currency.

40.6.5.2 Price Factor Dependency

Commodity No Touch Option

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.6.5.3 Properties

See Section 40.1.1 for descriptions of the common properties of this deal.

40.6.5.4 Deal Representation

The Commodity No Touch Option is an atomic deal.

40.6.5.5 Valuation

In Adaptiv Analytics an Commodity No Touch Option deal can be valued using the `TouchOption-Valuation` model. For details about the valuation for this deal, see Theory Guide [7, § 4.1.27.1 [One-Touch and No-Touch Options and Rebates](#)].

40.6.5.6 Tuning Parameters and Valuation Settings

Monitoring Period: The model exercises knock-in or knock-out on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Section 37.4.14 and the Theory Guide [7, § 4.1.30.1 [Monitoring Dates](#)].

40.6.5.7 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.6.5.8 Limitations

See Section 38.1.3 for descriptions of the general commodity derivative limitations of this deal.

40.6.6 Commodity Double One Touch Option

40.6.6.1 Overview

This deal type is for double one-touch options on an underlying commodity price. The barrier monitoring frequency may be specified. The option pays fixed amounts conditional on barrier touching; the payment timing may be either upon touching or at expiry. Different payoffs may be specified for the upper and lower barriers.

The deal is always settled for net value with a single cashflow in the payoff currency.

40.6.6.2 Price Factor Dependency

Commodity Double One Touch Option

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.6.6.3 Properties

See Section 40.1.1 for descriptions of the common properties of this deal.

40.6.6.4 Deal Representation

The Commodity Double One Touch Option is an atomic deal.

40.6.6.5 Valuation

In Adaptiv Analytics an Commodity Double One Touch option deal can be valued using the `Double-TouchOptionValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.1.28.1 One-Touch and No-Touch Options and Rebates].

40.6.6.6 Tuning Parameters and Valuation Settings

Monitoring Period: The model exercises knock-in or knock-out on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Section 37.4.14 and the Theory Guide [7, § 4.1.30.1 Monitoring Dates].

40.6.6.7 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.6.6.8 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

40.6.7 Commodity Double No Touch Option

40.6.7.1 Overview

This deal type is for double no-touch options on an underlying commodity. The barrier monitoring frequency may be specified. The option pays fixed amounts conditional on neither barrier being touched during the life of the option.

40.6.7.2 Price Factor Dependency

Commodity Double No Touch Option

- └ Commodity Price (§ 4.4)
- └ Commodity Price / FX Rate Correlation (§ 12.2)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Volatility (§ 11.2.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.6.7.3 Properties

See Section 40.1.1 and Section 37.2 for descriptions of the common properties of this deal.

40.6.7.4 Deal Representation

The Commodity Double No Touch Option is an atomic deal.

40.6.7.5 Valuation

In Adaptiv Analytics a Commodity Double No Touch option deal can be valued using the `Double-TouchOptionValuation` model. For details about the valuation for this deal, see Section 37.3.8.2.

40.6.7.6 Tuning Parameters and Valuation Settings

Monitoring Period: The model exercises knock-in or knock-out on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Section 37.4.14 and the Theory Guide [7, § 4.1.30.1 [Monitoring Dates](#)].

40.6.7.7 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

40.6.7.8 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

40.6.8 Commodity Partial-Time Barrier Option

40.6.8.1 Overview

This deal type is for partial-time barrier options on an underlying commodity. In this type of option, the period over which the barrier is effective is a subset of the lifetime of the option. The barrier monitoring frequency may be specified.

Theory Guide [4.1.29](#)

Let t_1 denote the Barrier Limit Date, which must be before the option expiry date T . There are three types of partial-time barrier option.

Type A: Barrier At Start is Yes. The barrier period starts at the trade date and ends at t_1 . Up (down) options are knocked out or knocked in at the first date $t \leq t_1$ for which $S(t)$ is above (below) the barrier.

Type B1: Barrier At Start is No and Barrier Type is either In or Out. The barrier period starts at t_1 and ends at T . The option is knocked out or knocked in at the first date $t \geq t_1$ for which $S(t)$ touches the barrier (from either above or below). The asset price at the trade date may be either above or below the barrier.

Type B2: Barrier At Start is No and Barrier Type is either Down And In, Up And In, Down And Out or Up And Out. The barrier period starts at t_1 and ends at T . Up (down) options are knocked out or knocked in at the first date $t \geq t_1$ for which $S(t)$ is above (below) the barrier. Note that an up (down) option is triggered immediately at t_1 if $S(t_1)$ is above (below) the barrier.

40.6.8.2 Price Factor Dependency

Commodity Partial-Time Barrier Option

- └ Commodity Price (§ [4.4](#))
- └ Commodity Price / FX Rate Correlation (§ [12.2](#))
- └ Commodity Price Volatility (§ [11.2.6](#))
- └ Convenience Yield (§ [7.2](#))
- └ Discount Rate (§ [6.2](#))
- └ FX Volatility (§ [11.2.4](#))
- └ FX Rate (§ [4.2](#))
- └ Interest Rate (§ [6.1](#))

40.6.8.3 Properties

See Section [40.1.1](#) and Section [37.2](#) for descriptions of the common properties of this deal.

Barrier At Start: This represents whether the period over which the barrier is effective begins at the trade date. If Barrier At Start is set to **Yes** then the barrier is effective between Start Date and Barrier Limit Date. If Barrier At Start is set to **No**, then the barrier is effective from the Barrier Limit Date until the option Maturity date (T)

Barrier Limit Date: This represents the limit date of the barrier (t_1) and must be before the maturity of the option T . This is an input to determine the period over which the barrier is effective.

40.6.8.4 Deal Representation

The Commodity Partial-Time Barrier Option is an atomic deal.

40.6.8.5 Valuation

In Adaptiv Analytics a Commodity Partial-Time Barrier Option deal can be valued using the `Partial-TimeBarrierOptionValuation` model.

The valuation of this deal is described in Section [37.3.19](#).

40.6.8.6 Tuning Parameters and Valuation Settings

Monitoring Period: The model exercises knock-in or knock-out on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the Monitoring Period parameter. See Section [37.4.14](#) and the Theory Guide [[7](#), § [4.1.30.1 Monitoring Dates](#)].

40.6.8.7 Assumptions

See Section [40.1.2](#) for descriptions of the general commodity derivative assumptions of this deal.

40.6.8.8 Limitations

See Section [40.1.3](#) for descriptions of the general commodity derivative limitations of this deal.

40.7 Commodity Variance Swap Deal Types

40.7.1 Commodity Variance Swap

40.7.1.1 Overview

This deal type represents swaps on the variance of a commodity price.

40.7.1.2 Price Factor Dependency

Commodity Variance Swap

- └ Commodity Price (§ 4.4)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.7.1.3 Properties

See Section 40.1.1 for descriptions of the common properties of this deal.

Effective Date: The date at which the period of reference variance begins.

Maturity Date: The date at which the period of reference variance ends and the swap is settled.

Notional: The notional principal amount of the swap denominated in the settlement currency.

Number Of Returns: The number of discrete returns used to calculate the final reference variance. If set to zero, then Adaptiv Analytics calculates the number of returns.

Theory Guide 4.1.44

The number of returns n_0 is set to Number Of Returns if it is positive. Otherwise, Analytics calculates n_0 as follows. If the deal has a holiday calendar then $n_0 + 1$ is the number of business dates in the period $[T_0, T]$ (inclusive of T_0 and T). If the deal does not have a holiday calendar then $n_0 = 252(T - T_0)$.

Pay Receive: When set to Pay, the bank pays the fixed strike and receives the realized variance. When set to Receive, the bank receives the fixed strike and pays the realized variance.

Realized Variance: The sum of the squared log price returns up to the base calculation date. If left undefined, Adaptiv Analytics will calculate the realized variance from the rate fixings file.

Strike: The strike variance of the swap.

40.7.1.4 Deal Representation

The Commodity Variance Swap is an atomic deal.

40.7.1.5 Valuation

In Adaptiv Analytics an Commodity Variance Swap deal can be valued using the `CommodityVarianceSwapValuation` model. The pricing approach used that of in Demeterifi et al [20]. For details about the valuation for this deal, see Theory Guide [7, § 4.1.44 Variance and Volatility Swap].

Payoff: The variance swap payoff is given by

Theory Guide 4.1.44

The payoff of a variance swap on an asset price S is $100^2 N (\bar{\sigma}(T_0, T)^2 - K^2)$, where N is the notional amount, $\bar{\sigma}(T_0, T)$ is the realized volatility from the effective date T_0 to the maturity date T , and K is the strike price. For example, if $N = 10$, $K = 0.20$ and $\bar{\sigma} = 0.25$ at maturity then the payoff is $10(25^2 - 20^2) = 2250$.

Calculation of Realized Variance: The calculation of realized variance is given by

Theory Guide 4.1.44

The realized volatility becomes known at the maturity date and is given by

$$\bar{\sigma}(T_0, T)^2 = \frac{252}{n_0} \sum_{i=1}^n (\log S(t_i) - \log S(t_{i-1}))^2, \quad (40.7.1)$$

where t_0, t_1, \dots, t_n are the observation dates for the asset price between the effective date and the maturity date ($T_0 \leq t_0 < t_1 < \dots < t_n \leq T$), and n_0 is the number of returns expected at the effective date (based on the number of scheduled trading dates in the deal period).

Realized and Expected Variance: The reference variance of the swap is decomposed into the sum of realized past variance and expected future variance. Variance which is realized as of the base calculation date may be specified directly on the deal; if it is not, then Adaptiv Analytics will calculate it from the rate fixings file. Realized variance may be further decomposed into variance which is realized as of the base calculation date and variance which is realized during the course of simulation along scenario paths. The total reference variance is therefore the sum of actual historical variance, simulated historical variance, and expected future variance.

40.7.1.6 Tuning Parameters and Valuation Settings

Monitoring Period: The dates upon which the realized variance is calculated are determined from the Effective Date, Maturity Date and this Monitoring Period.

Number Of Strikes: The number of strikes used in the discrete approximation to the integral which gives the continuous time limit of the expectation of future variance. The default is 50. Higher numbers of strikes require more computation time.

40.7.1.7 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

Variances of Disjoint Periods are Independent: The variances of two non-overlapping periods are assumed to be independent, so that the total variance of two disjoint periods can be calculated by adding the variances of each period.

40.7.1.8 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

Discrete Approximation of the Continuous Time Integral: The valuation of a variance swap requires the calculation of the expectation of future variance. The Demeterifi approach is to express the continuous time limit of this expectation as an integral, and then calculate the integral with a discrete approximation.

No Reference Period Offsets: The period over which the reference variance is calculated runs from the effective date to the maturity date. There is no provision to offset the reference period from these dates.

40.7.2 Commodity Volatility Swap

40.7.2.1 Overview

This deal type represents swaps on the volatility of an commodity price.

40.7.2.2 Price Factor Dependency

Commodity Volatility Swap

- └ Commodity Price (§ 4.4)
- └ Commodity Price Volatility (§ 11.2.6)
- └ Convenience Yield (§ 7.2)
- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

40.7.2.3 Properties

See Section 40.1.1 for descriptions of the common properties of this deal.

Effective Date: The date at which the period of reference volatility begins.

Maturity Date: The date at which the period of reference volatility ends and the swap is settled.

Notional: The notional principal amount of the swap denominated in the settlement currency.

Number Of Returns: The number of discrete returns used to calculate the final reference volatility. If set to zero, then Adaptiv Analytics calculates the number of returns.

Theory Guide 4.1.44

The number of returns n_0 is set to Number Of Returns if it is positive. Otherwise, Analytics calculates n_0 as follows. If the deal has a holiday calendar then $n_0 + 1$ is the number of business dates in the period $[T_0, T]$ (inclusive of T_0 and T). If the deal does not have a holiday calendar then $n_0 = 252(T - T_0)$.

Pay Receive: When set to Pay, the bank pays the fixed strike and receives the realized volatility. When set to Receive, the bank receives the fixed strike and pays the realized volatility.

Realized Variance: The sum of the squared log price returns up to the base calculation date. If left undefined, Adaptiv Analytics will calculate the realized variance from the rate fixings file.

Strike: The strike volatility of the swap.

40.7.2.4 Deal Representation

The Commodity Volatility Swap is an atomic deal.

40.7.2.5 Valuation

In Adaptiv Analytics an Commodity Volatility Swap deal can be valued using the `CommodityVolatilitySwapValuation` model. The pricing approach used that of in Demeterifi et al [20]. For details about the valuation for this deal, see Theory Guide [7, § 4.1.44 Variance and Volatility Swap].

Payoff: The volatility swap payoff is given by

Theory Guide 4.1.44.2

A volatility swap is similar to a variance swap but the payoff is $100N(\bar{\sigma}(T_0, T) - K)$.

Calculation of Realized Volatility: The calculation of realized volatility is given by

Theory Guide 4.1.44

The realized volatility becomes known at the maturity date and is given by

$$\bar{\sigma}(T_0, T)^2 = \frac{252}{n_0} \sum_{i=1}^n (\log S(t_i) - \log S(t_{i-1}))^2, \quad (40.7.2)$$

where t_0, t_1, \dots, t_n are the observation dates for the asset price between the effective date and the maturity date ($T_0 \leq t_0 < t_1 < \dots < t_n \leq T$), and n_0 is the number of returns expected at the effective date (based on the number of scheduled trading dates in the deal period).

Realized and Expected Variance: The reference volatility of the swap is decomposed into the sum of realized past volatility and expected future volatility. Volatility which is realized as of the base calculation date may be specified directly on the deal; if it is not, then Adaptiv Analytics will calculate it from the rate fixings file. Realized volatility may be further decomposed into volatility which is realized as of the base calculation date and variance which is realized during the course of simulation along scenario paths. The total reference volatility is therefore the sum of actual historical volatility, simulated historical volatility, and expected future volatility.

40.7.2.6 Tuning Parameters and Valuation Settings

Monitoring Period: The dates upon which the realized volatility is calculated are determined from the Effective Date, Maturity Date and this Monitoring Period.

Number Of Strikes: The number of strikes used in the discrete approximation to the integral which gives the continuous time limit of the expectation of future volatility. The default is 50. Higher numbers of strikes require more computation time.

40.7.2.7 Assumptions

See Section 40.1.2 for descriptions of the general commodity derivative assumptions of this deal.

Variances of Disjoint Periods are Independent: The variances of two non-overlapping periods are assumed to be independent, so that the total variance of two disjoint periods can be calculated by adding the variances of each period.

40.7.2.8 Limitations

See Section 40.1.3 for descriptions of the general commodity derivative limitations of this deal.

Discrete Approximation of the Continuous Time Integral: The valuation of a volatility swap requires the calculation of the expectation of future volatility. The Demeterifi approach is to express the continuous time limit of this expectation as an integral, and then calculate the integral with a discrete approximation.

No Reference Period Offsets: The period over which the reference volatility is calculated runs from the effective date to the maturity date. There is no provision to offset the reference period from these dates.

Part VI

OTC Derivatives: Interest Rates

Chapter 41

Interest Rates

41.1 Fixed Rate Deposit

41.1.1 Overview

This deal type is for fixed rate deposits. The deal holder (the borrower) receives the principal amount at the effective date, pays fixed interest on the principal and pays the principal amount at the maturity date.

41.1.2 Price Factor Dependency

- Fixed Rate Deposit
 - └ FX Rate (§ 4.2)
 - └ Discount Rate (§ 6.2)
 - └ Interest Rate (§ 6.1)

41.1.3 Properties

Currency

ID of the settlement currency. For example, USD.

Discount Rate

ID of the interest rate price factor (or discount rate price factor) used to discount the cashflows. For example, USD.AAA. The currency of the interest rate price factor must be the settlement currency. If left blank, the ID of the settlement currency is used.

Accrual Calendars

Specifies one or more holiday calendars used when calculating accrual dates and accrual year fractions. If not provided then all calendar days are business days and dates are not adjusted.

Payment Calendars

Specifies one or more holiday calendars used when calculating the payment dates. If not provided then all calendar days are business days and dates are not adjusted.

Accrual Day Count

Day count convention used to calculate the accrual year fractions. See Section 3.3.4 for more information about day counts in Adaptiv Analytics.

Accrual Adjustment Method

Date adjustment method for accrual dates. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

First Coupon Date

Unadjusted first coupon date.

Penultimate Coupon Date

Unadjusted penultimate coupon date.

Roll Convention

Roll convention used when generating payment and accrual dates. See Section 3.3.6 for more information about roll conventions in Adaptiv Analytics.

Roll Day Of Month

Day of month for roll convention Day Of Month. For example, enter 28 for the 28th day of the month.

Roll Direction

Forward or Backward. Roll direction used when generating payment and accrual dates.

Amortisation

Amortisation schedule consisting of a list of (Date, Amount) pairs, where the Amount is the amount by which the principal amount is reduced at the Date. An increase in principal amount is represented by a negative Amount.

Effective Date

Unadjusted deal start date.

Effective Date Adjustment Method

Date adjustment method for the effective date. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

Maturity Date

Unadjusted deal end date.

Maturity Date Adjustment Method

Date adjustment method for the maturity date. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

Payment Frequency

Frequency of the payments. If set to 0M then there is a single payment.

Interest Frequency

Frequency of the interest accrual periods. If set to 0M then the payment frequency is used. Compounding deals have Interest Frequency less than the payment frequency.

Payment Timing

Begin, End or Discounted. Timing of interest payments. Either at end of interest accrual period (End), start of interest accrual period (Begin), or start of interest accrual period with discounting (Discounted).

Payment Adjustment Method

Date adjustment method for payment dates. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

Payment Offset

Number of business days between the accrual and payment dates.

Compounding

Yes or No. Set to Yes for compounding of fixed interest.

Rate Currency

ID of the currency of the fixed interest rate. For example, USD. If left blank, the currency of the rate is the settlement currency.

FX Reset Offset

Offset used to calculate the FX reset dates. For each cashflow, the FX reset date is calculated by subtracting FX Reset Offset business days from cashflow's payment date.

Known FX Rates

List of reset dates and corresponding known FX rates. FX rates are entered as number of units of settlement currency per unit of interest rate currency.

Use Initial Stub Rate

Yes or No. Set to Yes to apply Initial Stub Rate.

Initial Stub Rate

Fixed rate for initial stub accrual period. Entered as a decimal or as a percentage. For example, enter 5% or 0.05 for 5%.

Use Final Stub Rate

Yes or No. Set to Yes to apply Final Stub Rate.

Final Stub Rate

Fixed rate for final stub accrual period. Entered as a decimal or as a percentage. For example, enter 5% or 0.05 for 5%.

Amount

Principal amount in units of settlement currency.

Interest Rate

Fixed interest rate. Rates are entered in percentage. For example, enter 5 for 5%.

Interest Rate Schedule

List of fixed rates and corresponding dates. Each item in the schedule is allocated to the cashflow with Accrual Start Date closest to the item's date, unless the cashflow has already been allocated an item with a closer date. If a cashflow is allocated an item in the schedule then the cashflow Rate is set to the item's value, otherwise the cashflow Rate is set the Interest Rate on the deal. Rates in the schedule are entered in percentage. For example, enter 5 for 5%.

41.1.4 Deal Representation

The Fixed Rate Deposit is a deal skin that builds into a Fixed Interest Cashflow List deal. See the Deal Skins Guide [2]. For details about the generation of the cashflow list deals, see the Theory Guide [7, § 4.3.19 Fixed Rate Loan and Deposit, § 4.3.18 Fixed Swap Leg and § 1.3 Date Generation].

41.1.5 Valuation

The Fixed Rate Deposit deal is valued using the DealSkinValuation model, under which the value of deal is the value of the underlying Fixed Interest Cashflow List deal (§ 42.1).

41.2 Fixed Rate Loan

41.2.1 Overview

This deal type is for fixed rate loans. The deal holder (the lender) pays the principal amount at the effective date, receives fixed interest on the principal and receives the principal amount at the maturity date.

41.2.2 Price Factor Dependency

Fixed Rate Loan

- └ FX Rate (§ 4.2)
- └ Discount Rate (§ 6.2)
- └ Interest Rate (§ 6.1)

41.2.3 Properties

The Fixed Rate Loan deal has the same properties as the Fixed Rate Deposit deal (§ 41.1).

41.2.4 Deal Representation

The Fixed Rate Loan is a deal skin that builds into a Fixed Interest Cashflow List deal. See the Deal Skins Guide [2]. For details about the generation of the cashflow list deals, see the Theory Guide [7, § 4.3.19 Fixed Rate Loan and Deposit, § 4.3.18 Fixed Swap Leg and § 1.3 Date Generation].

41.2.5 Valuation

The Fixed Rate Loan deal is valued using the `DealSkinValuation` model, under which the value of deal is the value of the underlying Fixed Interest Cashflow List deal (§ 42.1).

41.3 Cap/Floor

41.3.1 Overview

A Cap/Floor deal is a series of call/put options on an underlying interest rate. The Cap/Floor deal type can be used for average rate, CMS and quanto caps/floors.

41.3.2 Price Factor Dependency

Cap/Floor

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Rate / Interest Rate Correlation (§ 12.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)
- └ Interest Rate / Interest Rate Correlation (§ 12.2)
- └ Interest Rate Volatility (§ 11.3.4)
- └ Interest Yield Volatility (§ 11.3.5)

41.3.3 Properties

Currency

ID of the settlement currency. For example, USD.

Discount Rate

ID of the interest rate price factor (or discount rate price factor) used to discount the cashflows. For example, USD.AAA. The currency of the interest rate price factor must be the settlement currency. If left blank, the ID of the settlement currency is used.

Discount Rate Volatility

ID of the interest rate volatility price factor or interest yield volatility price factor used for the volatility of the discount rate. Examples, USD, USD.BBB, USD.CAPVOLATILITY. If left blank, the ID of the settlement currency is used.

Accrual Calendars

Specifies one or more holiday calendars used when calculating accrual dates and accrual year fractions. If not provided then all calendar days are business days and dates are not adjusted.

Payment Calendars

Specifies one or more holiday calendars used when calculating the payment dates. If not provided then all calendar days are business days and dates are not adjusted.

Index Calendars

Specifies one or more holiday calendars used when calculating rate start dates, rate end dates and rate year fractions. If not provided then all calendar days are business days and dates are not adjusted.

Index Publication Calendars

Specifies one or more holiday calendars used when calculating the rate reset date from the accrual date and index offset. If not provided then all calendar days are business days and dates are not adjusted.

Forecast Rate

ID of the interest rate price factor used to calculate forward interest rates. For example, USD.AAA.

If left blank, the discount interest rate price factor is used. The payoff is quanto when the currency of the forecast interest rate price factor is different from the settlement currency of the deal.

Forecast Rate Volatility

ID of the interest rate volatility price factor or interest yield volatility price factor used for the volatility of the forecast rate. Examples, USD, USD.BBB, USD.CAPVOLATILITY. If left blank, the ID of the forecast rate currency is used.

Buy Sell

Buy or Sell. Determines whether the holder is long (Buy) or short (Sell) the cap/floor.

Effective Date

Unadjusted deal start date.

Effective Date Adjustment Method

Date adjustment method for the effective date. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

Maturity Date

Unadjusted deal end date.

Maturity Date Adjustment Method

Date adjustment method for the maturity date. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

Principal

Principal amount in units of settlement currency.

Amortisation

Amortisation schedule consisting of a list of (Date, Amount) pairs, where the Amount is the amount by which the principal amount is reduced at the Date. An increase in principal amount is represented by a negative Amount.

Payment Timing

Begin, End or Discounted. Timing of interest payments. Either at end of interest accrual period (End), start of interest accrual period (Begin), or start of interest accrual period with discounting (Discounted).

Payment Adjustment Method

Date adjustment method for payment dates. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

Payment Offset

Number of business days between the accrual and payment dates.

Accrual Day Count

Day count convention used to calculate the accrual year fractions. See Section 3.3.4 for more information about day counts in Adaptiv Analytics.

Accrual Adjustment Method

Date adjustment method for accrual dates. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

First Coupon Date

Unadjusted first coupon date.

Penultimate Coupon Date

Unadjusted penultimate coupon date.

Roll Convention

Roll convention used when generating payment and accrual dates. See Section 3.3.6 for more information about roll conventions in Adaptiv Analytics.

Roll Day Of Month

Day of month for roll convention Day Of Month. For example, enter 28 for the 28th day of the month.

Roll Direction

Forward or Backward. Roll direction used when generating payment and accrual dates.

Reset Type

Standard, Advance or Arrears. Timing of the rate fixing. Either at the start of the accrual period (Standard), or at the end of the accrual period (Arrears), or at the start of the previous accrual period (Advance).

Index Tenor

Floating rate tenor. If set to 0M then the interest frequency is used.

Index Day Count

Day count convention used to calculate the floating rate year fractions. Set to either the day count convention of the money-market (LIBOR) rate or the fixed-side day count convention of the swap (CMS) rate. See Section 3.3.4 for more information about day counts in Adaptiv Analytics.

Index Frequency

Fixed side frequency of the swap (CMS) rate. The floating rate is a swap rate when the Index Frequency is greater than 0M and less than the Index Tenor.

Index Offset

Number of business days between the rate reset and rate start dates.

Index Adjustment Method

Date adjustment method used to calculate rate end dates. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

Known Rates

List of reset dates and corresponding known interest rates. Rates are entered in percentage. For example, enter 5 for 5%.

Rate Fixing

ID used to obtain a rate fixing value. For example, USD.LIBOR,3M. If left blank defaults to Forecast Rate,Index Tenor. Written to the Rate Fixing property of the cashflows in the floating interest cashflow list when the deal is built.

Payment Interval

Frequency of the payments. If set to 0M then there is a single payment.

Reset Frequency

Frequency of the rate observations. If set to 0M then the interest frequency is used. Averaging deals have Reset Frequency less than the interest frequency.

Averaging Method

Average Interest or Average Rate. Type of payoff for interest rate products with averaging: average of payoffs (Average Interest) or payoff on average rate (Average Rate). Used when Reset Frequency is less than the interest frequency.

Cap/Floor Rate

Cap/floor strike rate. Rates are entered in percentage. For example, enter 5 for 5%.

Cap/Floor Rate Schedule

List of cap/floor strike rates and corresponding dates. Each item in the schedule is allocated to the cashflow with `Accrual Start Date` closest to the item's date, unless the cashflow has already been allocated an item with a closer date. If a cashflow is allocated an item in the schedule then the cashflow `Cap/Floor Strike` is set to the item's value, otherwise the cashflow `Cap/Floor Strike` is set the `Cap/Floor Rate` on the deal. Rates in the schedule are entered in percentage. For example, enter 5 for 5%.

41.3.4 Deal Representation

The Cap/Floor deal is a deal skin that builds into a Floating Interest Cashflow List deal. See the Deal Skins Guide [2]. For details about the generation of the cashflow list deals, see the Theory Guide [7, § 4.3.31 [Cap, Floor and Collar](#), § 4.3.22 [Floating Swap Leg](#) and § 1.3 [Date Generation](#)].

41.3.5 Valuation

The Cap/Floor deal is valued using the `DealSkinValuation` model, under which the value of deal is the value of the underlying Floating Interest Cashflow List deal (§ 42.2).

41.4 Digital Cap/Floor

41.4.1 Overview

A Digital Cap/Floor deal is a series of digital call/put options on an underlying interest rate. The Digital Cap/Floor deal type can be used for average rate, CMS and quanto digital caps/floors.

41.4.2 Price Factor Dependency

Digital Cap/Floor

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Rate / Interest Rate Correlation (§ 12.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)
- └ Interest Rate / Interest Rate Correlation (§ 12.2)
- └ Interest Rate Volatility (§ 11.3.4)
- └ Interest Yield Volatility (§ 11.3.5)

41.4.3 Properties

The Digital Cap/Floor deal has all the properties of the Cap/Floor deal (§ 41.3) and two additional properties used to define the digital payoff:

Digital Payoff

Digital payoff amount.

Digital Payoff Rate

Digital payoff rate. Entered as a decimal or as a percentage. For example, enter 5% or 0.05 for 5%.

41.4.4 Deal Representation

The Digital Cap/Floor deal is a deal skin that builds into a Floating Interest Cashflow List deal. See the Deal Skins Guide [2]. For details about the generation of the cashflow list deals, see the Theory Guide [7, § 4.3.32 Digital Cap and Floor, § 4.3.22 Floating Swap Leg and § 1.3 Date Generation].

41.4.5 Valuation

The Digital Cap/Floor deal is valued using the `DealSkinValuation` model, under which the value of deal is the value of the underlying Floating Interest Cashflow List deal (§ 42.2).

41.5 FRA

41.5.1 Overview

This deal type is for forward rate agreements.

41.5.2 Price Factor Dependency

FRA

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

41.5.3 Properties

For an overview and description of the properties of the deal, see the deal definition in the Integrated documentation [4, Portfolio: FRA].

41.5.4 Deal Representation

The FRA is an atomic deal.

41.5.5 Valuation

For details about the valuation for this deal, see the Theory Guide [7, § 4.3.2.3 FRA].

FRA are often quoted in terms such as 3x6 or 1x4, where the first term corresponds to the effective date and the second term to the maturity date. In Adaptiv Analytics, these 2 dates must be specified explicitly. Together with optional calendar and optional date adjustment methods, they allow for precise date generation for the accrual start, accrual end date, rate start date and rate end date.

The deal either pays at the beginning or at the end of the accrual period and there are three payoff variants.

Theory Guide 4.3.2.3

If the payment timing is Begin then the payment date is T_1 and the discounting method can be either ISDA, ISDA Yield or None. If the payment timing is End then the payment date is T_2 and the discounting method must be None.

Theory Guide 4.3.2.3

If the payment timing is Begin and the discounting method is ISDA then the settlement cashflow is

$$\frac{\delta P(L(t_0) - K)\alpha}{1 + L(t_0)\alpha} \quad (41.5.1)$$

at T_1 , where P is the principal amount, K is the FRA Rate, and either $\delta = 1$ for a Borrower deal or $\delta = -1$ for a Lender deal. The value of the FRA at valuation date t is

$$\frac{\delta P(L(t \wedge t_0) - K)\alpha D(t, T_1)}{1 + L(t \wedge t_0)\alpha} [t \leq T_1]. \quad (41.5.2)$$

If the payment timing is Begin and the discounting method is ISDA Yield then the settlement cashflow is

$$\delta P \left(\frac{1}{1 + K\alpha} - \frac{1}{1 + L(t_0)\alpha} \right) = \frac{\delta P(L(t_0) - K)\alpha}{(1 + L(t_0)\alpha)(1 + K\alpha)} \quad (41.5.3)$$

at T_1 , which is the ISDA-method payoff divided by the constant factor $1 + K\alpha$.

If the payment timing is Begin and the discounting method is None then the settlement cashflow is $\delta P(L(t_0) - K)\alpha$ at T_1 . The value of the FRA at valuation date t is $\delta P(L(t \wedge t_0) - K)\alpha D(t, T_1) [t \leq T_1]$.

If the payment timing is End then the settlement cashflow is $\delta P(L(t_0) - K)\alpha$ at T_2 . The value of the FRA at valuation date t is $\delta P(L(t \wedge t_0) - K)\alpha D(t, T_2) [t \leq T_2]$.

Unlike most other interest rate deals, which pay interest at the end of the accrual period, standard FRAs pay a settlement amount at the start of the accrual period. ISDA specifies that for a FRA settled before the end of the accrual period, the settlement amount need to be "discounted", rendering the contract equivalent to a FRA paid in arrears. More specifically, the settlement amount is adjusted by the interest that would have been earned if the settlement amount was invested at the start of the accrual period and paid at the end. Adaptiv Analytics supports 2 adjustment methods: ISDA and ISDA Yield corresponding to 2006 ISDA Definitions "FRA Discounting" and "FRA Yield Discounting". For example, Standard FRAs are defined by setting Payment Timing = Begin, by setting Discounting Method = ISDA or Discounting Method = ISDA Yield according to the market convention of the deal currency. For AUD and NZD, the market convention is Discounting Method = ISDA Yield.

Some FRAs pay a settlement amount at the end of accrual period with the floating rate resetting at the start of the accrual period. This corresponds to the natural time lag for the rate so no adjustment to the settlement amount is needed, and is defined by setting Payment Timing = End and Discounting Method = None. The present value is the discounted difference between the fixed and floating rate scaled by the principal amount.

41.5.6 Tuning Parameters and Valuation Settings

41.5.6.1 Settlement Offset

This functionality has been implemented for the LCH fire drill.

Theory Guide 4.3.17.1

If the valuation model parameter Use Settlement Offset is Yes then the valuation model ignores cashflows with payment date before the settlement date t_s , where s is the Settlement Offset, t_s is calculated by adding $s + 1$ business days to the base valuation date, and addition of business days is with respect to the holiday calendar defined by Settlement Offset Calendars.

The settlement offset s is usually either 0, 1 or 2 and cannot be negative. In the case $s = 0$, the settlement date is the business day following the base valuation date, and hence cashflows on the base valuation date are ignored.

41.5.6.2 Cashflow Rounding

Cashflow rounding should be set in accordance with the market convention.

Theory Guide 4.3.17.2

If the valuation model parameter Cashflow Rounding is Nearest or Next Lower then rounding is applied to each cashflow amount.

41.5.7 Assumptions

41.5.7.1 Cashflow Discounting

The valuation relies on the fair value assumption ie the deal value is the value of discounted cash-flow.

41.5.7.2 Reset Date and Known Rate

If the reset date is before the calculation base date, the floating rate has already been fixed and the cashflow is no longer stochastic. In this case, the floating rate is determined as:

Theory Guide [4.3.2.3](#)

If $t_0 \leq 0$ and Use Known Rate is Yes then $L(t_0) = R$, where R is the Known Rate. Suppose $t_0 \leq 0$ and Use Known Rate is No. If an interest rate fixing R is available for the fixing ID (Rate Fixing) at date t_0 (see Section [1.7](#)) then $L(t_0) = R$. Otherwise $L(t_0) = (D_f(0, t_1 - t_0) / D_f(0, t_2 - t_0) - 1) / \alpha_2$.

41.5.7.3 Index Tenor Unspecified

Theory Guide [4.3.2.3](#)

Let τ denote the index tenor and I denote the index adjustment method. The rate start date t_1 and rate end date t_2 are given by $t_1 = T_1$ and $t_2 = (t_1 + \tau)(I_{\mathcal{H}})$ when $\tau > 0$ d, or otherwise $t_2 = T_2$.

41.5.7.4 Reset Date Unspecified

Theory Guide [4.3.2.3](#)

If the reset date t_0 is not specified on the deal then $t_0 = t_1$.

41.5.8 Limitations

41.5.8.1 Convexity Correction

In Adaptiv Analytics, the FRA valuation is model independent; it relies on discounting the settlement amount back to the valuation date. There is no support for convexity correction.

The accrual period and the rate period as well as the payment timing are all specified independently in Adaptiv Analytics. It is therefore possible to configure a FRA deal that should attract a convexity correction; for example, when the accrual period and rate period don't match or when the FRA payment is at the beginning of the accrual period and there is no adjustment to the settlement amount. This convexity correction term would depend on the particular choice of diffusion for the underlying rate and would increase as the rate end date and payment date diverge.

Chapter 42

Interest Cashflow Lists

42.1 Fixed Interest Cashflow List

42.1.1 Overview

This deal has a list of fixed interest cashflows. The deal buyer receives the cashflows in the list.

42.1.2 Price Factor Dependency

Fixed Interest Cashflow List

- └ FX Rate (§ 4.2)
- └ Discount Rate (§ 6.2)
- └ Interest Rate (§ 6.1)
- └ Recovery Rate (§ 9.3)
- └ Survival Probability (§ 9.1)

42.1.3 Properties

Currency

ID of the settlement currency. For example, USD.

Discount Rate

ID of the interest rate price factor (or discount rate price factor) used to discount the cashflows. For example, USD.AAA. The currency of the interest rate price factor must be the settlement currency. If left blank, the ID of the settlement currency is used.

Buy Sell

Buy or Sell. Determines whether the cashflows in the list are received (Buy) or paid (Sell).

Cashflows

List of fixed interest cashflows and properties of the cashflow list.

Items

List of fixed interest cashflows.

Notional

Notional principal amount in units of settlement currency.

Rate

Fixed interest rate. Entered as a decimal or as a percentage. For example, enter 5% or 0.05 for 5%.

Accrual Start Date

Start of the period over which interest is accrued.

Accrual End Date

End of the period over which interest is accrued.

Accrual Day Count

Day count convention used to calculate the accrual year fraction when `Accrual Year Fraction` is zero. See Section 3.3.4 for more information about day counts in Adaptiv Analytics.

Accrual Year Fraction

Year fraction from `Accrual Start Date` to `Accrual End Date`.

Fixed Amount

Fixed amount added to the interest amount.

Discounted

Yes or No. Set to Yes for a discounted cashflow payoff.

FX Reset Date

Observation date for FX rate. Used when the rate currency is different from the settlement currency and `Known FX Rate` is zero.

Known FX Rate

The cashflow payoff is multiplied by `Known FX Rate` when the rate currency is different from the settlement currency and `Known FX Rate` is positive.

Payment Date

Cashflow payment date.

Compounding

Yes or No. Set to Yes for compounding of the fixed interest.

Description

Deal description. If a Description is specified then the deal Summary is set to this Description.

Rate Currency

ID of the currency of the fixed interest rate. For example, USD. If left blank, the currency of the rate is the settlement currency.

Calendars

Specifies one or more holiday calendars used when calculating accrued interest and accrual year fractions. If not provided then all calendar days are business days and dates are not adjusted.

Issuer

ID of the issuer and the ID of the credit rating price factor. For example, IBM.

Survival Probability

ID of the survival probability price factor. For example, IBM or IBM.SENIOR. If left blank, the ID of the issuer or name is used.

Recovery Rate

ID of the recovery rate price factor. For example, BOND. If left blank, the ID of the issuer or name is used.

Repo Rate

ID of the repo interest rate price factor. For example, USD.AAA. The currency of the interest rate price factor must be the settlement currency. If left blank, the discount interest rate price factor is used.

Settlement Date

Settlement date for a forward deal on the cashflow list.

Settlement Amount

Amount settled at the Settlement Date for a forward deal on the cashflow list.

Settlement Style

Cash or Physical. Settlement method for a forward deal on the cashflow list: cash settled (Cash) or deliver the underlying cashflows (Physical). The deal must have a Settlement Date when Settlement Style is Cash.

Settlement Amount Is Clean

Yes or No. Set to Yes if the Settlement Amount excludes accrued interest. Set to No if the Settlement Amount includes accrued interest.

Is Defaultable

Yes or No. Set to No to discount the net forward value with the Repo Rate for forward deals. Set to Yes to discount only the settlement cashflow with the Repo Rate and add it to the present value of the risky-discounted bond cashflows. Used when the deal has a Settlement Date.

Investment Horizon

End date for the deal's exposure profile.

Missing Cashflow Properties: If the Fixed Interest Cashflow List deal is entered in the system directly, rather than being built from a deal skin, the cashflow-level Accrual Year Fraction values can be omitted, in which case they are calculated from the cashflow-level Accrual Day Count and the deal's holiday calendar, as described in Theory Guide [7, § 1.5 Missing Cashflow Dates and Year Fractions].

42.1.4 Deal Representation

The Fixed Interest Cashflow List is an atomic deal.

42.1.5 Valuation

For details of the valuation model, see the Theory Guide [7, § 4.3.4 Fixed and Floating Interest Cashflow List, § 4.3.5 Fixed Interest Cashflow and § 4.3.6 Fixed Interest Cashflow List with Compounding].

The value of a fixed interest cashflow is the cashflow payoff multiplied by the discount factor at the cashflow payment date. The discount factor comes from the interest rate price factor specified by the Discount Rate.

A forward bond deal builds into a 'forward' Fixed Interest Cashflow List deal, with a Settlement Date and Settlement Amount. The model supports valuation of cash-settled and physically-settled forward deals.

The model supports fixed interest cashflows where the fixed interest is compounded at the fixed rate.

The model also supports discounted cashflows, where the cashflow payoff is discounted at the fixed rate, and usually paid at the start of the accrual period.

42.1.6 Tuning Parameters and Valuation Settings

Use Settlement Offset, Settlement Offset, Settlement Offset Calendars: When Use Settlement Offset is Yes, defines a settlement date such that cashflows with payment date before the settlement date are ignored by the valuation model. Use Settlement Offset defaults to No. Used to match LCH Fire Drill valuations. See the Theory Guide [7, § 4.3.17.1 Settlement Offset].

Cashflow Rounding: Nearest, Next Lower or None. Rounding method applied to each cashflow amount. Defaults to None. See the Theory Guide [7, § 4.3.17.2 [Cashflow Rounding](#)].

Exclude Principal Cashflows: Yes or No. Set to Yes to make the valuation model ignore all principal cashflows, which are represented by Fixed Amount values on the interest cashflows. Defaults to No. Used when calculating sensitivities for SIMM. See the Theory Guide [7, § 4.3.17.3 [Exclude Principal Cashflows](#)].

Use Survival Probability: Yes or No. Set to Yes to allow the valuation model to take account of default of the underlying issuer or counterparty (Issuer) at a future date (after the valuation date). Defaults to No. See the Theory Guide [7, § 4.3.4.1 [Valuation using Survival Probability](#)].

Respect Default: Yes or No. Set to Yes to allow the valuation model to value the deal when the underlying issuer or counterparty (Issuer) has defaulted. Defaults to No. See the Theory Guide [7, § 4.3.4.2 [Valuation at Default](#)].

Dynamic Dates Grid: An optional grid, e.g. 1d 1w 1m(1m) 3m(3m), used to calculate dates on the valuation profile. Defaults to no grid. Use a grid for faster (but less accurate) calculation of exposure profiles for cashflow list deals with many payment dates. See the Theory Guide [7, § 4.3.4.4 [Dynamic Dates Grid](#)].

42.1.7 Assumptions

For the valuation of 'risky' cashflow list deals (Use Survival Probability is Yes), the usual assumptions are made when calculating the value of the payment at default. The value of the deal at default (Respect Default is Yes) is the outstanding principal amount multiplied by the recovery rate from the recovery rate price factor. See Theory Guide [7, § 4.3.4 [Fixed and Floating Interest Cashflow List](#)].

42.2 Floating Interest Cashflow List

42.2.1 Deal

42.2.1.1 Overview

This deal has a list of generalized floating interest cashflows. The deal buyer receives the cashflows in the list.

Theory Guide [4.3.7](#)

A floating interest cashflow has a generalized payoff which is linear combination of a swaplet, a caplet and a floorlet on the same reference rate. The reference rate is either a simply-compounded (LIBOR) rate or swap (CMS) rate. Reverse floater payoffs can be defined using the cashflow's rate multiplier and rate constant. Caplets and floorlets can have an upper and/or lower barrier, or a digital payoff. The cashflow is quanto when the forecast rate currency not the same as settlement currency.

Some examples of floating interest cashflows are:

- a swaplet with a fixed margin rate
- a reverse floater swaplet with an embedded floor on the reverse rate
- a digital caplet
- a quanto CMS caplet.

A Floating Interest Cashflow List deal can be valued using either the standard valuation model (`CFFloatingInterestListValuation`) or the Hull-White valuation model (`CapHullWhiteValuation`).

42.2.1.2 Deal Representation

The Floating Interest Cashflow List is an atomic deal.

42.2.1.3 Properties

Currency

ID of the settlement currency. For example, USD.

Discount Rate

ID of the interest rate price factor (or discount rate price factor) used to discount the cashflows. For example, USD.AAA. The currency of the interest rate price factor must be the settlement currency. If left blank, the ID of the settlement currency is used.

Buy Sell

Buy or Sell. Determines whether the cashflows in the list are received (Buy) or paid (Sell).

Cashflows

List of floating interest cashflows and properties of the cashflow list.

Items

List of floating interest cashflows.

Notional

Notional principal amount in units of settlement currency.

Accrual Start Date

Start of the period over which interest is accrued.

Accrual End Date

End of the period over which interest is accrued.

Accrual Day Count

Day count convention used to calculate the accrual year fraction when `Accrual Year Fraction` is zero. See Section 3.3.4 for more information about day counts in Adaptiv Analytics.

Accrual Year Fraction

Year fraction from `Accrual Start Date` to `Accrual End Date`.

Resets

List of floating rate resets.

Reset Date

Observation date for floating rate.

Rate Start Date

Start of floating rate period.

Rate End Date

End of floating rate period.

Rate Year Fraction

Year fraction from `Rate Start Date` to `Rate End Date`.

Rate Tenor

Floating rate tenor.

Rate Day Count

Day count convention used to calculate the rate year fraction when `Rate Year Fraction` is zero. Set to either the day count convention of the money-market (LIBOR) rate or the fixed-side day count convention of the swap (CMS) rate. See Section 3.3.4 for more information about day counts in Adaptiv Analytics.

Rate Frequency

Fixed side frequency of the swap (CMS) rate. The floating rate is a swap rate when the `Rate Frequency` is greater than 0M and less than the `Rate Tenor`.

Rate Fixing

ID used to obtain a rate fixing value. For example, USD.LIBOR,3M.

Use Known Rate

Yes or No. Set to Yes if the floating interest rate is known.

Known Rate

Known rate used when `Use Known Rate` is Yes. Entered as a decimal or as a percentage. For example, enter 5% or 0.05 for 5%.

Weight

Weight assigned to rate observation. Defaults to 1.

Margin

Margin rate added to the floating interest rate. Entered in basis points. For example, enter 50 bp or 0.005 for 50 basis points.

Fixed Amount

Fixed amount added to the interest amount.

FX Reset Date

Observation date for FX rate. Used when the forecast rate currency is different from the settlement currency and `Known FX Rate` is zero.

Known FX Rate

The cashflow payoff is multiplied by `Known FX Rate` when the forecast rate currency is different from the settlement currency and `Known FX Rate` is positive.

Rate Rounding

Number of decimal places to use when rounding the cashflow's rate or average rate in percentage points. The rate is not rounded when `Rate Rounding` is zero.

Payment Date

Cashflow payment date.

Compounding Method

None, Include Margin, Flat, Exclude Margin or Exponential. Compounding method for cashflow lists built from floating swap legs with payment frequency greater than interest frequency.

Averaging Method

Average Interest or Average Rate. Averaging method for cashflow lists built from floating swap legs with reset frequency less than interest frequency: average of payoffs (`Average Interest`) or payoff on average rate (`Average Rate`).

Properties

List of floating interest cashflow properties.

First Cashflow Index

Index of the first cashflow to which these properties apply. The cashflow properties apply to all cashflows with zero-based index greater than or equal to `First Cashflow Index`, and less than the `First Cashflow Index` of the next item, when there is one. For example, if the list of cashflow properties has two items with `First Cashflow Index` 0 and 2 then: the first item applies to the cashflows with index 0 and 1, and the second item applies to the cashflows with index greater than or equal to 2.

Digital Payoff

Digital payoff amount.

Digital Payoff Rate

Digital payoff rate. Entered as a decimal or as a percentage. For example, enter 5% or 0.05 for 5%.

Rate Constant

Fixed rate added to floating interest rate. Entered as a decimal or as a percentage. For example, enter 5% or 0.05 for 5%.

Rate Multiplier

Multiplier for the floating interest rate. Defaults to 1.

Swap Multiplier

Scaling factor for swaplet payoff. Defaults to 1.

Cap Multiplier

Scaling factor for caplet payoff.

Cap Strike

Cap strike rate. Entered as a decimal or as a percentage. For example, enter 5% or 0.05 for 5%.

Floor Multiplier

Scaling factor for floorlet payoff.

Floor Strike

Floor strike rate. Entered as a decimal or as a percentage. For example, enter 5% or

0.05 for 5%.

Use Cap Lower Barrier

Yes or No. Set to Yes to apply Cap Lower Barrier. When set to No, the lower barrier is Cap Strike.

Cap Lower Barrier

Lower barrier rate for the caplets. Entered as a decimal or as a percentage. For example, enter 5% or 0.05 for 5%.

Use Cap Upper Barrier

Yes or No. Set to Yes to apply Cap Upper Barrier. When set to No, there is no upper barrier.

Cap Upper Barrier

Upper barrier rate for the caplets. Entered as a decimal or as a percentage. For example, enter 5% or 0.05 for 5%.

Use Floor Lower Barrier

Yes or No. Set to Yes to apply Floor Lower Barrier. When set to No, there is no lower barrier.

Floor Lower Barrier

Lower barrier rate for the floorlets. Entered as a decimal or as a percentage. For example, enter 5% or 0.05 for 5%.

Use Floor Upper Barrier

Yes or No. Set to Yes to apply Floor Upper Barrier. When set to No, the upper barrier is Floor Strike.

Floor Upper Barrier

Upper barrier rate for the floorlets. Entered as a decimal or as a percentage. For example, enter 5% or 0.05 for 5%.

Exponential Multiplier

Multiplier used in the exponential compounding method. Defaults to 100%. Entered as a decimal or as a percentage. For example, enter 110% or 1.1 for 110%.

Exponential Margin

Margin rate used in the exponential compounding method. Entered in basis points. For example, enter 50 bp or 0.005 for 50 basis points.

Exponential Exponent

Exponent used in the exponential compounding method.

Discounted

Yes or No. Set to Yes for a discounted cashflow payoff.

Description

Deal description. If a Description is specified then the deal Summary is set to this Description.

Discount Rate Cap Volatility

ID of the interest rate volatility price factor used for the volatility of the discount rate. Examples, USD, USD.BBB, USD.CAPVOLATILITY. If left blank, the ID of the discount rate is used.

Discount Rate Swaption Volatility

ID of the interest rate yield volatility price factor used for the volatility of the discount rate. Examples, USD, USD.BBB, USD.CAPVOLATILITY. If left blank, the ID of the discount rate is used.

Forecast Rate

ID of the interest rate price factor used to calculate forward interest rates. For example, USD.AAA.

If left blank, the discount interest rate price factor is used. The payoff is quanto when the currency of the forecast interest rate price factor is different from the settlement currency of the deal.

Forecast Rate Cap Volatility

ID of the interest rate volatility price factor used for the volatility of the forecast rate. Examples, USD, USD.BBB, USD.CAPVOLATILITY. If left blank, the ID of the underlying interest rate is used.

Forecast Rate Swaption Volatility

ID of the interest yield volatility price factor used for the volatility of the forecast rate. Examples, USD, USD.BBB, USD.CAPVOLATILITY. If left blank, the ID of the underlying interest rate is used.

Issuer

ID of the issuer and the ID of the credit rating price factor. For example, IBM.

Survival Probability

ID of the survival probability price factor. For example, IBM or IBM.SENIOR. If left blank, the ID of the issuer or name is used.

Recovery Rate

ID of the recovery rate price factor. For example, BOND. If left blank, the ID of the issuer or name is used.

Repo Rate

ID of the repo interest rate price factor. For example, USD.AAA. The currency of the interest rate price factor must be the settlement currency. If left blank, the discount interest rate price factor is used.

Settlement Date

Settlement date for a forward deal on the cashflow list.

Settlement Amount

Amount settled at the Settlement Date for a forward deal on the cashflow list.

Settlement Style

Cash or Physical. Settlement method for a forward deal on the cashflow list: cash settled (Cash) or deliver the underlying cashflows (Physical). The deal must have a Settlement Date when Settlement Style is Cash.

Settlement Amount Is Clean

Yes or No. Set to Yes if the Settlement Amount excludes accrued interest. Set to No if the Settlement Amount includes accrued interest.

Is Defaultable

Yes or No. Set to No to discount the net forward value with the Repo Rate for forward deals. Set to Yes to discount only the settlement cashflow with the Repo Rate and add it to the present value of the risky-discounted bond cashflows. Used when the deal has a Settlement Date.

Investment Horizon

End date for the deal's exposure profile.

Accrual Calendars

Specifies one or more holiday calendars used when calculating accrual dates and accrual year fractions. If not provided then all calendar days are business days and dates are not adjusted.

Rate Calendars

Specifies one or more holiday calendars used when calculating rate start dates, rate end dates

and rate year fractions. If not provided then all calendar days are business days and dates are not adjusted.

Rate Offset

Number of business days between the rate reset and rate start dates.

Rate Adjustment Method

Date adjustment method used when calculating rate end dates.

Rate Sticky Month End

See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics. Yes or No. Used to calculate missing rate end dates. If set to Yes, the rate end date is set to the last business day of the month when the rate start date is the last business day of the month and the rate tenor is a number of months or years.

Missing Cashflow Properties: If the Floating Interest Cashflow List deal is entered in the system directly, rather than being built from a deal skin, certain cashflow- and reset-level property values can be omitted: Accrual Year Fraction, Rate Start Date, Rate End Date and Rate Year Fraction. Missing property values are calculated from the deal-level properties Rate Calendars, Rate Offset, Rate Adjustment Method, Rate Sticky Month End, as described in Theory Guide [7, § 1.5 Missing Cashflow Dates and Year Fractions].

42.2.2 Standard Valuation Model (CFFloatingInterestListValuation)

For details of this model, see the Theory Guide [7, § 4.3.4 Fixed and Floating Interest Cashflow List, § 4.3.7 Floating Interest Cashflow— § 4.3.10 Floating Interest Cashflow List with Compounding].

42.2.2.1 Price Factor Dependency

Floating Interest Cashflow List

- └ FX Rate (§ 4.2)
- └ Discount Rate (§ 6.2)
- └ Interest Rate (§ 6.1)
- └ Interest Rate Volatility (§ 11.3.4)
- └ Interest Yield Volatility (§ 11.3.5)
- └ Recovery Rate (§ 9.3)
- └ Survival Probability (§ 9.1)

42.2.2.2 Valuation

The valuation model values each cashflow under the Linear Swap Rate Model of Hunt and Kennedy [32]. This model is used because it provides an analytical valuation of swaptlets, caplets/floorlets and digital caplets/floorlets on either a simply-compounded (LIBOR) or CMS rate, with arbitrary payment date. The multi-currency version of the Hunt-Kennedy model is applied to value quanto deals, where the currency of forecast rate is not the same as the settlement currency. For example, the model can value arrears fixing swaptlets and caplets, CMS swaptlets and caplets, and quanto versions of these. For details of the Hunt and Kennedy models, see the Theory Guide [7, § D.8 Linear Swap Rate Model].

The model supports floating interest cashflows with compounding. OIS legs build into Floating Interest Cashflow List deals with daily compounding, and the valuation of these includes rounding of OIS rate and other modifications to match LCH Fire Drill valuations. See the Theory Guide [7, § 4.3.10 Floating Interest Cashflow List with Compounding].

The model supports swaplets and caplets/floorlets on average rates, and averages of swaplets and caplets/floorlets (for range accrual swap legs). See the Theory Guide [7, § 4.3.9 Floating Interest Cashflow with Averaging].

A forward FRN deal builds into a ‘forward’ Floating Interest Cashflow List deal, with a Settlement Date and Settlement Amount. The model supports valuation of cash-settled and physically-settled forward deals. See the Theory Guide [7, § 4.3.4 Fixed and Floating Interest Cashflow List].

The model also supports discounted cashflows, where the cashflow payoff is discounted at the floating rate, and usually paid at the start of the accrual period.

42.2.2.3 Tuning Parameters and Valuation Settings

Use Settlement Offset, Settlement Offset, Settlement Offset Calendars: When Use Settlement Offset is Yes, defines a settlement date such that cashflows with payment date before the settlement date are ignored by the valuation model. Use Settlement Offset defaults to No. Used to match LCH Fire Drill valuations. See the Theory Guide [7, § 4.3.17.1 Settlement Offset].

Cashflow Rounding: Nearest, Next Lower or None. Rounding method applied to each known or estimated cashflow amount. Defaults to None. See the Theory Guide [7, § 4.3.17.2 Cashflow Rounding].

Convexity Correction: Yes or No. Set to No to turn off the convexity corrections in the valuation. Defaults to Yes. See the Theory Guide [7, § 4.3.7.3 Valuation].

Quanto Correction: Yes or No. Set to No to turn off the quanto corrections in the valuation. Defaults to Yes. See the Theory Guide [7, § 4.3.7.3 Valuation].

Convexity Low Rate Limit: Threshold for low rate limit when valuing under the Normal model. Defaults to one basis point. See the Theory Guide [7, § 4.3.15.5 Normal Models].

Faster Averaging Valuation: Yes or No. Set to Yes to enable an approximation that gives faster valuation of floating interest cashflows with averaging. Defaults to Yes. See the Theory Guide [7, § 4.3.9.3 Faster Averaging Valuation].

OIS Cashflow Group Size: Set to a value greater than 1 to enable an approximation that gives faster valuation of floating interest cashflows with daily compounding. Defaults to 1. See the Theory Guide [7, § 4.3.10.3 Faster OIS Valuation].

OIS Rate Rounding: Number of decimal places of rounding applied to each OIS rate when valuing floating interest cashflows with daily compounding, with OIS Cashflow Group Size less than or equal to 1. Defaults to 0 (no rounding). See the Theory Guide [7, § 4.3.10.2 OIS Valuation].

Exclude Principal Cashflows: Yes or No. Set to Yes to make the valuation model ignore all principal cashflows, which are represented by Fixed Amount values on the interest cashflows. Defaults to No. Used when calculating sensitivities for SIMM. See the Theory Guide [7, § 4.3.17.3 Exclude Principal Cashflows].

Use Survival Probability: Yes or No. Set to Yes to allow the valuation model to take account of default of the underlying issuer or counterparty (Issuer) at a future date (after the valuation date). Defaults to No. See the Theory Guide [7, § 4.3.4.1 Valuation using Survival Probability].

Respect Default: Yes or No. Set to Yes to allow the valuation model to value the deal when the underlying issuer or counterparty (Issuer) has defaulted. Defaults to No. See the Theory Guide [7, § 4.3.4.2 Valuation at Default].

Dynamic Dates Grid: An optional grid, e.g. 1d 1w 1m(1m) 3m(3m), used to calculate dates on the valuation profile. Defaults to no grid. Use a grid for faster (but less accurate) calculation of exposure profiles for cashflow list deals with many payment dates. See the Theory Guide [7, § 4.3.4.4 Dynamic Dates Grid].

42.2.2.4 Assumptions

The model of Hunt and Kennedy [32] assumes lognormal rates. The Adaptiv Analytics valuation model has been extended to support normally distributed rates. This extension is described in the Theory Guide [7, § D.8 Linear Swap Rate Model].

If the interest rate volatility price factor has distribution type set to `Lognormal` and non-zero Shift value then the model assumes that rates have a shifted lognormal distribution.

The Hunt-Kennedy model assumes deterministic volatilities, which are therefore independent of the level of strike when valuing caplets and floorlets. The Adaptiv Analytics valuation model adapts the Hunt-Kennedy model by using an implied volatility for the option strike in the Black or Bachelier formula, while using ATM implied volatilities in the formulas for convexity- and quanto-adjusted rates. These volatilities are obtained from the either the Interest Rate Volatility or Interest Yield Volatility price factor.

The multi-currency version of the Hunt-Kennedy model is used for quanto deals. The multi-currency model is defined with a settlement-currency rate (\hat{r}), which has the same definition (tenor, day count convention, fixed side frequency, etc.) as the underlying rate (r).

When the forecast rate currency is the same as the settlement currency but the forecast interest rates are not the same as discount interest rates, the deal is valued in the same way as a quanto deal but with: the correlation between the FX rate and r set to zero; and the correlation between r and \hat{r} set to 1.

Digital caplets and floorlets are valued as the limit of two standard call options, which introduces an extra term in the valuation formula that depends on the derivative of the implied volatility with respect to the strike. This derivative is estimated by requesting volatilities from the volatility price factor at the strike plus and minus one basis point.

For the valuation of ‘risky’ cashflow list deals (`Use Survival Probability` is Yes), the usual assumptions are made when calculating the value of the payment at default. The value of the deal at default (`Respect Default` is Yes) is the outstanding principal amount multiplied by the recovery rate from the recovery rate price factor. See Theory Guide [7, § 4.3.4 Fixed and Floating Interest Cashflow List].

42.2.2.5 Limitations

Under the lognormal Hunt-Kennedy model, the convexity- and quanto-adjusted rates may become very large when volatilities are large or for cashflows with a long time from the valuation date to the reset date, which can lead to nonsensical valuations. See the Theory Guide [7, § 4.3.7.4 Log-normal Model and § 4.3.7.6 Quanto]. The recommended mitigation for this is to set the `Convexity Correction` valuation model parameter to No for specific deals, e.g. using deal tags.

Convexity corrections are not supported for floating interest cashflows with compounding (`Compounding Method` not equal to `None`) or discounting (`Discounted` set to Yes). In these cases, there may be a convexity correction but it is usually small because the compounding or discounting of the payoff compensates for the delay or advance in payment date. See the Theory Guide [7, § 4.3.10 Floating Interest Cashflow List with Compounding].

Valuation under the assumption of shifted lognormal rates is supported only for standard caplets and floorlets.

When the reference rate is a swap rate, an approximation is used to calculate forward swap rates. See the Theory Guide [7, § 4.3.7.2 Rates].

A moment-matching approximation is used in the valuation of caplets and floorlets on average rates. See the Theory Guide [7, § 4.3.9 Floating Interest Cashflow with Averaging].

For barrier caplets and floorlets, the barrier status (knocked-in or knocked-out) is determined by a single observation of the reference rate at the rate reset date. Continuously observed barriers are not supported.

42.2.3 Hull-White Valuation Model (CapHullWhiteValuation)

For details of this model, see the Theory Guide [7, § 4.3.4 Fixed and Floating Interest Cashflow List and § 4.3.13 Floating Interest Cashflow under Hull-White Model].

42.2.3.1 Price Factor Dependency

Floating Interest Cashflow List

- └ FX Rate (§ 4.2)
- └ Discount Rate (§ 6.2)
- └ Interest Rate (§ 6.1)
- └ Hull White 1 Factor Model Parameters
- └ LGM Model Parameters

42.2.3.2 Valuation

This valuation model is used during the calibration of the one-factor Hull-White and LGM interest rate models. It can value standard-payoff swaptlets, caplets and floorlets on a simply compounded rate.

42.2.3.3 Tuning Parameters and Valuation Settings

Use Settlement Offset, Settlement Offset, Settlement Offset Calendars: When `Use Settlement Offset` is `Yes`, defines a settlement date such that cashflows with payment date before the settlement date are ignored by the valuation model. `Use Settlement Offset` defaults to `No`. Used to match LCH Fire Drill valuations. See the Theory Guide [7, § 4.3.17.1 Settlement Offset].

Cashflow Rounding: `Nearest`, `Next Lower` or `None`. Rounding method applied to each known or estimated cashflow amount. Defaults to `None`. See the Theory Guide [7, § 4.3.17.2 Cashflow Rounding].

Model Parameters Type: `Hull White` or `LGM`. The model parameters price factor type. Defaults to `Hull White`.

Model Parameters: ID of model parameters price factor. If not specified, the ID of the forecast interest rate price factor is used.

42.2.3.4 Assumptions

The mean reversion rate (α) is constant when the valuation model uses the Hull-White 1 Factor Model Parameters price factor.

42.2.3.5 Limitations

The model does not support valuation of Floating Interest Cashflow List deals where

- any of the cashflows has a non-standard payoff (e.g. digital, barrier and rate multiplier)
- any of the underlying rates is compounded
- any of the underlying rates is a CMS rate
- the deal is quanto.

The model does not support default of underlying issuer or counterparty, i.e. the `Use Survival Probability` and `Respect Default` valuation model parameters are not available.

The model does not support valuation of forward deals on the underlying cashflow list. The model ignores the `Settlement Date`, `Settlement Amount` and `Settlement Style` properties of the deal.

Chapter 43

Swaps

43.0.1 Overview

A swap exchanges one series of interest rate payments for another; each series of payments is called a swap leg. The economic value of a swap arises from differences between the terms of the swap legs. In Adaptiv Analytics, swap legs are implemented with fixed or floating cashflow lists which are built from deal skins; the deal skins correspond to commonly traded terms, such as fixed for floating interest rate legs (interest rate swaps), legs differing by reference interest rate (basis swaps), and legs paying in different currencies (currency swaps). All swap types in Adaptiv Analytics support the features common to the underlying cashflow lists, such as amortisation of principal, stub initial or final payments, and payment in advance or arrears. The floating legs of swaps may have quanto payments, referring to a rate in a currency different from that of the swap leg payment currency. The reference rate of floating legs of swaps other than overnight index swaps may have tenors that are shorter or longer than the payment frequency, and in particular may be a constant maturity swap rate (CMS).

43.0.2 Properties

Here are properties commonly found on swaps in Adaptiv Analytics.

43.0.2.1 Accrual Adjustment Method

The date adjustment method for the accrual dates of a swap leg. See Section 3.3.5 for details on date adjustment. In general, separate accrual adjustment method properties are required for each swap leg.

43.0.2.2 Accrual Calendars

A list of holiday calendars used when calculating accrual period start and end dates and accrual year fractions for a swap leg. The union of all holidays in each calendar are treated as non-business days. If no holiday calendars are provided, then all calendar days are treated as business days and dates are not adjusted. In general, separate accrual calendars are required for each swap leg.

43.0.2.3 Amortisation

An amortisation schedule consist of a list of (Date, Amount) pairs, where the Amount is the amount by which the principal is reduced at the Date. An increase in principal is represented by a negative Amount.

43.0.2.4 Currency

The ID of the FX price factor for the currency in which swap leg cashflows are denominated. In general, currency swaps require a separate currency property for each swap leg.

43.0.2.5 Discount Rate

The ID of the interest rate price factor used to discount swap leg cashflows. If this ID is not specified, then the Currency will be used as the discount interest rate ID. In general, currency swaps require a separate discount rate property for each swap leg.

43.0.2.6 Discount Rate Volatility

The ID of the interest rate volatility price factor representing the volatility of the discount rate. If not specified, the ID of the discount interest rate is used. In general, currency swaps require a separate discount rate volatility property for each swap leg.

43.0.2.7 Effective Date

The unadjusted start date of the swap. The start of the first accrual period of each swap leg is calculated by adjusting this date.

43.0.2.8 Effective Date Adjustment Method

The date adjustment method for the effective date. See Section 3.3.5 for details on date adjustment.

43.0.2.9 First Coupon Date

The unadjusted payment date of the first coupon of a swap leg. Used when there is a stub first coupon. In general, separate first coupon date properties are required for each swap leg.

43.0.2.10 Floating Margin

A fixed margin rate added to a floating interest leg. In general, swaps which support multiple floating legs require a separate margin property for each potential floating leg.

43.0.2.11 Frequency

The period between the regular payments of a swap leg. If set to 0, there is a single payment at maturity. In general, separate frequency properties are required for each swap leg.

43.0.2.12 Index Adjustment Method

The date adjustment method for the reference interest rate end dates on a floating interest leg. In general, swaps which support multiple floating legs require a separate index adjustment method property for each potential floating leg. See Section 3.3.5 for details on date adjustment.

43.0.2.13 Index Calendars

The list of holiday calendars used when calculating the start and end dates and the year fraction of the reference interest rate for a floating swap leg. The union of all holidays in each calendar are treated as non-business days. If no holiday calendars are provided, then all calendar days are treated as business days and dates are not adjusted. In general, swaps which support multiple floating legs require a separate index calendars property for each potential floating leg.

43.0.2.14 Index Day Count

The day count convention used to calculate the year fractions for the reference interest rate of a floating leg. In general, swaps which support multiple floating legs require a separate index day count property for each potential floating leg. See Section 3.3.4 for more information about day counts in Adaptiv Analytics.

43.0.2.15 Index Frequency

The frequency of the reference rate for a floating swap leg. When set to 0, it is assumed to match the payment frequency. When greater than 0 but less than the index tenor, the reference rate is assumed to be a constant maturity swap rate with swap maturity equal to the index tenor and swap payment frequency equal to the index frequency. In general, swaps which support multiple floating legs require separate index frequency properties for each potential floating leg.

43.0.2.16 Index Offset

The number of business days between a reset date and the start of the associated reference rate period. In general, swaps which support multiple floating legs require a separate index offset method property for each potential floating leg.

43.0.2.17 Index Publication Calendars

The list of holiday calendars used when calculating reset dates from accrual dates and the index offset. The union of all holidays in each calendar are treated as non-business days. If no holiday calendars are provided, then all calendar days are treated as business days and dates are not adjusted. In general, swaps which support multiple floating legs require a separate index publication calendars property for each potential floating leg.

43.0.2.18 Index Tenor

The tenor of the reference rate for a floating swap leg. When set to 0, it is assumed to match the payment frequency. When index frequency is greater than 0 and the index tenor is greater than the index frequency, the reference rate is assumed to be a constant maturity swap rate with swap maturity equal to the index tenor and swap payment frequency equal to the index frequency. In general, swaps which support multiple floating legs require separate index tenor properties for each potential floating leg.

43.0.2.19 Interest Rate

The ID of the interest rate price factor used to calculate the reference interest rates for a floating leg. If not specified, the discount rate is used. The payoff is quanto when the currency of this interest rate price factor is different from the settlement currency of the deal. In general, swaps which support multiple floating legs require a separate interest rate property for each potential floating leg.

43.0.2.20 Interest Rate Volatility

The ID of the interest rate volatility price factor representing the volatility of the reference interest rate. If not specified, the ID of the reference interest rate is used. In general, swaps which support multiple floating legs require a separate interest rate volatility property for each potential floating leg.

43.0.2.21 Known Rates

A list of historical rates that can be used to override the rate fixings file for a floating leg. The rates are represented as Date - Value pairs. The dates denote reset dates and the values denote reset rates. In general, swaps which support multiple floating legs require a separate known rates property for each potential floating leg.

43.0.2.22 Maturity Date

The unadjusted maturity date of the swap. The end of the last accrual period for all swap leg is calculated by adjusting this date.

43.0.2.23 Maturity Date Adjustment Method

The date adjustment method for the maturity date. See Section 3.3.5 for details on date adjustment.

43.0.2.24 Payment Adjustment Method

The date adjustment method for the payment dates of a swap leg. See Section 3.3.5 for details on date adjustment. In general, separate payment adjustment method properties are required for each swap leg.

43.0.2.25 Payment Calendars

The list of holiday calendars used when calculating the payment dates of a swap leg. The union of all holidays in each calendar are treated as non-business days. If no holiday calendars are provided, then all calendar days are treated as business days and payment dates are not adjusted. In general, separate payment calendar properties are required for each swap leg.

43.0.2.26 Payment Offset

The number of business days between the accrual end dates and the associated payment dates of a swap leg. In general, separate payment offset properties are required for each swap leg.

43.0.2.27 Penultimate Coupon Date

The unadjusted payment date of the penultimate coupon of a swap leg. Used when there is a stub last coupon. In general, separate penultimate coupon date properties are required for each swap leg.

43.0.2.28 Principal

The initial notional principal amount of a swap in units of the currency. In general, currency swaps require a separate principal property for each swap leg.

43.0.2.29 Rate Constant

A fixed rate added to the reference interest rate of a floating leg. In general, swaps which support multiple floating legs require a separate rate constant property for each potential floating leg.

43.0.2.30 Rate Fixing

The interest rate fixing ID used to find historical rates in the rate fixing file. If not specified, the ID will be formed from the reference interest rate and interest index tenor. In general, swaps which support multiple floating legs require a separate rate fixing property for each potential floating leg.

43.0.2.31 Rate Multiplier

A multiplier for a floating leg interest rate. In general, swaps which support multiple floating legs require a separate rate multiplier property for each potential floating leg.

43.0.2.32 Rate Type

This property controls whether a swap leg is `Fixed` or `Floating`. For swap types such as interest rate swap which must be fixed on one side, the rate type is conventionally associated with the pay leg. Swaps which may be fixed on both sides, such as currency swap, must have separate rate type properties for both pay and receive legs. A fixed leg is built into a fixed interest cashflow list and a floating leg is built into a floating interest cashflow list.

43.0.2.33 Reset Type

The timing of the rate fixing relative to the accrual period for a floating leg. Either at the start of the accrual period (*Standard*), or at the end of the accrual period (*Arrears*), or at the start of the previous accrual period (*Advance*). In general, swaps which support multiple floating legs require a separate reset type property for each potential floating leg.

43.0.2.34 Roll Convention

The date roll convention when adjusting payment and accrual dates for a swap leg. In general, separate roll convention properties are required for each swap leg.

43.0.2.35 Roll Day Of Month

The day of month to use when the roll convention is *Day Of Month*. In general, separate roll day of month properties are required for each swap leg.

43.0.2.36 Roll Direction

Specifies whether swap leg dates roll *Forward* or *Backward* when adjusting dates. See Section 3.3.5 for details. In general, separate roll direction properties are required for each swap leg.

43.0.2.37 Stub

A stub is a compound property consisting of sub-properties which control the generation of stub (short or long) coupons. Stub coupons are assumed to be the initial or the final coupons of a swap leg. In general, separate initial and final stub properties are required for each swap leg. Stub coupon generation is described in Theory Guide [7, § 4.3.2.6 [Floating Interest Cashflow \(Interpolated\)](#)]. The sub-properties are:

Interpolated Rate Rounding

The interpolated rate is rounded to $n + 2$ decimal places, where n = *Interpolated Rate Rounding*.

Floating Rate Method

This may be *None*, *Interpolated*, or *Accrual End Date*.

Forecast Rate 1

The ID of the interest rate price factor for the first forecast rate.

Forecast Rate 2

The ID of the interest rate price factor for the second forecast rate.

Rate 1 Fixing

The interest rate fixing ID used for the first forecast rate. If not specified, the ID will be formed from the first forecast rate and first rate tenor. The interest rate fixing ID is used to find known rate fixing values.

Rate 1 Tenor

The tenor of the first forecast rate.

Rate 2 Fixing

The interest rate fixing ID used for the second forecast rate. If not specified, the ID will be formed from the second forecast rate and second rate tenor. The interest rate fixing ID is used to find known rate fixing values.

Rate 2 Tenor

The tenor of the second forecast rate.

Known Rate

The historically fixed stub coupon rate.

Use Known Rate

The historical rate is taken from the `Known Rate` instead of the rate fixing file when this is set to `Yes`.

43.0.2.38 Swap Rate

The interest rate of a fixed leg.

43.0.2.39 Timing

The timing of payments relative to accrual periods for a swap leg. Either at the end of the accrual period (`End`), at the start of the accrual period (`Begin`), or at the start of the accrual period but discounted as if paid at the end (`Discounted`). In general, separate timing properties are required for each swap leg.

43.0.3 Tuning Parameters and Valuation Settings

For the parameters and settings of the valuation models for the underlying fixed and floating cashflow lists, see Section 42.1 and Section 42.2 respectively.

43.0.4 Assumptions

With the exception of MtM currency swap, we assume that swap legs can be valued independently; the representation in Adaptiv Analytics is equivalent to a structured deal containing cashflow lists for each swap leg. For the assumptions of the underlying fixed and floating cashflow lists, see Section 42.1 and Section 42.2 respectively.

43.0.5 Limitations

For the limitations of the underlying fixed and floating cashflow lists, see Section 42.1 and Section 42.2 respectively.

43.1 Interest Rate Swap**43.1.1 Overview**

An interest rate swap exchanges a series of fixed interest payments for a series of floating interest payments. All payments must be denominated in the same currency, but the floating interest payments may be quanto. Floating interest payments may be indexed to a constant maturity swap.

43.1.2 Price Factor Dependency

Interest Rate Swap

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Rate / Interest Rate Correlation (§ 12.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)
- └ Interest Rate / Interest Rate Correlation (§ 12.2)
- └ Interest Rate Volatility (§ 11.3.4)

└ Interest Yield Volatility (§ 11.3.5)

43.1.3 Properties

See 43.0.2 for common swap properties. In addition, interest rate swap has the following properties.

43.1.3.1 Averaging Cutoff Offset

This property defines the effective last reset date when there is averaging and daily rate resets. If the averaging cutoff offset is c , then for a given accrual period with m rate resets, the last $c + i + 1$ resets fix to same rate as the $(m - c - i)$ th reset, where i is the index offset. For example, when $m = 30$, $c = 2$ and $i = -1$, both the 30th and 29th reset fix to the rate for the 29th reset.

43.1.4 Deal Representation

The Interest Rate Swap is a deal skin that builds into a fixed interest cashflow list and a floating interest cashflow list. See the Deal Skins Guide [2, [Interest Rate Swap](#)].

43.1.5 Valuation

In Adaptiv Analytics an Interest Rate Swap deal can be valued using the `DealSkinValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.3.25 [Interest Rate Swap](#), § 4.3.18 [Fixed Swap Leg](#), § 4.3.22 [Floating Swap Leg](#)].

43.2 Overnight Index Swap

43.2.1 Overview

An overnight index swap exchanges a series of interest payments referring to an overnight floating rate for a series of fixed interest payments. The settlement is in a single currency, but the floating leg payments may be quanto. Floating leg payments are made periodically by compounding the overnight reference rate.

43.2.2 Price Factor Dependency

Overnight Index Swap

- └ FX Rate (§ 4.2)
- └ FX Rate / Interest Rate Correlation (§ 12.2)
- └ Interest Rate (§ 6.1)
- └ Interest Rate / Interest Rate Correlation (§ 12.2)
- └ Interest Rate Volatility (§ 11.3.4)
- └ Interest Yield Volatility (§ 11.3.5)

43.2.3 Properties

See 43.0.2 for common swap properties.

43.2.4 Deal Representation

The Overnight Index Swap is a deal skin that builds into a fixed interest cashflow list deal and a floating interest cashflow list deal. See the Deal Skins Guide [2, [Overnight Index Swap](#)].

43.2.5 Valuation

In Adaptiv Analytics an Overnight Index Swap deal can be valued using the `DealSkinValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.3.26 [Overnight Index Swap](#), § 4.3.24 [OIS Cashflow](#)].

43.3 Basis Swap

43.3.1 Overview

A basis swap exchanges one series of floating interest rate payments for another. Both legs are denominated in the same currency, and consequently share the same principal and amortisation schedule.

43.3.2 Price Factor Dependency

Basis Swap

- └ FX Rate (§ 4.2)
- └ FX Rate / Interest Rate Correlation (§ 12.2)
- └ Interest Rate (§ 6.1)
- └ Interest Rate / Interest Rate Correlation (§ 12.2)
- └ Interest Rate Volatility (§ 11.3.4)
- └ Interest Yield Volatility (§ 11.3.5)

43.3.3 Properties

See 43.0.2 for common swap properties.

43.3.4 Deal Representation

The Basis Swap is a deal skin that builds into two floating interest cashflow list deals. See the Deal Skins Guide [2, [Interest Rate Swap](#)].

43.3.5 Valuation

In Adaptiv Analytics a Basis Swap deal can be valued using the `DealSkinValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.3.27 [Basis Swap](#), § 4.3.18 [Fixed Swap Leg](#), § 4.3.22 [Floating Swap Leg](#)].

43.4 Currency Swap

43.4.1 Overview

A currency swap exchanges a series of interest rate payments in one currency for a series in another. The interest payments on either side of the swap may be fixed interest payments or floating interest payments. The swap may also include an exchange of principal payments at the beginning of the swap, or at the end, or at both the beginning and end. Quanto payments are supported. The pay and receive legs of a currency swap support separate amortisation schedules.

43.4.2 Price Factor Dependency

Currency Swap

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ FX Rate / Interest Rate Correlation (§ 12.2)
- └ Interest Rate (§ 6.1)
- └ Interest Rate / Interest Rate Correlation (§ 12.2)
- └ Interest Rate Volatility (§ 11.3.4)
- └ Interest Yield Volatility (§ 11.3.5)

43.4.3 Properties

See 43.0.2 for common swap properties. In addition, currency swap has the following properties.

43.4.3.1 Pay Amortisation

The amortisation schedule for the pay leg, denominated in the pay currency and applied to the initial pay principal. See Section 43.0.2.3 for a description of amortisation schedules.

43.4.3.2 Principal Exchange

This specifies what exchange of principal payments are made for the swap. Principal may be exchanged on the effective date (*Start*), on the maturity date (*Maturity*), on both effective and maturity dates (*Start Maturity*), or not at all (*None*).

43.4.3.3 Receive Amortisation

The amortisation schedule for the receive leg, denominated in the receive currency and applied to the initial receive principal. See Section 43.0.2.3 for a description of amortisation schedules.

43.4.4 Deal Representation

The Currency Swap is a deal skin that builds into two cashflow lists. These may be either fixed interest cashflow lists or floating interest cashflow lists. See the Deal Skins Guide [2, [Currency Swap](#)].

43.4.5 Valuation

In Adaptiv Analytics a Currency Swap deal can be valued using the `DealSkinValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.3.29 [Currency Swap](#)].

43.5 MtM Cross Currency Swap

43.5.1 Overview

An MtM cross currency swap is a currency swap in which the principal of one leg is adjusted for each payment such that it has the same value as the principal on the unadjusted leg according to the spot FX rate prevailing at the time the adjustment is made. These principal adjustments are accompanied by payments to settle the change in value resulting from the change in principal; this is the sense in which the swap is a mark-to-market swap.

The MtM cross currency swap supports an amortisation schedule that applies to the principal of the unadjusted leg. Amortisation dates are adjusted to coincide with the closest accrual date, so that the principal for each payment is constant for each accrual period.

The MtM cross currency swap does not support all of the features supported by the currency swap; see the section on limitations for details.

43.5.2 Price Factor Dependency

MtM Cross Currency Swap

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

43.5.3 Properties

See 43.0.2 for common swap properties. In addition, MtM cross currency swap has the following properties.

43.5.3.1 Principal

Represents the initial notional principal amount of the unadjusted leg, in units of the unadjusted leg settlement currency. The principal of the adjusted leg is calculated from the unadjusted leg principal at prevailing FX rates.

43.5.3.2 Amortisation

The amortisation schedule applies to the unadjusted leg of the swap. See Section 43.0.2.3 for a description of amortisation schedules.

43.5.3.3 MtM Side

Defines the adjusted side. When set to Pay, the pay leg principal is adjusted and when set to Receive, the receive leg principal is adjusted.

43.5.3.4 FX Reset Offset

Offset used to calculate FX reset dates on the adjusted side. For each cashflow on the adjusted side, the FX reset date is calculated by subtracting FX Reset Offset business days from cashflow's accrual start date.

43.5.3.5 Known FX Rates

List of adjusted-side reset dates and corresponding known FX rates specified in the form of (Date, Value) pairs. The known FX rates must be entered in units of adjusted-side currency per unit of unadjusted-side currency.

43.5.4 Deal Representation

The MtM Cross Currency Swap is a deal skin that builds into a pair of opposing Interest Cashflow Lists, which may be Fixed or Floating; see the Theory Guide [7, § 4.3.39 MtM Cross Currency Swap].

Theory Guide 4.3.39

An MtM cross-currency swap builds into two fixed or floating interest cashflow list deals in the same way as a currency swap (see Section 4.3.29), except that:

- For both legs, the cashflow notional amounts are generated from the Principal and Amortization, with amortization amounts shifted to coincide with the closest accrual date.
- No principal or amortization cashflows are generated.
- For each cashflow on the adjusted leg, the FX reset date is $T_1 - fb$, where T_1 is the accrual start date, f is the FX Reset Offset, and addition of business days is with respect to the leg's accrual holiday calendar.

Note however that, in order to support the MtM reset feature, the MtM Cross Currency Swap uses an atomic valuation model.

43.5.5 Valuation

In Adaptiv Analytics a MtM Cross Currency Swap deal can be valued using the `MtMCrossCurrencySwapValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.3.39 MtM Cross Currency Swap].

The valuation of an MtM Cross Currency Swap by the `MtMCrossCurrencySwapValuation` model values is similar method to that of Currency Swaps (cf. the sum of two cashflow lists, section 43.4.5), in that the swap is decomposed into a number of cashflows whose value is calculated independently, before being aggregated into the overall value of the deal. Each cashflow may independently include Start and/or Maturity Principal exchange.

The MtM Cross Currency Swap differs from the Currency swap in that the principal of one leg (the adjusted leg) will always be adjusted by exchange of notional to match value of the other leg (the unadjusted leg), converted at the prevailing spot FX rate between the two currencies. The conversion is performed via the definition of an adjustment factor, $A(t)$, through which the principal of unadjusted leg is related to that of the adjusted leg at time t .

Theory Guide 4.3.39.1

For cashflows in the adjusted leg:

$$A(t) = \begin{cases} X_0 & X_0 > 0 \\ X(t) & X_0 = 0 \text{ and } t \geq t'_0 \\ F(t, t'_0) & X_0 = 0 \text{ and } t < t'_0, \end{cases} \quad (43.5.1)$$

where X_0 is the known FX rate, t'_0 is the FX reset date, and $X(t)$ and $F(t, T)$ are the spot and forward prices of unadjusted leg currency in adjusted leg currency.

Following this adjustment, the valuation of each cashflow is determined as for a fixed- or floating-cashflow list (see sections 42.1 and 42.2).

43.5.5.1 Alternative Interest Rate Cashflow List Representation

It is possible to value a MtM Cross Currency swap at the base date using a pair of Interest Rate Cashflow List deals where the notional amount of each future reset period is set to the expected notional calculated from FX forward rates using no arbitrage principle.

However, when FX rates are simulated it is not possible to replicate credit exposure using this approach. This arises because the notional amounts in future reset periods are a function of future FX rates, and consequently stochastic.

43.5.6 Tuning Parameters and Valuation Settings

43.5.6.1 Exclude Principal Cashflows:

Yes or No. When set to Yes, the valuation model will exclude principal when the principal amounts are known at the time of deal valuation. Defaults to No. Used when calculating sensitivities for SIMM. See the Theory Guide [7, § 4.3.17.3 [Exclude Principal Cashflows](#)].

43.5.7 Assumptions

For the assumptions of the underlying fixed and floating cashflow lists, see Section 42.1 and Section 42.2 respectively.

43.5.7.1 Tolerance for Exclude Principal Cashflows

As the start, end, and FX reset dates of cashflows on the unadjusted leg may not coincide exactly with the equivalent dates on the adjusted leg, Adaptiv Analytics assumes cashflow dates amounts are coincident when falling within a tolerance period of 7 days. This requirement arises since forecast principal cashflows for the adjusted leg are dependent on the forecast principal cashflows of the unadjusted leg.

For more details, see the Theory Guide [7, § 4.3.39.2 [Exclude Principal Cashflows](#)].

43.5.8 Limitations

For the limitations of the underlying fixed and floating cashflow lists, see Section 42.1 and Section 42.2 respectively.

43.5.8.1 CMS Rates

The MtM cross currency swap does not support CMS rates on floating legs.

43.5.8.2 Compounding

The compounding in the Adaptiv Analytics valuation model is restricted.

Theory Guide 4.3.39.1

The valuation model requires that: each floating interest cashflow is a swaplet on a simply-compounded rate, with cashflow payoff given by Equation (4.339) with $\eta = 1$, $\kappa = 0 = \lambda$, $A = 1$ and $B = 0$; fixed interest cashflow lists have Compounding set to No, and floating interest cashflow lists have Compounding Method set to None.

43.5.8.3 Convexity Correction

As MtM Cross-Currency Swaps are valued by a cashflow list model, convexity corrections are neglected.

The valuation formula for floating interest cashflows neglects the convexity correction that arises from taking the expectation of the product of the interest rate and the FX rate. MtM cross-currency swaps are strongly path-dependent.

43.5.8.4 No Quanto Adjustments

The MtM cross currency swap does not support quanto adjustments when the currency of the reference interest rate of a swap leg does not match the payment currency.

43.5.8.5 Stub Rates

Pay and Receive Initial and Final Stubs are not supported for MtM Cross Currency Swaps.

Chapter 44

Swaptions

44.1 Swaption

44.1.1 Overview

This deal type is for European options on an underlying interest rate swap, in turn consisting of a fixed and floating interest cashflow list.

A Swaption can be valued using either the standard valuation model (`SwaptionValuation`) or the Hull-White valuation model (`SwaptionHullWhiteValuation`).

44.1.2 Deal Representation

The Swaption is a deal skin that builds into a fixed interest cashflow list and a floating interest cashflow list. See the Deal Skins Guide [2, [Swaption](#)].

44.1.3 Properties

Currency

Settlement currency. For example, USD.

Discount Rate

ID of the interest rate price factor (or discount rate price factor) used to discount the cashflows. For example, USD.AAA. The currency of the interest rate price factor must be the settlement currency. If left blank, the ID of the settlement currency is used.

Forecast Rate

ID of the interest rate price factor used to calculate forward interest rates. For example, USD.AAA. If left blank, the discount interest rate price factor is used. The payoff is quanto when the currency of the forecast interest rate price factor is different from the settlement currency of the deal.

Forecast Rate Volatility

ID of the interest rate volatility price factor or interest yield volatility price factor used for the volatility of the forecast rate. Examples, USD, USD.BBB, USD.CAPVOLATILITY. If left blank, the ID of the forecast rate's currency is used.

Buy Sell

Buy or Sell. Determines whether the holder is long (Buy) or short (Sell) the deal.

Payer Receiver

Payer or Receiver. Determines whether the option holder pays the fixed (Payer) or receives the fixed (Receiver) leg of the underlying swap deal.

Principal

Principal amount in units of settlement currency.

Pay Amortisation

Amortisation schedule for the pay leg consisting of a list of (Date, Amount) pairs, where the Amount is the amount by which the principal amount is reduced at the Date. An increase in principal amount is represented by a negative Amount.

Receive Amortisation

Amortisation schedule for the receive leg consisting of a list of (Date, Amount) pairs, where the Amount is the amount by which the principal amount is reduced at the Date. An increase in principal amount is represented by a negative Amount.

Option Expiry Date

Option expiry date.

Settlement Date

The settlement date of a cash settled swaption. This property is only required for cash settled swaptions; for physically settled swaptions, Settlement Date will be ignored.

Swap Effective Date

Unadjusted start date of the underlying swap.

Swap Effective Date Adjustment Method

Date adjustment method for the swap effective date. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

Swap Maturity Date

Unadjusted maturity date of the underlying swap.

Swap Maturity Date Adjustment Method

Date adjustment method for the swap maturity date. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

Pay Frequency

Frequency of the payments on the pay leg. If set to 0M then there is a single payment.

Receive Frequency

Frequency of the payments on the receive leg. If set to 0M then there is a single payment.

Pay Timing

Begin or End. Timing of interest payments for the pay leg. Either at end of interest accrual period (End) or start of interest accrual period (Begin).

Receive Timing

Begin or End. Timing of interest payments for the receive leg. Either at end of interest accrual period (End) or start of interest accrual period (Begin).

Pay Payment Adjustment Method

Date adjustment method for payment dates for the pay leg. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

Receive Payment Adjustment Method

Date adjustment method for payment dates for the receive leg. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

Pay Payment Offset

Number of business days between the accrual and payment dates for the pay leg.

Receive Payment Offset

Number of business days between the accrual and payment dates for the receive leg.

Pay Day Count

Day count convention for the pay leg used to calculate the accrual year fractions. See Section 3.3.4 for more information about day counts in Adaptiv Analytics.

Receive Day Count

Day count convention for the receive leg used to calculate the accrual year fractions. See Section 3.3.4 for more information about day counts in Adaptiv Analytics.

Pay Accrual Adjustment Method

Date adjustment method for accrual dates for the pay leg. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

Receive Accrual Adjustment Method

Date adjustment method for accrual dates for the receive leg. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

Swap Rate

Fixed interest rate. Rates are entered in percentage. For example, enter 5 for 5%.

Reset Type

Standard, Advance or Arrears. Timing of the rate fixing. Either at the start of the accrual period (Standard), or at the end of the accrual period (Arrears), or at the start of the previous accrual period (Advance).

Index Tenor

Floating rate tenor. If set to 0M then the interest frequency is used.

Index Day Count

Day count convention used to calculate the floating rate year fractions. Set to either the day count convention of the money-market (LIBOR) rate or the fixed-side day count convention of the swap (CMS) rate. See Section 3.3.4 for more information about day counts in Adaptiv Analytics.

Index Offset

Number of business days between the rate reset and rate start dates.

Index Adjustment Method

Date adjustment method used to calculate rate end dates. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

Floating Margin

Margin rate added to the floating interest rate. Rates are entered in basis points. For example, enter 50 for 50 basis points.

Margin Schedule

List of margin rates and corresponding dates. Each item in the schedule is allocated to the cashflow with Accrual Start Date closest to the item's date, unless the cashflow has already been allocated an item with a closer date. If a cashflow is allocated an item in the schedule then the cashflow Margin is set to the item's value, otherwise the cashflow Margin is set the Margin/Floating Margin on the deal. Rates in the schedule are entered in basis points. For example, enter 50 for 50 basis points.

Settlement Style

Cash or Physical. Option settlement method: cash settled (Cash) or deliver the underlying (Physical).

Pay Calendars

Specifies one or more holiday calendars for the pay leg used when calculating accrual dates and payment dates. If not provided then all calendar days are business days and dates are not adjusted.

Pay Payment Calendars

Specifies one or more holiday calendars for the pay leg used when calculating the payment dates. If not provided then all calendar days are business days and dates are not adjusted.

Receive Calendars

Specifies one or more holiday calendars for the receive leg used when calculating accrual dates and payment dates. If not provided then all calendar days are business days and dates are not adjusted.

Receive Payment Calendars

Specifies one or more holiday calendars for the receive leg used when calculating the payment dates. If not provided then all calendar days are business days and dates are not adjusted.

Index Calendars

Specifies one or more holiday calendars used when calculating rate start dates, rate end dates and rate year fractions. If not provided then all calendar days are business days and dates are not adjusted.

Index Publication Calendars

Specifies one or more holiday calendars used when calculating the rate reset date from the accrual date and index offset. If not provided then all calendar days are business days and dates are not adjusted.

Pay First Coupon Date

Unadjusted first coupon date for the pay leg.

Pay Penultimate Coupon Date

Unadjusted penultimate coupon date for the pay leg.

Pay Roll Convention

Roll convention for generating payment and accrual dates for the pay leg. See Section 3.3.6 for more information about roll conventions in Adaptiv Analytics.

Pay Roll Day Of Month

Day of month for roll convention Day Of Month for the pay leg. For example, enter 28 for the 28th day of the month.

Pay Roll Direction

Forward or Backward. Roll direction for generating payment and accrual dates for the pay leg.

Receive First Coupon Date

Unadjusted first coupon date for the receive leg.

Receive Penultimate Coupon Date

Unadjusted penultimate coupon date for the receive leg.

Receive Roll Convention

Roll convention for generating payment and accrual dates for the receive leg. See Section 3.3.6 for more information about roll conventions in Adaptiv Analytics.

Receive Roll Day Of Month

Day of month for roll convention Day_Of_Month for the receive leg. For example, enter 28 for the 28th day of the month.

Receive Roll Direction

Forward or Backward. Roll direction for generating payment and accrual dates.

Rate Multiplier

Multiplier for the floating interest rate. Defaults to 1 and must be positive.

44.1.4 Standard Valuation Model (SwaptionValuation)

44.1.4.1 Price Factor Dependency

Swaption

- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)
- └ Interest Yield Volatility (§ 11.3.5)
- └ CMS Rate Correlation (§ 12.3), when Forward Start (§ 44.1.4.3) is Yes.

44.1.4.2 Valuation

The standard swaption valuation model prices a European swaption with swap rate considered to be either normally or lognormally distributed¹. For details of this model, see the Theory Guide [7, § 4.3.40 Swaption].

44.1.4.3 Tuning Parameters and Valuation Settings

Forward Start: Yes or No. If Yes, the deal is valued as a forward start swaption, whereby the implied volatility of the swaption is calculated from the implied volatilities of two standard swaptions and a correlation. When Forward_Start is Yes, the valuation requires the effective date of the underlying swap to be at least one fixed or floating coupon period (whichever is larger) after the option expiry date. For details, see the Theory Guide [7, § 4.3.40.9 Volatility for Forward Start Swaptions]. Defaults to No.

44.1.4.4 Assumptions

Swap rate distribution: The swap rate is assumed to be distributed as specified on the forecast rate volatility price factor:

Theory Guide 1.8.2

If the Distribution Type is Lognormal then the price factor values are lognormal volatilities (implied Black volatilities) and the valuation models assume that rates have a lognormal distribution. If the Distribution Type is Normal then the price factor values are normal volatilities (implied Bachelier volatilities) and the valuation models assume that rates have a normal distribution. The default Distribution Type is Lognormal.

The interest rate volatility price factor has a Shift value. The Shift must be zero when the Distribution Type is Normal. If the Distribution Type is Lognormal and the Shift is not zero then the valuation models assume that rates have a shifted lognormal distribution.

It is further assumed that the swap rate distribution at the exercise date is the same as that at the valuation date (in particular, the volatility is treated as deterministic [35]). For details, see the Theory Guide [7, § 4.3.40.5 Lognormal Model and § 4.3.40.6 Normal Model].

Constant effective strike: The effective strike is constant in the special case of constant fixed rate and margin, when the payment dates and accrual periods of the underlying swap's fixed and floating legs agree. In general, the effective strike is stochastic. The model assumes that the effect of this stochasticity is small enough to be neglected, so that the effective strike can be treated as constant. For details, see the Theory Guide [7, § 4.3.40.1 Underlying Swap].

¹See [35] for a basic derivation of the lognormal model.

Cash-settled swaptions: The model assumes that the settlement date of cash-settled swaptions is close to option expiry. This allows the discount rate between the two dates to be treated as evolving approximately deterministically. For details, see the Theory Guide [7, § 4.3.40.4 Cash Settled Swaption].

Effective tenor for amortising swaptions: The volatility surface is looked up by tenor, expiry and strike. When the swaption is on an amortising swap, the model constructs an effective tenor to look up the volatility by using the tenor of a vanilla swap of matching duration (in general, this tenor must be interpolated from those of two vanilla swaps). The resulting volatility is therefore approximate. For details, see the Theory Guide [7, § 4.3.40.8 Effective Tenor for Amortizing Swaptions].

Volatility for forward-starting swaptions: As explained in the Theory Guide [7, § 4.3.40.9 Volatility for Forward Start Swaptions]:

Theory Guide 4.3.40.9

For a forward start swaption, the effective date of the underlying swap is several months or years after the option expiry date. Swap rate volatilities are available only for standard swaptions where the underlying swap starts at most a few days after the option expiry. Following Massar [39], the implied volatility of the forward start swaption is calculated from the implied volatilities of two standard swaptions and a correlation.

This then involves additional assumptions and approximations:

Theory Guide 4.3.40.9

Let $s_k(t)$ denote the swap rate from t_0 to T_i and $F_k(t)$ the corresponding fixed-side PVBP, for $k \in \{1, 2\}$. The valuation model requires the principal amount to be constant (no amortization) and assumes that t_0 is a whole number of fixed-side periods and a whole number of floating side periods before T_1 . Then the PVBPs and floating side values are related by:

$$F(t) = F_2(t) - F_1(t) \quad (44.1.1)$$

$$s(t)F(t) = s_2(t)F_2(t) - s_1(t)F_1(t) \quad (44.1.2)$$

for $t \leq t_0$. For a given valuation date t , the random variable $F_2(t_0)/F(t_0)$ is approximated by the constant $\omega = F_2(t)/F(t)$. Under this approximation,

$$s(t_0) = \omega s_2(t_0) - (\omega - 1)s_1(t_0). \quad (44.1.3)$$

No convexity corrections: The model assumes that there are no significant convexity corrections, and so values the underlying floating interest cashflows without any such corrections.

44.1.4.5 Limitations

Restrictions: The underlying swap is subject to the following restrictions:

1. Each floating interest cashflow is a swaption on a simply-compounded rate [7, § 4.3.40.1 Underlying Swap].
2. There is no compounding [7, § 4.3.40.1 Underlying Swap].
3. Forward-starting swaps cannot be amortised [7, § 4.3.40.9 Volatility for Forward Start Swaptions].

Large discount rate volatilities: The assumption of constant effective strike will break down when the discount rate volatility is sufficiently high.

44.1.5 Hull-White Valuation Model (SwaptionHullWhiteValuation)

44.1.5.1 Price Factor Dependency

Floating Interest Cashflow List

- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)
- └ Hull White 1 Factor Model Parameters
- └ LGM Model Parameters

44.1.5.2 Valuation

This valuation model is used during the calibration of the one-factor Hull-White and LGM interest rate models. For details of this model, see the Theory Guide [7, § 4.3.40.10 Valuation under Hull-White Model and § D.1.6.5 Swaption], where it is explained that:

Theory Guide [D.1.6.5](#)

The value of a European swaption under the one-factor Hull-White and LGM models is calculated using the decomposition of Jamshidian [34]. Following Henrard [28, Theorem 2], the method can be generalized to allow a deterministic spread between the forecast rate and the discount rate, as described in Section [D.1.6.3](#).

44.1.5.3 Tuning Parameters and Valuation Settings

Model Parameters Type: Hull White or LGM. The model parameters price factor type. Defaults to Hull White.

Model Parameters: ID of model parameters price factor. If not specified, the ID of the forecast interest rate price factor is used.

44.1.5.4 Assumptions

Constant mean reversion rate: The mean reversion rate (α) is constant when the valuation model uses the Hull-White 1 Factor Model Parameters price factor.

Deterministic relation between forecast and discount rates: The model assumes a deterministic relation between forecast and discount rates as described in the Theory Guide [7, § [D.1.6.3 Forecast Rate](#)].

Cashflow rate end and payment dates: The model makes an approximation based on the assumption that the rate end date and payment date for a cashflow are no more than a few days apart. For details, see the Theory Guide [7, § [D.1.6.5 Swaption](#)]. Note that the restrictions on the underlying swap listed in § [44.1.5.5](#) ensure this assumption holds.

44.1.5.5 Limitations

The underlying swap is subject to the following restrictions:

1. Each floating interest cashflow is a swaption on a simply-compounded rate [7, § [4.3.40.1 Underlying Swap](#)].

2. There is no compounding [7, § 4.3.40.1 Underlying Swap].
3. Each cashflow has precisely one reset with rate end date and payment date not more than 10 days apart [7, § 4.3.40.10 Valuation under Hull-White Model].
4. The rate start date of the first floating interest cashflow is before the payment date of the first fixed interest cashflow [7, § 4.3.40.10 Valuation under Hull-White Model].

44.2 American and Bermudan Swaptions and Cancellable Swaps

44.2.0.1 Overview

This section covers American and Bermudan options on an underlying interest rate swap, and cancellable swaps, which are interest rate swaps where one party has the right to cancel the swap, with either American or Bermudan option style. Adaptiv Analytics values all such deals using the same methodology: a tree model due to Järvinen (2000) [36].

The subsequent sections (§ 44.2.0.2 through to § 44.2.0.6) cover the common functionality shared by these deal types.

44.2.0.2 Properties

American and Bermudan swaptions and cancellable swaps share the following properties:

Currency

Settlement currency. For example, USD.

Discount Rate

ID of the interest rate price factor (or discount rate price factor) used to discount the cashflows. For example, USD.AAA. The currency of the interest rate price factor must be the settlement currency. If left blank, the ID of the settlement currency is used.

Forecast Rate

ID of the interest rate price factor used to calculate forward interest rates. For example, USD.AAA. If left blank, the discount interest rate price factor is used. The payoff is quanto when the currency of the forecast interest rate price factor is different from the settlement currency of the deal.

Forecast Rate Volatility

ID of the interest rate volatility price factor or interest yield volatility price factor used for the volatility of the forecast rate. Examples, USD, USD.BBB, USD.CAPVOLATILITY. If left blank, the ID of the forecast rate's currency is used.

Principal

Principal amount in units of settlement currency.

Swap Effective Date

Unadjusted start date of the underlying swap.

Swap Maturity Date

Unadjusted maturity date of the underlying swap.

Pay Frequency

Frequency of the payments on the pay leg. If set to 0M then there is a single payment.

Receive Frequency

Frequency of the payments on the receive leg. If set to 0M then there is a single payment.

Pay Day Count

Day count convention for the pay leg used to calculate the accrual year fractions. See Section 3.3.4 for more information about day counts in Adaptiv Analytics.

Receive Day Count

Day count convention for the receive leg used to calculate the accrual year fractions. See Section 3.3.4 for more information about day counts in Adaptiv Analytics.

Initial Swap Rate

Fixed interest rate. Rates are entered in percentage. For example, enter 5 for 5%.

Floating Margin

Margin rate added to the floating interest rate. Rates are entered in basis points. For example, enter 50 for 50 basis points.

Margin Schedule

List of margin rates and corresponding dates. Each item in the schedule is allocated to the cashflow with `Accrual Start Date` closest to the item's date, unless the cashflow has already been allocated an item with a closer date. If a cashflow is allocated an item in the schedule then the cashflow `Margin` is set to the item's value, otherwise the cashflow `Margin` is set the `Margin/Floating Margin` on the deal. Rates in the schedule are entered in basis points. For example, enter 50 for 50 basis points.

Rate Multiplier

Multiplier for the floating interest rate. Defaults to 1 and must be positive.

Amortisation

Amortisation schedule consisting of a list of (`Date`, `Amount`) pairs, where the `Amount` is the amount by which the principal amount is reduced at the `Date`. An increase in principal amount is represented by a negative `Amount`.

Rate Schedule

Schedule of strike or coupon rates (`Value`) and corresponding dates (`Date`). If `Schedule_Type` is `None` then the schedule is ignored. If `Schedule_Type` is `Strike` then each item in the schedule is allocated to the accrual date closest to the item's date, unless the accrual date has already been allocated an item with a closer date; if an accrual date has not been allocated a strike then its strike is the `Initial_Swap_Rate`. If `Schedule_Type` is `Coupon` then each item in the schedule is allocated to the cashflow with accrual end date closest to the item's date, unless the cashflow has already been allocated an item with a closer date; if a cashflow is allocated an item in the schedule then its fixed rate is set to the item's rate, otherwise the fixed rate is set to the `Initial_Swap_Rate`. Rates in the schedule are entered in percentage. For example, enter 5 for 5%.

First Exercise Date

First exercise date. Defines a lower bound on the accrual dates at which the Bermudan option is exercisable.

Last Exercise Date

Last exercise date. Defines an upper bound on the accrual dates at which the Bermudan option is exercisable.

Exercise Fees

List of exercise dates (`Date`) and corresponding exercise fees as a percentage of the principal (`Value`). Each item in the list is allocated to the accrual date closest to the item's date, unless the accrual date has already been allocated an item with a closer date. For Bermudan options, when a list of exercise fees is specified, the option is exercisable only at the accrual start dates which have been allocated a fee; otherwise, the option is exercisable at all accrual start dates. Fees are entered in percentage. For example, enter 5 for 5%.

Known Rates

List of reset dates (`Date`) and corresponding known interest rates (`Value`). Rates are entered in percentage. For example, enter 5 for 5%.

Max Nodes

Maximum number of time steps in the binomial tree. Deal parameter `Max_Nodes` overrides valuation model parameter `Max_Nodes` when the deal parameter value is greater than zero.

Step Size

Size of time step in the binomial tree. For example, 1M. Deal parameter `Step_Size` overrides

valuation model parameter `Step_Size` when the deal parameter value is a non-zero term.

Rate Fixing

ID used to obtain a rate fixing value. For example, `USD.LIBOR,3M`. If left blank defaults to `Forecast_Rate,Tenor`, where `Tenor` is the floating side frequency.

Fixed Calendars

Specifies one or more holiday calendars used when calculating accrual dates and accrual year fractions for the fixed leg. If not provided then all calendar days are business days and dates are not adjusted.

Float Calendars

Specifies one or more holiday calendars for the floating leg used when calculating accrual dates, accrual year fractions and payment dates. If not provided then all calendar days are business days and dates are not adjusted.

44.2.0.3 Valuation

Analytics values Bermudan Swaption deals using the `SwaptionBermudanValuation` model. For details of the this model, see the Theory Guide [7, §4.3.41 [Bermudan Swaption](#)]:

Theory Guide [4.3.41](#)

Analytics uses a pricing model based on Järvinen [36]. Discounting factors are treated as deterministic and the underlying forward swap rates are driven by a single Wiener process, and are either lognormally or normally distributed. The swap rates are evolved on a standard binomial tree. This method is fast and uses swaption volatilities directly, and hence does not require any calibration.

American Swaption and Cancellable Swap deals are valued using the `SwaptionAmericanValuation` and `CancellableSwapValuation` models, respectively. These are essentially variants of the Bermudan model. Here, we describe the core features of this model before giving specific details of the variants.

44.2.0.4 Tuning Parameters and Valuation Settings

Binomial Tree Parameters: The geometry of the tree is controlled by two parameters: `Step_Size` and `Max_Nodes`:

Theory Guide [4.3.41.3](#)

The time step Δ in the binomial tree is controlled by two parameters of the valuation model: the step size Δ_0 and the maximum number of nodes N . The minimum step size Δ_{\min} is the time from the valuation date to the last exercise date divided by N . The maximum step size Δ_{\max} is the length of the fixed-side coupon period. The time step is given by

$$\Delta = \min(\max(\Delta_{\min}, \Delta_0), \Delta_{\max}). \quad (44.2.1)$$

Both of these parameters can be defined globally in the valuation model as well as on individual deals.

Max Nodes: Maximum number of time steps in a binomial tree. Deal parameter `Max_Nodes` overrides valuation model parameter `Max_Nodes` when the deal parameter value is greater than zero.

Step Size: Size of time step in the binomial tree. For example, 1M, Deal parameter Step_Size overrides valuation model parameter Step_Size when the deal parameter is a non-zero term.

Step Size and Max Nodes are generally deal-specific to allow fine accuracy control. The user should determine their own settings based on their own analysis of accuracy/performance trade-offs.

Early Exercise Today: Adaptiv Analytics can stop the option from being exercised on the base date of the calculation, via the Early Exercise Today parameter of the valuation model. Let the valuation date t correspond to one of the exercise dates, such that t is in the Exercise Fees schedule, if one has been specified, or is one of the accrual start dates. The option can be exercised at $t = 0$ only if Early Exercise Today is set to Yes. Otherwise, if Early Exercise Today is No, the option can be exercised at t only if $t > 0$. The default value for Early Exercise Today is Yes. The setting of this parameter is important for calculations such as VaR, sensitivities and stress calculations. When Early Exercise Today is Yes, an inconsistency can exist where under a subset of scenarios the option will be exercised at $t = 0$, and under the remaining scenarios the option will not be exercised.

44.2.0.5 Assumptions

Swap Rates and Volatility Surface: The valuation model assumes the underlying swap rates are either normal or log-normal based on the volatility surface.

Theory Guide 1.8.2

If the Distribution Type is Lognormal then the price factor values are lognormal volatilities (implied Black volatilities) and the valuation models assume that rates have a lognormal distribution. If the Distribution Type is Normal then the price factor values are normal volatilities (implied Bachelier volatilities) and the valuation models assume that rates have a normal distribution. The default Distribution Type is Lognormal.

The interest rate volatility price factor has a Shift value. The Shift must be zero when the Distribution Type is Normal. If the Distribution Type is Lognormal and the Shift is not zero then the valuation models assume that rates have a shifted lognormal distribution.

Theory Guide 4.3.41

The swap rates follow the dynamics

$$ds_i(t) = \sigma_i s_i(t)^\beta dW(t), \quad (44.2.2)$$

where either $\beta = 1$ when the Distribution Type of the forecast rate volatility is Lognormal, or $\beta = 0$ when the Distribution Type is Normal.

and the model has a limited support for volatility skew, where the volatility parameter σ_i is interpolated off a single point on the volatility surface:

Theory Guide 4.3.41

σ_i is the forecast rate volatility at time t for expiry date t_i , tenor $t_n - t_i$ and strike $K_i(t)$.

Deterministic Discounting Factors: While we impose a stochastic dynamic on the swap rate itself, the model simultaneously assumes that the numeraire associated with the model, present value of a basis point (PVBP) factor, is deterministic. More specifically:

Theory Guide 4.3.41

The swap rates are stochastic but the PVBP factors are approximated as deterministic and given by

$$F_i(T) = \frac{F_i(t)}{D(t, T)} \quad (44.2.3)$$

for $t \leq T \leq t_{i+1}$. Under this assumption, all the swaption measures are identical and the swap rates are all martingales under the same measure. Under this measure, there is a Wiener process $W(t)$ that drives all the swap rates.

The assumption of deterministic PVBP discount factors makes this a fast one-factor interest rate model where the swap rates can be evolved on a standard binomial tree. The fact that this model simultaneously assumes a stochastic process on the swap rate itself, while also assuming that the PVBP factors are deterministic implies that the model may not be ideal when the discount rate volatility is significant compared to forecast rate volatility.

44.2.0.6 Limitations

Exercise Dates: It is assumed that the exercise dates of Bermudan-style deals fall on fixed-side coupon dates. American-style deals can be exercised continuously between the fixed-side coupon dates that are closest to the first and last exercise dates. More precisely:

Theory Guide 4.3.41

Consider a Bermudan swaption with fixed-side accrual dates t_0, t_1, \dots, t_n , fixed-side notional amounts P_1, \dots, P_n , and fixed-side accrual year fractions $\alpha_1, \dots, \alpha_n$. The exercise dates are a subset of $\{t_0, \dots, t_{n-1}\}$. If the option is exercised at t_i then the underlying swap has accrual dates t_i, t_{i+1}, \dots, t_n and coupon dates t_{i+1}, \dots, t_n , and the owner of the swaption pays a fee κ_i at t_i .

Theory Guide 4.3.41.1

Let t_l be the date in $\{t_0, \dots, t_{n-1}\}$ that is closest to the First Exercise Date. Let t_u be the date in $\{t_0, \dots, t_{n-a}\}$ that is closest to the Last Exercise Date, where either $a = 0$ for a Bermudan option or $a = 1$ for an American option.

The Exercise Fees schedule consists of a list of (T, f) pairs where T is a date and f is a percentage exercise fee. The exercise fees in the schedule are assigned to the accrual dates t_0, t_1, \dots, t_n using the method of Section 1.6.1. If t_i has been assigned a fee f then $\kappa_i = P(t_i)f$, where $P(t)$ is the outstanding principal amount at t ; otherwise $\kappa_i = 0$.

If the schedule is empty then the Bermudan option is exercisable at each t_i for which $l \leq i \leq u$. Otherwise, the Bermudan option is exercisable at each t_i for which $l \leq i \leq u$ and t_i has been assigned a fee. The American option is exercisable at all dates T for which $t_l \leq T \leq t_u$.

Exercise Conditions in Ageing: Within an ageing simulation, the model exercises the option in any of the exercise dates when they are optimal, i.e. when the value at time of exercise is the greater of the payoff of immediate exercise and the value of continuing to hold the option:

Theory Guide 4.3.41

Let $V(t)$ denote the value of the swaption at time t . If the swaption is exercised at time t_i then its value is $A\delta(s_i(t_i) - K_i(t_i))F_i(t_i)$, where either $\delta = 1$ for a payer swaption or $\delta = -1$ for a receiver swaption. If not exercised at t_i then its value is $F_i(t_i)\mathbb{E}_{t_i}^{(i)}(V(t_j)/F_i(t_j))$, where t_j is the next exercise date after t_i and $\mathbb{E}^{(i)}$ denotes expectation in the swaption measure corresponding to the i^{th} underlying swap. Therefore,

$$V(t_i) = \max \left(A\delta(s_i(t_i) - K_i(t_i))F_i(t_i) - \kappa_i, F_i(t_i)\mathbb{E}_{t_i}^{(i)} \left(\frac{V(t_j)}{F_i(t_j)} \right) \right). \quad (44.2.4)$$

This concept of optimal exercise is idealised, and ignores effects such as counterparty credit risk, funding, liquidity, and capital, and may differ from actual exercise patterns.

Settlement Date for Bermudan Options: The behaviour of the settlement date is implemented as follows:

Theory Guide [4.3.41.5](#)

Suppose the option is exercised at date T , where $t_i \leq T < t_{i+1}$. Let $U_T(t)$ denote the value of the underlying swap with effective date T and fixed-side coupon date t_{i+1}, \dots, t_n . If the option is cash settled then $V(T) = U_T(T) - \kappa_i$, $V(t) = 0$ for $t > T$ and the cash settled at time T is $V(T)$. If the option is physically settled then $V(T) = U_T(T) - \kappa_i$, $V(t) = U_T(t)$ for $t > T$ and the cash settled at time T is $-\kappa_i$.

This means that if the option is exercised early and cash settled, the deal PV is zero after the exercise date T until the option expiry date. If the option is exercised early and physically settled, the deal PV is set to the value of the underlying swap after the exercise date T and until the Bermudan swaption option expiry date. In other words, in this case, the deal continues to contribute the exposure until the option expiry date.

44.2.1 Bermudan Swaption

44.2.1.1 Overview

A Bermudan Swaption deal represents a Bermudan-style option on an underlying interest rate swap.

44.2.1.2 Price Factor Dependency

Bermudan Swaption

- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)
- └ Interest Yield Volatility (§ 11.3.5)

44.2.1.3 Properties

The Bermudan Swaption has the following properties in addition to those given in § 44.2.0.2:

Buy Sell

Buy or Sell. Determines whether the holder is long (Buy) or short (Sell) the deal.

Payer Receiver

Payer or Receiver. Determines whether the option holder pays the fixed (Payer) or receives the fixed (Receiver) leg of the underlying swap deal.

Settlement Style

Cash or Physical. Option settlement method: cash settled (Cash) or deliver the underlying

Schedule Type

Strike, Coupon or None. Determines how Rate_Schedule is used. Rate_Schedule can be used to specify variable strikes (Strike), variable fixed coupons (Coupon), or not used (None).

44.2.1.4 Deal Representation

The Bermudan Swaption is an atomic deal.

44.2.1.5 Valuation

Adaptiv Analytics values a Bermudan Swaption using the SwaptionBermudanValuation model described in § 44.2.0.2 through to § 44.2.0.6.

44.2.1.6 Assumptions

This product is subject to the assumptions given in § 44.2.0.5.

44.2.1.7 Limitations

This product is subject to the limitations given in § 44.2.0.6.

44.2.2 American Swaption

44.2.2.1 Overview

An American Swaption deal represents an American-style option on an underlying interest rate swap.

44.2.2.2 Price Factor Dependency

American Swaption

- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)
- └ Interest Yield Volatility (§ 11.3.5)

44.2.2.3 Properties

The American Swaption has the following properties in addition to those given in § 44.2.0.2:

Buy Sell

Buy or Sell. Determines whether the holder is long (Buy) or short (Sell) the deal.

Payer Receiver

Payer or Receiver. Determines whether the option holder pays the fixed (Payer) or receives the fixed (Receiver) leg of the underlying swap deal.

Settlement Style

Cash or Physical. Option settlement method: cash settled (Cash) or deliver the underlying

Schedule Type

Strike, Coupon or None. Determines how Rate_Schedule is used. Rate_Schedule can be used to specify variable strikes (Strike), variable fixed coupons (Coupon), or not used (None).

44.2.2.4 Deal Representation

The American Swaption is an atomic deal.

44.2.2.5 Valuation

Adaptiv Analytics values an American Swaption using the `SwaptionAmericanValuation` model, which is in essence identical to the `SwaptionBermudanValuation` model described in § 44.2.0.2 through to § 44.2.0.6, extended to allow for continuous exercise between fixed-side coupon dates. For details about the valuation for this deal, see the Theory Guide [7, § 4.3.41.4 American Swaption].

44.2.2.6 Assumptions

This product is subject to the assumptions given in § 44.2.0.5.

44.2.2.7 Limitations

This product is subject to the following limitations in addition to those given in § 44.2.0.6:

Interpolation: For an American Swaption exercised at a date between two fixed-side coupon dates, the value of the underlying cashflows at exercise is approximated by interpolating the PVBP, swap rate and effective strike of the underlying swaps at the two coupon dates.

Delivery under early exercise: For American Swaption deals with physical delivery that are exercised early, the underlying swap is not delivered until the settlement date.

44.2.3 Cancellable Swap

44.2.3.1 Overview

A Cancellable Swap deal represents an interest rate swap where one party has the right to cancel the swap, with either American or Bermudan option style.

44.2.3.2 Price Factor Dependency

Cancellable Swap

- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)
- └ Interest Yield Volatility (§ 11.3.5)

44.2.3.3 Properties

The Cancellable Swap has the following properties in addition to those given in § 44.2.0.2:

Option Buy Sell

Buy or Sell. Determines whether the holder is long (Buy) or short (Sell) the deal.

Option Style

Bermudan or American. Option style: Bermudan or American.

Pay Rate Type

Fixed or Floating. Interest rate type for the pay leg.

44.2.3.4 Deal Representation

The Cancellable Swap is an atomic deal.

44.2.3.5 Valuation

Adaptiv Analytics values an Cancellable Swap using the `CancellableSwapValuation` model.

A Cancellable Swap is treated as a portfolio of an underlying interest rate swap and a swaption on a swap that is opposite to the original underlying swap, such that the total value of the swaps after exercise is zero.

The swaption is valued by the model described in § 44.2.0.2 through to § 44.2.0.6. The underlying swap is valued consistently with that model.

For details about the valuation for this deal, see the Theory Guide [7, § 4.3.41.6 Cancellable Swap].

44.2.3.6 Assumptions

This product is subject to the assumptions given in § 44.2.0.5.

44.2.3.7 Limitations

This product is subject to the limitations given in § 44.2.0.6. When the option style is American, it is subject to the additional limitations given in § 44.2.2.7.

Chapter 45

Fixed Income

45.1 FRN Forward

45.1.1 Overview

This deal type is for cash settled floating rate note (FRN) forwards.

45.1.2 Price Factor Dependency

FRN Forward

- └ FX Rate (§ 4.2)
- └ Discount Rate (§ 6.2)
- └ Interest Rate (§ 6.1)
- └ Interest Rate Volatility (§ 11.3.4)
- └ Interest Yield Volatility (§ 11.3.5)
- └ Recovery Rate (§ 9.3)
- └ Survival Probability (§ 9.1)

45.1.3 Properties

Currency

ID of the settlement currency. For example, USD.

Discount Rate

ID of the interest rate price factor (or discount rate price factor) used to discount the cashflows. For example, USD.AAA. The currency of the interest rate price factor must be the settlement currency. If left blank, the ID of the settlement currency is used.

Repo Rate

ID of the repo interest rate price factor. For example, USD.AAA. The currency of the interest rate price factor must be the settlement currency. If left blank, the discount interest rate price factor is used. (Text; Optional).

Buy Sell

Buy or Sell. Determines whether the holder is long (Buy) or short (Sell) the FRN.

Issue Date

Unadjusted bond issue date.

Issue Date Adjustment Method

Date adjustment method for the issue date. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

Bond Maturity Date

Unadjusted bond maturity date.

Bond Maturity Date Adjustment Method

Date adjustment method for the bond maturity date. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

First Coupon Date

Unadjusted first coupon date.

Penultimate Coupon Date

Unadjusted penultimate coupon date.

Roll Convention

Roll convention used when generating payment and accrual dates. See Section 3.3.6 for more information about roll conventions in Adaptiv Analytics.

Roll Day Of Month

Day of month for roll convention Day Of Month. For example, enter 28 for the 28th day of the month.

Roll Direction

Forward or Backward. Roll direction used when generating payment and accrual dates.

Coupon Interval

Frequency of the coupon payments. If set to 0M then there is a single coupon payment.

Accrual Day Count

Day count convention used to calculate the accrual year fractions. See Section 3.3.4 for more information about day counts in Adaptiv Analytics.

Accrual Adjustment Method

Date adjustment method for accrual dates. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

Payment Timing

Begin, End or Discounted. Timing of interest payments. Either at end of interest accrual period (End), start of interest accrual period (Begin), or start of interest accrual period with discounting (Discounted).

Payment Adjustment Method

Date adjustment method for payment dates. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

Payment Offset

Number of business days between the accrual and payment dates.

Notional

Notional principal amount in units of settlement currency.

Amortisation

Amortisation schedule consisting of a list of (Date, Amount) pairs, where the Amount is the amount by which the principal amount is reduced at the Date. An increase in principal amount is represented by a negative Amount.

Accrual Calendars

Specifies one or more holiday calendars used when calculating accrual dates and accrual year

fractions. If not provided then all calendar days are business days and dates are not adjusted.

Payment Calendars

Specifies one or more holiday calendars used when calculating the payment dates. If not provided then all calendar days are business days and dates are not adjusted.

Issuer

ID of the issuer and the ID of the credit rating price factor. For example, IBM.

Survival Probability

ID of the survival probability price factor. For example, IBM or IBM.SENIOR. If left blank, the ID of the issuer or name is used.

Recovery Rate

ID of the recovery rate price factor. For example, BOND. If left blank, the ID of the issuer or name is used.

Settlement Date

Settlement date of the forward deal.

Price

Settlement price for the forward deal. Prices are entered in percentage. For example, enter 100 for 100%.

Price Is Clean

Yes or No. Set to Yes if the contractual price excludes interest accrued up to the Settlement Date.

Is Defaultable

Set to No to discount the net forward value with the Repo Rate for forward deals. Set to Yes to discount only the settlement cashflow with the Repo Rate and add it to the present value of the risky-discounted bond cashflows. Used when the deal has a Settlement Date.

Forecast Rate

ID of the interest rate price factor used to calculate forward interest rates. For example, USD.AAA. If left blank, the discount interest rate price factor is used. The payoff is quanto when the currency of the forecast interest rate price factor is different from the settlement currency of the deal.

Forecast Rate Volatility

ID of the interest rate volatility price factor or interest yield volatility price factor used for the volatility of the forecast rate. Examples, USD, USD.BBB, USD.CAPVOLATILITY. If left blank, the ID of the forecast rate currency is used.

Discount Rate Volatility

ID of the interest rate volatility price factor or interest yield volatility price factor used for the volatility of the discount rate. Examples, USD, USD.BBB, USD.CAPVOLATILITY. If left blank, the ID of the settlement currency is used.

Index Calendars

Specifies one or more holiday calendars used when calculating rate start dates, rate end dates and rate year fractions. If not provided then all calendar days are business days and dates are not adjusted.

Index Publication Calendars

Specifies one or more holiday calendars used when calculating the rate reset date from the accrual date and index offset. If not provided then all calendar days are business days and dates are not adjusted.

Margin

Margin rate added to the floating interest rate. Rates are entered in basis points. For example, enter 50 for 50 basis points.

Margin Schedule

List of margin rates and corresponding dates. Each item in the schedule is allocated to the cashflow with `Accrual Start Date` closest to the item's date, unless the cashflow has already been allocated an item with a closer date. If a cashflow is allocated an item in the schedule then the cashflow `Margin` is set to the item's value, otherwise the cashflow `Margin` is set the `Margin` on the deal. Rates in the schedule are entered in basis points. For example, enter 50 for 50 basis points.

Reset Type

Standard, Advance or Arrears. Timing of the rate fixing. Either at the start of the accrual period (Standard), or at the end of the accrual period (Arrears), or at the start of the previous accrual period (Advance).

Index Tenor

Floating rate tenor. If set to 0M then the interest frequency is used.

Index Day Count

Day count convention used to calculate the floating rate year fractions. Set to either the day count convention of the money-market (LIBOR) rate or the fixed-side day count convention of the swap (CMS) rate. See Section 3.3.4 for more information about day counts in Adaptiv Analytics.

Index Frequency

Fixed side frequency of the swap (CMS) rate. The floating rate is a swap rate when the `Index Frequency` is greater than 0M and less than the `Index Tenor`.

Index Offset

Number of business days between the rate reset and rate start dates.

Index Adjustment Method

Date adjustment method used to calculate rate end dates. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

Known Rates

List of reset dates and corresponding known interest rates. Rates are entered in percentage. For example, enter 5 for 5%.

Rate Fixing

ID used to obtain a rate fixing value. For example, USD.LIBOR,3M. If left blank defaults to `Forecast Rate,Index Tenor`. Written to the `Rate Fixing` property of the cashflows in the floating interest cashflow list when the deal is built.

Initial Stub

Details of initial stub accrual period.

Interpolated Rate Rounding

Number of decimal places to use when rounding the percentage interpolated stub rate. The rate is not rounded when `Interpolated Rate Rounding` is set to zero.

Rate 1 Fixing

Rate fixing ID for the first reference rate. For example, USD.LIBOR,3M.

Rate 2 Fixing

Rate fixing ID for the second reference rate. For example, USD.LIBOR,3M.

Rate 1 Tenor

Tenor of the first reference rate.

Rate 2 Tenor

Tenor of the second reference rate.

Forecast Rate 1

ID of the interest rate price factor used to calculate forward interest rates for the first reference rate. For example, USD.AAA. If left blank, the discount interest rate price factor is used.

Forecast Rate 2

ID of the interest rate price factor used to calculate forward interest rates for the second reference rate. For example, USD.AAA. If left blank, the discount interest rate price factor is used.

Known Rate

Value of stub rate used when `Use Known Rate` is set to Yes. Entered as a decimal or as a percentage. For example, enter 5% or 0.05 for 5%.

Use Known Rate

Yes or No. Set to Yes when the stub rate is known.

Final Stub

Details of final stub accrual period. `Final Stub` has the same properties as `Initial Stub`.

45.1.4 Deal Representation

The FRN Forward deal is a deal skin that builds into a Floating Interest Cashflow List deal. See the Deal Skins Guide [2]. The deal builds into a cash-settled cashflow list deal; only cashflows with payment date after the settlement date are included in the cashflow list. For more details about the generation of the cashflow list deals, see the Theory Guide [7, § 4.3.47 FRN and FRN Forward, § 4.3.22 Floating Swap Leg and § 1.3 Date Generation].

45.1.5 Valuation

The FRN Forward deal is valued using the `DealSkinValuation` model, under which the value of deal is the value of the underlying Floating Interest Cashflow List deal (§ 42.2).

45.2 Bond Forward

45.2.1 Overview

This deal type is for cash settled bond forwards.

45.2.2 Price Factor Dependency

Bond Forward

- └ FX Rate (§ 4.2)
- └ Discount Rate (§ 6.2)
- └ Interest Rate (§ 6.1)
- └ Recovery Rate (§ 9.3)
- └ Survival Probability (§ 9.1)

45.2.3 Properties

Currency

ID of the settlement currency. For example, USD.

Discount Rate

ID of the interest rate price factor (or discount rate price factor) used to discount the cashflows. For example, USD.AAA. The currency of the interest rate price factor must be the settlement currency. If left blank, the ID of the settlement currency is used.

Repo Rate

ID of the repo interest rate price factor. For example, USD.AAA. The currency of the interest rate price factor must be the settlement currency. If left blank, the discount interest rate price factor is used. (Text; Optional).

Buy Sell

Buy or Sell. Determines whether the holder is long (Buy) or short (Sell) the bond.

Issue Date

Unadjusted bond issue date.

Issue Date Adjustment Method

Date adjustment method for the issue date. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

Bond Maturity Date

Unadjusted bond maturity date.

Bond Maturity Date Adjustment Method

Date adjustment method for the bond maturity date. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

First Coupon Date

Unadjusted first coupon date.

Penultimate Coupon Date

Unadjusted penultimate coupon date.

Roll Convention

Roll convention used when generating payment and accrual dates. See Section 3.3.6 for more information about roll conventions in Adaptiv Analytics.

Roll Day Of Month

Day of month for roll convention Day Of Month. For example, enter 28 for the 28th day of the month.

Roll Direction

Forward or Backward. Roll direction used when generating payment and accrual dates.

Coupon Interval

Frequency of the coupon payments. If set to 0M then there is a single coupon payment.

Accrual Day Count

Day count convention used to calculate the accrual year fractions. See Section 3.3.4 for more information about day counts in Adaptiv Analytics.

Accrual Adjustment Method

Date adjustment method for accrual dates. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

Payment Timing

Begin, End or Discounted. Timing of interest payments. Either at end of interest accrual period (End), start of interest accrual period (Begin), or start of interest accrual period with discounting (Discounted).

Payment Adjustment Method

Date adjustment method for payment dates. See Section 3.3.5 for more information about date adjustment methods in Adaptiv Analytics.

Payment Offset

Number of business days between the accrual and payment dates.

Notional

Notional principal amount in units of settlement currency.

Amortisation

Amortisation schedule consisting of a list of (Date, Amount) pairs, where the Amount is the amount by which the principal amount is reduced at the Date. An increase in principal amount is represented by a negative Amount.

Accrual Calendars

Specifies one or more holiday calendars used when calculating accrual dates and accrual year fractions. If not provided then all calendar days are business days and dates are not adjusted.

Payment Calendars

Specifies one or more holiday calendars used when calculating the payment dates. If not provided then all calendar days are business days and dates are not adjusted.

Issuer

ID of the issuer and the ID of the credit rating price factor. For example, IBM.

Survival Probability

ID of the survival probability price factor. For example, IBM or IBM.SENIOR. If left blank, the ID of the issuer or name is used.

Recovery Rate

ID of the recovery rate price factor. For example, BOND. If left blank, the ID of the issuer or name is used.

Settlement Date

Settlement date of the forward deal.

Price

Settlement price for the forward deal. Prices are entered in percentage. For example, enter 100 for 100%.

Price Is Clean

Yes or No. Set to Yes if the contractual price excludes interest accrued up to the Settlement Date.

Is Defaultable

Set to No to discount the net forward value with the Repo Rate for forward deals. Set to Yes to discount only the settlement cashflow with the Repo Rate and add it to the present value of the risky-discounted bond cashflows. Used when the deal has a Settlement Date.

Coupon Rate

Fixed coupon rate. Rates are entered in percentage. For example, enter 5 for 5%.

Coupon Rate Schedule

List of fixed rates and corresponding dates. Each item in the schedule is allocated to the cashflow with Accrual Start Date closest to the item's date, unless the cashflow has already been allocated an item with a closer date. If a cashflow is allocated an item in the schedule then the cashflow Rate is set to the item's value, otherwise the cashflow Rate is set the Coupon Rate on the deal. Rates in the schedule are entered in percentage. For example, enter 5 for 5%.

Use Initial Stub Rate

Yes or No. Set to Yes to apply Initial Stub Rate.

Initial Stub Rate

Fixed rate for initial stub accrual period. Entered as a decimal or as a percentage. For example, enter 5% or 0.05 for 5%.

Use Final Stub Rate

Yes or No. Set to Yes to apply Final Stub Rate.

Final Stub Rate

Fixed rate for final stub accrual period. Entered as a decimal or as a percentage. For example, enter 5% or 0.05 for 5%.

45.2.4 Deal Representation

The Bond Forward deal is a deal skin that builds into a Fixed Interest Cashflow List deal. See the Deal Skins Guide [2]. The deal builds into a cash-settled cashflow list deal; only cashflows with payment date after the settlement date are included in the cashflow list. For more details about the generation of the cashflow list deals, see the Theory Guide [7, § 4.3.46 Bond and Bond Forward, § 4.3.18 Fixed Swap Leg and § 1.3 Date Generation].

45.2.5 Valuation

The Bond Forward deal is valued using the DealSkinValuation model, under which the value of deal is the value of the underlying Fixed Interest Cashflow List deal (§ 42.1).

45.3 Bond Option

45.3.1 Overview

This deal type is for European bond options.

45.3.2 Price Factor Dependency

Bond Option

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)
- └ Interest Yield Volatility (§ 11.3.5)
- └ Recovery Rate (§ 9.3)
- └ Survival Probability (§ 9.1)

45.3.3 Properties

For an overview and description of the properties of the deal, see the deal definition in the Integrated documentation [4, Portfolio: Bond Option].

45.3.4 Deal Representation

The Bond Option is an atomic deal.

45.3.5 Valuation

In Adaptiv Analytics, a bond option deal can be valued using the `BondOptionValuation` model.

Theory Guide [4.3.51](#)

European bond options are valued using Black's model on the forward bond price.

For details about the valuation for this deal, see the Theory Guide [7, § [4.3.51 Bond Option](#)].

45.3.6 Tuning Parameters and Valuation Settings

45.3.6.1 Use Survival Probability

`Use Survival Probability` controls whether the issuer's survival probability is used to determine the bond forward value.

When `Use Survival Probability=No`, only the discount rate specified on the deal is used to discount future bond cashflows. When `Use Survival Probability=Yes`, both the discount rate and the issuer's survival probability are used.

Theory Guide [4.3.51](#)

When Use Survival Probability is No the forward bond price at time $t \leq T$ is given by

$$F(t, T) = \frac{1}{D(t, T)} \left(\sum_{i=1}^n P_i c \alpha_i D(t, t_i) [T < t_i] + P(t_n) D(t, t_n) + \sum_{j=1}^m a_j D(t, s_j) [T < s_j \leq t_n] \right), \quad (45.3.1)$$

where D is the discount factor for the discount rate (see Section 1.6.6).

When Use Survival Probability is Yes the forward bond price at time $t \leq T$ is given by

$$F(t, T) = \frac{1}{D(t, T)} \left(\sum_{i=1}^n P_i c \alpha_i D(t, t_i) S(t, t_i) [T < t_i] + P(t_n) D(t, t_n) S(t, t_n) + \sum_{j=1}^m a_j D(t, s_j) S(t, s_j) [T < s_j \leq t_n] + P(T) R (1 - S(t, T)) D(t, T) + \sum_{i=1}^n P(\bar{t}_i) R (S(t, \bar{t}_{i-1}) - S(t, \bar{t}_i)) D(t, \bar{t}_i) [T < \bar{t}_i] \right), \quad (45.3.2)$$

where $S(t, u)$ is the issuer's probability of survival to time u , R is the recovery rate on the survival probability price factor, $\bar{t}_i = \max(t_i, T)$ and $\bar{t}_i = (\bar{t}_{i-1} + \bar{t}_i)/2$.

The discount rate passed to the deal can represent either a risk-free rate or risk-adjusted discount rate depending on how the market data was set up. In the latter case, users should select `Use Survival Probability=No` to avoid double counting the issuer's creditworthiness when calculating the bond forward price.

45.3.6.2 Respect Default

The valuation model property `Respect Default` controls the behaviour of the bond option valuation when the issuer defaults.

Theory Guide 4.3.51

If the deal has an issuer whose credit rating is stochastic under Monte Carlo simulation then the issuer may go into default on some scenarios. If the valuation model parameter `Respect Default` is Yes then the valuation model estimates the value of the deal at default using the recovery rate price factor specified on the deal.

Let τ denote the time of default. The value of the option at a time $t \geq \tau$ is modified by multiplying the forward bond price $F(t, T)$ by $D(t, T)R(\tau)$, where R is the realized recovery rate.

When `Respect Default = No`, the bond valuation does not depend on the issuer's credit rating and therefore is unaffected by the issuer's default. Note that this statement is true even if the credit rating is simulated within the calculation, for example, this can happen when another deal in the portfolio has a dependency on this particular issuer's credit rating.

45.3.7 Assumptions

45.3.7.1 Bond forward price volatility

The (constant) volatility used by the Black's formula is the bond forward price volatility σ_P .

Volatilities for bond options are generally quoted as yield volatilities, Adaptiv Analytics follows market convention by converting a yield volatility to a price volatility using the modified duration.

Theory Guide [4.3.51](#)

The price volatility σ_P is calculated from the yield volatility as described in Section [D.12.5](#), applied with T equal to the option expiry date. The yield volatility is obtained from the interest yield (swaption) volatility price factor at time t for expiry date T , tenor $t_n - T$ and yield strike $k = y(K; T, t_n, c, \tau)$, where τ is the coupon interval and $y(F; T, M, c, \tau)$ is the yield function defined in Section [D.12.2](#).

45.3.7.2 Black's modelling assumptions – Lognormality and constant volatility

The underlying bond exhibits pull-to-par behaviour also called reduction of maturity: as the bond approaches its maturity date, all the bond cashflows become known, the bond value converges to par value, therefore decreasing its volatility. However, the Black's model assumes the bond forward price $F(t, T)$ is a lognormal variable under T -forward measure with a constant volatility so it is unable to capture the pull-to-par behaviour.

The Black's assumptions are usually deemed reasonable in the literature if the time to expiry of the option is relatively short compared to time to maturity of the underlying bond.

45.3.8 Limitations

45.3.8.1 Defaultable bond – Value of payment on default

Let τ denote the issuer's time of default. If $\tau \in (\tilde{t}_{i-1}, \tilde{t}_i]$, Adaptiv Analytics assumes the payment on default is made on $\bar{t}_i = (\tilde{t}_{i-1} + \tilde{t}_i)/2$ and the recovery value is calculated from the outstanding principal at \bar{t}_i , discounted at \bar{t}_i .

Indeed, we need to approximate the value of payment on default

$$\begin{aligned} V(t) &= \int_T^{t_n} P(u)RS(t, u)h(t, u)D(t, u)du \\ &= \sum_{i=1}^n \int_{\tilde{t}_{i-1}}^{\tilde{t}_i} P(u)RS(t, u)h(t, u)D(t, u) [T < u] du \end{aligned} \quad (45.3.3)$$

Using results from Theory Guide [\[7, § 4.4.1.1 Value of Payment on Default\]](#),

Theory Guide [4.4.1.1](#)

Let $g(t)$ be a deterministic function of time. Consider a cashflow that pays $g(u)$ at time u if default occurs at time u , where $t_1 < u \leq t_2$. The value of the cashflow at time t , where $t \leq t_1$, is given by

$$V(t) = \int_{t_1}^{t_2} D(t, u)S(t, u)h(t, u)g(u) du. \quad (45.3.4)$$

Theory Guide [4.4.1.1](#)

Define $\bar{t} = (t_1 + t_2)/2$. The second method approximates the payoff by assuming that $g(\bar{t})$ is paid at time \bar{t} if default occurs between t_1 and t_2 . Under this assumption, the value of the cashflow at

time t , where $t \leq t_1$, is given by

$$V(t) = g(\bar{t})D(t, \bar{t})(S(t, t_1) - S(t, t_2)). \quad (45.3.5)$$

and noticing $g(u) = P(u)R[T < u]$, $t_1 = \tilde{t}_{i-1}$ and $t_2 = \tilde{t}_i$, $V(t)$ can be approximated by $\sum_{i=1}^n P(\bar{t}_i)R(S(t, \tilde{t}_{i-1}) - S(t, \tilde{t}_i))D(t, \bar{t}_i)[T < t_i]$.

45.3.8.2 No Settlement Lag

The option expiry date of the deal serves as both the fixing date for the contract and the settlement date. There is no provision for a settlement lag between fixing and payment.

45.4 Treasury Lock

45.4.1 Overview

A treasury lock is an OTC interest rate derivative that is the equivalent, to the buyer, of a forward sale of a reference treasury bond. It pays the difference between the market yield on the fixing date and the contract yield, multiplied by the PVBP of the reference bond.

45.4.2 Price Factor Dependency

Treasury Lock

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)
- └ Interest Rate Volatility (§ 11.3.4)

45.4.3 Properties

45.4.3.1 Bond Coupon

The fixed coupon of the reference bond.

45.4.3.2 Bond Interest Rate

The ID of the interest rate price factor used to discount the cashflows of the bond to the maturity date of the deal. The currency of this interest rate must match the currency of the treasury lock. If the bond interest rate is not specified, the currency ID is used.

45.4.3.3 Bond Maturity

The maturity date of the reference bond.

45.4.3.4 Bond Notional

The notional principal amount of the reference bond.

45.4.3.5 Buy Sell

When set to Buy, the deal is equivalent to a forward sale of the reference bond. When set to Sell, the deal is equivalent to a forward purchase of the reference bond.

45.4.3.6 Contract Yield

The deal has positive value to the buyer if the yield of the reference bond at the deal maturity date is greater than the contract yield. It has negative value if the reference bond yield is less than the contract yield.

45.4.3.7 Coupon Interval

The period between coupon payments of the reference bond. If set to 0M, there is a single coupon at the bond maturity.

45.4.3.8 Currency

The settlement currency of the deal.

45.4.3.9 Maturity Date

The maturity date is used as both the fixing date and the settlement date of the deal.

45.4.3.10 Repo Interest Rate

The ID of the interest rate price factor used to discount the settlement cashflow. The currency of this interest rate must match the currency of the treasury lock. If the repo interest rate is not specified, the currency ID is used.

45.4.4 Deal Representation

The Treasury Lock is an atomic deal.

45.4.5 Valuation

In Adaptiv Analytics a Treasury Lock deal can be valued using the `TreasuryLockValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.3.50 [Treasury Lock](#)].

45.4.6 Tuning Parameters and Valuation Settings

The `TreasuryLockValuation` model has no tuning parameters or valuation settings.

45.4.7 Assumptions

45.4.8 Limitations

45.4.8.1 Approximation of PVBP

The PVBP is approximated by the continuous duration of the reference bond.

45.4.8.2 Limited Reference Bond Terms

The terms of the reference bond are limited to maturity, coupon, and coupon interval. Payment dates are assumed to be regular, counting back from the maturity date at the coupon interval. There is no support for detailed terms such as odd first or last coupons, nor date adjustments for the cashflows.

45.4.8.3 No Associated Bond Issuer

There is no support for associating the bond with an issuer; consequently there is no support for modeling the reference bond value upon default of the issuer, nor is there support for pricing using the survival probability method.

45.4.8.4 No Settlement Lag

The maturity date is used as both the fixing date of the reference bond yield and the settlement date. There is no provision for a settlement lag.

Part VII

OTC Derivatives: Credit

Chapter 46

Default Swaps

46.1 Common Properties

The properties described below are often found on default swap deal types.

46.1.1 Accrual Day Count

Day count convention used to calculate the interest payments.

46.1.2 Accrued To End Period

If `Accrue Fee` and this property are set to `Yes`, then on default the whole coupon is to be paid by the protection buyer, not only the accrued portion. If `Accrue Fee` is set to `No`, this property is ignored.

46.1.3 Accrue Fee

Set to `Yes` if the protection buyer pays the accrued portion of the current payment in the event of default.

46.1.4 Amortisation

Permits an amortisation schedule for the principal to be specified as a list of (`Date`, `Amount`) pairs, where `Date` represents the date of this amortisation and `Amount` represents the amount by which the principal is reduced by the amortisation. A positive value for `Amount` represents a fall in the principal amount while a negative value for `Amount` represents a rise in the principal amount.

46.1.5 Buy Sell

Determines whether the holder is long (Buy) or short (Sell) protection.

46.1.6 Calendars

Specifies one or more holiday calendars used when calculating accrual period dates, accrual year fractions and payment dates. If not provided then all calendar days are business days and dates are not adjusted.

46.1.7 Currency

The ID of the FX price factor for the currency in which deal cashflows are denominated.

46.1.8 Digital Recovery

Payment on default as a percentage of notional amount. This must be between zero and one. This property is ignored if `Is Digital` is set to `No`. Values are entered as a decimal or as a percentage. For example, enter 5% or 0.05 for 5%.

46.1.9 Discount Rate

ID of the discount rate price factor used to discount the cashflows. For example, `USD.AAA`. The currency of this price factor must be the settlement currency. If left blank, the ID of the settlement currency will be used.

46.1.10 Effective Date

The contract start date.

46.1.11 First Coupon Date

Date of first coupon. This date will be ignored under the ISDA09 standard. Under the ISDA03 standard, this date will not be adjusted for standard CDS roll dates.

46.1.12 ISDA Standard

Indicate whether this deal's coupon schedule is in accordance with the ISDA09 standard or the ISDA03 standard. The ISDA09 standard expects the Pay Frequency to be 3 months and the effective and maturity dates to fall on standard CDS roll dates, which are 20 Mar/Jun/Sep/Dec (holiday-adjusted for effective date, unadjusted for maturity date). If a non-standard effective date is entered on an ISDA09 deal, it will be adjusted to the latest adjusted standard date on or before the specified date; a non-standard maturity date will be adjusted to the earliest unadjusted standard date after the specified date, unless the specified date is within 7 days of the preceding standard date (e.g. a maturity date of 27 Mar will be adjusted to 20 Mar, but 28 Mar will be adjusted to 20 Jun).

46.1.13 Is Digital

Set to `Yes` to use Digital Recovery to determine the payment in the event of default.

46.1.14 Maturity Date

The contract end date.

46.1.15 Pay Frequency

Period between payments. If this property is set to `0M`, then the payment periods will be determined by the `Effective Date` and `Maturity Dates`.

46.1.16 Pay Rate

The fixed payment rate, entered in basis points.

46.1.17 Penultimate Coupon Date

Date of the penultimate coupon. This date will be ignored under the ISDA09 standard. Under the ISDA03 standard, this date will not be adjusted for standard CDS roll dates.

46.1.18 Principal

Principal amount in units of settlement currency.

46.1.19 Protection Paid At Maturity

If set to **Yes**, the payoff in case of default is paid at the maturity of the deal; if set to **No**, it is paid at the time of default.

46.1.20 Recovery Rate

ID of the recovery rate price factor used to obtain the deal specific recovery rate. For example, BOND. If left blank, the ID of the issuer will be used. This property is ignored unless the Respect Default property of the deal's valuation model is set to 'Yes'.

46.1.21 Survival Probability

ID of the survival probability price factor. For example, IBM or IBM.SENIOR. If left blank, the ID of the issuer will be used.

46.1.22 Upfront

The amount paid upfront on **Upfront Date** by the protection buyer, expressed as a percentage of the notional.

46.1.23 Upfront Date

The date on which the upfront payment is paid.

46.2 Common Date Generation

Explicit dates used during the valuation calculations are generated from the parametric representation of the deals.

Theory Guide 4.4.4

Accrual start dates, accrual end dates, accrual year fractions and payment dates are generated from the deal's effective date E , maturity date M , first coupon date, penultimate coupon date, payment frequency τ (Pay Frequency or Coupon Interval), accrual day count convention (Accrual Day Count or Pay Day Count), and holiday calendar (Calendars or Pay Calendars), as described in Section 1.3.2. Let t_1, \dots, t_n , T_1, \dots, T_n and $\alpha_1, \dots, \alpha_n$ denote the accrual end dates, payment dates and accrual year fractions, respectively, and let t_0 denote the first accrual start date. For a given valuation date t , define $\tilde{t}_i = \max(t_i, t)$ and $\bar{t}_i = (\tilde{t}_{i-1} + \tilde{t}_i)/2$.

The accrual period principal amounts P_1, \dots, P_n are generated from the deal's principal amount and amortization schedule as described in Section 1.4.

For credit default swaps (credit default swap, index default swap, credit default swap option and N-to-default swap), the last accrual end date and last accrual year fraction are modified as follows:

- t_n is the maturity date M (which may be unadjusted)
- α_n is calculated from t_{n-1} to $M + 1d$.

The input dates have the following restrictions.

Theory Guide 4.4.5

A *CDS roll date* is a date that is either the 20th of March, June, September or December. An *adjusted CDS roll date* is a CDS roll date adjusted Following with respect to the deal's holiday calendar. When ISDA Standard is ISDA 09: the maturity date must be a CDS roll date, the effective date must be either a CDS roll date or an adjusted CDS roll date, and the first and penultimate coupon dates are not used. The specified maturity date M is replaced by the first CDS roll date T for which $T + 7d \geq M$. The specified effective date E is replaced by the last CDS roll date S for which $S \leq E$.

46.3 Credit Default Swap

46.3.1 Overview

This deal type is for single name credit default swaps under the ISDA standards of 2003 and 2009.

46.3.2 Price Factor Dependency

Credit Default Swap

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)
- └ Recovery Rate (§ 9.3)
- └ Survival Probability (§ 9.1)

46.3.3 Properties

See section 46.1 for a description the common properties.

46.3.3.1 Name

ID of the issuer. For example, IBM. If the `Respect Default` property of the deal's valuation model is set to `Yes`, this is also the ID of the credit rating price factor used to simulate the issuer's credit rating.

46.3.4 Deal Representation

The `Credit Default Swap` is a deal skin that builds into a `Credit Default Swap (Explicit)` deal. See section 46.4 and the Deal Skins Guide [2, [Credit Default Swap](#)].

The `Credit Default Swap` deal skin takes into account the `ISDA Standard` property and then generates the coupon details using the standard `Adaptiv Analytics` utilities, described in section 46.2, and then creates a `Credit Default (Explicit)` child deal which these details populated.

If the `Upfront Date` property is populated then a `Cashflow Fixed` child deal is also created.

Additionally the building process is controlled by system-wide configuration.

Theory Guide 4.4.5

If the configuration setting `BUILD DEAL SKINS INTO SEPARATE LEGS` is `Yes` (see *Configuration Settings* in the *Analytics Technical Guide*) then the credit default swap builds into two credit default swap (explicit) deals: one leg with `Leg Type` set to `Protection`, `Pay Rate` set to 0 and `Accrue Fee` set to `No`; and a second leg with `Leg Type` set to `Premium`, `Is Digital` set to `Yes` and `Digital Recovery` set to 100%. The legs are ordered with the pay leg first.

If the configuration setting is `No` (or the setting is not specified) then the credit default swap deal builds into a single credit default swap (explicit) deal with `Leg Type` set to `Net`.

A `Credit Default Swap` can be built into two `Credit Default Swap (Explicit)` child deals to support valuation of protection and premium legs separately. If this is not required then building to a single child deals is recommended because this will produce faster valuations.

46.3.5 Valuation

Credit Default Swap deals are valued using the DealSkinValuation model. For details about the valuation for this deal, see the section on the Credit Default Swap (Explicit) (section 46.4.5). The dates used for valuation are described in section 46.2.

46.4 Credit Default Swap (Explicit)

46.4.1 Overview

The deal type for valuing credit default swap-like deals. It is independent of conventions and standards because cashflow details are supplied to it explicitly.

46.4.2 Price Factor Dependency

Credit Default Swap (Explicit)

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)
- └ Recovery Rate (§ 9.3)
- └ Survival Probability (§ 9.1)

46.4.3 Properties

See section 46.1 for a description of the common properties.

46.4.3.1 Coupon Schedule

List of coupon payment details.

- **Accrual Start** - Start date of the period over which interest is accrued.
- **Accrual End** - End date of the period over which interest is accrued.
- **Accrual Year Fraction** - Year fraction from Accrual Start to Accrual End. If not supplied then this is calculated from Accrual Start, Accrual End and Accrual Day Count.
- **Accrual Day Count** - Day count convention used to calculate the accrual year fraction when Accrual Year Fraction is zero.
- **Principal** - Cashflow principal.
- **Payment Date** - Payment date of the cashflow.

46.4.4 Deal Representation

The Credit Default Swap (Explicit) deal is an atomic deal. It is the valuation model used behind other variants of credit default swaps.

46.4.5 Valuation

This deal is valued using the `DefaultSwapExplicitValuation`, see Theory Guide [7, § 4.4.5 Credit Default Swap] and [7, § 4.4.6 Credit Default Swap (Explicit)] for the details of the calculation.

The deal can be configured for a digital credit default swap with `Is Digital` set to `Yes`. In this case the recovery rate used in the pricing calculations is taken from the deal property `Digital Recovery`. Otherwise the recovery rate is taken from the `Survival Probability` price factor (see section 9.1).

The valuation setting `Full Calculation` controls how the valuation model performs the pricing calculation. The first method is when it is set to `Yes`.

Theory Guide 4.4.1.1

The first method follows the ISDA CDS Standard Model [33] by assuming a constant forward hazard rate \bar{h} between t_1 and t_2 , and a constant forward interest rate f between t_1 and t_2 , so that

$$S(t, u) = S(t, t_1)e^{-\bar{h}(u-t_1)} \quad (46.4.1)$$

$$D(t, u) = D(t, t_1)e^{-f(u-t_1)}, \quad (46.4.2)$$

where \bar{h} and f are given by

$$\bar{h} = \frac{1}{t_2 - t_1} \log \left(\frac{S(t, t_1)}{S(t, t_2)} \right) \quad (46.4.3)$$

$$f = \frac{1}{t_2 - t_1} \log \left(\frac{D(t, t_1)}{D(t, t_2)} \right). \quad (46.4.4)$$

The second method is when Full Calculation is No.

Theory Guide 4.4.1.1

Define $\bar{t} = (t_1 + t_2)/2$. The second method approximates the payoff by assuming that $g(\bar{t})$ is paid at time \bar{t} if default occurs between t_1 and t_2 . Under this assumption, the value of the cashflow at time t , where $t \leq t_1$, is given by

$$V(t) = g(\bar{t})D(t, \bar{t})(S(t, t_1) - S(t, t_2)). \quad (46.4.5)$$

To facilitate the decomposition of a credit default swap into two legs the Credit Default Swap (Explicit) deal can be configured to price either the net of both legs, or just the protection or premium legs. This is controlled by the Leg Type deal property and the functionality is described in section 46.3.4.

46.4.6 Tuning Parameters and Valuation Settings

46.4.6.1 Respect Default

The Respect Default valuation setting controls the behaviour of the valuation model when simulating the issuer's credit rating and it goes into default.

Theory Guide 4.4.3

If the deal has a reference entity whose credit rating is stochastic under Monte Carlo simulation then the entity may go into default on some scenarios. If the valuation model parameter Respect Default is Yes then the valuation model estimates the value of the deal at default using the recovery rate price factor specified on the deal.

Credit default swaps pay $P(1 - R) - A$ on the first valuation date on or after the default and are terminated thereafter, where R is the realized recovery rate, P is the principal amount and A is the accrued fee (if any) at the time of default.

46.4.6.2 Full Calculation

The `Full Calculation` valuation setting controls which method is used to price the cashflows. When `No` a more approximate method is used, which is faster. When `Yes` the slower full calculation method is used. For details of each method see section 46.4.5.

46.4.7 Assumptions

46.4.7.1 Look-back period

Under the ISDA 2009 standards [38], the look-back period for a credit events is 60 days, and as long as the default is deemed to have happened within this period and the event is raised during the same period, a protection payoff might be due. Adaptiv Analytics assumes that the survival probability of today is 1. However, there is a non-zero probability that the reference entity defaulted in the last 60 days and the survival probability of today could be less than 1.

46.4.7.2 Counterparty Risk

The risk that the counterparty defaults and is unable to pay either the protection payment or the premium payment is not included in the model. The modelling of default within the model only concerns the referenced entity. Therefore, the `Survival Probability` property shown in section 46.1 is for the referenced name rather than the counterparty.

46.4.7.3 Interest Rates

It is assumed that hazard rates are not correlated with risk-free interest rates.

46.4.7.4 Forward Hazard Rates

When `Full Calculation` is set to `Yes` the valuation model assumes that the forward hazard rate is constant over the duration of the cashflow. It also assumes that the forward interest rate is constant over the same period.

Theory Guide 4.4.1.1

The first method follows the ISDA CDS Standard Model [33] by assuming a constant forward hazard rate \bar{h} between t_1 and t_2 , and a constant forward interest rate f between t_1 and t_2 , so that

$$S(t, u) = S(t, t_1)e^{-\bar{h}(u-t_1)} \quad (46.4.6)$$

$$D(t, u) = D(t, t_1)e^{-f(u-t_1)}, \quad (46.4.7)$$

where \bar{h} and f are given by

$$\bar{h} = \frac{1}{t_2 - t_1} \log \left(\frac{S(t, t_1)}{S(t, t_2)} \right) \quad (46.4.8)$$

$$f = \frac{1}{t_2 - t_1} \log \left(\frac{D(t, t_1)}{D(t, t_2)} \right). \quad (46.4.9)$$

Note that this assumption is made purely to facilitate the evaluation of the payment-on-default integral.

Theory Guide 4.4.1.1

Let $g(t)$ be a deterministic function of time. Consider a cashflow that pays $g(u)$ at time u if default occurs at time u , where $t_1 < u \leq t_2$. The value of the cashflow at time t , where $t \leq t_1$, is given by

$$V(t) = \int_{t_1}^{t_2} D(t, u) S(t, u) h(t, u) g(u) du. \quad (46.4.10)$$

It places no restrictions on the hazard rate data held within the Survival Probability price factors. The input hazard rate curve can have any number of points during the cashflow period. The assumption also does not change the way Survival Probability price factors calculate their value from the input hazard rate curve. The Survival Probability price factors shown in the expression for the constant forward hazard rate, \bar{h} , are evaluated in the normal way.

When Full Calculation is set to No the mid-point assumption (see section 46.4.7.5) means that it is not necessary to make the assumption of constant forward hazard rates so this is not done.

46.4.7.5 Default Timing

When Full Calculation is set to No it is assumed that if default occurs within the cashflow period the payment is made at the mid-point of the cashflow.

Note that this is just for the purpose of pricing future cashflows and has no bearing on default timing when Credit Rating price factors are simulated in a calculation. In that case the time of default is determined by the credit rating price model and the behaviour of this model is described as in section 46.4.6.1.

When Full Calculation is set to Yes there is no restriction on default timing for the purpose of pricing, it can occur at any point during the cashflow period.

46.4.7.6 Initiation of the Default Payment

It is assumed that the default payment is not liable before the effective date of the swap.

46.4.8 Limitations

46.4.8.1 ISDA 2015

Adaptiv Analytics currently has no support for the ISDA 2015 standard.

46.4.8.2 Seniority Classes and Restructuring Clauses

Adaptiv Analytics has no explicit representation for different seniority classes or restructuring classes. However, it is possible to define multiple Survival Probability price factors for a given referenced entity. These price factors can contain alternate hazard rate and recovery rate values.

46.5 Index Default Swap

46.5.1 Overview

This deal type is for default swaps on credit default swap indexes.

46.5.2 Price Factor Dependency

Index Default Swap

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)
- └ Recovery Rate (§ 9.3)
- └ Survival Probability (§ 9.1)

46.5.3 Properties

See section 46.1 for a description of the common properties.

46.5.3.1 Index

An index, used to define the index default swap. The components of Index are:

ID An ID of the Index (e.g. ITRAXX), used if Issuers list is not populated. If used, index default swap will build into CDS (Explicit) deal with Name set to ID.

Issuers

A list of the issuers that make up the index. The weights in the list must be positive and add up to 1.

Name

An ID of the issuer (e.g. IBM).

Weight

The weight factor associated with the issuer.

Survival Probability

ID of the survival probability price factor used to obtain the survival probability for this counterparty. If left blank, the ID of the counterparty's name will be used.

Recovery Rate

ID of the recovery rate price factor used to obtain the recovery rate for this counterparty. If left blank, the ID of the counterparty's name will be used.

46.5.4 Deal Representation

The Index Default Swap is a deal skin that builds into a one or multiple Credit Default Swap (Explicit) deals. See section 46.4 and the Deal Skins Guide [2, Index Default Swap].

Theory Guide 4.4.8

The index default swap deal has the same properties as the credit default swap deal except for having an Index instead of a Name. The Index has an ID and a list of issuers.

If the index default swap has an Index with N issuers then it builds into a set of N credit default swap (explicit) deals. The Name, Survival Probability and Recovery Rate of the k^{th} deal is set

to the Name, Survival Probability and Recovery Rate of the k^{th} issuer. The principal amounts in the coupon schedule of the k^{th} deal are multiplied by ω_k , where ω_k is the Weight of the k^{th} issuer. The issuer weights satisfy $\sum_{k=1}^N \omega_k = 1$.

If the index default swap has an Index with an empty list of issuers then it builds into a single credit default swap (explicit) deal with Name set to the ID of the Index.

The Index Default Swap deal skin takes into account the ISDA Standard property and then generates coupon details using the standard Adaptiv Analytics utilities, described in section 46.2. These coupon details are mapped to each Credit Default (Explicit) underlying deal.

If the Upfront Date property is populated then a Cashflow Fixed underlying deal is also created.

46.5.5 Valuation

Index Default Swap deals are valued using the DealSkinValuation model (section 3.3.1). For more details about the valuation see the Theory Guide [7, § 4.4.8 Index Default Swap] and the section on the Credit Default Swap (Explicit) (section 46.4.5).

Chapter 47

Total Return Swaps

47.1 Total Return Swaps Container

47.1.1 Overview

This deal type is for a fixed-income total return swap. The deal is a container deal with a funding leg, which is a fixed or floating swap leg, and a reference leg which can be either a fixed or floating rate bond. Such a swap transfers the total return (including interim cash flows and capital appreciation or depreciation) of a reference asset from one party to another. A total return swap involves swapping an obligation to pay interest (pay leg or funding leg) based on a specified fixed or floating interest rate in return for an obligation representing the total return on a specified reference asset (reference leg). The two legs are related in that the valuation model calculates the notional amount of the funding leg from the price of the reference leg.

47.1.2 Price Factor Dependency

Total Return Swap

- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)
- └ Recovery Rate (§ 9.3)
- └ Survival Probability (§ 9.1)

47.1.3 Properties

47.1.3.1 Independent Amount Type

Specifies type of the deal specific independent amount. possible choices are `None`, `Fixed` and `Dynamic`.

47.1.3.2 Independent Amount Curves

Specifies the deal specific independent amount curves if any as a list of (Curve, credit rating). For each curve enter the points as a comma separated list of (time to maturity, value) pairs. Values are from Bank's perspective. For example, enter (0,100), (1,120), (2,90) for a two year profile starting at 90, ending at 100 and reaching 120 at the midpoint. When Independent Amount Type is `Fixed` the curve values are interpreted as actual collateral amounts denominated in Independent Amount Currency. When Independent Amount Type is `Dynamic` the curve values are interpreted as

proportions of the deal notional. For example, a curve value of 0.05 is interpreted as 5 percent of the deal notional.

47.1.3.3 Independent Amount Currency

ID of currency in which the independent amount is specified. Used when Independent Amount Type is Fixed.

47.1.3.4 Currency

ID of the deal currency. For example, USD.

47.1.3.5 Buy Sell

Determines whether the holder receives the returns stream (including the cash flows and price appreciation) from the reference asset and pays interests and price depreciation or vice versa. Buy Sell of the container must be the same as that of the reference leg and opposite of that of the funding leg.

47.1.3.6 Effective Date

Specifies the unadjusted start date of the total return swap. For forward starting deals this will be in future.

47.1.3.7 Swap Maturity Date

Unadjusted maturity date of the underlying swap.

47.1.3.8 Reset Frequency

Specifies the reset frequency to be used in order to generate reset dates for a resetting TRS. Reset dates are the dates between which price appreciation and depreciation of reference asset is calculated.

47.1.3.9 Reference Asset Properties

List of properties of reference asset. The components of Reference Asset Properties are:

Reference

ID of underlying reference asset deal which is TRS reference leg.

Initial Unit

Number of units of the reference asset at the base date.

Price

Price of the reference asset at the base date.

FX Rate

FX Rate at the base date which will be applied to the given reference Price to represent it in the deal's currency. If the given price is already in the deal's currency FX Rate should be set to 1.0, and if the given price is in any other currency; the reference asset's currency for instance, then FX Rate should be set so that when multiplied by the given price produce the price in the deal's currency.

Known Prices

List of known reset dates before the base date and corresponding known asset prices.

Date

The date at which the reference asset price is given.

Asset Price

Price of reference asset at given date.

FX Rate

FX Rate at given date which will be applied to the given asset price to represent it in deal's currency.

47.1.3.10 Funding Leg Reference

Reference ID of the underlying funding leg deal.

47.1.3.11 PV Accrued

Specifies a list of payment amounts and dates which can represent any gain or loss amount on the reference leg and will be added to the cashflows on the reference asset side by the valuation model. The currency of PV accrued amount is assumed to be the same as deal currency. The components of PV Accrued are:

Date

Date of the cashflow.

Amount

Amount of the cashflow.

47.1.4 Deal Representation

The total return swap container deal is an atomic container deal.

47.1.5 Valuation

A Total Return Swap Container can be valued using the `TotalReturnSwapContainerDealValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.4.13 [Total Return Swap Container](#)].

47.1.5.1 MtM Adjustment

For various reasons there may be mismatch between model price and market price of reference asset, in order to reconcile the two prices an MtM adjustment is applied to forward price of reference asset. see Theory Guide [7, § 4.4.13.3.1 [MtM Adjustment](#)].

47.1.5.2 Deal Independent Amount

If the `Independent Amount Type` is `Dynamic` TRSC valuation is able to produce deal level independent amount as a percentage of the notional.

Theory Guide [4.4.13.6](#)

TRSC deal can also produce dynamic deal-level independent amounts when the deal property `Independent Amount Type` is `Dynamic`. The dynamic IA in base currency is given by

$$I(t) = N\tilde{F}(\tau_{\ell(t)}, \tau_{\ell(t)})a(M_1 - t)X_{\text{base}}(t) [t \geq E], \quad (47.1.1)$$

where $\ell(t)$ is the last reset date index l for which $\tau_l < t$, $a(t)$ is the independent amount factor from the deal property `Independent Amount Curves`, and X_{base} is the price of the reference asset currency in base currency.

47.1.6 Assumptions

47.1.6.1 Reference Leg

- Reference leg can be either a Bond or FRN.
- Valuation of reference leg is done with valuation parameter `Respect Default` set to Yes and `Use Survival Probability` set to Yes.

47.1.6.2 Funding Leg

- Funding leg can be either a Fixed or Floating swap leg.
- Valuation of funding leg is done with `Respect Default` set to No and `Use Survival Probability` set to No.

47.1.6.3 Currencies

- No assumption is made on the currencies of the funding leg and reference leg being the same.
- The currency of the `PV Accrued` amounts is assumed to be the same as payment currency of the deal.
- The currency of the funding leg must be the same as the currency of the TRSC deal.

47.1.6.4 Payment Frequency and reset dates

- No assumption is made on the payment frequency of the legs to be the same; they can be different and also different from reset frequency. Note that reset frequency will be used to create future reset dates at which reference asset price appreciation or depreciation will be calculated to be included in the stream of returns.
- If no reset frequency is specified, reset frequency is assumed to be the same as payment frequency of the reference leg.
- Swap maturity date is considered as a reset date so valuation model account for appreciation or depreciation of reference asset up until the maturity date.

47.1.7 Limitations

47.1.7.1 Quanto payoff

Quanto payoff is not supported.

47.1.7.2 Funding Leg reference rate

Reference rate of the funding leg has to be simply compounded (standard LIBOR); i.e. cashflows should be known or otherwise rate end date should be close to payment date. Swap rates are not supported.

47.1.7.3 Reference asset type limitation

Reference leg can be only be a Bond or FRN. Other deal types such as callable bond or convertible bond, MBS or basket of fixed income reference assets are not supported.

47.1.7.4 Reference asset amortisation

Amortisation schedule of the principal amount of reference asset (Bond or FRN) is not supported.

47.1.7.5 Resurrection of defaulted obligors

Sometimes when an obligor defaults, banks replace the reference asset with a similar asset with similar yield and rating for the remainder of the TRS life. This feature is not supported.

47.1.7.6 Other Liquidation Events

Some assets can terminate before maturity for reasons other than obligor default. An examples would be exercise of call option. In this sort of termination similar to resurrection of defaulted obligor banks sometimes replace the reference asset with a similar asset for the remainder of the TRS life. This feature similarly is not supported.

Part VIII

OTC Derivatives: Energy

Chapter 48

Energy

48.1 Energy Valuation Models

48.1.1 Common Properties

The properties described below are often found on energy deal types.

48.1.1.1 Currency

The ID of the FX price factor for the currency in which deal cashflows are denominated when the Payoff Type is Standard, or the currency in which the energy commodity price is assumed to be denominated when the Payoff Type is Quanto or Compo.

48.1.1.2 Payoff Currency

The ID of the FX price factor of the currency in which deal cashflows are denominated. This property may be left empty when the Payoff Type is Standard.

48.1.1.3 Discount Rate

The ID of the interest rate price factor used to discount deal cashflows. If this ID is not specified, then the Currency will be used as the discount interest rate ID.

48.1.1.4 Sampling Type

The ID of the forward price sample price factor used to define reference price sampling convention.

48.1.1.5 FX Sampling Type

The ID of the forward price sample price factor used to define FX sampling convention.

48.1.1.6 Reference Type

The ID of the reference price price factor used to define the energy reference price. This requires the reference price price factor and the forward price price factor given by the `ForwardPrice` property of that reference price price factor.

48.1.1.7 Reference Volatility

The ID of the reference volatility price factor used to value quanto deals. If left blank, the ID of the reference price price factor will be used. This requires the reference volatility price factor, the reference price price factor, the forward price price factor given by the `ReferencePrice` property of the reference

volatility price factor and the forward price volatility price factor given by the `ForwardPriceVol` property of the reference volatility. This property is required for quanto deals and ignored otherwise.

48.1.2 Assumptions

The assumptions stated below are applicable to all energy deal types.

48.1.2.1 Gas day assumption

In energy markets, commodity gas may have a concept of ‘gas days’, whereby time periods (day, month, year, etc.) are defined starting at the x – th hour of the day. However, Adaptiv Analytics has no concept of sub-daily divisions of time, so this concept can be ignored and the supply of all energy commodities assumed to start and end at 00:00.

48.1.2.2 Risk-neutral Drift Correction for Cross Currency Deals

In theory, the valuation model should apply a change of measure correction to account for the correlation between FX rate and energy price. This is not supported in Adaptiv Analytics. Instead it is assumed that the correlation between the FX rate and the energy price is zero.

48.1.2.3 FX Conversion & Averaging

For all energy deals specified in a currency other than the price factor currency, conversion is applied from price factor currency to deal currency.

Theory Guide [4.2.2.6](#)

If Average FX is No then each price sample is converted to deal currency at the prevailing spot FX rate. A fixing price which encompasses N samples is given in deal currency by:

$$F^f(t, T^f) = \frac{1}{N} \sum_{i=1}^N F(t_i^s, T^f) X(t_i^s), \quad (48.1.1)$$

where $F(t, T)$ is the forward price in the price factor currency and $X(t)$ denotes the price of a unit of price factor currency, measured in deal currency.

Adaptiv Analytics additionally supports several variations of FX-adjusted price fixings, which are used when Average FX is No.

Theory Guide [4.2.2.6](#)

The average FX rate, \bar{X} , for a deal in which the FX averaging period spans M samples is given by either:

$$\bar{X}(t, t_s^X, t_e^X, \mathcal{S}_X) = \frac{1}{M} \sum_{i=1}^M X(t_i^X) \quad (48.1.2)$$

under the standard method, or

$$\frac{1}{\bar{X}(t, t_s^X, t_e^X, \mathcal{S}_X)} = \frac{1}{M} \sum_{i=1}^M \frac{1}{X(t_i^X)} \quad (48.1.3)$$

under the inverted method.

48.1.3 Limitations

The limitations stated below are applicable to all energy deal types.

48.1.3.1 Fixing Conventions

The Reference Price construction does not (easily) support some price fixing conventions which are found in the physical energy market. The main limitations are as follows:

- Relative date fixings, eg day ahead, quarter year and year ahead.
- Fixing is a weighted average of price observations
- Fixing is an average of multiple forward prices (e.g. average of April / May / June 2017 monthly forwards)

48.1.3.2 Holiday Calendars

Adaptiv Analytics does not differentiate between non-business days falling on weekends and holidays. This distinction can be significant for some physical energy contracts where (for example) the price index is normally observed on Saturdays, other than Saturdays which are deemed to be public holidays.

48.1.3.3 FX Averaging

Some FX averaging methods are applied in the market which are not available in Adaptiv Analytics, such as:

$$\bar{X}(t, t_s^X, t_e^X, S_X) = \frac{\text{Average}[S(t_i)]}{\text{Average}[X(t_j)]} \quad (48.1.4)$$

and

$$\bar{X}(t, t_s^X, t_e^X, S_X) = \frac{\text{Average}[S(t_i)]}{\text{Average}[1/X(t_j)]}. \quad (48.1.5)$$

48.1.3.4 Credit Exposure of Physical Contracts

The treatment of credit exposure in the base Energy Physical Leg product is rather simplified; for example

- A single MTM value is assumed within the physical delivery period, instead of a binary ‘certain’ and ‘uncertain’ breakdown to reflect the portion of the energy asset that has been delivered or is still outstanding.
- No consideration of ‘grace period’, i.e. the physical energy supply is assumed to cease immediately following a settlement failure.

48.1.3.5 Delivery

Adaptiv Analytics has several constraints around delivery possibilities, with the following delivery circumstances not supported:

- Intra-day delivery periods (e.g., although see indirect usage in Section 10.2.6.4);
- Delivery of non-constant volumes per period;
- Multiple delivery periods per payment.

48.2 Energy Cashflow Products

48.2.1 Energy Cashflow Products Valuation Models

48.2.1.1 Limitations

The following trade features are not supported for linear energy cashflow deals in base Adaptiv Analytics:

- Price index has non-standard payment dates (i.e., the delivery date offset on the market quoted price does not match the delivery date offset on the deal);
- Pre-paid forward contract. Some energy contracts have payment before the start of the physical delivery period. This requires a discounting adjustment which is not applied in the base Adaptiv Analytics model;
- Payment date before the end of the averaging observation period. Some physical energy contracts are paid up *early*, with an additional settlement adjustment after the end of the price observation period when the final settlement value is known.

48.2.2 Energy Physical Fixed

48.2.2.1 Overview

The Energy Physical Fixed deal type is a deal with multiple delivery periods, each with a payment date and daily delivery volume. If the delivery period spans multiple days, it is assumed that the daily volume will be delivered each day (i.e., constant delivery over the period covered). It follows that a variable delivery schedule can be modelled by a series of deliveries, each covering a fraction of the overall delivery period (e.g., a single day) but with a different amount delivered per period. For such a series of payments to represent the same overall delivery period, all involved payments should share the same payment date.

The deliveries in the Energy Physical Fixed are thus characterised by a set of dates:

- Delivery period start and end;
- Volume delivered daily within this period;
- Fixed price for the period;
- Payment date (this is relevant for discounting).

It is not necessary for the interval between first and last delivery to be completely covered by the deliveries in the deal, although this is usually the case.

Payments may occur in a different currency than the market quotation one. The Energy Physical Fixed is the only product in base Adaptiv Analytics that supports physical settlement, via the delivery of the energy commodity specified by its forward curve in the `Energy` parameter.

Theory Guide [4.2.12](#)

The buyer of a physical forward pays cash and receives a physical energy commodity. As discussed in Section [4.2.1](#), energy commodities must usually be delivered over a multi-day period starting at t_s^D and ending at t_e^D . Payment, however, is made on a single day t^P which is generally after delivery is complete.

48.2.2.2 Price Factor Dependency

Energy Physical Fixed

- └ Forward Price (§ [10.2](#))
- └ FX Rate (§ [4.2](#))
- └ Interest Rate (§ [6.1](#))
- └ Reference Price (§ [10.5](#))

48.2.2.3 Properties

For an overview and description of the properties of these deals, see the deal definition in the Integrated documentation [[4](#), Portfolio: Energy Physical Fixed].

48.2.2.4 Deal Representation

The Energy Physical Fixed is an atomic deal.

48.2.2.5 Valuation

In Adaptiv Analytics an Energy Physical Fixed deal can be valued using the `EnergyPhysicalFixed-Valuation` model. For details about the valuation for this deal, see the Theory Guide [[7](#), § [4.2.13](#)].

A physical fixed contract is a forward contract settled with continuous physical delivery (or a strip of such contracts) with the price K fixed on the trade date. The contract value to the energy buyer is the value of any undelivered energy less the value of the payment, if not yet made

$$V^D (\|t_e^D - \max(t_s^D, t)\| S^R(t, t, t_e^s, \mathcal{S}) - \|t_e^D - t_s^D\| K) D(t, t^P), \quad (48.2.1)$$

where $\|t_e^D - \max(t_s^D, t)\|$ denotes the number of days remaining in the delivery period.

48.2.2.6 Limitations

No support for hourly and sub-hourly deliveries for power markets: Power markets usually operate in sub-hourly granularity. However, since Adaptiv Analytics does not support any sub-daily granularity, any real physical power deal needs to be divided into typical periods (e.g., peak/base or peak/off-peak). This leads to lack of accuracy in valuation of these deals, because it is not possible to account for non-constant volume within the period; see also Section 10.2.4.4 for the pricing limitations.

No Support of actual vs. forecasted volumes on power and gas physical deals: In Energy markets, most deals with physical delivery differentiate between agreed (forecasted) volume for the future time periods and actual measured volume, which is known for past time periods. Adaptiv Analytics does not contain this concept and considers any physical deal as having just one volume, which is known on the trading day.

Prepayments and discount: Some energy deals are pre-paid, meaning payment date is before delivery date. There is no discount adjustment in this case.

No payment adjustments based on actual volume: Some physical energy contracts are paid up early, with an additional settlement adjustment after real volume of the deal is known. Since Adaptiv Analytics does not distinguish between planned (forecasted) and actual volumes (see above), it is not possible to capture payment adjustments based on actual volumes delivered.

48.2.3 Floating Energy Cashflow List

48.2.3.1 Overview

This deal type is for a strip of floating energy cashflows.

This deal is a general representation of a cashflow, with no properties that are special for energy.

48.2.3.2 Price Factor Dependency

Floating Energy Cashflow List

- └ Forward Price (§ 10.2)
- └ Forward Price Sample (§ 10.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)
- └ Reference Price (§ 10.5)

48.2.3.3 Properties

For an overview and description of the properties of the deal, see the deal definition in the Integrated documentation [4, Portfolio: Energy Floating Cashflow List].

48.2.3.4 Deal Representation

The Floating Energy Cashflow List is an atomic deal.

48.2.3.5 Valuation

In Adaptiv Analytics an Floating Energy Cashflow List deal can be valued using the `FloatingEnergyValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.2.9 Energy Cashflows].

Theory Guide 4.2.9.2

The time t value of an energy cashflow paid at T indexed to volume V of energy at a price equal to a function of the reference price S^R is:

$$V \left(A S^R(t, t_s^s, t_e^s, S) + b \right) D(t, T). \quad (48.2.2)$$

where A is the Price Multiplier and b is the Fixed Basis.

48.2.4 Energy Fixed-Float Swap

48.2.4.1 Overview

This deal type is for vanilla energy Fixed-Float swaps.

Energy Fixed-floating swaps are defined by a series of swaps each characterised by a set of dates:

- Delivery period start and end dates;
- Volume delivered in that period;
- Fixed price for that period;
- Realised period and corresponding price (this is the period for which the floating price is already fixed, with a fixed price that needs to be captured manually);
- Realised period start and end for FX and corresponding FX rate (on the assumption that FX fixing can differ from floating price fixing);
- Payment date (relevant for discounting).

It is not necessary that the interval from first to last delivery is completely covered by the swaps, although it is unusual for this not to be the case. Within Adaptiv Analytics, payment may occur in a different currency from that in which market quotes are reported.

The floating index is given by the reference type curve in combination with sampling type. The reference type defines the price factor and the sampling type defines the method of calculation price fixing.

48.2.4.2 Price Factor Dependency

Energy Fixed-Float Swap

- └ Forward Price (§ 10.2)
- └ Forward Price Sample (§ 10.4)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)
- └ Reference Price (§ 10.5)

48.2.4.3 Properties

For an overview and description of the properties of these deals, see the deal definition in the Integrated documentation [4, Portfolio: Energy Fixed-Float Swap].

48.2.4.4 Deal Representation

The Energy Fixed-Float Swap is an atomic deal.

48.2.4.5 Valuation

In Adaptiv Analytics an Energy Fixed-Float Swap deal can be valued using the `EnergySwapValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.2.8 Fixed-Float Swap].

48.2.4.6 Assumptions

Equal weight or price observations: It is assumed that all price observations are equally weighted.

48.2.4.7 Limitations

Formula pricing: For Energy Swaps, instead of being directly specified by a price factor, a floating price may sometimes be specified by a formula (such as averaging) applied to price factor.

Provision for such pricing in Adaptiv Analytics is limited to simple linear ($Ax + B$) cases, while some formulas commonly used within energy markets are not supported. For example, formulas of the type 'NPQRS'¹.

¹The 'NPQRS' formula means averaging with N = number of months to compute the average, P = number of months representing the offset between the application period and the averaging period, Q = number of months where the average applies, R = Month of the start of the application period in the reference year, S = The year of reference. Usually, $R = 1$ and S = [the year of the application period].

48.3 Energy Option Deal Types

48.3.1 Energy Option Valuation Models

48.3.1.1 Common Properties

The following are important features of Energy Option Models:

FX Averaging: The choice of FX averaging method (see Sections [48.1.2.3](#) and [48.1.3.3](#)).

Support of Energy Baskets: Baskets of energy prices, which may include Quanto and/or Compo Components, are an important facet of energy options (e.g., see the Theory Guide [[7](#), § [4.2.5 Energy Basket of Prices](#)]).

Options on energy baskets are not normally traded explicitly, but instead implicitly result from physical deals with price formulas, where the formulas are non-linear on indices such as oil price. It is possible to calculate the breakdown of such deals into a set of forwards and options on a basket of prices, and value them as with Adaptiv Analytics option models. Although Adaptiv Analytics does not provide a methodology to break down physical deals with complex price formulas into the individual components, the methodology to value the results of such a breakdown is provided.

Adaptiv Analytics assumes that for energy baskets, compo and quanto components will obey a basic convention regarding currency:

Theory Guide [4.2.5.1](#)

In an energy basket, if none of the components are quanto/compo then price factor currency of all the components should be same. If any of the basket components is quanto/compo then for all components, the component currency and the price factor currency should be same.

Energy baskets of Returns: Adaptiv Analytics provides support for the concept of a basket of returns.

Theory Guide [4.2.6](#)

Analytics supports cashflows and European options on a basket of returns on energy reference prices. Energy swap legs, caps and floors on a basket of returns can be constructed using a structured deal containing a series of cashflows, European call options or European put options on a basket of returns respectively.

Implied volatility: The implied volatility format for Asian options is assumed to be the same as for European options on a bullet forward reference price. The Adaptiv Analytics pricing model converts the input volatility to a volatility of an average reference price by moment matching. The entire forward price curve is assumed to be driven by a single geometric Brownian motion.

48.3.1.2 Limitations

Delivery settled options: For most products (except Energy Physical Fixed; see Section [48.2.2](#)), Adaptiv Analytics only supports cash settled and financially settled options on Energy (ie, the option delivers into a financial Energy swap or forward).

Price stochastic processes: The assumption that price factors follow geometric Brownian motion is often used in energy markets, mainly due to the simplicity of this model. However, multiple research papers show that prices in energy markets tend instead to follow a mean reverting process.

However, at present, Adaptiv Analytics only supports Brownian motion for Energy Option valuation models.

This limitation is equally valid for implied volatility calculation.

Option types: There are typically two types of options found in energy trading: options on a physical energy commodity with an associated spot price; and options on forward or futures contracts for an energy commodity, characterised by a given maturity, with an associated forward/futures price. Adaptiv Analytics supports only options on financial forwards or swaps, with no option for physical underlyings.

Exercise types: There are several different exercise types which can be observed in energy markets: for example, European, American, Asian and Bermudan style exercise are all found. Of these, Adaptiv Analytics only supports European style exercise and (with some limitations) Asian style exercise.

48.3.2 Energy Option

48.3.2.1 Overview

This deal type is for options on an underlying energy asset, and their quanto or compo variants.

48.3.2.2 Price Factor Dependency

Energy Option

- └ Forward Price (§ 10.2)
- └ Forward Price Sample (§ 10.4)
- └ Forward Price Volatility (§ 11.4.1)
- └ FX Rate (§ 4.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)
- └ Reference Price (§ 10.5)
- └ Reference Volatility (§ 11.4.2)

48.3.2.3 Properties

For an overview and description of the properties of these deals, see the deal definition in the Integrated documentation [4, Portfolio: Energy Option].

48.3.2.4 Deal Representation

The Energy Option is an atomic deal.

48.3.2.5 Valuation

In Adaptiv Analytics an Energy Option deal can be valued using the `EnergySingleOptionValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.2.14 [European Options on Financial Forward Contracts](#)].

These options are valued using the Black model, discounted between valuation date t and end date T by discount factor $D(t, T)$:

Theory Guide [4.2.14](#)

European options on financial forward contracts are valued using the Black model with the volatility of the forward rate derived from the underlying energy volatility surface. Consider a European option on a financial contract reference price $S^R(t, t_s^s, t_e^s, \mathcal{S})$, where t_s^s is the start of the sampling period, and t_e^s is the end of the sampling period and expiry date of the option. The value of the option with strike K and settlement date T is

$$\mathcal{B}_\delta \left(\mathbb{E}_t(A), \bar{K}, w(t, t_e^s, t_s^s, t_e^s, \mathcal{S}) \right) D(t, T), \quad (48.3.1)$$

where A is the stochastic part of $S^R(t, t_s^s, t_e^s, \mathcal{S})$, \bar{K} is the adjusted strike, $w(t, t_e^s, t_s^s, t_e^s, \mathcal{S})$ is the standard deviation of $\log A$, \mathcal{B}_δ is the Black formula defined in Section [D.3.1](#), and either $\delta = +1$ for a call option or $\delta = -1$ for a put option. A , \bar{K} and $w(t, t_e^s, t_s^s, t_e^s, \mathcal{S})$ are defined in Section [4.2.3](#).

48.3.2.6 Limitations

Asian style exercise options: Adaptiv Analytics does not explicitly specify exercise style as a deal parameter; hence, European style exercise is assumed. However, if the sampling method implies averaging, the option is implicitly settled against average prices, which can thus be considered Asian style exercise. The only Asian style options supported are those which can be expressed through the sample methods described in Section 10.4.

Consequently, the implied volatility for Asian options is assumed to be the same as for European options on a bullet forward reference price. The pricing model converts the input volatility to a volatility of an average reference price by moment matching, with the entire forward price curve assumed to be driven by a single geometric Brownian motion.

Volatility term structure: Energy markets may exhibit a volatility term structure that changes between long- and short-term; this variation is not considered by the Adaptiv Analytics option valuation models. This becomes especially relevant in the case of Asian style options with longer averaging periods.

48.3.3 Energy Cap/Floor

48.3.3.1 Overview

This deal type is for energy caps/floors on an underlying energy asset, and their quanto or compo variants.

Like the Energy options above, European style exercise is supported explicitly, while Asian style exercise can be represented by averaging caps/floors through an appropriate choice of Sampling Method.

48.3.3.2 Price Factor Dependency

Energy Cap/Floor

- └ Forward Price (§ 10.2)
- └ Forward Price Sample (§ 10.4)
- └ Forward Price Volatility (§ 11.4.1)
- └ FX Rate (§ 4.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)
- └ Reference Price (§ 10.5)
- └ Reference Volatility (§ 11.4.2)

48.3.3.3 Properties

For an overview and description of the properties of these deals, see definitions in the Integrated documentation [4, Portfolio: Energy Cap, Energy Floor].

48.3.3.4 Deal Representation

The Energy Cap and the Energy Floor are atomic deals.

48.3.3.5 Valuation

In Adaptiv Analytics Energy Cap/Floor deals can be valued using the `EnergyCapValuation` model or the `EnergyFloorValuation` model, respectively. For details about these valuations, see the Theory Guide [7, § 4.2.14 [European Options on Financial Forward Contracts](#), § 4.2.15 [Caps and Floors on Financial Forward Contracts](#)].

Theory Guide [4.2.15](#)

A cap (floor) is a strip of independent call (put) options. As such its value is equal to the sum of the values of the component options, each valued as described in Section [4.2.14](#).

48.3.3.6 Limitations

As Energy Caps and Floors are formed of a strip of European style options, all limitations for Energy Options also apply for Caps and Floors.

48.4 Energy Swaption Deal Types

48.4.1 Energy Swaption

48.4.1.1 Overview

This deal type is for a European-style option on a vanilla fixed-float energy swap, which may be settled for cash or exercised into the underlying swap.

Theory Guide [4.2.19](#)

An energy swaption is an European-style option to enter into an energy swap. The underlying swap has features covered by the energy fixed-float swap described in [Section 4.2.8](#), which can either be physically delivered or cash-settled.

48.4.1.2 Price Factor Dependency

Energy Swaption

- └ Forward Price (§ [10.2](#))
- └ Forward Price Sample (§ [10.4](#))
- └ Forward Price Volatility (§ [11.4.1](#))
- └ FX Rate (§ [4.2](#))
- └ FX Volatility (§ [11.2.4](#))
- └ Interest Rate (§ [6.1](#))
- └ Reference Price (§ [10.5](#))
- └ Reference Volatility (§ [11.4.2](#))

48.4.1.3 Properties

For an overview and description of the properties of the deal, see the deal definition in the Integrated documentation [[4](#), Portfolio: Energy Swaption].

48.4.1.4 Deal Representation

The Energy Swaption is an atomic deal.

48.4.1.5 Valuation

In Adaptiv Analytics an Energy Swaption deal can be valued using the `EnergySwaptionValuation` model. For details about the valuation for this deal, see the Theory Guide [[7](#), § [4.2.19 Energy Swaption](#)].

An Energy Swaption can be considered as average price (Asian) options, since the swap contract specifies a set of predetermined settlement dates, as well as the amount of commodity involved in the swaplet on each settlement date. For each settlement date, it is the floating price that determines the value of the cashflow for that date, so the average is defined in terms of the observed prices at a set of predetermined fixing dates during the period preceding the specified settlement dates. The standard Black methodology used for Energy Options is not applicable here; instead, Adaptiv Analytics uses a one-factor Clewlow-Strickland model which simultaneously models the evolution of the entire forward curve, conditional on the initial (observed) forward curve.

48.4.1.6 Assumptions

As the energy swaption consists of an option to enter into a swap, the assumptions made by Adaptiv Analytics for this model are the same as those for the swap (see Section 48.2.4.6).

48.4.1.7 Limitations

As the energy swaption consists of an option to enter into a swap, the limitations on Energy Fixed-Float swaps also apply for this model (see Section 48.2.4.7).

Term volatility structure limitation: The One-factor Clewlow-Strickland model neglects the fact that energy price volatility has a specific term structure, especially in power markets. Two-factor models more appropriately reflect the observed volatility term structure, including separate long- and short-term volatility, but are not supported for energy in Adaptiv Analytics. Swaps with longer delivery periods are more acutely impacted by this limitation.

Part IX

OTC Derivatives: Mortgages & Securities Lending

Chapter 49

Mortgage

49.1 Mortgage Deal Types

49.1.1 Overview

Adaptiv Analytics supports two types of Mortgage Backed Security (MBS) bond: the Fixed Rate MBS Bond described in § 49.1.6 and the Floating Rate MBS Bond described in § 49.1.7.

These deal types model a given fixed-coupon or floating-rate MBS tranche, respectively. The Theory Guide explains:

Theory Guide [4.8.1](#)

The elementary security modeled by Analytics is the MBS tranche. It is currently represented as a product type as a Fixed or Floating MBS Bond (see [4.8.2](#)), and it is the underlying security of supported mortgage products.

The subsequent section (§ 49.1.2 through to § 49.1.5) cover the common functionality shared by the Fixed and Floating Rate MBS Bond.

49.1.2 Properties

Buy Sell

Buy or Sell. Determines whether the holder is long (Buy) or short (Sell) the deal.

Pool Number

Mortgage pool identifier (for information only).

Issue Date

Issue Date (for information only).

Issuer

The name of the issuer (for information only).

Insurer

The name of the insurer (for information only).

Payment Schedule

List of payment dates.

Payment Frequency

Period between MBS payments. This property must not be zero.

Original Principal

MBS bond principal amount on issue date in units of settlement currency.

Current Principal

MBS bond principal amount at base valuation date in units of settlement currency.

Maturity Schedule

List specifying the fraction of maturing mortgages in a tranche by date. These dates must be a subset of the payment dates of the tranche.

Weighted Average Maturity

Weighted average mortgage amortization period for underlying mortgages.

Prepayment Rate

ID of the prepayment rate price factor used to construct prepayment rates.

Currency

ID of the settlement currency. For example, USD.

Discount Rate

ID of the interest rate price factor (or discount rate price factor) used to discount the cashflows. For example, USD.AAA. The currency of the interest rate price factor must be the settlement currency. If left blank, the ID of the settlement currency is used.

MBS Compounding

Compounding period of the MBS rate.

Mortgage Compounding

Compounding period of the underlying mortgage rate.

49.1.3 Valuation

An MBS bond (or equivalently, as explained above, an MBS tranche) is valued using the `MBSBondValuation` model. For details about the valuation, see the Theory Guide [7, § 4.8 Mortgage Products], which explains that it is treated as an effective single notional mortgage.

Theory Guide 4.8.1

The MBS tranche is a bond based on a pass-through interest in a pool of mortgages sufficiently similar that their characteristics can be handled on an average basis as if the bond were based on a single underlying mortgage subject to both scheduled and unscheduled amortization. This notional mortgage is characterized by a weighted average coupon and weighted average amortization period and is treated as if it pays cashflows at a simple set of periodic monthly dates, assumed to be based on equal payments that blend interest and amortization of principal.

The scheduled amortization referred to above is due to contractually-obliged payments made by the holders of the underlying mortgages. The unscheduled amortization is due to optional partial or full prepayments of the mortgages made outside of the contractual schedule.

49.1.4 Assumptions**49.1.4.1 Notional mortgage**

It is assumed that it indeed makes sense to treat the tranche as a single effective mortgage, i.e. that the underlying mortgages are “sufficiently similar” to each other.

Analytics does not record details of the individual component mortgages, so is unable to validate whether they satisfy this assumption.

49.1.4.2 Mortgage amortization

The Theory Guide explains that:

Theory Guide 4.8.1.2

The weighted average amortization period may be longer than the maturity of the mortgages (that is, the notional mortgage may be a 'balloon' mortgage.) It is anticipated that the underlying mortgages in the pool will be chosen to have maturities that are similar but possibly shorter than the maturity of the mortgage tranche; thus, the tranche is endowed with a schedule that specifies the fraction of maturing mortgages by date.

The schedule mentioned is the provided by the `Maturity_Schedule` property.

49.1.4.3 Forecast payments

The Theory Guide explains that:

Theory Guide 4.8.1.4

The spot prepayment rate is treated as identical to the realized prepayment over the term of the rate for pricing purposes. With this treatment, prepayment for the i^{th} period is deterministic as of t_{i-1} .

49.1.5 Limitations

49.1.5.1 Prepayment

As mentioned in § 8.1, the prepayment rate combines both liquidation and partial prepayment into a single rate and does not distinguish between them.

Furthermore:

Theory Guide 4.8.1.1

A single prepayment rate applies to the entire tranche in a given payment period. Note, however, that although the effect of prepayment on mortgage bond principal is modeled, the effect on weighted average amortization period is not: both this and the weighted average coupon are treated as deterministic.

49.1.6 Fixed MBS Bond

49.1.6.1 Overview

A Fixed MBS Bond represents an MBS bond as described in § 49.1.1 through to § 49.1.5, with a fixed coupon rate and based on a pool of fixed-coupon mortgages.

49.1.6.2 Price Factor Dependency

Fixed or Floating MBS Bond

- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)
- └ Prepayment Rate (§ 8.1)

49.1.6.3 Properties

The Fixed MBS Bond has the following properties in addition to those given in § 49.1.2:

Coupon

Fixed coupon rate. Entered as a decimal or as a percentage. For example, enter 5% or 0.05 for 5%.

Weighted Average Coupon

Weighted average fixed coupon rate for an MBS. Entered as a decimal or as a percentage. For example, enter 5% or 0.05 for 5%

49.1.6.4 Deal Representation

The Fixed MBS Bond is an atomic deal.

49.1.6.5 Assumptions

This product is subject to the assumptions given in § 49.1.4.

49.1.6.6 Limitations

This product is subject to the limitations given in § 49.1.5.

49.1.7 Floating MBS Bond

49.1.7.1 Overview

A Floating MBS Bond represents an MBS bond as described in § 49.1.1 through to § 49.1.5, with a floating rate and based on a pool of adjustable-rate mortgages, in which the bond and mortgage pool have distinct fixed spreads over distinct reference rates.

49.1.7.2 Price Factor Dependency

Fixed or Floating MBS Bond

- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)
- └ Prepayment Rate (§ 8.1)

49.1.7.3 Properties

The Floating MBS Bond has the following properties in addition to those given in § 49.1.2:

MBS Forecast Rate

ID of the interest rate price factor used to calculate forward MBS interest rates. For example, CAD.MBS. If left blank, the ID of Currency is used.

Mortgage Forecast Rate

ID of the interest rate price factor used to calculate forward mortgage interest rates. For example, CAD.PRIME. If left blank, the ID of Currency is used.

MBS Spread

MBS spread rate. Entered as a decimal or as a percentage. For example, enter 5% or 0.05 for 5%.

Mortgage Spread

Mortgage spread rate. Entered as a decimal or as a percentage. For example, enter 5% or 0.05 for 5%.

Known MBS Rates

List of payment dates and corresponding known MBS rates.

Known Mortgage Rates

List of payment dates and corresponding known mortgage rates.

49.1.7.4 Deal Representation

The Floating MBS Bond is an atomic deal.

49.1.7.5 Assumptions

This product is subject to the assumptions given in § 49.1.4.

49.1.7.6 Limitations

This product is subject to the limitations given in § 49.1.5.

Chapter 50

Securities Lending

50.1 Security Lending Set

50.1.1 Overview

Adaptiv Analytics has a system of container deals that support the calculation of potential future exposure for security lending or repo transactions. This system comprises a top-level container called `Security Lending Set` which contains one or more sub-containers `Security Lending Leg` and `Security Collateral Leg` to represent loans and collateral respectively. The contents of the leg containers are expected to be cash or negotiable securities, but this is not enforced. Cash may be represented with a loan.

A security lending set can represent a single transaction, but it is intended to support the representation of collections of loans with consolidated collateral. In order to associate a particular security position with a particular collateral position, it must be placed in a dedicated security lending set.

The security lending set is analogous to a collateralized portfolio of bilateral derivatives used in a Credit Monte Carlo simulation, except that both the collateral and the positions collateralized are expected to be cash or negotiable securities. Unlike the collateral representation that Adaptiv Analytics uses for bilateral derivatives, the security positions held in security lending and collateral legs are expected to be actual traded securities, rather than notional constant maturity securities. Therefore, a loan cannot be extended longer than the maturity of the security loaned.

Accrued fees may be included in the exposure calculation.

See Theory Guide [7, §4.9.5 [Security Lending Set](#)] for details about the security lending set and its associated legs.

50.1.2 Price Factor Dependency

The security lending set has no direct price factor dependencies. However, it inherits the dependencies of the deals it contains.

50.1.3 Properties

50.1.3.1 Base Collateral Call Date

This property specifies the first date of the call schedule when the `Collateral Call Frequency` is slower than daily. Subsequent call dates are determined by adding the call frequency to this date and then adjusting using the deal calendars. If used, it should be on or before the base calculation date; if after the base calculation date, or left blank, then the base calculation date is used instead.

50.1.3.2 Borrower Lender

From the bank perspective, the `Borrower` holds the security legs and the `Lender` holds the collateral legs.

50.1.3.3 Collateral Call Frequency

The term between unadjusted call dates. Collateral calls during simulation can be prevented by setting this to zero.

50.1.3.4 Currency

This property is not currently used by Adaptiv Analytics.

50.1.3.5 Effective Date

The starting date of the lending transaction. This may be in the future with respect to the base calculation date.

50.1.3.6 Enforce Netting

When set to `Yes`, exposure is calculated from the difference between the market value of the lending legs and the market value of the collateral legs. When set to `No`, the exposure to the lender is the value of the lending legs and the exposure to the borrower is the value of the collateral legs.

50.1.3.7 Liquidation Period

The number of days required to liquidate securities held after the default of the counterparty has been established. The market values of the lending legs and collateral legs may diverge over this period, so that it is possible for a security lender to have exposure even if overcollateralized. No collateral, loaned securities, or cash are exchanged with the counterparty during the liquidation period. Any cash paid by held securities during the liquidation period is retained by the security holder.

50.1.4 Deal Representation

The Security Lending Set is an atomic container deal.

50.1.5 Valuation

In Adaptiv Analytics a Security Lending Set deal can be valued using the `SecurityLendingSetValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.9.5 [Security Lending Set](#)].

50.1.6 Tuning Parameters and Valuation Settings

50.1.6.1 Forward Looking Closeout

When set to `No`, standard, or backward looking closeout is used, in which default is assumed to have occurred one liquidation period before an exposure reporting date. When set to `Yes`, default is assumed to occur on the exposure reporting date; the difference between loan and collateral value one liquidation period after the reporting date is attributed to the reporting date itself.

50.1.6.2 Same Day Collateral

When set to `Yes`, collateral is assumed to be delivered on the same day that it is called, unless the counterparty defaults. When set to `No`, collateral is assumed to be delivered the day after the call date.

50.1.7 Assumptions

50.1.7.1 Exposure to be Collateralized

The exposure to be collateralized is assumed to be the market value of the securities loaned.

50.1.7.2 Fees not Collateralized

Although fees contribute to exposure, they are assumed not to affect collateral.

50.1.7.3 No Exposure Before Effective Date

There is assumed to be no credit exposure before the effective date of the security lending set.

50.1.7.4 Passthrough of Security Cashflows

Cashflows such as coupons or dividends paid by loaned securities are assumed to be passed through immediately to the lender by the borrower unless the borrower defaults.

50.1.7.5 Payments Held as Cash During Liquidation

Cashflows such as coupons or dividends paid by loaned securities are assumed to be held as cash during the liquidation period, rather than reinvested in some asset.

50.1.7.6 Replacement of Collateral Cashflows and Maturing Collateral

Collateral cashflows such as coupons and dividends are assumed to be replaced by the same value in the asset that paid them. Maturing collateral assets are assumed to be replaced by increasing the remaining collateral assets in proportion to their market value at the time of maturity.

50.1.7.7 Security Holder is the Owner of Record

The holder of securities is assumed to receive payments such as coupons and dividends directly.

50.1.8 Limitations

50.1.8.1 Positive Security Principal

The notional principal amount of securities such as bonds must be at least 10^{-6}

50.1.8.2 Fee Payment Timing

The payment timing of fees is approximated by paying at maturity of the security lending set. There is no support for settling net at month end, for example.

50.1.8.3 No Daylight Collateral Calls

The collateral call frequency cannot be faster than daily.

50.1.8.4 No Repo Margining

Collateral calls are applied to all of the collateral legs in proportion to their market value. There is no provision to designate one leg as the margining leg.

50.1.8.5 No Settlement Risk

Adaptiv Analytics does not model the settlement risks that arise from security lending or repo transactions.

50.1.8.6 No Two-way Security Lending Sets

The security legs held within a single security lending set must either all be loaned or all be borrowed. Therefore, it is generally not possible to represent all of the securities lending transactions done with a particular counterparty within a single security lending set, even if they are managed on a consolidated basis operationally.

50.1.8.7 Only PFE Calculation Supported

The security lending set is intended only for PFE calculation using a Credit Monte Carlo. Note that Adaptiv Analytics does not report the market value or market risk of a security lending set.

50.2 Security Lending Leg

50.2.1 Overview

A security lending leg is a container deal that may contain any deals with single-signed values, such as a position in an equity or bond, or a loan. The number of deals that may be contained is not limited, but is usually one in practice. For details about this deal, see the Theory Guide [7, § 4.9.5.1 [Security Lending Leg](#)].

50.2.2 Price Factor Dependency

Security Lending Leg

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

Note that a security lending leg also inherits price factor dependencies from the deals it contains.

50.2.3 Properties

50.2.3.1 Currency

The ID of the FX rate price factor in which fees and cashflows are consolidated.

50.2.3.2 Discount Rate

The ID of the interest rate price factor used to discount fees. The currency of this interest rate must match the leg Currency. If not specified, Currency will be used.

50.2.3.3 Fee Type

The form that the lending fee takes, if there is one. May be `None`, `Fixed`, or `Fraction Of MtM`.

50.2.3.4 Fixed Fee

When the fee type is `Fixed`, the fee is specified as an absolute amount.

50.2.3.5 Fractional Fee

When the fee type is `Fraction Of MtM`, the fee is specified as a fraction of the market value of the security leg, in basis points.

50.2.3.6 Maturity Date

The end date of this lending leg.

50.2.4 Deal Representation

The Security Lending Leg is an atomic container deal.

50.2.5 Valuation

In Adaptiv Analytics a Security Lending Leg deal can be valued using the `SecurityLendingLegValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.9.5.1 [Security Lending Leg](#)].

50.2.6 Tuning Parameters and Valuation Settings

The SecurityLendingLegValuation model has no tuning parameters or valuation settings.

50.2.7 Assumptions

The Security Lending Leg is a component of the security lending system. See Section 50.1.7 for a description of the assumptions of this system.

50.2.8 Limitations

The Security Lending Leg is a component of the security lending system. See Section 50.1.8 for a description of the limitations of this system.

50.3 Security Collateral Leg

50.3.1 Overview

A security collateral leg is a container deal that may contain any deals with non-zero, single-signed values, such as a position in an equity or bond, or a loan. The number of deals that may be contained is not limited, but is usually one in practice. For details about this deal, see the Theory Guide [7, § 4.9.5.2 [Security Collateral Leg](#)].

50.3.2 Price Factor Dependency

Security Collateral Leg

- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

Note that a security collateral leg also inherits price factor dependencies from the deals it contains.

50.3.3 Properties

50.3.3.1 Collateral Day Count

The day count convention used to calculate interest on the collateral when the fee type is `Rebate`.

50.3.3.2 Collateral Interest Rate

The ID of the interest rate price factor used to calculate the gross interest before rebates earned on collateral when the fee type is `Rebate`.

50.3.3.3 Currency

The ID of the FX rate price factor in which fees and cashflows are consolidated.

50.3.3.4 Discount Rate

The ID of the interest rate price factor used to discount fees. The currency of this interest rate must match the leg `Currency`. If not specified, `Currency` will be used.

50.3.3.5 Fee Type

The form that the collateral fee takes, if there is one. May be `None`, `Fixed`, or `Rebate`.

50.3.3.6 Fixed Fee

When the fee type is `Fixed`, the fee is specified as an absolute amount.

50.3.3.7 Haircut

The percentage by which the market value of collateral called exceeds the deemed value for collateralization. For example, 5% indicates that a market value of \$105 worth of the collateral leg would be required to collateralize \$100 of loans.

50.3.3.8 Rebate Day Count

The day count convention used to calculate rebate interest on the collateral when the fee type is `Rebate`.

50.3.3.9 Rebate Rate

The rate, in basis points, at which the lender pays interest to the borrower on collateral when the fee type is `Rebate`.

50.3.3.10 Standalone Maturity Date

When there are no security lending legs, then the collateral legs are standalone, and the maturity of the security lending set cannot be determined from lending legs. In this case, each collateral leg is assumed to mature on its standalone maturity date.

50.3.4 Deal Representation

The `Security Collateral Leg` is an atomic container deal.

50.3.5 Valuation

In `Adaptiv Analytics` a `Security Collateral Leg` deal can be valued using the `SecurityCollateralLegValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.9.5.2 [Security Collateral Leg](#)].

50.3.6 Tuning Parameters and Valuation Settings

The `SecurityCollateralLegValuation` model has no tuning parameters or valuation settings.

50.3.7 Assumptions

The `Security Collateral Leg` is a component of the security lending system. See Section 50.1.7 for a description of the assumptions of this system.

50.3.8 Limitations

The `Security Collateral Leg` is a component of the security lending system. See Section 50.1.8 for a description of the limitations of this system.

Part X

Exchange-Traded Derivatives

Chapter 51

Futures

51.1 Futures Valuation Models

51.1.1 Common Properties

The properties described below are often found on futures and futures option deal types.

51.1.1.1 Buy Sell

Buy denotes a bought futures position, or option on futures. Sell denotes a sold futures position, or option on futures.

51.1.1.2 Calendar

Name of the calendar used to calculate the simply compounded rate underlying the interest rate futures and futures option contract.

51.1.1.3 Contract

ID of futures contract that determines the ID of the futures price or futures basis price factor. The price factor ID is of the form of Contract.Delivery, where the delivery code is in the format of MMMyy. For example, if the Contract is CME.ED, and the Settlement Date of the futures contract is September 17, 2014 then the price factor ID is CME.ED.SEP14.

51.1.1.4 Contract Size

Notional principal amount per contract.

51.1.1.5 Currency

ID of the FX price factor for the currency in which deal cashflows are denominated.

51.1.1.6 Day Count

Specifies the day count convention used. See Section 3.3.4 for more information about day counts in Adaptiv Analytics.

51.1.1.7 Discount Rate

The ID of the interest rate price factor used to discount deal cashflows. If this ID is not specified, then the Currency will be used as the discount interest rate ID.

51.1.1.8 Equity

Underlying equity name for the equity futures or futures option contract.

51.1.1.9 Expiry Date

Last trading date of the futures or futures option contract.

51.1.1.10 Forecast Rate

ID of the interest rate price factor used to calculate forward interest rates.

51.1.1.11 Forecast Rate Volatility

ID of the interest rate volatility price factor or interest yield volatility price factor used for the volatility of the forecast rate.

51.1.1.12 FX Volatility

ID of the FX volatility price factor to be used by the FX Futures option valuation.

51.1.1.13 Issuer

ID of the issuer and the ID of the credit rating price factor used by bond futures and bond futures option contracts.

51.1.1.14 Option Style

This may be American Or European.

51.1.1.15 Option Type

This may be Call or Put.

51.1.1.16 Premium Type

Some options pay a premium `Upfront` at the time of the option purchase, in this case, there is no market-to-market margining on the option during the life of the contract (e.g. CME for eurodollars futures option). Others have a futures-style margining (`Margin`) where variation margins are settled daily according to the changing value of the option (e.g. LIFFE and EUREX futures).

51.1.1.17 Price

Transaction price of the futures position.

51.1.1.18 Recovery Rate

ID of the recovery rate price factor used by bond futures and bond futures option contracts when `Respect Default=Yes Or Use Survival Probability=Yes`.

51.1.1.19 Repo Rate

ID of the repo interest rate price factor used by bond futures and bond futures contracts.

51.1.1.20 Settlement Date

Settlement date of the futures contract or last settlement date of the delivery period for physically settled futures contract.

51.1.1.21 Settlement Style

Option settlement style: cash settled (Cash) or deliver the underlying (Physical).

51.1.1.22 Strike

Strike price of the futures option.

51.1.1.23 Survival Probability

ID of the survival probability price factor used by bond futures and bond futures option contracts when `Respect Default=Yes` Or Use `Survival Probability=Yes`.

51.1.1.24 Tenor

Tenor of the underlying of the interest rate futures and futures option contract.

51.1.1.25 Underlying Currency

ID of the foreign currency for the FX futures and futures option contract. For example, USD. The underlying exchange rate for the deal is the amount of Currency per unit of Underlying Currency.

51.1.1.26 Units

Number of futures contracts.

51.1.2 Tuning Parameters and Valuation Settings

The valuation settings described below are often found on futures and futures option deal valuations.

Convexity Correction: Convexity Correction is supported for interest rate futures and interest rate futures options when `Convexity Correction` is set to `Yes`, see the Theory Guide for details [7, § 4.6.4.1 Interest Rate Future]. In this case, the valuation model also depends on the volatility of the forecast interest rate specified in `Forecast Rate Volatility`.

Early Exercise Today: American options are exercised only at times after the base calculation date unless this parameter is `Yes`. See 37.3.6.1.

Monitoring Period: The model exercises American options on the union of valuation grid dates and on monitoring dates. The selection of monitoring dates is controlled by the `Monitoring Period` parameter. See Theory Guide [7, § 4.1.18.4 Monitoring Dates] for details on the use of this parameter.

Respect Default: The valuation model property `Respect Default` controls the behaviour of the bond futures or bond futures option valuation when the issuer defaults.

Theory Guide 4.6.5

Let τ denote the time of default. Under the standard valuation model, the value of the deal at a time $t \geq \tau$ is modified by multiplying the forward bond price $P(t)$ by $D(t, t_0)R(\tau)$, where R is the realized recovery rate and t_0 is the futures expiry date.

When `Respect Default = No`, the valuation doesn't depend on the issuer's credit rating and therefore is unaffected by the issuer's default. Note that this statement is true even if the credit rating is

simulated within the calculation, for example, this can happen when another deal in the portfolio has a dependency on this particular issuer's credit rating.

Use Survival Probability: Use Survival Probability controls whether the issuer's survival probability is used to determine the forward price of the CTD bond associated with the bond futures or bond futures option contract.

When Use Survival Probability=No, only the discount rate specified on the deal is used to discount future bond cashflows. When Use Survival Probability=Yes, both the discount rate and the issuer's survival probability are used.

Theory Guide 4.6.5

When Use Survival Probability is Yes the forward price of the CTD bond is given by

$$P(t) = \frac{1}{D_r(t, T)} \left(\sum_{t_i > T} c\alpha_i D(t, t_i) S(t, t_i) + D(t, t_n) S(t, t_n) + R(1 - S(t, T)) D(t, T) + \sum_{t_i > T} R(S(t, \tilde{t}_{i-1}) - S(t, \tilde{t}_i)) D(t, \bar{t}_i) \right), \quad (51.1.1)$$

where $S(t, u)$ is the issuer's probability of survival to time u , R is the recovery rate on the survival probability price factor, $\tilde{t}_i = \max(t_i, T)$ and $\bar{t}_i = (\tilde{t}_{i-1} + \tilde{t}_i)/2$.

The discount rate passed to the deal can represent either a risk-free rate or risk-adjusted discount rate depending on how the market data was set up. In the latter case, users should select Use Survival Probability=No to avoid double counting the issuer's creditworthiness when calculating the bond forward price.

51.1.3 Assumptions

The assumptions stated below are commonly applicable to futures and futures option deal types.

There is a choice of valuation models for futures, the futures valuation model which prices the futures as a forward, and the MtM valuation model, which uses units times price.

The recommended model is the futures valuation model; the futures is priced as a forward plus a time decaying futures basis accounting for the difference between the quoted futures price and the forward price calculated by Adaptiv Analytics. The underlying futures and futures options are modelled consistently with their underlying risk factors and captures correctly the convergence of the futures price to the price of the underlying as we approach the settlement date. The basis ensures the futures price calculated by Adaptiv Analytics matches the quoted futures market price perfectly at the base date.

Conversely, the MtM valuation models the futures price directly and cannot provide such consistent modelling. In particular, there is no guarantee that the futures price at the settlement date equals the underlying price. This is why this model is not recommended for PFE and may only be considered in specific application, for example for a calculation over a short time horizon like VaR where the futures basis is large compared to the theoretical forward price and therefore dominates the present value.

51.1.3.1 MtM futures Valuation

The underlying stochastic variable for the MtM futures valuation model is the futures price itself.

Theory Guide 4.6

When mark-to-market valuation models are used, the futures price factor value $G(t)$ can be evolved using any of the asset price models of Section 1.3. A futures price factor behaves like an asset price whose forward prices are equal to its spot price (the price factor's interest rates and asset yields are zero).

51.1.3.2 Standard Futures Valuation

The standard futures model assumes the futures price is the sum of the forward price and a deterministic basis.

Theoretical Futures Price: The theoretical futures price is calculated as follows:

Theory Guide 4.6.1.1

For futures on short-term interest rates, the standard valuation models calculate a theoretical futures price $\hat{G}(t)$ under the Ho-Lee model. For other futures contracts, define $\hat{G}(t) = F(t)$.

where $F(t)$ denote the forward price of the underlying at time t for delivery at time T .

Futures Basis: The *futures basis* price factor is defined as follows:

Theory Guide 4.6.1.1

Define the *futures basis* $H(t)$ to be the difference between the futures price and the forward price or theoretical futures price: $H(t) = G(t) - \hat{G}(t)$.

The futures basis is optional except for bond futures and bond futures options where it is used to define the CTD bond. Some markets have a small or negligible basis, the basis can be set to zero by leaving the `Contract deal` property empty.

Futures price floored: The futures price is floored as follows:

Theory Guide 4.6.1.1

Under the standard valuation models, the value of the futures deal is given by Equation (4.748) with the futures price $G(t)$ set to the floored sum of the forward or theoretical futures price $\hat{G}(t)$ and a proportion of the initial basis $H(0)$ that declines to zero as the valuation date t approaches the settlement date T :

$$G(t) = \max \left(\hat{G}(t) + \left(\frac{T-t}{T} \right) H(0), 10^{-10} \right). \quad (51.1.2)$$

$H(0)$ is the initial value (Basis) on the Bond Futures Basis price factor (for bond futures contracts) or the Futures Basis price factor (for other futures contracts). Note that the initial basis may be negative but the futures price is floored at 10^{-10} .

51.1.3.3 Futures Option

Futures Price for Option Valuation: Futures options are options on the futures price valued under the standard futures valuation, not the quoted market futures prices. See section 51.1.3.2 for

information about the standard model.

European Option: European options are valued using the Black's formula where the underlying variable is the future price.

Theory Guide 4.6.8

The value of the European option at date $t < t_0$ is given by

$$V(t) = Q\mathcal{B}_\delta(G(t), K, \sigma\sqrt{t_0 - t}) e^{-r(t_0 - t)}, \quad (51.1.3)$$

where \mathcal{B}_δ is the Black formula defined in Section D.3.1.

American Option: American options are valued using the Bjerksund and Stensland where the underlying variable is the future price.

Theory Guide 4.6.8

American options on futures prices are valued using the analytic approximation of Section 4.1.18 with

- the futures price $G(t)$ playing the role of the asset price
- the interest rate r set to $-\log(D(t, T))/(T - t)$
- the carry rate b set to zero
- the volatility σ set to the implied volatility of the asset price for time t , expiry date t_0 and strike K .

Most futures options are American. However, there are 2 cases where an American option is in fact valued as a European option. The first is when the option has futures-style margining; the American and European option values are the same:

Theory Guide 4.6.8

If the premium type is Margin then the option contract is marked-to-market daily in the same way as a futures contract, giving rise to positive or negative variation margin flows. These options are nominally American but early exercise is never advantageous to holder of the option. The price of the option contract is the expected value of the option payoff $Q \max(\delta(G(t_0) - K), 0)$ in the risk-neutral measure. The value of the option at date $t < t_0$ is given by the undiscounted Black formula:

$$V(t) = Q\mathcal{B}_\delta(G(t), K, \sigma\sqrt{t_0 - t}). \quad (51.1.4)$$

The second is when the interest rate is assumed to be normally distributed for valuation purposes, see section 11.3.1.1.

51.1.4 Limitations

The limitations stated below are commonly applicable to futures and futures option deal types.

51.1.4.1 Futures Convexity Correction

Unlike forward contracts, futures are settled daily. The convexity correction arises from the interest paid on excess margins received or paid. This correction depends on the correlation between the

futures value and the interest accrued on the margin account balance. It increases with time to maturity and its precise form is dependent on the interest rate and underlying futures dynamics. In Adaptiv Analytics the convexity correction is supported for interest rate deposit futures but is ignored for any other kind of futures.

51.1.4.2 Defaultable bond future – Value of payment on default

Let's call τ the issuer's time of default. If $\tau \in (\tilde{t}_{i-1}, \tilde{t}_i]$, Adaptiv Analytics assumes the payment on default is made on $\bar{t}_i = (\tilde{t}_{i-1} + \tilde{t}_i)/2$ and the recovery value is discounted at \bar{t}_i .

Indeed, we need to approximate the value of payment on default

$$\begin{aligned} V(t) &= \int_T^{t_n} RS(t, u)h(t, u)D(t, u)du \\ &= \sum_{i=1}^n \int_{\tilde{t}_{i-1}}^{\tilde{t}_i} RS(t, u)h(t, u)D(t, u) [T < u] du \end{aligned} \quad (51.1.5)$$

Using results from Theory Guide [7, § 4.4.1.1 Value of Payment on Default],

Theory Guide 4.4.1.1

Let $g(t)$ be a deterministic function of time. Consider a cashflow that pays $g(u)$ at time u if default occurs at time u , where $t_1 < u \leq t_2$. The value of the cashflow at time t , where $t \leq t_1$, is given by

$$V(t) = \int_{t_1}^{t_2} D(t, u)S(t, u)h(t, u)g(u) du. \quad (51.1.6)$$

Theory Guide 4.4.1.1

Define $\bar{t} = (t_1 + t_2)/2$. The second method approximates the payoff by assuming that $g(\bar{t})$ is paid at time \bar{t} if default occurs between t_1 and t_2 . Under this assumption, the value of the cashflow at time t , where $t \leq t_1$, is given by

$$V(t) = g(\bar{t})D(t, \bar{t})(S(t, t_1) - S(t, t_2)). \quad (51.1.7)$$

and noticing $g(u) = R[T < u]$, $t_1 = \tilde{t}_{i-1}$ and $t_2 = \tilde{t}_i$, $V(t)$ can be approximated by $\sum_{i=1}^n R(S(t, \tilde{t}_{i-1}) - S(t, \tilde{t}_i))D(t, \bar{t}_i)[T < \tilde{t}_i]$.

AUD and NZD futures and futures options: AUD and NZD futures and futures options rely on variable tick size, known as yield-settled futures. Adaptiv Analytics doesn't support this market convention.

51.2 FX Futures Deal Types

51.2.1 FX Futures

51.2.1.1 Overview

This deal type is for FX futures. For an overview and description of the properties of the deal, see the deal definition in the Integrated documentation [4, Portfolio: FX Futures].

51.2.1.2 Price Factor Dependency

FX Futures - FX Future Valuation

- └ Discount Rate (§ 6.2)
- └ Futures Basis (§ 5.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

FX Futures - FX Future MtM Valuation

- └ Futures Price (§ 4.6)
- └ FX Rate (§ 4.2)

51.2.1.3 Properties

See 51.1.1 for descriptions of the common properties of this deal.

51.2.1.4 Deal Representation

The FX Future is an atomic deal.

51.2.1.5 Valuation

In Adaptiv Analytics an FX Futures deal can be valued using either the `FXFutureMtMValuation` model or the `FXFutureValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.6.1 Futures Pricing].

The buy and sell forward prices for the FX Futures are calculated as for the FX Spot (section 38.2.1) using the `Interest Rate` property of the FX rate price factors.

51.2.1.6 Tuning Parameters and Valuation Settings

Not applicable.

51.2.1.7 Assumptions

See 51.1.3 for descriptions of the general futures and futures options assumptions of this deal.

51.2.1.8 Limitations

See 51.1.4 for descriptions of the general futures and futures options limitations of this deal.

51.2.2 FX Futures Option

51.2.2.1 Overview

This deal type is for European and American options on FX futures. For an overview and description of the properties of the deal, see the deal definition in the Integrated documentation [4, Portfolio: FX Futures Option].

The buy and sell forward prices for the FX Futures Option are calculated as for the FX Spot (section 38.2.1) using the `Interest Rate` property of the FX rate price factors.

51.2.2.2 Price Factor Dependency

FX Futures Option

- └ Discount Rate (§ 6.2)
- └ Futures Basis (§ 5.2)
- └ FX Rate (§ 4.2)
- └ FX Volatility (§ 11.2.4)
- └ Interest Rate (§ 6.1)

51.2.2.3 Properties

See 51.1.1 for descriptions of the common properties of this deal.

51.2.2.4 Deal Representation

The FX Futures Option is an atomic deal.

51.2.2.5 Valuation

In Adaptiv Analytics an FX Futures Option deal can be valued using the `FXFutureOptionValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.6.8 Futures Option].

51.2.2.6 Tuning Parameters and Valuation Settings

See 51.1.2 for descriptions of the general futures and futures options tuning parameters and valuation settings of this valuation.

51.2.2.7 Assumptions

See 51.1.3 for descriptions of the general futures and futures options assumptions of this deal.

51.2.2.8 Limitations

See 51.1.4 for descriptions of the general futures and futures options limitations of this deal.

51.3 Equity Futures Deal Types

51.3.1 Equity Futures

51.3.1.1 Overview

This deal type is equity futures. For an overview and description of the properties of the deal, see the deal definition in the Integrated documentation [4, Portfolio: Equity Futures].

51.3.1.2 Price Factor Dependency

Equity Futures - Equity Future Valuation

- └ Discount Rate (§ 6.2)
- └ Equity Price (§ 4.3)
- └ Futures Basis (§ 5.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

Equity Futures - Equity Future MtM Valuation

- └ Futures Price (§ 4.6)
- └ FX Rate (§ 4.2)

51.3.1.3 Properties

See 51.1.1 for descriptions of the common properties of this deal.

51.3.1.4 Deal Representation

The Equity Futures is an atomic deal.

51.3.1.5 Valuation

In Adaptiv Analytics an Equity Futures deal can be valued using either the `EquityFutureMtMValuation` model or the `EquityFutureValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.6.1 Futures Pricing].

51.3.1.6 Tuning Parameters and Valuation Settings

Not applicable.

51.3.1.7 Assumptions

See 51.1.4 for descriptions of the general futures and futures options assumptions of this deal.

51.3.1.8 Limitations

See 51.1.4 for descriptions of the general futures and futures options limitations of this deal.

51.3.2 Equity Futures Option

51.3.2.1 Overview

This deal type is for options on equity futures (European and American). For an overview and description of the properties of the deal, see the deal definition in the Integrated documentation [4, Portfolio: Equity Futures Option].

51.3.2.2 Price Factor Dependency

Equity Futures Option

- └ Discount Rate (§ 6.2)
- └ Equity Price (§ 4.3)
- └ Equity Price Volatility (§ 11.2.5)
- └ Futures Basis (§ 5.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

51.3.2.3 Properties

See 51.1.1 for descriptions of the common properties of this deal.

An `Equity Volatility` property is defined explicitly for the Equity Futures Option; see section 11.2.5.1 for details.

51.3.2.4 Deal Representation

The Equity Futures Option is an atomic deal.

51.3.2.5 Valuation

In Adaptiv Analytics an Equity Futures Option deal can be valued using the `EquityFutureOptionValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.6.8 Futures Option].

51.3.2.6 Tuning Parameters and Valuation Settings

See 51.1.2 for descriptions of the general futures and futures options tuning parameters and valuation settings of this valuation.

51.3.2.7 Assumptions

See 51.1.3 for descriptions of the general futures and futures options assumptions of this deal.

51.3.2.8 Limitations

See 51.1.4 for descriptions of the general futures and futures options limitations of this deal.

51.4 Interest Rate Futures Deal Types

51.4.1 Interest Rate Futures

51.4.1.1 Overview

This deal type is for interest rate deposit futures contracts, it is only suitable for contract with bullet fixing such as Eurodollar futures. For an overview and description of the properties of the deal, see the deal definition in the Integrated documentation [4, Portfolio: Interest Rate Futures].

51.4.1.2 Price Factor Dependency

Interest Rate Futures - IR Future Valuation

- └ Discount Rate (§ 6.2)
- └ Futures Basis (§ 5.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)
- └ Interest Rate Volatility (§ 11.3.4)

Interest Rate Futures - IR Future MtM Valuation

- └ Futures Price (§ 4.6)
- └ FX Rate (§ 4.2)

51.4.1.3 Properties

See 51.1.1 for descriptions of the common properties of this deal.

51.4.1.4 Deal Representation

The Interest Rate Futures is an atomic deal.

51.4.1.5 Valuation

In Adaptiv Analytics an Interest Rate Futures deal can be valued using either the `IRFutureMtMValuation` model or the `IRFutureValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.6.4 Interest Rate Futures].

51.4.1.6 Tuning Parameters and Valuation Settings

See 51.1.2 for descriptions of the general futures and futures options tuning parameters and valuation settings of this valuation.

51.4.1.7 Assumptions

See 51.1.3 for descriptions of the general futures and futures options assumptions of this deal.

Interest Rate Futures Convexity Correction: The optional convexity correction term is calculated as follows:

Theory Guide 4.6.4.1

The formula for the futures rate under the Ho-Lee model is given here and in Kirikos and Novak [37]. Under the Ho-Lee model, the futures rate is given by

$$1 + \alpha_1 \hat{L}(t) = (1 + \alpha_1 L(t)) \exp \left(\zeta^2 \left(1 + \frac{T-t}{2(t_1-T)} \right) \right), \quad (51.4.1)$$

where $\zeta^2 = (t_1 - T)^2 (T - t) \sigma^2$ is the variance of $\log D(T, t_1)$ and σ is the short rate volatility. Section D.1.6.4 shows that the value of the ATM caplet is

$$(2\Phi(\tfrac{1}{2}\zeta) - 1) (1 + \alpha_1 L(t)) D(t, t_1). \quad (51.4.2)$$

ζ is calculated from either the implied Black volatility or implied Bachelier volatility of $L(T)$.

See also 51.1.2.

51.4.1.8 Limitations

See 51.1.4 for descriptions of the general futures and futures options limitations of this deal.

51.4.2 Interest Rate Futures Option

51.4.2.1 Overview

This deal type is for options on an underlying interest rate deposit futures contract, with European or American exercise. For an overview and description of the properties of the deal, see the deal definition in the Integrated documentation [4, Portfolio: Interest Rate Futures Option].

51.4.2.2 Price Factor Dependency

Interest Rate Futures Option

- └ Discount Rate (§ 6.2)
- └ Futures Basis (§ 5.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)
- └ Interest Rate Volatility (§ 11.3.4)

51.4.2.3 Properties

See 51.1.1 for descriptions of the common properties of this deal.

51.4.2.4 Deal Representation

The Interest Rate Futures Option is an atomic deal.

51.4.2.5 Valuation

In Adaptiv Analytics an Interest Rate Futures Option deal can be valued using the `IRFutureOptionValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.6.8.1 Interest Rate Futures Option].

51.4.2.6 Tuning Parameters and Valuation Settings

See 51.1.2 for descriptions of the general futures and futures options tuning parameters and valuation settings of this valuation.

51.4.2.7 Assumptions

See 51.1.3 for descriptions of the general futures and futures options assumptions of this deal.

51.4.2.8 Limitations

See 51.1.4 for descriptions of the general futures and futures options limitations of this deal.

51.4.3 Bond Futures

51.4.3.1 Overview

This deal type is for bond futures contracts. For an overview and description of the properties of the deal, see the deal definition in the Integrated documentation [4, Portfolio: Bond Futures].

51.4.3.2 Price Factor Dependency

Bond Futures - Bond Future Valuation

- └ Bond Futures Basis (§ 5.3)
- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)
- └ Recovery Rate (§ 9.3)
- └ Survival Probability (§ 9.1)

Bond Futures - Bond Future MtM Valuation

- └ Futures Price (§ 4.6)
- └ FX Rate (§ 4.2)

51.4.3.3 Properties

See 51.1.1 for descriptions of the common properties of this deal.

51.4.3.4 Deal Representation

The Bond Futures is an atomic deal.

51.4.3.5 Valuation

In Adaptiv Analytics a Bond Futures deal can be valued using either the `BondFutureMtMValuation` model or the `BondFutureValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.6.5 Bond Futures].

Bond Futures Valuation: The Adaptiv Analytics bond futures valuation model has a dependency on the bond futures basis price factor so it must be populated when using that model.

51.4.3.6 Tuning Parameters and Valuation Settings

See 51.1.2 for descriptions of the general futures and futures options tuning parameters and valuation settings of this valuation.

51.4.3.7 Assumptions

See 51.1.3 for descriptions of the general futures and futures options assumptions of this deal.

51.4.3.8 Limitations

See 51.1.4 for descriptions of the general futures and futures options limitations of this deal.

51.4.4 Bond Futures Option

51.4.4.1 Overview

This deal type is for options on an underlying bond futures contract (European and American). For an overview and description of the properties of the deal, see the deal definition in the Integrated documentation [4, Portfolio: Bond Futures Option].

51.4.4.2 Price Factor Dependency

Bond Futures Option

- └ Bond Futures Basis (§ 5.3)
- └ Credit Rating (§ 9.2)
- └ Discount Rate (§ 6.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)
- └ Interest Yield Volatility (§ 11.3.5)
- └ Recovery Rate (§ 9.3)
- └ Survival Probability (§ 9.1)

51.4.4.3 Properties

See 51.1.1 for descriptions of the common properties of this deal.

Yield Volatility: ID of the interest yield volatility price factor used for the volatility of the underlying interest rate.

51.4.4.4 Deal Representation

The Bond Futures Option is an atomic deal.

51.4.4.5 Valuation

In Adaptiv Analytics a Bond Futures Option deal can be valued using the `BondFutureOptionValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.6.8.2 Bond Futures Option].

51.4.4.6 Tuning Parameters and Valuation Settings

See 51.1.2 for descriptions of the general futures and futures options tuning parameters and valuation settings of this valuation.

51.4.4.7 Assumptions

See 51.1.3 for descriptions of the general futures and futures options assumptions of this deal.

Bond forward price volatility: The (constant) volatility used by the Black's formula is the CTD bond price volatility.

Volatilities for bond options are generally quoted as yield volatilities, Adaptiv Analytics follows market convention by converting a yield volatility to a price volatility using the modified duration.

Theory Guide 4.6.8.2

The price volatility of the CTD bond is calculated from the yield volatility as described in Section D.12.5, applied with T equal to the futures settlement date. The yield volatility is obtained from the interest yield volatility price factor at time t for expiry date t_0 , tenor $M - T$ and yield strike $k = y(\phi K + A; T, M, c, \tau)$, where M , c and τ are respectively the maturity date, coupon rate and coupon interval of the CTD bond, and $y(P; T, M, c, \tau)$ is the yield function defined in Section D.12.2.

51.4.4.8 Limitations

See 51.1.4 for descriptions of the general futures and futures options limitations of this deal.

51.5 Energy Futures Deal Types

51.5.1 Energy Futures

51.5.1.1 Overview

This deal type is for energy future contracts with arbitrary delivery periods.

51.5.1.2 Price Factor Dependency

Energy Futures - Energy Future Valuation

- └ Discount Rate (§ 6.2)
- └ Equity Price (§ 4.3)
- └ Forward Price (§ 10.2)
- └ Futures Basis (§ 5.2)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)
- └ Reference Price (§ 10.5)

Energy Futures - Energy Future MtM Valuation

- └ Futures Price (§ 4.6)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

A special case of the Energy Future is the One Month Energy Future:

Theory Guide [4.6.6.2](#)

A one month energy future is a deal skin that builds into an energy future (explicit) deal with a single delivery date at the settlement date of the futures contract.

Sampling a single point on the curve is equivalent to taking an average over the whole month if the forward curve (which uses flat left interpolation) is constant over the one-month period.

51.5.1.3 Properties

Properties common to all futures deal types can be found in Section [51.1.1](#), with further properties common to energy deals is described in Section [48.1.1](#). For Energy Futures, the `Energy` property refers to the ID of the reference price price factor used to define the energy reference price (i.e., the `Reference Type` property found on other energy products).

All additional properties define the period over which delivery is to occur:

Theory Guide [4.6.6.3](#)

An energy future is a deal skin that builds into an energy future (explicit) deal with daily delivery dates from the First Delivery Date to the Last Delivery Date. Delivery dates on or before Realized Energy Average Date are assigned the known price Realized Energy Average.

51.5.1.4 Deal Representation:

The Energy Future is a deal skin that builds into an Energy Future (Explicit). See the Deal Skins Guide [2, [Energy Future](#)].

The underlying Energy Future (Explicit) is an atomic deal.

51.5.1.5 Valuation

In Adaptiv Analytics an Energy Future can be valued using the `DealSkinValuation` model, while the two valuation models are available for the underlying Energy Future (Explicit) deal type: the standard `ExplicitEnergyFutureValuation` model and the mark-to-market `ExplicitEnergyMtMValuation` model.

The forward price driving the valuation of the Energy Future (Explicit) deal is defined by a weighted list of delivery dates T_1, \dots, T_n . Denoting the weights as $\omega_1, \dots, \omega_n$.

Theory Guide [4.6.6.1](#)

The underlying forward price at time t is the weighted average of forward prices given by

$$F(t) = \frac{\sum_{i=1}^n \omega_i F(t \wedge T_i, T_i)}{\sum_{i=1}^n \omega_i}. \quad (51.5.1)$$

Let F_i denote the known price assigned to T_i in the sampling data list. The value of $F(T_i, T_i)$ for $T_i \leq 0$ is defined as follows: if $F_i \neq 0$ then $F(T_i, T_i) = F_i$, otherwise $F(T_i, T_i) = F(0, 0)$.

For details about the valuation for this deal, see the Theory Guide [7, § [4.6.6 Energy Futures](#)].

51.5.1.6 Tuning Parameters and Valuation Settings

Not applicable.

51.5.1.7 Assumptions

See [51.1.3](#) for descriptions of the general futures and futures options assumptions of this deal, and see [48.1.2](#) for common assumptions of energy deals.

51.5.1.8 Limitations

See [51.1.4](#) for descriptions of the general futures and futures options limitations of this deal, and see [48.1.3](#) for common limitations of energy deals.

51.5.2 Energy Futures Option

51.5.2.1 Overview

This deal type is for energy future options, either American or European styles.

51.5.2.2 Price Factor Dependency

Energy Future Option

- └ Daily Reference Price (§ 10.5)
- └ Discount Rate (§ 6.2)
- └ Forward Price (§ 10.2)
- └ Forward Price Volatility (§ 11.4.1)
- └ FX Rate (§ 4.2)
- └ Interest Rate (§ 6.1)

51.5.2.3 Properties

Properties common to all futures deal types can be found in Section 51.1.1, with further properties common to energy deals in described in Section 48.1.1.

For Energy Futures Option, the Energy property refers to

. The Energy Futures Option additionally requires a Forward Volatility property, which is an ID referring to a forward price volatility price factor.

51.5.2.4 Deal Representation

The Energy Future Option is an atomic deal.

51.5.2.5 Valuation

In Adaptiv Analytics an Energy Future Option can be valued using the `EnergyFutureOptionValuation` model. For details about the valuation for this deal, see the Theory Guide [7, § 4.6.8 Futures Option].

51.5.2.6 Tuning Parameters and Valuation Settings

See 51.1.2 for descriptions of the general futures and futures options tuning parameters and valuation settings of this valuation.

51.5.2.7 Assumptions

See 51.1.3 for descriptions of the general futures and futures options assumptions of this deal, and see 48.1.2 for common assumptions of energy deals.

51.5.2.8 Limitations

See 51.1.4 for descriptions of the general futures and futures options limitations of this deal, and see 48.1.3 for common limitations of energy deals.

Part XI

Calculations

Chapter 52

Credit Monte Carlo Calculation

52.1 Parameter tuning - Scenario Time Grid

The scenario time grid defines the set of dates where the risk factors are simulated. When a risk factor is requested on a date which was not simulated, the risk factor is interpolated linearly. For more information, refer to Theory Guide [7, § 1.2.1 [Discrete Realizations](#)].

There is no universal setting and the appropriate set up depends on multiple factors including portfolio composition and size, base time grid settings, whether the deals are collateralized etc. The following guidelines are designed to be a starting point for users setting up the scenario time grid for their Monte Carlo calculations, balancing their own specific accuracy versus performance criteria and tailoring to suit the input.

It is important to select a scenario time grid that is granular enough to generate sufficiently dense risk factor paths to drive the stochastic processes underpinning the calculation. For example, path dependent stochastic models (eg Hull and White) require a more granular resolution than non path dependent stochastic models (eg GBM model with constant drift and volatility), path dependent deals also benefit from additional scenario time points.

Conversely, increasing the time grid resolution impacts the calculation performance.

One of the main factors to consider is whether the deals are collateralized. For uncollateralised calculation, it is possible to use a 'fine' scenario time grid for shorter horizon and gradually space out the risk factor simulation dates for longer horizon. When collateral is present, the collateral balance is a highly path dependent variable and so risk factors need to be simulated more regularly. Appropriate tracking of the collateral balance is key to accurately compute collateralized exposure, including exposure spike resulting from imperfect collateralisation of the portfolio (close out period, MTA, threshold etc). In this case, it is advised to use a scenario time grid frequency smaller or equal to the close out period (if multiple netting pools are present with different close out periods, selecting the shortest close out period is advised).

Part XII

Glossary

Chapter 53

Glossary

α	accrual year fraction (calculated using a day count convention)
$A(T_1, T_2)$	seasonal price index adjustment factor between dates T_1 and T_2
ATM	at the money
\mathfrak{B}	Bachelier formula
\mathcal{B}	Black formula
b	carry rate (interest plus all other costs, less benefits)
CDS	credit default swap
CIR	Cox-Ingersoll-Ross
CMS	constant maturity swap
C	credit valuation adjustment
δ	+1 for call or -1 for put
δ	time increment, tenor period or term
Δ	duration
Δ	time increment
$D(t, T)$	discount factor at time t for maturity T (discount rate)
$D_f(t, T)$	discount factor at time t for maturity T (forecast rate)
$D_d(t, T)$	discount factor at time t for maturity T (domestic currency)
$D_f(t, T)$	discount factor at time t for maturity T (foreign currency)
E	exposure
E	exposure at default
\bar{E}	expected exposure
\hat{E}	expected positive exposure
ETF	exchange traded fund
EVO	exposure value override
\bar{F}	effective expected exposure
\hat{F}	effective expected positive exposure
fol	Following date adjustment method
$F(t, T)$	forward price at time t for maturity T
$\Phi(x)$	cumulative normal distribution function
$\Phi(x, y, \rho)$	cumulative bivariate normal distribution function
FX	foreign exchange
GBM	geometric Brownian motion
GLD	generalized lambda distribution
GOU	Geometric Ornstein-Uhlenbeck
H	barrier level
$h(t)$	hazard rate at time t
$h(t, T)$	forward hazard rate at time t for maturity T
I	price index for inflation calculations
I_P	published price index value

I_R	reference price index value
IRC	Incremental Risk Charge
K	contractual price or option strike price
L	loss
\bar{L}	expected loss
$L(t)$	simply compounded rate at time t
$L(s, t, \tau)$	simply compounded rate at time s for period from t to $t + \tau$
log	natural logarithm: $e^{\log(x)} = \exp(\log(x)) = x$
mfoll	Modified Following date adjustment method
mprec	Modified Preceding date adjustment method
MtM	mark-to-market
prec	Preceding date adjustment method
\mathbb{P}	probability measure
P	bond price
P	price factor
OAS	option adjusted spread
OU	Ornstein-Uhlenbeck
PCA	principal components analysis
PVBP	price value of basis point
q	equity dividend rate
r	interest rate
$r_\tau(t)$	zero coupon rate at time t for tenor τ
r	credit rating
R	recovery rate
R	risk factor
$S(t)$	asset price at time t
$S(t, T)$	survival probability at time t for maturity T
$s(t)$	forward swap rate at time t
RNG	Random number generator
SDE	stochastic differential equation
t	valuation date
T	payment date or expiry date
t_0	reset date
t_1	rate start date
τ	time interval or term
τ	time of default
V	deal or portfolio value
\hat{V}	collateralized value
W	Wiener process (Brownian motion)
$X(t)$	foreign exchange rate at time t
y	bond yield

Iverson Bracket	$[P] = \begin{cases} 1 & \text{if } P \text{ is true} \\ 0 & \text{otherwise} \end{cases}$
Max	$x \vee y = \max(x, y)$
Min	$x \wedge y = \min(x, y)$
Floor	$\lfloor x \rfloor = \text{greatest integer not greater than } x$
Ceiling	$\lceil x \rceil = \text{least integer not less than } x$

Part XIII

Bibliography

Bibliography

- [1] Adaptiv Analytics. Analytics Workspace User Guide. *FIS*, 2020.
- [2] Adaptiv Analytics. Deal Skins. *FIS*, 2020.
- [3] Adaptiv Analytics. Extensibility Guide. *FIS*, 2020.
- [4] Adaptiv Analytics. F1 Documentation. *FIS*, 2020.
- [5] Adaptiv Analytics. Interfacing Guide. *FIS*, 2020.
- [6] Adaptiv Analytics. Proxying Rules Guide. *FIS*, 2020.
- [7] Adaptiv Analytics. Theory Guide. *FIS*, 2020.
- [8] T. Anderson and I. Olkin. Maximum likelihood estimation of the parameters of a multivariate normal distribution. Technical Report 38, Department of Statistics, Stanford University, 1979.
- [9] Leif B. G. Andersen. Markov models for commodity futures: Theory and practice. *Quantitative Finance*, 10:831–854, 09 2008.
- [10] Petter Bjerksund and Gunnar Stensland. Closed-Form Approximation of American Options. *Scandinavian Journal of Management*, 9:87–99, 1993.
- [11] Petter Bjerksund and Gunnar Stensland. Closed form valuation of American options. Technical report, Norwegian School of Economics and Business Administration, Bergen, 2002.
- [12] C. Blum, Ludger Overbeck, and Christoph Wagner. An introduction to credit risk modeling. 01 2002.
- [13] Damiano Brigo and Fabio Mercurio. *Interest Rate Models — Theory and Practice*. Springer-Verlang, Berlin, 2006.
- [14] Iain J. Clark. *Foreign exchange option pricing: A practitioner's Guide*. John Wiley & Sons, Ltd, 2011.
- [15] Les Clewlow and Chris Strickland. Valuing Energy Options in a One Factor Model Fitted to Forward Prices. (10), April 1999.
- [16] Les Clewlow and Chris Strickland. *Energy Derivatives: Pricing and Risk Management*. 01 2000.
- [17] Les Clewlow and Chris Strickland. A multi-factor model for energy derivatives. *QFRC Res. Pap. Ser.*, 28, 01 2000.
- [18] Rama Cont and Sana Ben Hamida. Recovering volatility from option prices by evolutionary optimization. *Journal of Computational Finance*, 8(4):43–76, 01 2005.
- [19] A. Conze and R. Viswanathan. Path dependent options: The case of lookback options. *Journal of Finance*, 46:1893–1907, 1979.
- [20] K. Demeterifi and J. Zou E. Derman, M. Kamal. *More Than You Ever Wanted to Know About Volatility Swaps*. Goldman Sachs working paper, 1999.

- [21] Darrell Duffie, Jun Pan, and Kenneth Singleton. Transform analysis and asset pricing for affine jump-diffusions. *Econometrica*, 68(6):1343–1376, 2000.
- [22] Gary Dunn. A multiple period gaussian jump to default risk model. *Economic & financial modelling : a journal of the European Economics and Financial Centre*, 15:153–198, 04 2008.
- [23] R. Geske. The valuation of compound options. *Journal of Financial Economics*, 7:63–81, 1979.
- [24] B. Goldman, H. Sosin, and M. Gatto. Path dependent options: Buy at the low, sell at the high. *Journal of Finance*, 34(5):1111–1127, 1979.
- [25] Frank E Harrell and C E Davis. A new distribution-free quantile estimator. *Biometrika*, 69(3):635–640, 1982.
- [26] E. Haug. Barrier put-call transformations. *Working Paper*, 172, 1999.
- [27] E. Haug. *The Complete Guide to Option Pricing Formulas*. McGraw Hill, New York, 2 edition, 2007.
- [28] Marc Henrard. Hull-White One Factor Model: Results and Implementation. <http://docs.opengamma.com/display/DOC/Quantitative+Documentation>, 2012.
- [29] Steven L. Heston. A Closed-Form Solution for Options with Stochastic Volatility with Applications to Bond and Currency Options. *The Review of Financial Studies*, 6(2):327–343, 04 2015.
- [30] John C. Hull. *Options, Futures, and Other Derivatives*. Springer-Verlang, Berlin, 2006.
- [31] John C Hull and Alan D White. Valuing credit default swaps ii. *The Journal of Derivatives*, 8(3):12–21, 2001.
- [32] P. Hunt and J. Kennedy. *Financial Derivatives in Theory and Practice*. Wiley, 2000.
- [33] ISDA. ISDA CDS Standard Model. <http://cdsmodel.com/cdsmodel/>.
- [34] Farshid Jamshidian. An Exact Bond Option Pricing Formula. *Journal of Finance*, 44:206–209, 1989.
- [35] Farshid Jamshidian. Sorting Out Swaptions. *Risk*, 9(3):59–60, March 1996.
- [36] S. Järvinen. Bermudan Swaption Pricing: A Simple Binomial Model. *Department of Finance and Accounting, Helsinki School of Economics*, 2000.
- [37] G. Kirikos and D. Novak. *Convexity Conundrums*. pages 60–61, 1997.
- [38] Markit. The CDS Big Bang: Understanding the Changes to the Global CDS Contract and North American Conventions. *The markit magazine*, March 2009.
- [39] M. Massar. Pricing of Forward Start Swaptions. 2008.
- [40] Sergei Mikhailov and Ulrich Nögel. Heston’s stochastic volatility model implementation, calibration and some extensions. *Wilmott magazine*, page 74–79, 2003.
- [41] William H. Press, Saul A. Teukolsky, William T. Vetterling, and Brian P. Flannery. *Numerical Recipes in C (2Nd Ed.): The Art of Scientific Computing*. Cambridge University Press, New York, NY, USA, 1992.
- [42] Riccardo Rebonato. *Modern Pricing of Interest-rate Derivatives: The LIBOR Market Model and Beyond*. Princeton University Press, Princeton, NJ, 01 2002.
- [43] M. Rubinstein. Options for the undecided. *Risk*, 4(4), 1991.
- [44] Erik Schlögl. *Arbitrage-Free Interpolation in Models of Market Observable Interest Rates*, pages 197–218. Springer Berlin Heidelberg, Berlin, Heidelberg, 2002.

- [45] Michael Stein. Large sample properties of simulations using latin hypercube sampling. *Technometrics*, 29(2):143–151, 1987.
- [46] Rainer Storn and Kenneth Price. Differential evolution – a simple and efficient heuristic for global optimization over continuous spaces. *Journal of Global Optimization*, 11(4):341–359, Dec 1997.
- [47] Anders B. Trolle and Eduardo S. Schwartz. Unspanned Stochastic Volatility and the Pricing of Commodity Derivatives. *The Review of Financial Studies*, 22(11):4423–4461, 05 2009.
- [48] Jianwei Zhu. A simple and exact simulation approach to heston model. *SSRN Electronic Journal*, 07 2008.