Financial Risk&Regulation

Valuation of interest rate derivatives

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Interest rate derivatives are important elements in both the financial markets and the banking product portfolios. In addition to the basic interest rate swaps, options on swaps and bonds, interest rate floor and cap products are also present explicitly or embedded in other financial instruments. Accurate valuation and a good assessment of their risks are also important when developing a proper accounting assessment, hedging strategy, measuring counterparty risks, and managing interest rate risk in banking books. In this newsletter, we describe the main types of these transactions as well as the most important pricing models.

Risks

Derivatives are traditional products in the financial markets and have evolved in parallel. Their importance for financial institutions is huge, so it is extremely important to develop an appropriate evaluation and risk management framework. Derivatives cannot be valued in the same way as traded shares or foreign exchange rates, as prices are generally not observable due to the unique nature of the contracts. Therefore, it is required to develop pricing models that are properly calibrated to ensure that both the pricing and risk measurement are appropriate. Accounting standards therefore attach great importance to valuation and related hedge accounting. Similarly, in the Basel framework for banking regulation the main task of the counterparty risk management and interest rate risk management in the banking book, among other things, are to achieve an appropriate risk level. In the case of interest rate in banking book, it should be emphasized that embedded bond options are also expected to be treated, which was also reported in our February 2022 newsletter.

Types of interest rate derivatives

An interest rate derivative is a financial instrument with a value that is linked to the movements of an interest rate or rates. Interest rate derivatives are often used to hedge interest rate risks but can also be used to take an interest rate position in the hope of future profit. Of the many possible categories, three main types are highlighted in this newsletter.

Swaptions

A product based on swaps is a swap option, in which the conditions under which the holder of the option may enter into an interest rate swap are specified in the contract. The underlying interest rate swap is typically a simple, fixed and a floating interest rate swap.

The advantage of swaption transactions is that they allow the holder of the option to switch between fixed and floating interest rates, depending on which is more profitable at the expiration. This makes it possible to take positions and manage the risk of certain special instruments. For example, if a

borrowing customer has the right to switch between fixed and floating interest rates, or in the case of fixed interest rate contract, to prepay without additional costs, it can be considered as an implicit swaption position. In such cases, it may be necessary to evaluate the swaption to price the client interest rate, evaluate the position and hedge the risk.

Bond options

A bond option is an option where one of the parties has the right to sell or buy a particular bond on pre-determined terms (date, price etc.). These types of options are often embedded in the terms of the bond, for example, giving the issuer a repurchase option.

A typical example of a callable bond is a bond issued for regulatory purpose, such as AT1, T2, or MREL compliant resources. EBA reports on AT1 equity assets and TLAC / MREL bonds also highlight that many bonds have such options. Reports add that repurchases are in many cases tied to significant, unforeseen regulatory or tax changes.

In general, repurchase and other options favorable to the issuer increase the level of interest that investors would expect from a bond. If the bond contains an option that is favorable to the investor, such as a redeemability option, it will reduce the interest on the bond.

Interest rate cap and floors

In the OTC market, popular interest rate option offered by financial institutions is the interest rate cap or floor. These are intended to provide protection against interest rates rising or falling below a pre-determined level. In addition to products that are explicitly traded in the market, such options are typically embedded into loans and floating rate bonds.

The former case must also be taken into account interest rate risk management, because it is a typical contractual point that the reference rate of the loan cannot be negative. With this practice the Bank protects its own interest margin, but it is important to take this into account when measuring interest rate risks for both EVE and NII. It should also be taken into account when applying a hedging strategy, since the actual behavior of a floating rate loan with an interest rate floor is more like a fixed interest rate in a low interest rate environment due to low cash flow and high present value volatility.

An example for a floating-rate bond is 2027/B government security issued by ÁKK, where the minimum interest rate based on the BUBOR 3M reference rate is 0.01%, i.e. it cannot be zero or negative.

Main pricing models

Pricing interest rate options is a more complex task than pricing derivatives for a stock or currency. This is because their value is influenced by the shape of the yield curve, which follows a complex process.

In the simpler models, the implicit assumption is a perfect correlation of the different points of the yield curve, but the more advanced models also allow different movements of the short and long ends of the yield curve. Below are two fundamental examples of simpler models.

Bachelier (normal) model

The Frenchman Louis Bachelier was one of the firsts to develop an option pricing model in which he approached the stochastically descriptive process of exchange rate change with the arithmetic Brownian motion. The procedure he developed was sidelined due to the use of the Black model, which later became widespread and is based on geometric Brownian motion. Interestingly, however, it has recently come to the foreground again due to the model's ability to handle negative exchange rates as well. As a result, the Chicago Mercantile Exchange (CME) and the Intercontinental Exchange (ICE), among others, has been using this model from April 2020 to price certain options.

The basic assumption of the model is that forward interest rates can be described by an arithmetic Brownian motion, which at any given moment can be described as follows:

$$dF_t = \sigma_N dW_t$$

where F_t denotes the forward interest rate, W_t denotes the term expressing Brownian motion, σ_N denotes the assumed volatility for pricing, and t is the time in the subscript.

Figure 1 shows the possible interest rate trajectories of the Bachelier model produced by Monte-Carlo simulation.

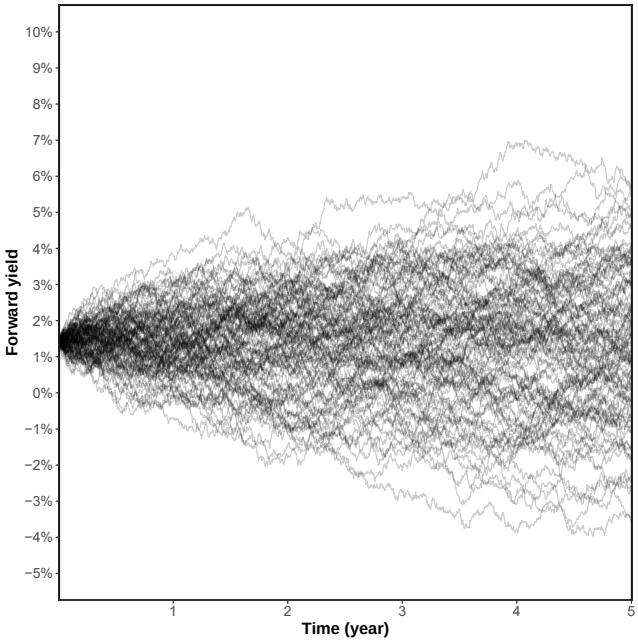


Figure 1: 5-year swaption forward interest rate trajectories based on the Bachelier model (volatility: 88.64%, forward swap rate: 1.42%)

Black (log-normal) model

One of the most common models for pricing options is the Black-Scholes model and its counterpart for pricing interest rate derivatives, the Black model. In this way, the development of the forward exchange rate can be expressed similarly to the Bachelier model, but in this case it can be described by geometric Brownian motion with σ_{LN} volatility:

$$dF_t = F_t \sigma_{LN} dW_t$$

where F_t denotes the forward interest rate, W_t denotes the term expressing standard Brownian motion, σ_{LN} denotes the volatility assumed for pricing, and t is the time in the subscript.

It is worth mentioning, that the counterparty risk standard capital requirements methodology (SA-CCR) also uses this (EU/2021/931), but with a level shift and pre-fixed volatility parameters.

Figure 2 shows the possible interest rate trajectories of the Black model generated by Monte-Carlo simulation.

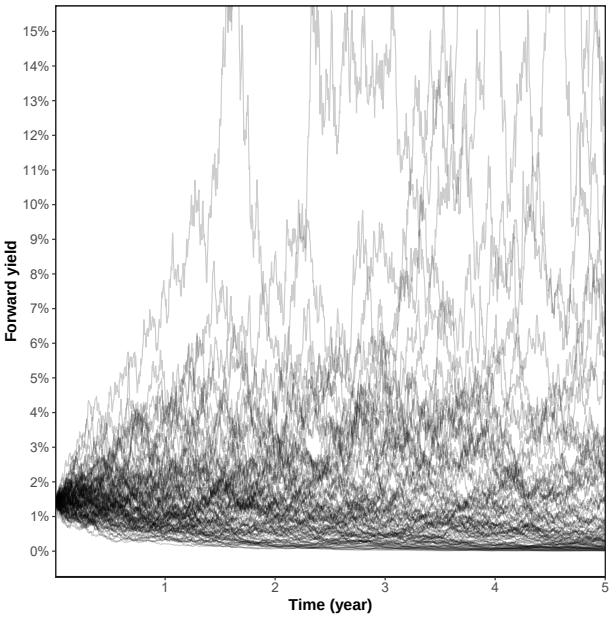


Figure 2: 5-year forward swaption rate trajectories calculated with the Black model (volatility: 69.96%, forward swap rate: 1.42%)

Implied volatility surfaces

When using each option pricing model, most of the parameters of the tested products are known, however, volatility is an exception, as future volatility is not known in advance. Furthermore, the models assume that volatility is constant over time and is independent of other option parameters. In practice, these assumptions are not valid, so market participants use special volatility parameters in their valuation, which are either discounted from the prices of similar options or based on market volatility forecasts. These are not undistorted predictions of future volatility, as the non-normal nature of yield distributions as well as demand and supply dynamics are all reflected in the implied volatility parameters, which are product- and model-dependent, as we shall see later.

Figure 3 shows the volatility of each maturity at the fixed interest rates used for the cap and floor options.

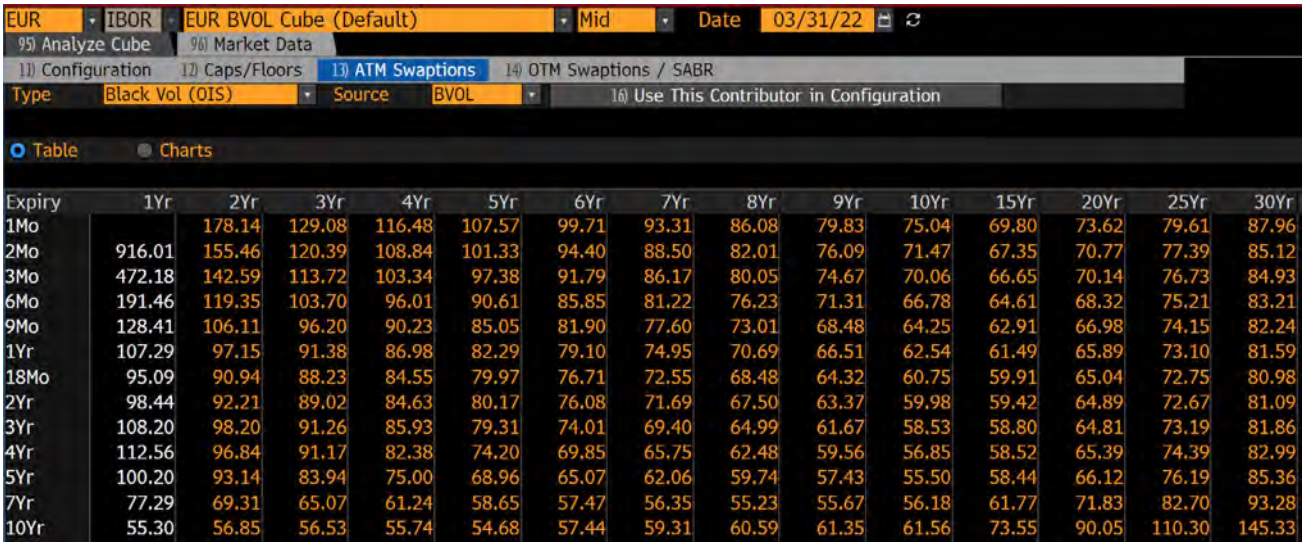
Expiry	-0.50%	-0.25%	-0.13%	ATM	0.00%	0.13%	0.25%	0.50%	1.00%	1.50%	2.00%	2.50%	3.00%	4.00%	5.00%
1Yr	44.90	54.00	59.02	64.87	64.10	69.19	74.25	84.23	103.45	121.73	139.26	156.17	172.59	204.22	234.61
18Mo	62.56	67.21	71.46	88.43	75.90	80.27	84.50	92.59	108.35	124.37	140.51	156.54	172.36	203.23	233.10
2Yr	79.76	80.91	83.63	102.74	86.81	90.08	93.33	99.69	112.58	126.41	140.98	155.88	170.83	200.41	229.31
3Yr	105.09	101.69	101.02	115.99	101.20	102.03	103.32	106.71	115.63	126.88	139.72	153.38	167.39	195.53	223.26
4Yr	106.84	104.71	104.28	118.00	104.40	105.00	105.96	108.66	116.38	126.55	138.32	150.91	163.86	189.90	215.59
5Yr	104.26	103.30	103.28	117.51	103.65	104.37	105.38	108.04	115.41	124.91	135.75	147.28	159.08	182.73	205.99
6Yr	101.04	100.88	101.14	115.59	101.69	102.52	103.57	106.20	113.15	121.86	131.67	142.01	152.55	173.61	194.31
7Yr	98.00	98.27	98.66	112.43	99.29	100.13	101.15	103.63	109.99	117.81	126.54	135.70	145.03	163.69	182.07
8Yr	94.97	95.48	95.95	109.23	96.61	97.45	98.44	100.77	106.61	113.67	121.47	129.65	137.96	154.62	171.08
9Yr	92.16	92.83	93.34	106.23	94.02	94.84	95.78	97.98	103.37	109.79	116.84	124.20	131.68	146.70	161.61
10Yr	89.36	90.16	90.70	103.08	91.38	92.19	93.10	95.17	100.14	105.96	112.28	118.86	125.54	138.96	152.36
12Yr	84.19	85.20	85.82	97.80	86.54	87.35	88.24	90.20	94.71	99.84	105.33	110.97	116.69	128.17	139.67
15Yr	78.15	79.26	79.89	90.73	80.59	81.36	82.19	83.95	87.89	92.24	96.82	101.52	106.27	115.88	125.60
20Yr	70.97	72.21	72.88	82.22	73.60	74.36	75.15	76.80	80.33	84.09	87.98	91.92	95.90	103.95	112.11
25Yr	66.67	67.98	68.68	76.98	69.41	70.17	70.95	72.57	75.99	79.56	83.21	86.90	90.61	98.12	105.72
30Yr	63.46	64.78	65.48	72.79	66.21	66.96	67.73	69.31	72.59	75.99	79.43	82.89	86.35	93.34	100.40

Figure 3: Implicit normal volatility of Cap and Floor EUR options (source: Bloomberg)

Figure 4 and Figure 5 show the normal and lognormal volatility values for swaption transactions, which depend on both the maturity of the option and the swap. In addition, volatility is even affected by the moneyness nature of the option, the figures show the ATM (at-the-money) case.

Expiry	1Yr	2Yr	3Yr	4Yr	5Yr	6Yr	7Yr	8Yr	9Yr	10Yr	15Yr	20Yr	25Yr	30Yr
1Mo	75.42	106.95	111.48	110.65	108.97	105.47	101.89	96.86	93.24	90.23	90.44	90.75	90.17	90.16
2Mo	75.11	103.49	107.20	106.73	104.77	101.42	98.80	93.84	90.24	87.45	87.84	87.74	87.34	86.84
3Mo	76.89	105.54	105.98	104.38	103.35	100.42	97.05	93.21	89.83	86.47	87.08	86.88	86.94	86.72
6Mo	97.59	112.26	110.17	106.96	102.98	99.77	96.14	92.75	89.17	85.56	86.12	85.71	85.55	85.10
9Mo	105.12	114.81	110.85	106.53	101.42	98.74	95.13	91.85	88.19	84.56	85.02	84.39	84.34	83.90
1Yr	111.92	116.43	111.74	106.34	101.37	97.99	94.62	91.10	87.59	83.92	83.72	83.08	82.93	82.81
18Mo	114.71	114.46	110.28	105.05	100.02	96.62	93.33	89.97	86.47	82.74	81.85	81.16	80.98	80.50
2Yr	115.28	113.02	107.97	103.29	98.78	95.49	92.21	88.87	85.42	81.81	80.18	79.36	78.86	78.33
3Yr	113.89	111.28	106.03	100.82	95.85	93.04	89.79	86.43	83.15	79.73	77.10	75.88	75.25	74.75
4Yr	109.91	107.42	102.44	97.16	92.52	89.59	86.65	83.82	80.80	77.69	74.52	73.25	72.39	71.76
5Yr	103.54	101.98	97.58	93.02	88.64	86.17	83.69	81.25	78.70	75.94	72.41	70.89	70.08	69.32
6Yr	97.35	95.78	91.94	88.33	84.88	82.82	80.77	78.59	76.51	74.43	70.89	69.26	68.13	67.10
7Yr	91.68	90.01	87.07	84.19	81.38	79.74	78.04	76.25	74.57	72.95	69.40	67.66	66.25	65.07
8Yr	87.36	85.97	83.47	81.01	78.58	77.12	75.63	74.07	72.63	71.19	67.77	65.77	64.22	62.94
9Yr	83.31	82.11	79.92	77.91	75.79	74.54	73.25	71.92	70.61	69.37	65.99	63.83	62.18	60.74
10Yr	79.57	78.60	76.73	74.94	73.04	72.05	70.91	69.80	68.67	67.62	64.24	61.96	60.15	58.61
12Yr	74.84	74.12	72.73	71.28	69.73	68.90	67.97	67.07	66.18	65.35	61.80	59.37	57.63	56.01
15Yr	68.43	67.65	66.79	65.88	64.86	64.33	63.70	63.03	62.46	61.86	58.16	55.42	53.75	52.10
20Yr	61.51	61.38	60.82	60.19	59.59	59.29	58.94	58.50	58.05	57.55	53.94	51.03	49.28	47.43
25Yr	58.79	58.61	58.26	57.71	57.24	56.78	56.15	55.55	54.98	54.51	50.71	47.59	45.57	43.69
30Yr	56.55	56.54	56.34	55.98	55.58	54.96	54.17	53.38	52.48	51.90	47.69	44.57	42.50	40.54

Figure 4: Implicit normal volatility of swap EUR options (source: Bloomberg)



Expiry	1Yr	2Yr	3Yr	4Yr	5Yr	6Yr	7Yr	8Yr	9Yr	10Yr	15Yr	20Yr	25Yr	30Yr
1Mo		178.14	129.08	116.48	107.57	99.71	93.31	86.08	79.83	75.04	69.80	73.62	79.61	87.96
2Mo	916.01	155.46	120.39	108.84	101.33	94.40	88.50	82.01	76.09	71.47	67.35	70.77	77.39	85.12
3Mo	472.18	142.59	113.72	103.34	97.38	91.79	86.17	80.05	74.67	70.06	66.65	70.14	76.73	84.93
6Mo	191.46	119.35	103.70	96.01	90.61	85.85	81.22	76.23	71.31	66.78	64.61	68.32	75.21	83.21
9Mo	128.41	106.11	96.20	90.23	85.05	81.90	77.60	73.01	68.48	64.25	62.91	66.98	74.15	82.24
1Yr	107.29	97.15	91.38	86.98	82.29	79.10	74.95	70.69	66.51	62.54	61.49	65.89	73.10	81.59
18Mo	95.09	90.94	88.23	84.55	79.97	76.71	72.55	68.48	64.32	60.75	59.91	65.04	72.75	80.98
2Yr	98.44	92.21	89.02	84.63	80.17	76.08	71.69	67.50	63.37	59.98	59.42	64.89	72.67	81.09
3Yr	108.20	98.20	91.26	85.93	79.31	74.01	69.40	64.99	61.67	58.53	58.80	64.81	73.19	81.86
4Yr	112.56	96.84	91.17	82.38	74.20	69.85	65.75	62.48	59.56	56.85	58.52	65.39	74.39	82.99
5Yr	100.20	93.14	83.94	75.00	68.96	65.07	62.06	59.74	57.43	55.50	58.44	66.12	76.19	85.36
7Yr	77.29	69.31	65.07	61.24	58.65	57.47	56.35	55.23	55.67	56.18	61.77	71.83	82.70	93.28
10Yr	55.30	56.85	56.53	55.74	54.68	57.44	59.31	60.59	61.35	61.56	73.55	90.05	110.30	145.33

Figure 5: Implicit lognormal volatility of swap EUR options (source: Bloomberg)

Summary

As shown in the brief summary above, interest rate options have a number of forms and valuation approaches. In addition to the above, there are many other aspects that affect valuation and risk management, such as the role of credit spreads, the nature of margin settlements, exotic product features, or more advanced use of models, such as Hull-White (HW) or SABR (Stochastic, Alpha, Beta, Rho). In each case, it is a challenge to ensure that the parameters of the models and the focus of risk management are in line with market trading, liquidity and important trends. In addition to understanding the mathematical background, these aspects also necessitate the development of appropriate risk management, evaluation, accounting and technological processes.

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