Project-1: Issuer Callable Contingent Coupon Barrier Notes

Group:

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Contents

UBS AG $900,000 Trigger Callable Contingent Yield Notes

Introduction:

Value:

The estimated value of a note is **$974.5**

Data:

Most of the data is picked from the term sheet while data on interest rates, underlying volatility and dividend yield are taken from the Bloomberg portal.

		Time (Yrs)	Days
Trade Date	1/20/2023	0.000	0
Settlement Date	1/25/2023	0.014	5
Final Valuation Date	7/21/2025	2.501	913
Maturity Date	7/24/2025	2.510	916

Underlying asset	**The common stock of Signature Bank SBNY**
Principal Amount / Face Value	$1,000.00
Underlying Initial value	$127.79
Coupon Barrier 50% of the initial value	$63.90
Downside threshold 50% of the initial value	$63.90
Annual Contingent Coupon rate	15.50%
Monthly coupon rate	0.012917
Coupon dollar amount	$12.9167
Data collected from Bloomberg (*refer to screenshots)	
Volatility	0.4780
Risk neutral rate	0.037395
Risk-free rate	0.03738
Dividend yield (annual)	0.02912

Observation Dates	**Days**	**Coupon Payment Dates**	**Days**
21-Feb-23	32	24-Feb-23	35
20-Mar-23	59	23-Mar	62
20-Apr-23	90	25-Apr-23	95
22-May-23	122	25-May-23	125
20-Jun-23	151	23-Jun	154
20-Jul-23	181	25-Jul-23	186

21-Aug-23	213	24-Aug-23	216
20-Sep-23	243	25-Sep-23	248
20-Oct-23	273	25-Oct-23	278
20-Nov-23	304	24-Nov-23	308
20-Dec-23	334	26-Dec-23	340
22-Jan-24	367	25-Jan-24	370
20-Feb-24	396	23-Feb-24	399
20-Mar-24	425	25-Mar-24	430
22-Apr-24	458	25-Apr-24	461
20-May-24	486	23-May-24	489
20-Jun-24	517	25-Jun-24	522
22-Jul-24	549	25-Jul-24	552
20-Aug-24	578	23-Aug-24	581
20-Sep-24	609	25-Sep-24	614
21-Oct-24	640	24-Oct-24	643
20-Nov-24	670	25-Nov-24	675
20-Dec-24	700	26-Dec-24	706
21-Jan-25	732	24-Jan-25	735
20-Feb-25	762	25-Feb-25	767
20-Mar-25	790	25-Mar-25	795
21-Apr-25	822	24-Apr-25	825
20-May-25	851	23-May-25	854
20-Jun-25	882	25-Jun-25	887
21-Jul-25	913	24-Jul-25	916

Bloomberg data:

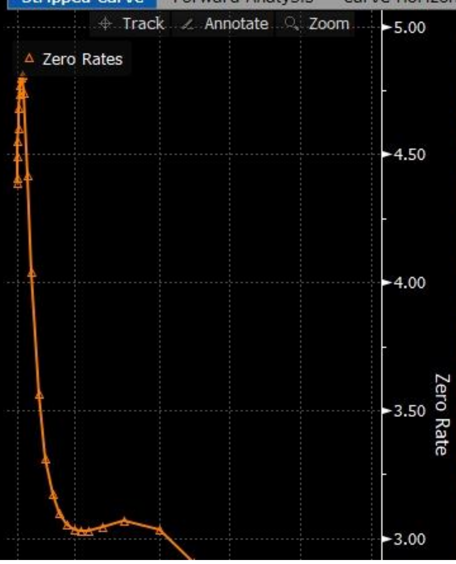
Additional curves in Curves Toolkit require a license by 31 MAY. More »

USD | 42 - USD OIS | Name USD OIS | Default | Privilege Global | 01/18/23

Curve Construction | Curve Analysis

Curve #	42 - USD OIS	Shift	+0.00 bp
Interpolation	Piecewise Linear (Simple)		
Settle Date	01/20/23		
Curve Side	Mid		

Stripped Curve | Forward Analysis | Curve Horizon



Date	Market Rate	Shift (bp)	Shifted Rate	Zero Rate	Discount
01/27/2023	4.33150	+0.00000	4.33150	4.38981	0.999158
02/03/2023	4.35250	+0.00000	4.35250	4.40922	0.998310
02/10/2023	4.43700	+0.00000	4.43700	4.49281	0.997418
02/21/2023	4.49745	+0.00000	4.49745	4.55082	0.996018
03/20/2023	4.55515	+0.00000	4.55515	4.60126	0.992590
04/20/2023	4.64200	+0.00000	4.64200	4.67937	0.988528
05/22/2023	4.70665	+0.00000	4.70665	4.73436	0.984300
06/20/2023	4.75275	+0.00000	4.75275	4.77136	0.980454
07/20/2023	4.78825	+0.00000	4.78825	4.79724	0.976492
10/20/2023	4.82975	+0.00000	4.82975	4.80929	0.964668
01/22/2024	4.78715	+0.00000	4.78715	4.73892	0.953469
07/22/2024	4.44115	+0.00000	4.44115	4.41749	0.935715
01/21/2025	4.08120	+0.00000	4.08120	4.04009	0.922172
01/20/2026	3.60342	+0.00000	3.60342	3.56266	0.898546
01/20/2027	3.35195	+0.00000	3.35195	3.31144	0.875861
01/20/2028	3.21275	+0.00000	3.21275	3.17292	0.853224
01/22/2029	3.13621	+0.00000	3.13621	3.09765	0.830109
01/22/2030	3.09331	+0.00000	3.09331	3.05641	0.807120
01/21/2031	3.06858	+0.00000	3.06858	3.03350	0.784327
01/20/2032	3.05942	+0.00000	3.05942	3.02675	0.761417

Figure 1Discount factors for Interest rates

21) Deal 1 | 22) +

31) Pricing | 32) Scenario | 33) Matrix | 34) Volatility | 35) Backtest

Underlying SBNY US Equity SIGNAT... Exercise European Trade 01/20/2023 16:30 98) Save Settings

Und. Price 127.8 USD Direction Buy Call 99) Export to Excel 97) Reset Settings

Y-Axis X-Axis

Moneyness	Maturity	1M	2M	3M	20M	30M	31M
100.00	Volatility	50.478%	49.387%	49.294%	48.143%	47.809%	47.766%
	Price (Total)	7.33	10.14	12.70	32.05	37.80	38.00
	Delta	52.33	54.23	55.74	63.87	65.36	65.06
105.00	Volatility	48.353%	48.078%	48.223%	47.747%	47.548%	47.468%
	Price (Total)	4.48	7.24	9.77	29.52	35.52	35.71
	Delta	38.57	44.08	47.58	60.89	63.00	62.74
110.00	Volatility	47.099%	47.021%	47.018%	46.984%	46.917%	46.848%
	Price (Total)	2.57	5.00	7.30	26.93	33.09	33.31
	Delta	26.09	34.38	39.47	57.74	60.52	60.31
115.00	Volatility	46.620%	45.510%	45.590%	46.377%	46.335%	46.277%
	Price (Total)	1.42	3.23	5.23	24.58	30.81	31.06
	Delta	16.47	25.31	31.56	54.69	58.04	57.88
120.00	Volatility	47.407%	44.899%	45.041%	46.148%	46.000%	45.961%
	Price (Total)	0.81	2.08	3.78	22.62	28.83	29.10
	Delta	10.29	18.11	24.85	51.81	55.66	55.57
125.00	Volatility	48.775%	45.104%	44.523%	45.454%	45.799%	45.757%
	Price (Total)	0.49	1.38	2.68	20.50	27.05	27.34
	Delta	6.50	12.87	19.11	48.73	53.39	53.33

Figure 2Volatility

USD Rate MMKt	4.743%
Dividend Yield	2.912%
Discounted Div Flow	0.99
Borrow Cost	0.000%

Figure 3Dividend Yield

Binomial Option Pricing Model:

Assumptions:

1. We considered Signature bank's common stock as our underlying asset. And we assumed the implied volatilities of European options from Bloomberg as the volatility for our pricing model.

2. USD OIS rates are taken as Interest rates. Two different rates are considered.

    a. Risk-neutral rate (r1), used for estimating the risk-neutral probabilities, is calculated between the Trade date and the Valuation date, by linear interpolation of discount factors available for dates in Bloomberg.
    b. Similarly risk-free rate (r2), used for discounting the value of options between steps of the binomial tree, is calculated between the Trade date and Maturity date

3. Dividends are assumed to be distributed biannually at regular intervals; in total, we have taken 5 dividend dates spread across the time horizon.

Model:

Defining parameters:

1. For better convergence, we have selected 10,000 steps for our tree, N = 10000.

Defining Function:

We have defined a function "Bin-icall" with 13 input parameters given below.

Bin_icall(N, S0, Face, ratio, sigma, r1, r2, T, cpn, tco, tac, DIV, TD)

Where,

1. N is the number of steps for building tree
2. S0 is the price of the underlying asset at time T = 0
3. Face is the principal amount as defined in the note
4. Ratio is the factor defined in the note for coupon barrier and downside threshold (same in our case)
5. Sigma is the volatility of the underlying asset
6. Risk-neutral rate used for calculating probabilities is defined as r1
7. Risk-free rate used for discounting values between time steps is defined as r2
8. T is the time till maturity
9. The monthly coupon rate is defined as cpn
10. The list of coupon dates is defined as 'tco'
11. The list of observation dates is defined as 'tac'
12. DIV is the dividend yield for six months.
13. TD is the list of dividends dates

Note: The function includes a subfunction Stock_tree for creating stock tree before calculating the option values.

We have created four temporary lists jco1, jco & jac1, jac for matching the j in the for-loop with coupon dates and observation dates.

Option value at maturity is the payoff at maturity which is the Principle amount + Coupon or Principle (1+underlying return) when the underlying is below the threshold as given in the term sheet.

We have discounted the maturity values for three days since the maturity date is 3 days after the valuation date.

And a separate for loop is used to create values of options at different steps denoted by j in the function moving 1 step backward each time starting from N-1.

And at each j we iterated for ‘i starting from 0 to j’ to estimate value of option_value[j,i]. Intermediary variables ‘cont’ and ‘exe’ are used to calculate option values for different conditions as given below;

When the j matches with the list of integer values of observation dates and meets the required condition that the underlying is above the barrier, the discounted coupon value is added to the temporary option value cont estimated using risk-neutral probability q and option values one step ahead.

And we take the minimum of temporary option values cont & exe (option value if executed immediately) and update the final option_value[j,i].

We have evaluated the option tree values with a smaller number of steps and confirmed the boundary, but as discussed in the later section our boundary is serrated which is attributed to the additional discounted coupons added to the option value.

Other formulae:

$$\Delta t = \frac{T}{N}$$

$$u = e^{r_1 \Delta t + \sigma \sqrt{\Delta t}}$$
$$d = e^{r_1 \Delta t - \sigma \sqrt{\Delta t}}$$

$$q = \frac{(e^{r_1 \Delta t} - d)}{(u - d)}$$

$$V_{[j,i]} = e^{-r_2 \Delta t}\{q\, V_{[j+1,i+1]} + (1 - q) V_{[j+1,i]}\}$$

$$cont = V_{[j,i]} + Face \times cpn \times e^{-r_2 \Delta t*}$$

Where delta t is the time between jth step and the coupon date*

Conclusion

Sensitivity analysis:

We have evaluated the value of options using a range of steps (100 – 1000). It is evident from the plot given below, that there is huge variance in the values of options, a clear sign of non-linearity. But over a large number of steps, 10010 we observed a convergence at 974.5.

```
In [67]: Bin_icall(10010, S0, Face, ratio, sigma, r1, r2, T, cpn, tco, tac, DIV, TD)

         u =  1.0076067012091268 d= 0.9924693329666647
         [1968.0, 3935.0, 5902.0, 7869.0, 9836.0]
         124.92465487935043 123.98388889919971 123.0502075144018

Out[67]: ([{'num_steps': 10010, 'Value': 974.5322177651393}],)
```

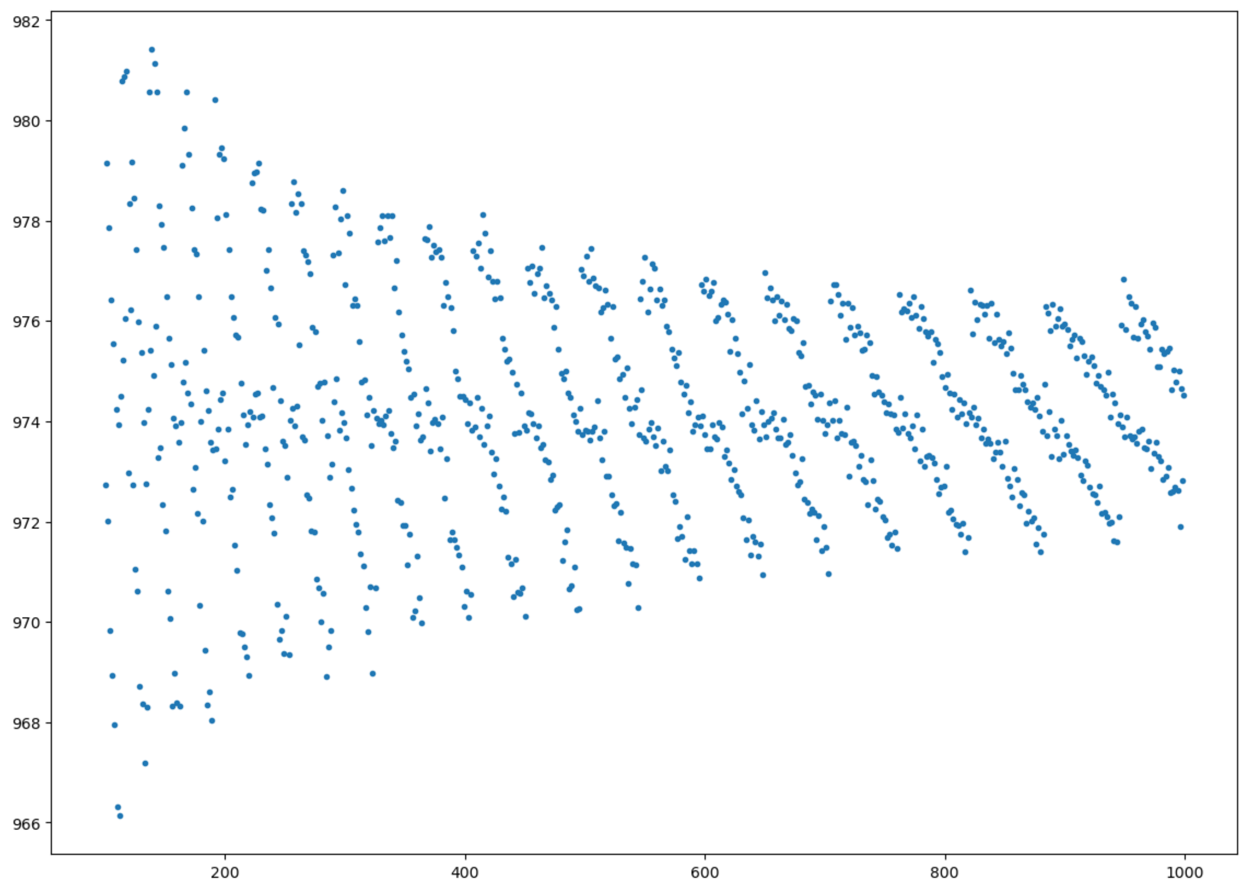


Figure 4Option value vs steps

We can also observe, that variance persists even after selecting either only even numbers or only odd number of steps.

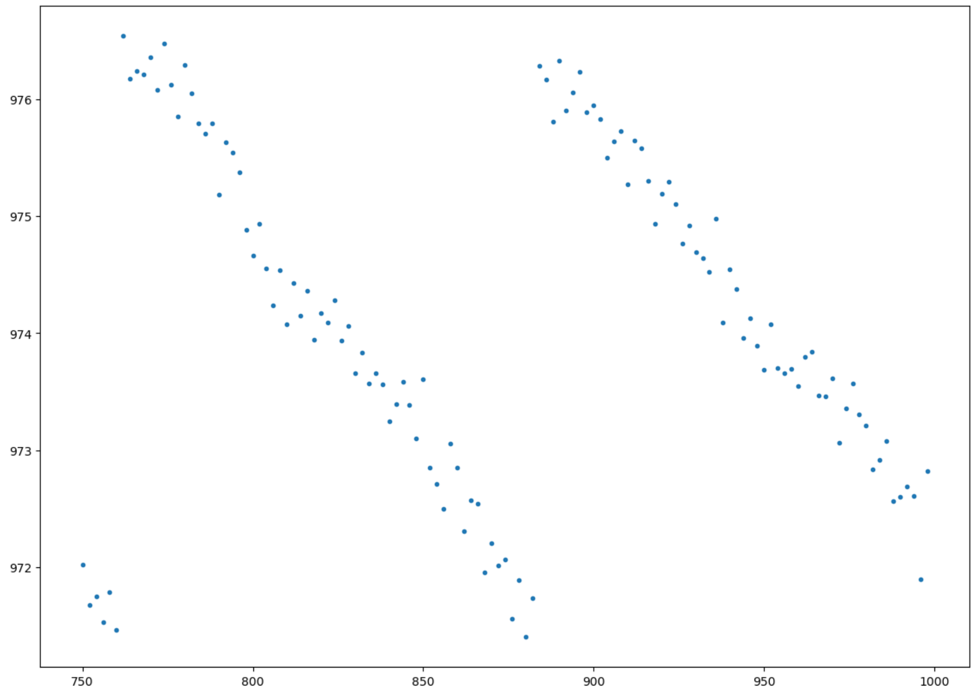


Figure 5 Even steps

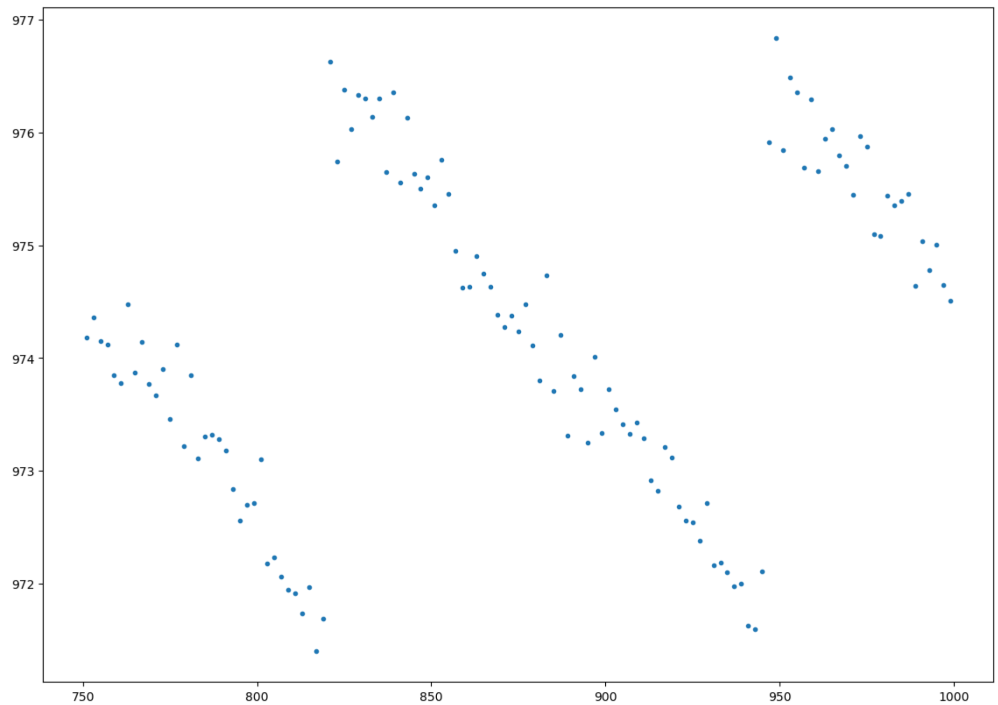


Figure 6 Odd Steps

Boundary plot:

As we can observe from the below plot the serrated boundary, i.e., the price of a later period dropping and again increasing is not expected. It is due to the addition of discounted coupons on the coupon dates thus causing the option value to jump. This irregular option price movement with respect to time steps is one of the significant factors for the variance in the option value with respect to number of steps.

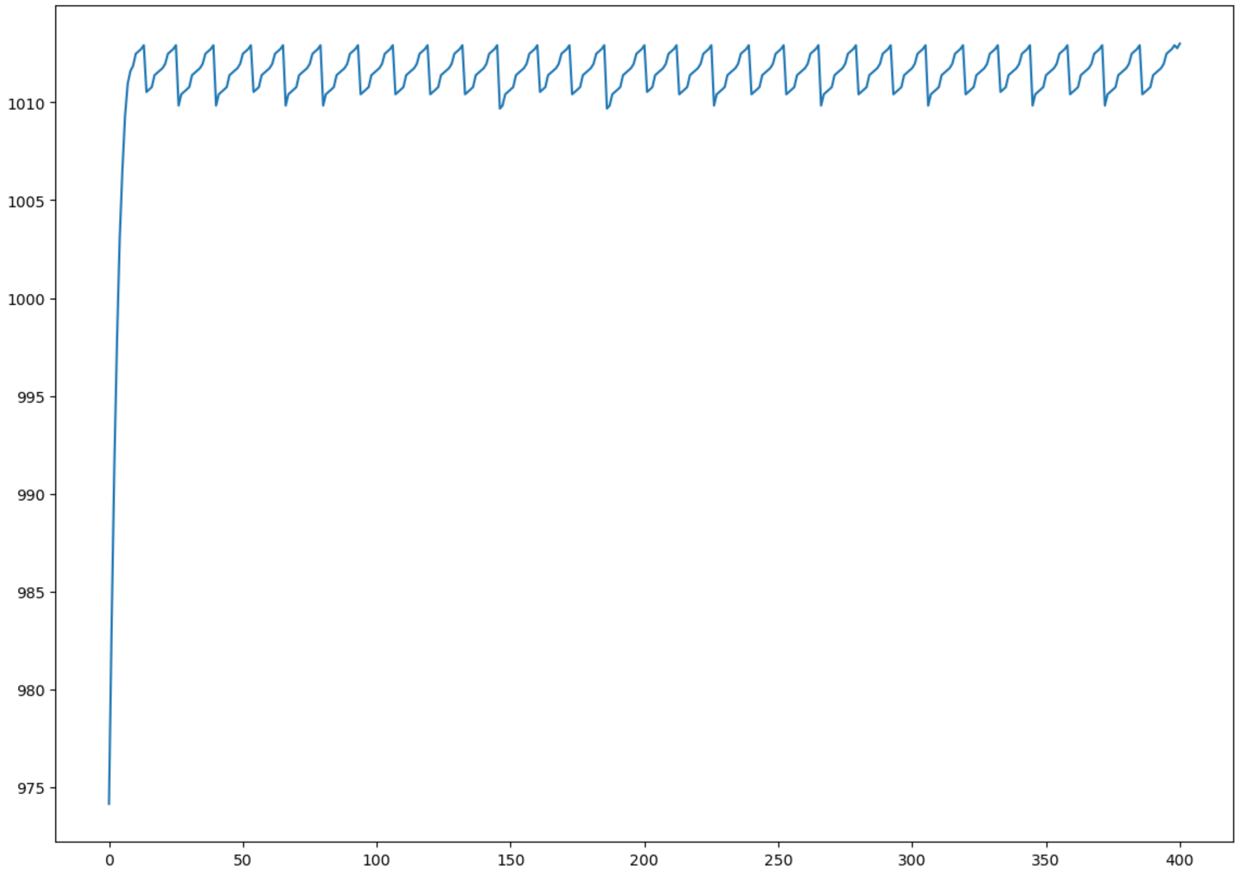


Figure 7 Boundary plot