Interest Rate Option Pricing with JSON Risk

Methodology and Comparison with QuantLib

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Evaluating European and Bermudan options on irregular cash flow structures is a key topic not only in a trading book context, but also in the context of interest rate risk in the banking book (IRRBB). Retail banks often have portfolios with thousands of loans and deposits with multiple call rights. This leads to a challenging situation:

- Missing or over-simplified modelling of these option portfolios may lead to incorrect **risk figures** and inadequate **steering impulses**, while
- accurate modelling of these option portfolios involves extensive calculations; an **efficient implementation** is required to avoid long calculation times or rising hardware cost.

In this document, we describe the methodology used in JSON Risk[1] for evaluating European and Bermudan options on irregular cash flow structures in JSON Risk's callable_bond instrument class. We carry out a benchmark comparison against a comparable QuantLib implementation to validate the methodology. Moreover, we show that the JSON Risk implementation is efficient enough to handle large portfolios with typical workloads even on standard desktop hardware.

Methodology

Introduction

The JSON Risk callable_bond instrument class supports a number of features needed to cover actual business in retail banks. These include

- amortizing or accreting notional structures,
- bespoke notional structures, allowing repayment schedules to differ from coupon dates,
- interest capitalization on coupon dates,
- predetermined changes in coupon rates, e.g., client pays 4% p.a. currently, but has negotiated a prolongation that fixes interest at 3.5% p.a. starting in two years,

If one or more of the features above are included in a bond-like instrument (e.g., a loan), we call the instrument **irregular**.

The Bachelier formula for swaptions is used to communicate market prices of standard swaptions with standard bullet (i.e. constant) underlying structures for a set of quoted expiries, terms, and strikes. For **European** options on bullet cash flow structures, this formula yields accurate prices. For European options on irregular instruments, a rate model like Hull-White or a basket replication approach such as the one suggested in Hunt and Kennedy ([1]) is needed for accurate pricing.

Considering **Bermudan** options on regular or irregular instruments, single-factor rate models are widely used in the context of risk management[2]. In order to cover both European and Bermudan calls on regular and irregular underlyings, JSON Risk implements an LGM model according to P.S. Hagan ([2]). As shown in [2], this model is mathematically equivalent to the one-factor Hull-White model.

In the sections below we describe the parametrisation used in JSON Risk.

Market data

The JSON Risk callable_bond instrument class supports assignment of

[1] JSON Risk is the free and open-source financial risk library and risk management tool developed and maintained by FRAME Consulting GmbH. Visit https://www.jsonrisk.de for more info.

[2] In banking book contexts, single factor models represent the high end. More sophisticated (e.g., multi-factor) models are mainly used in a trading context, depending on the complexity of trading activities.

- a **discount curve** (mandatory) that represents riskless zero-coupon yields,
- an additional **spread curve** (optional) that is added on top of the discount curve and used for evaluating the option and the underlying bond, but is not used in calibration,
- an additional scalar **residual spread** (optional) that is added on top of the discount curve and used for evaluating the option and the underlying bond, but is not used in calibration,
- a **forward curve** (mandatory) that is used for evaluating and calibrating to a set of swaptions (see sections below on calibration and multi curve adjustments),
- a **surface** (mandatory) that represents Bachelier model swaption volatilities,
- additional surfaces representing a swaption smile (optional).

Model parameters

As described in [2], the LGM model is parametrized by a discount curve and time-dependent parameter functions H and ζ, where

- the function $t \to H(t)$ corresponds to the mean reversion and
- the function $t \to \zeta(t)$ represents interest rate volatility.

As shown in [2], the LGM model is equivalent to the Hull-White model. In JSON Risk, the functions H and ζ are chosen such that the model is equivalent to a Hull-White model with constant mean reversion and time-dependent volatility. Prices for interest rate options depend only on those values of $\zeta(t)$ where t is one of the exercise times.

Users can choose the Hull-White mean reversion freely on instrument level and JSON Risk converts it automatically to the corresponding H function. By default, a Hull-White mean reversion of zero is applied.

The volatility parameter ζ is calibrated by matching the market prices of standard swaptions as described below. For analysis purposes, users can also supply a constant Hull-White volatility on instrument level. If the Hull-White volatility is set explicitly, JSON Risk skips the swaption selection and calibration steps.

Calibration to irregular structures

Calibration to a set of standard market instruments is one of the key steps in evaluating an exotic option. In this chapter, we assume a single-curve setup where we can represent a swap float leg as an exchange of notionals. This is called the bond representation of a swap. An additional adjustment for multi-curve setups is discussed below.

For the topic of calibration, we introduce the notion of economic equivalence. Two financial instruments are economically equivalent if they have the same value not only under current interest rates, but across a broad range of interest rate scenarios. Especially, two economically equivalent instruments are good hedges for one another.

For options on standard bullet structures, it is accurate to calibrate against a standard swaption for each call right, since the underlying of the bond option and the underlying of the swaption are economically equivalent, as shown on the picture below:

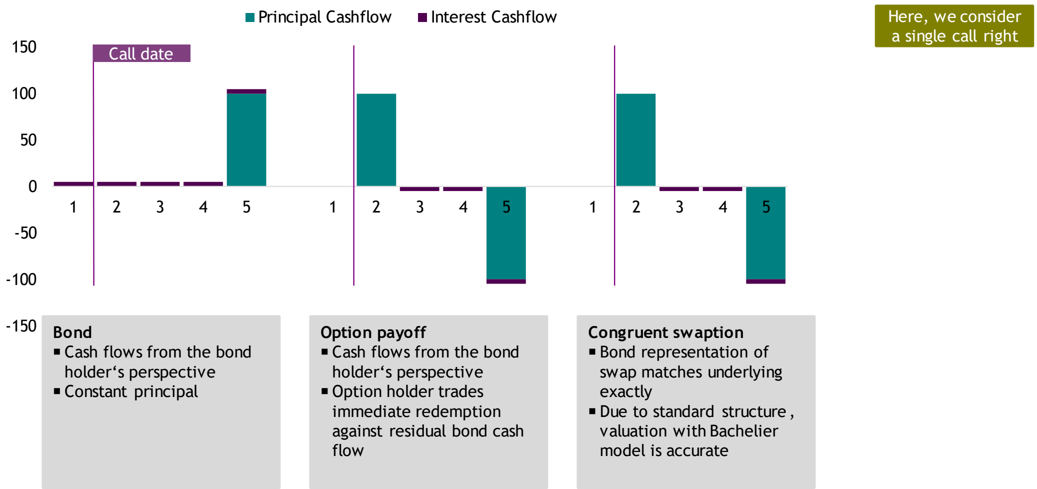

Figure 1: Congruent swaption for bullet structure

We call this the **simple approach** towards calibration, where the swaption starts on the call date and ends on the maturity date of the original bond. When irregular structures are concerned, the swaption selected according to the simple approach is no longer economically equivalent. We present two approaches for calibrating irregular structures.

The **equivalent swaption approach** starts off at the simple approach and then modifies features of the selected swaption to make its underlying swap more economically equivalent to the option payoff. For example, the maturity date, strike, or principal are modified in order to match present value, duration, and convexity of the option payoff cashflow. The equivalent swaption approach is also suggested in Hagan ([3]), Appendix A. The picture below illustrates it:

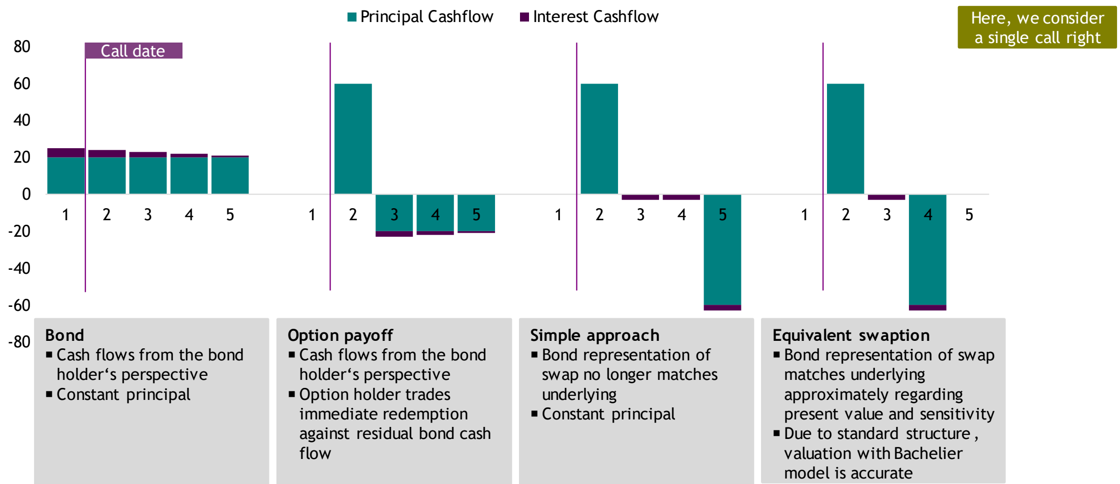

Figure 2: Equivalent swaption for amortizing structure

The **replicating basket** approach aims at replicating the payoff cash flow more exactly. While we consider only calibration here, Hunt and Kennedy ([1]) show that the resulting basket of swaptions, when evaluated with the plain Bachelier model, even matches the exact price for a single call right in the case of amortizing structures. The approach is illustrated in the picture below:

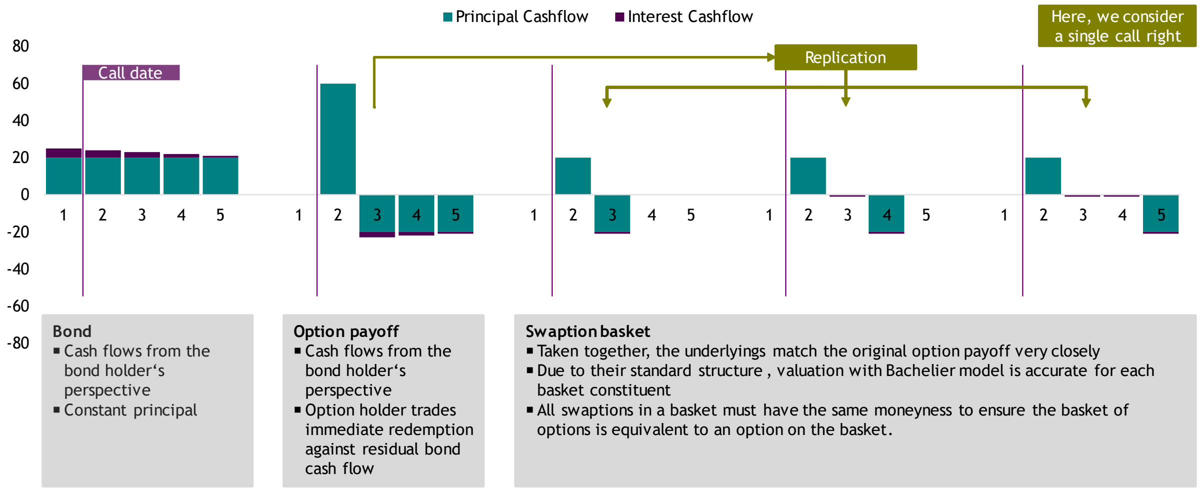

Figure 3: Basket replication for amortizing structure

In JSON Risk, the **equivalent swaption** approach is implemented. Economic equivalence of the option payoff and the selected swap is established by a simple scheme that is independent of the current interest rate levels:

1. Compute the IRR and the effective duration of the option payoff, capturing its main economic properties.
2. Create a swap with strike equal to the IRR computed before.
3. Choose the swap's maturity date iteratively such that the effective duration of the option payoff is matched approximately.
4. Create a swaption on the swap above and calibrate the LGM volatility parameter against this swaption.

We will see below that a fairly good match of the underlying against the option payoff under different interest rate scenarios is achieved with this approach. JSON Risk performs the steps above under the hood for each exercise date.

If a callable bond instrument is detected to be regular, the **simple approach** is used automatically. Users can also enforce the simple approach on instrument level by setting a flag.

Multi-Curve adjustments

The Hull-White model is a model of a single yield curve. Market quotes for swaption volatilities are based on multi-curve valuation, where the forward rates for the float leg of the swaptions are derived with a forward curve that is different from the discount curve used for discounting the cash flows of both legs. JSON Risk accounts for this while calibrating the model volatility.

Suppose we want to calibrate the model for some exercise date t_{ex} to a swaption with strike s and market price $M = PV_{MC}(s)$. The market price is derived from the discount curve, the forward curve and the swaption surface. The subscript MC stands for multi-curve valuation. If discount curve and forward curve are different, the single-curve present value $PV_{SC}(s)$ is different from the multi-curve present value, that is,

$$PV_{SC}(s) \neq PV_{MC}(s) = M.$$

JSON Risk then determines an adjusted strike s_{adj} such that

$$PV_{SC}\left(s_{adj}\right) = PV_{MC}(s) = M$$

and calibrates the model such that the model price for the swaption with strike s_{adj} matches the market price M of the original swaption.

Benchmarking against QuantLib

QuantLib Implementation

We choose a QuantLib based benchmark implementation since QuantLib is open-source and widely used in the market, not only as a validation and prototyping toolbox, but also at the core of production systems built around it. Quantlib implements a number of tools for pricing interest rate options. We choose a combination of the tools below:

- The **Gsr** model class, which is also an implementation of the Hull-White model supporting at least a constant mean reversion parameter and time dependent volatility;
- the **Gaussian1dNonstandardSwaptionEngine** pricing engine that supports amortization structures;
- the **MaturityStrikeByDeltaGamma** calibration strategy supported by QuantLib's basket generation engine, which supports an **equivalent swaption** approach similar to the one used in JSON Risk.

The choice of models and tools was suggested in [4]. The way equivalent swaptions are found in this QuantLib implementation differs from the approach employed in JSON Risk. QuantLib optimizes Maturity, Strike and Notional such that the present value and its first and second derivative with regard to the model state variable are matched up between original underlying payoff and the swap underlying the selected swaption.

Portfolio and parameters

We use EUR discount and forward curves and ATM swaption volatilities as of 2023-12-29. Our portfolio consists of 20 callable bonds with maturity in the end of 2043 differing across the following dimensions:

- Five first exercise dates (1Y, 3Y, 5Y, 7Y and 10Y)
- Two exercise types (European and yearly Bermudan)
- Two amortization types (bullet and linear amortization)

All bonds start with a notional of EUR 100,000.00 and have an annual 4% coupon rate. The notional of the amortizing bonds is reduced by EUR 5,000.00 every year. We evaluate the portfolio in JSON Risk and QuantLib under four different regimes:

1. Mean reversion 0.01 and calibration to market swaption volatility
2. Mean reversion 0.03 and calibration to market swaption volatility
3. Mean reversion 0.01 and constant Hull-White-Volatility 0.015 (no calibration)
4. Mean reversion 0.03 and constant Hull-White-Volatility 0.015 (no calibration)

The regimes without calibration are helpful for analysis purposes.

Results

Here, we present the results including Basis Point Values (BPV) and Differences for the first regime, mean reversion 0.01 and market volatility. The results for the other regimes are in the appendix.

For the **bullet products,** the two independent implementations essentially yield the same prices:

Option	JSON Risk Price	QuantLib Price	Difference	Basis Point Value	Abs. Difference (BPV)
01Y EUROPEAN	23,249.96	23,247.14	-2.82	-148.03	0.0
01Y BERMUDAN	24,500.95	24,495.90	-5.05	-137.43	0.0
03Y EUROPEAN	20,405.91	20,410.48	4.57	-121.31	0.0
03Y BERMUDAN	21,529.62	21,527.16	-2.46	-116.23	0.0
05Y EUROPEAN	17,654.16	17,654.69	0.53	-101.08	0.0
05Y BERMUDAN	18,578.67	18,569.58	-9.09	-98.38	0.1
07Y EUROPEAN	15,053.62	15,053.56	-0.06	-83.98	0.0
07Y BERMUDAN	15,779.54	15,773.77	-5.77	-82.52	0.1
10Y EUROPEAN	11,384.85	11,383.80	-1.05	-61.60	0.0
10Y BERMUDAN	11,868.54	11,861.18	-7.36	-61.01	0.1

Table 1: Mean reversion 0.01 and market volatility, bullet products

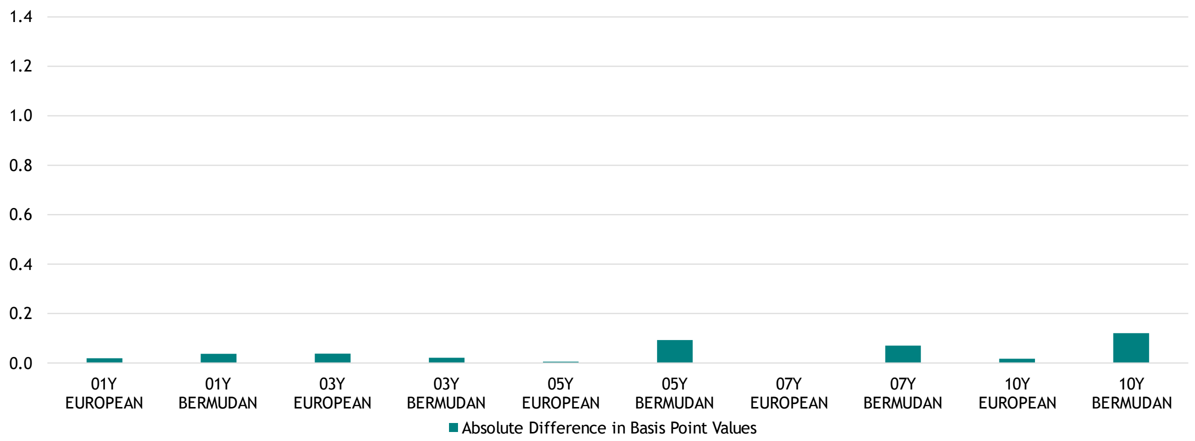

Figure 4: Differences for bullet products

The results for the **amortizing products** still show a very close match between the two independent implementations:

Option	JSON Risk Price	QuantLib Price	Difference	Basis Point Value	Abs. Difference (BPV)
01Y EUROPEAN	12,535.29	12,538.72	3.43	-72.97	0.0
01Y BERMUDAN	12,913.41	12,921.08	7.67	-69.50	0.1
03Y EUROPEAN	9,562.61	9,584.13	21.52	-52.78	0.4
03Y BERMUDAN	9,871.15	9,887.13	15.98	-51.34	0.3
05Y EUROPEAN	7,092.54	7,121.10	28.56	-38.27	0.7
05Y BERMUDAN	7,321.62	7,328.16	6.54	-37.61	0.2
07Y EUROPEAN	5,122.16	5,121.41	-0.75	-27.23	0.0
07Y BERMUDAN	5,280.37	5,264.62	-15.75	-26.93	0.6
10Y EUROPEAN	2,916.32	2,897.23	-19.09	-15.16	1.3
10Y BERMUDAN	2,994.11	2,974.71	-19.40	-15.09	1.3

Table 2: Mean reversion 0.01 and market volatility, amortizing products

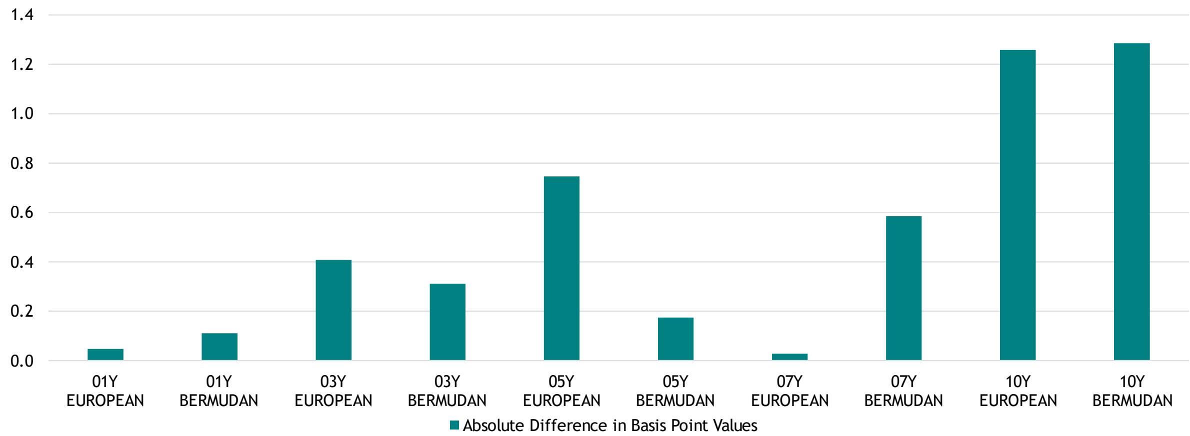

Figure 5: Differences for amortizing products

Although price differences are still rather insignificant, we would like to examine why they are more pronounced than in the bullet case. As can be seen in the appendix, the results for amortizing products without calibration are much closer, suggesting the selection of calibration instruments is the root cause for the differences.

Let us examine the **5Y EUROPEAN and 10Y EUROPEAN** instruments and start with what swaptions the engines selected for calibration for the single call right. Due to the linear amortization, the remaining notional of the underlying is 70.ooo after 5 Years and 45.000 after 10 Years.

Instrument	Engine	Notional	Expiry	Maturity	Strike
5Y	JSON Risk	70,000.00	2029-11-30	2037-02-03	4.055%
	QuantLib	52,665.56	2029-11-30	2039-09-30	4.113%
10Y	JSON Risk	45,000.00	2034-11-30	2039-10-13	4.056%
	QuantLib	35,668.13	2034-11-30	2041-03-29	4.035%

Table 3: Calibration instruments

We remember JSON Risk always selects a swaption with the same notional as the remaining principal of the underlying, and with a strike that matches the IRR of the underlying payoff. Then, it tries to find a maturity date that matches the effective duration of the underlying payoff. QuantLib in contrast optimizes maturity, strike and notional such that the present value and its first and second derivative with regard to the model state variable are matched up between original underlying payoff and the swap underlying the selected swaption. In both cases, 5Y and 10Y, QuantLib selects swaps with lower notionals and with longer maturities than JSON Risk does.

Note that the choice of notional of the swaption does not have any effect on the final price of the callable instrument, since the swaption is only used for determining the model parameters in the calibration step. For this reason, JSON Risk does not use the notional for any goal seeking.

From a functional perspective, a swaption is suited best for calibration if it is a good hedge for the original option. That is the case if the underlying of the swaption, under a broad range of interest rate environments, has the same value as the original underlying (see e.g. [3], Appendix A). Since the choice of notional is not relevant for the calibration result, we may scale the selected swaps such that both match the present value of the underlying exactly in the current interest rate environment. Then, we evaluate the original underlying as well as the “hedges” proposed by JSON Risk and QuantLib under parallel interest rate shifts ranging from -200BP to +200BP in order to represent completely different market environments. The picture below shows the PnLs for the 5Y European.

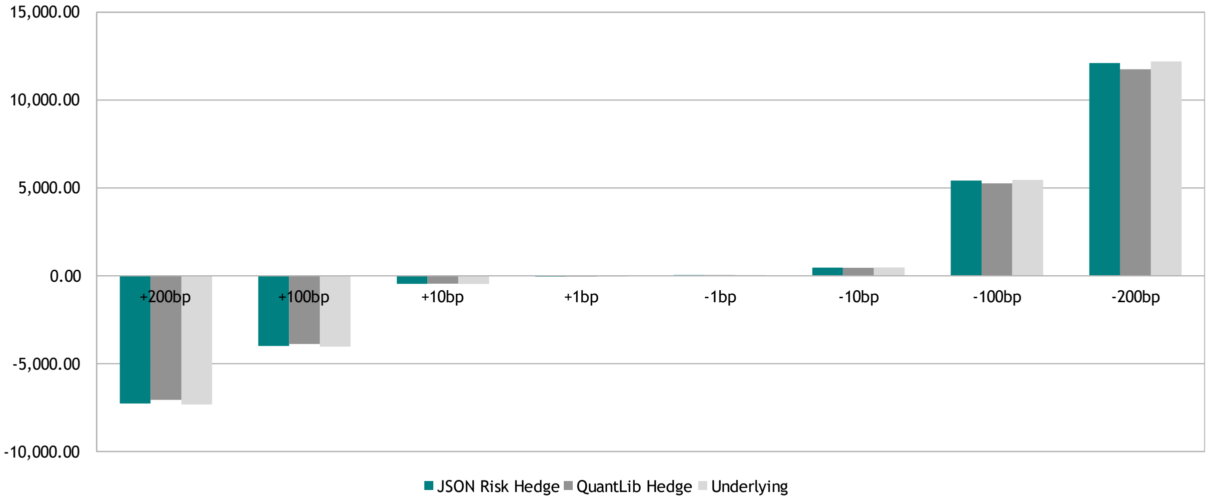

Figure 6: Hedge stability 5Y European

At first sight, the hedges seem rather in line, while differences are slightly higher for the QuantLib hedges. The next picture shows the PnLs for the 10Y European.

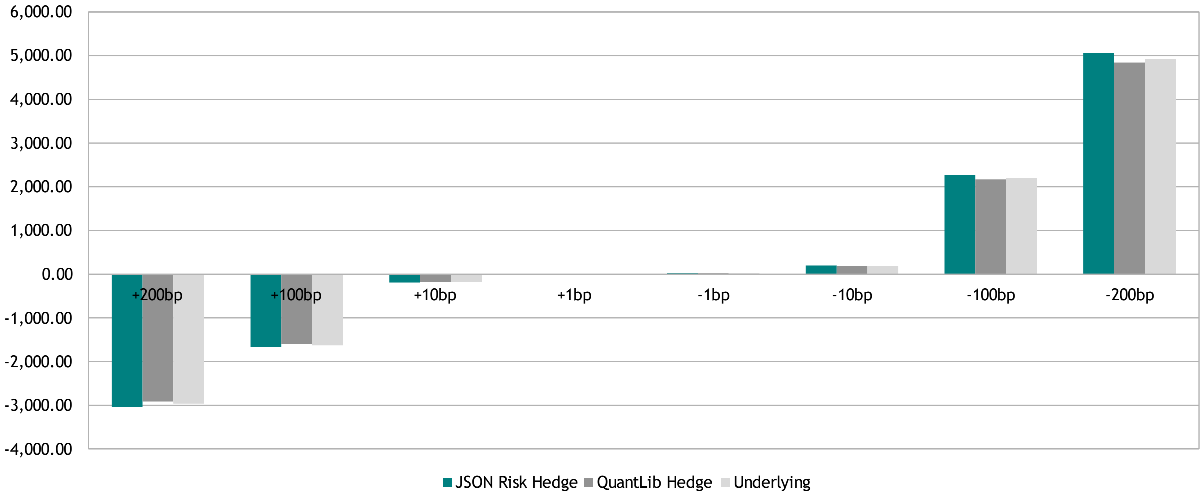

Figure 7: Hedge stability 10Y European

Here, the differences are slightly higher for the JSON Risk hedges. Examining other expiries and also other shifts, including the BCBS 368 tilts (Steepener, Flattener, Short Rate Up, Short Rate Down), show that the hedges generated by the two libraries match the underlying closely under a broad range of interest rate scenarios. The differences in the maturities and strikes explain why there are slight differences in the final prices for European and Bermudan options on the irregular structures between the libraries.

The JSON Risk App uses multiprocessing on all available CPUs on a system by default and is scalable across clusters easily. We have analysed JSON Risk performance based on a portfolio with 50.000 callable loans of various maturities under a set of 14 interest rate scenarios (see our feature [5]). Due to the scalable architecture of JSON Risk, the results allow execution time estimates for larger scenario sets, e.g. a typical 250-day Value-at-Risk (VaR) or a 10-year Stressed Value-at-Risk (SVaR). The execution time depends on the modelled exercise style. We have considered European and yearly Bermudan exercise styles. These are the results on off-the-shelf desktop hardware with 8 logical CPUs:

Scenarios	European Exercise	Bermudan Exercise
14 (Test Set)	76 Seconds	6 Minutes
250 (VaR)	23 Minutes	1 Hour 45 Minutes
2500 (SVaR)	3 Hours 45 Minutes	18 Hours

Table 4: Performance figures

Apart from the Stressed Value-at-Risk, an exercise that institutions typically do not run on a daily basis, these execution times fit into a night batch comfortably. If executed on industrial scale server hardware, execution times scale down linearly with the number of CPUs. E.g., on a cluster with four 20-core machines, the SVaR is done in under two hours and the regular VaR runs are a matter of minutes even with Bermudan exercise modelled.

In [5], we demonstrate that we can speed up JSON Risk even more – and at very low cost - with a modern serverless architecture.

Conclusion

Evaluation of European and Bermudan options on irregular cash flow structures is a key topic for the management of interest rate risk in the banking book. JSON Risk provides a state-of-the-art implementation for these products. The choice of calibration instruments is one of the main ingredients driving the quality of prices.

The comparison with another state-of-art implementation based on QuantLib tools shows that both implementations deliver essentially the same prices. With regard to calibration, both approaches use an equivalent swaption approach as suggested in [3], though the derivation of equivalent swaption parameters differs. A close look at the selected swaptions for calibration shows that both libraries select instruments that display similar behaviour as the original irregular structure under a broad range of interest rate scenarios.

Finally, JSON Risk users get state-of-the art modelling in a free and open-source product. Due to its efficiency and scalability, JSON Risk can accommodate typical workloads on small hardware even for large portfolios and scales up easily for more sophisticated and frequent workloads.

References

[1] P.J. Hunt, J.E. Kennedy, IMPLIED INTEREST RATE PRICING MODELS, Finance Stochast. 2, 275-293 (1998)

[2] Patrick .S. Hagan, EVALUATING AND HEDGING EXOTIC SWAP INSTRUMENTS VIA LGM

[3] Patrick S. Hagan, METHODOLOGY FOR CALLABLE SWAPS AND BERMUDAN “EXERCISE INTO” SWAPTIONS

[4] Peter Caspers, FOOLING AROUND WITH QUANTLIB, Blog entry on Gaussian Model, https://quantlib.wordpress.com/tag/representative-calibration-basket/

[5] Tilman Wolff-Siemssen, SERVERLESS COMPUTING IM RISIKOMANAGEMENT UND IN DER BANKSTEUERUNG, PowerPoint Slide Deck, https://frame-consult.de/docs/Serverless_Computing_Risikomanagement_Banksteuerung.pdf

Appendix

Here, we provide the figures for the valuation regimes not explicitly discussed above. The results for **mean reversion 0.03 and market swaption volatility** show the same pattern as for the one percent mean reversion: Prices match very closely for bullet products and less closely for amortizing products.

Option	JSON Risk Price	QuantLib Price	Difference	Basis Point Value	Abs. Difference (BPV)
01Y EUROPEAN	23,249.95	23,247.06	-2.89	-148.03	0.0
01Y BERMUDAN	24,797.98	24,792.65	-5.33	-136.24	0.0
03Y EUROPEAN	20,405.90	20,410.51	4.61	-121.31	0.0
03Y BERMUDAN	21,839.47	21,833.57	-5.90	-115.67	0.1
05Y EUROPEAN	17,654.16	17,654.71	0.55	-101.08	0.0
05Y BERMUDAN	18,855.49	18,845.90	-9.59	-98.13	0.1
07Y EUROPEAN	15,053.60	15,053.54	-0.06	-83.98	0.0
07Y BERMUDAN	16,004.84	15,998.55	-6.29	-82.44	0.1
10Y EUROPEAN	11,384.84	11,383.88	-0.96	-61.60	0.0
10Y BERMUDAN	12,007.12	11,998.71	-8.41	-61.04	0.1

Table 5: Mean reversion 0.03 and market volatility, bullet products

Option	JSON Risk Price	QuantLib Price	Difference	Basis Point Value	Abs. Difference (BPV)
01Y EUROPEAN	12,505.09	12,543.72	38.63	-73.25	0.5
01Y BERMUDAN	12,956.54	13,027.87	71.33	-69.25	1.0
03Y EUROPEAN	9,516.22	9,596.52	80.30	-52.97	1.5
03Y BERMUDAN	9,916.31	10,000.49	84.18	-51.22	1.6
05Y EUROPEAN	7,050.20	7,125.98	75.78	-38.38	2.0
05Y BERMUDAN	7,359.34	7,420.17	60.83	-37.56	1.6
07Y EUROPEAN	5,090.19	5,131.47	41.28	-27.28	1.5
07Y BERMUDAN	5,308.54	5,335.36	26.82	-26.92	1.0
10Y EUROPEAN	2,900.30	2,906.45	6.15	-15.17	0.4
10Y BERMUDAN	3,008.47	3,010.82	2.35	-15.09	0.2

Table 6: Mean reversion 0.03 and market volatility, amortizing products

In the regimes with **constant hull-white volatility**, the swaption selection and calibration steps are skipped. Consequently, we see very close matching of prices for bullets as well as amortizers.

Option	JSON Risk Price	QuantLib Price	Difference	Basis Point Value	Abs. Difference (BPV)
01Y EUROPEAN	25,485.09	25,485.45	0.36	-135.63	0.0
01Y BERMUDAN	29,929.99	29,905.19	-24.80	-122.44	0.2
03Y EUROPEAN	24,465.47	24,470.61	5.14	-112.43	0.0
03Y BERMUDAN	27,801.41	27,775.87	-25.54	-108.50	0.2
05Y EUROPEAN	22,667.53	22,672.39	4.86	-96.07	0.1
05Y BERMUDAN	25,082.63	25,054.98	-27.65	-95.16	0.3
07Y EUROPEAN	20,365.19	20,368.72	3.53	-82.07	0.0
07Y BERMUDAN	22,060.67	22,033.52	-27.15	-82.26	0.3
10Y EUROPEAN	16,259.20	16,259.25	0.05	-62.55	0.0
10Y BERMUDAN	17,155.81	17,137.75	-18.06	-63.09	0.3

Table 7: Mean reversion 0.01 and constant HW volatility, bullet products

Option	JSON Risk Price	QuantLib Price	Difference	Basis Point Value	Abs. Difference (BPV)
01Y EUROPEAN	13,623.99	13,621.65	-2.34	-66.71	0.0
01Y BERMUDAN	14,971.02	14,966.34	-4.68	-61.60	0.1
03Y EUROPEAN	11,366.44	11,370.94	4.50	-48.60	0.1
03Y BERMUDAN	12,297.81	12,296.79	-1.02	-47.17	0.0
05Y EUROPEAN	9,073.44	9,069.28	-4.16	-36.15	0.1
05Y BERMUDAN	9,666.15	9,662.42	-3.73	-35.81	0.1
07Y EUROPEAN	6,928.37	6,926.92	-1.45	-26.52	0.1
07Y BERMUDAN	7,285.42	7,279.66	-5.76	-26.52	0.2
10Y EUROPEAN	4,156.80	4,153.87	-2.93	-15.42	0.2
10Y BERMUDAN	4,300.42	4,295.89	-4.53	-15.50	0.3

Table 8: Mean reversion 0.01 and constant HW volatility, amortizing products

Option	JSON Risk Price	QuantLib Price	Difference	Basis Point Value	Abs. Difference (BPV)
01Y EUROPEAN	24,404.97	24,397.27	-7.70	-140.02	0.1
01Y BERMUDAN	28,161.07	28,142.01	-19.06	-125.24	0.2
03Y EUROPEAN	22,731.46	22,738.87	7.41	-114.61	0.1
03Y BERMUDAN	25,840.95	25,820.28	-20.67	-109.44	0.2
05Y EUROPEAN	20,670.45	20,671.05	0.60	-96.64	0.0
05Y BERMUDAN	23,069.25	23,047.85	-21.40	-95.01	0.2
07Y EUROPEAN	18,338.00	18,340.47	2.47	-81.60	0.0
07Y BERMUDAN	20,108.20	20,088.19	-20.01	-81.42	0.2
10Y EUROPEAN	14,481.49	14,475.79	-5.70	-61.32	0.1
10Y BERMUDAN	15,474.78	15,456.93	-17.85	-61.77	0.3

Table 9: Mean reversion 0.03 and constant HW volatility, bullet products

Option	JSON Risk Price	QuantLib Price	Difference	Basis Point Value	Abs. Difference (BPV)
01Y EUROPEAN	13,210.53	13,207.42	-3.11	-68.43	0.0
01Y BERMUDAN	14,402.44	14,399.77	-2.67	-63.05	0.0
03Y EUROPEAN	10,741.74	10,745.85	4.11	-49.45	0.1
03Y BERMUDAN	11,640.98	11,639.60	-1.38	-47.78	0.0
05Y EUROPEAN	8,416.61	8,418.75	2.14	-36.40	0.1
05Y BERMUDAN	9,022.57	9,018.75	-3.82	-35.93	0.1
07Y EUROPEAN	6,334.65	6,335.91	1.26	-26.42	0.0
07Y BERMUDAN	6,717.06	6,713.57	-3.49	-26.37	0.1
10Y EUROPEAN	3,743.55	3,740.73	-2.82	-15.15	0.2
10Y BERMUDAN	3,906.31	3,903.24	-3.07	-15.23	0.2

Table 10: Mean reversion 0.03 and constant HW volatility, amortizing products