Prepared for

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Insurance ALM | Second Order Interest Rate Risk Hedging

August 2021

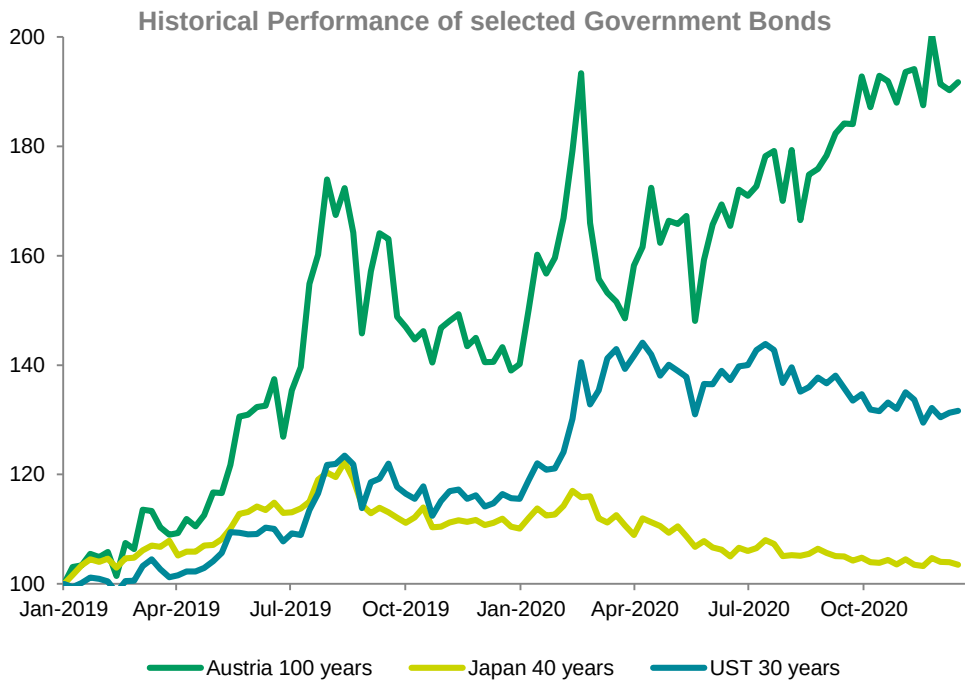
CRÉDIT AGRICOLE CORPORATE & INVESTMENT BANK

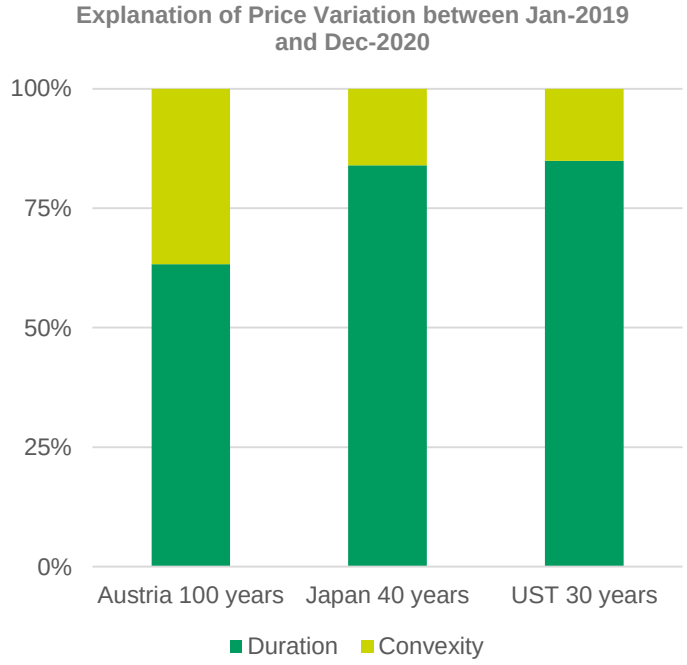
Risk Awards 2020 Winner — Crédit Agricole CIB Investment product of the year

Convexity and Duration Gap Management

Background: Convexity in Low Rates Environment

- More than 10 year after the Great Financial Crisis, interest rates of DM countries continue to converge to zero or even negative territory.
- Since then, Financial Institutions which have a structural duration gap between assets and liabilities due to scarcity of very long term assets are struggling to keep this duration gap stable when interest rates move.
- The culprit is convexity which now accounts for a much more significant portion in price movements of fixed income assets in low rates environment i.e. when rates drop, bonds with higher convexity appreciate more quickly than bonds with lower convexity than it used to.
- Convexity which used to be a less relevant parameter in fixed income portfolios has become a challenge for implementing a proper risk management framework.





- *"The (century) bond is among the best performing assets in the world this year."* Source **Financial Times**
- *"The higher the convexity, the quicker prices will rise as interest rates fall, and the opposite is true."* Source **Washington Post**
- *"Without asset managers scrambling to hedge their positions, the (US) 10-year yield might be a 0.25 point higher".* Source **The Wall Street Journal**
- *"Convexity hedging has totalled roughly $90 million per basis-point move in bond yield".* Source **Bloomberg**

What is convexity?

✓ Case study of a 30y bond with 1% coupon

- World of certainty i.e. 30y bond yields at 1% without doubt
  => 30y Bond with 1% coupon = 100% i.e. **yield of 1%**

- World with uncertainty, 30y bond yield either moves to 0% or to 2%, immediately, with equal probability
  - State yield = 0%: 30y Bond with 1% coupon = 130%
  - State yield = 2%: 30y Bond with 1% coupon = 77.6%

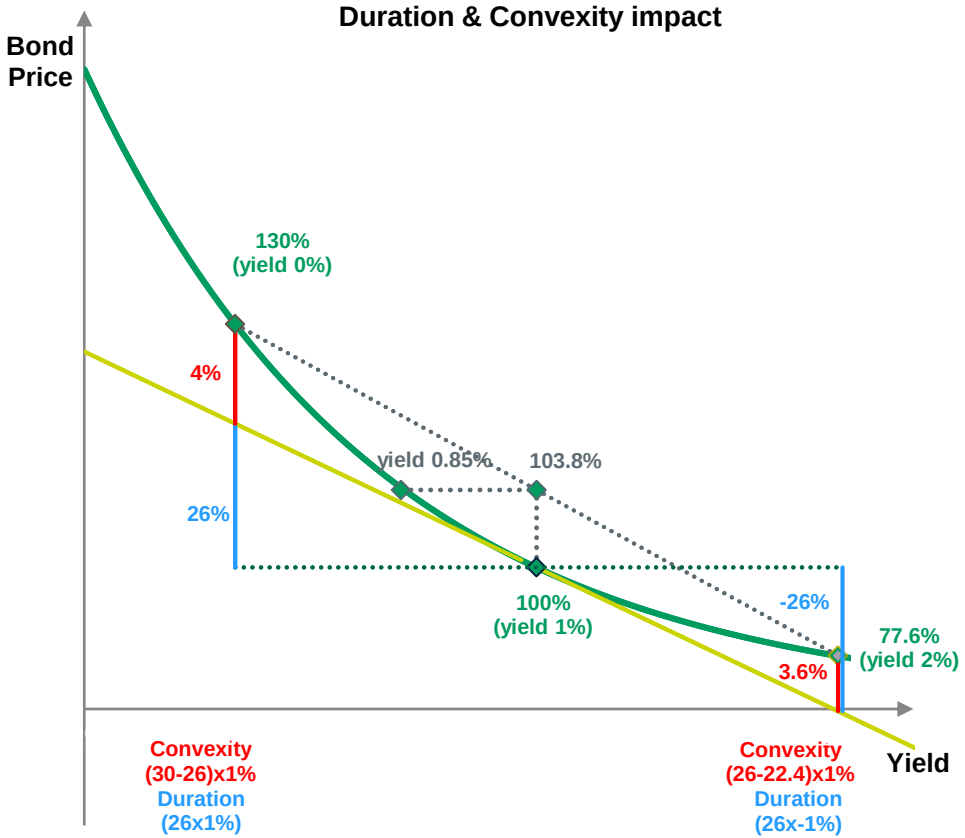
  => The expected Bond Price is 103.8% i.e. **yield of 0.85%**

- If we expect high volatility ⇔ we expect a high value of convexity ⇔ we are ready to pay more for the bond
- The convexity lowers the yield of the bond
- The convexity is financed by the roll down of the curve (homogeneous to duration x yield variation)

✓ Some intuitions

- The convexity is the non linear evolution of price with respect to rates
- The convexity shows the non linearity of duration with respect to rates
- The convexity embedded in the bond is an increasing function of duration (square of duration)

$$\Delta BondPrice = \underbrace{Duration \times \Delta r}_{Duration\ impact} + \underbrace{\Delta Duration \times \Delta r}_{Convexity\ impact}$$

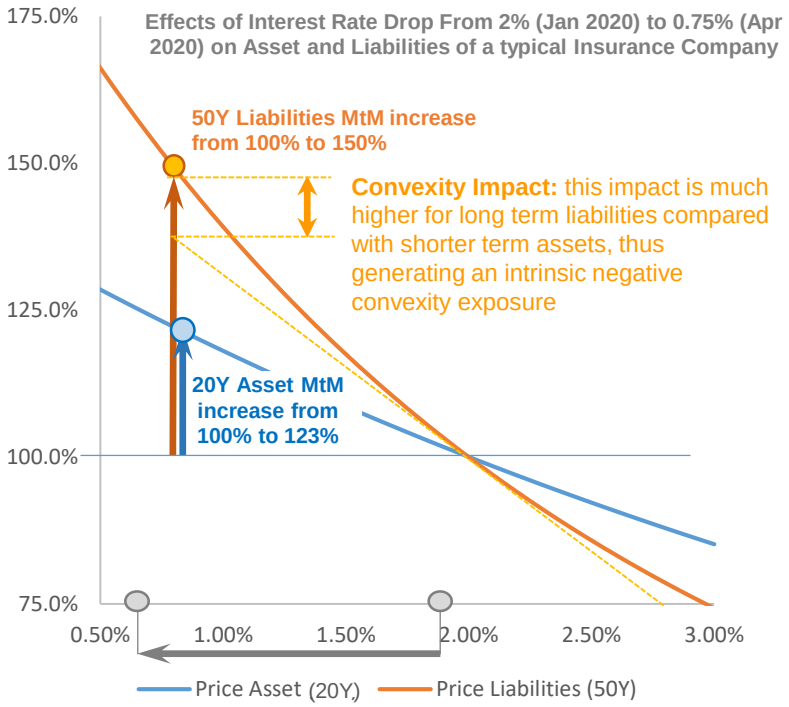


$$Duration\ impact \propto Maturity \times \Delta r$$

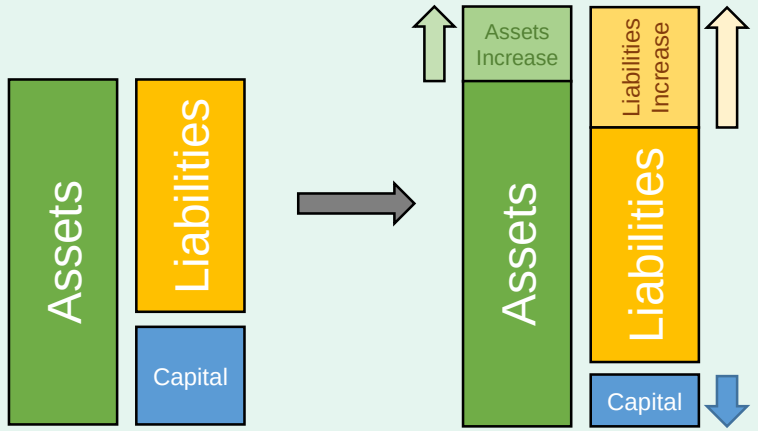
$$Convexity\ impact \propto \frac{(Maturity \times \Delta r)^2}{2}$$

Insurance Companies and Duration Gap Management

- The balance sheets of insurance companies are **structurally imbalanced** in term of exposure to interest rate with **very long term liabilities** and **shorter term assets** due to scarcity of long duration assets
- This **duration gap** between liabilities and assets can be hedged through linear instruments such as forward-starting IRS, Bond Forward, etc.
- However, with **interest rates plummeting**, the **change in duration gap** has become **material** with respect to any change in interest rates, because the **impact from convexity is drastically higher in low rates environment.**
- Typically, insurance companies have to **re-hedge their duration gap after a significant market move** by buying more assets when rates falls and selling assets when rates rise - a losing strategy in the long run, especially when volatility increases
- This is akin to **a structural short position in convexity** and some insurance companies have put in place **swaption purchase programmes** to cover this negative convexity exposure.



- A typical balance sheet of life insurance company experienced a drastic change during the 3-month window when COVID-19 crisis first hit the market
- Insurance companies under advanced solvency regimes have regulatory incentives to implement hedging strategies to reduce the volatility on duration gap as well as capital costs.



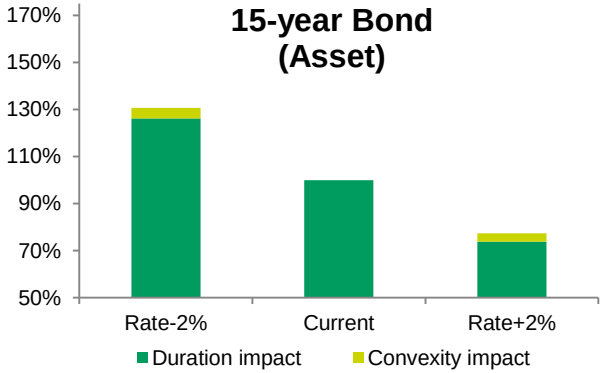
Negative Convexity and Feedback loop

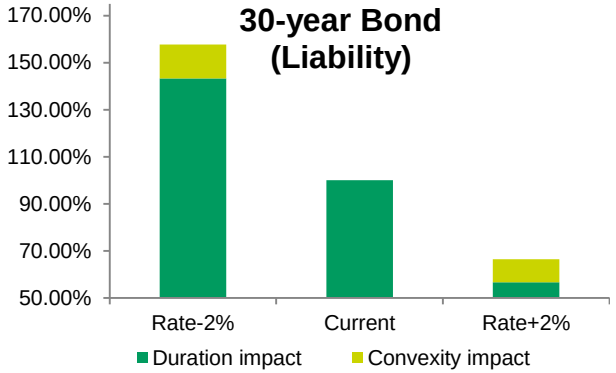
✓ Insurance Company have a Balance sheet with negative convexity

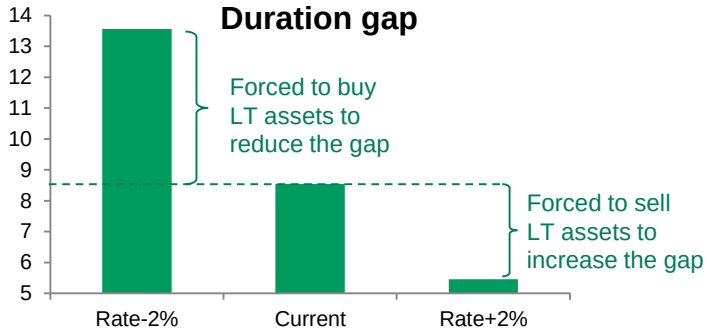
- Implied from duration gap between assets and liabilities
- Implied from options & guarantees
- Costly portfolio rebalancing:
  - **increase your loss**
  - **reduce your gains**

✓ Feedback loop – hunt for duration

- Insurance engaged in liability-driven investment strategy (LDI)
- When rates fall prices of longer-dated bonds are driven higher
- Serving to further lower long-term interest rates
- Eliciting yet additional purchases
- Which increases rates volatility







15-year Bond (Asset)	Rate-2%	Rate+2%
Duration impact	26%	-26%
Convexity impact	4.4%	3.6%
Bond value	131%	77%

30-year Bond (Liability)	Rate-2%	Rate+2%
Duration impact	43%	-43%
Convexity impact	14.4%	9.7%
Bond value	158%	66%

Duration	Rate-2%	Current	Rate+2%
15-year Bond	15.3	13.1	11.3
30-year Bond	28.9	21.6	16.8
Duration gap	13.6	8.6	5.5

- Duration impact homogeneous to opposite of rates shift and duration, ex: **26%** ~ -13 x -2%
- Convexity impact homogenous to rates shift and duration square, ex: **4%** ~ 0.5 x (13 x 2%)^2

Using CMS Options and Swaptions to generate convexity

- An easy way to **generate convexity** when interest rates go up or interest rates go down is to use options
- In the fixed income world, investor can use **Swaptions** or **CMS options** (options on Constant Maturity Swap)
- In order to get **non-directional exposure, Straddles** are often used (same strike on Receiver/Payer swaption)
- The **significant change of long term duration** when a shock is applied on the interest rate curve makes these products an **attractive tool to adjust the duration gap** in response to such interest rate curve movement

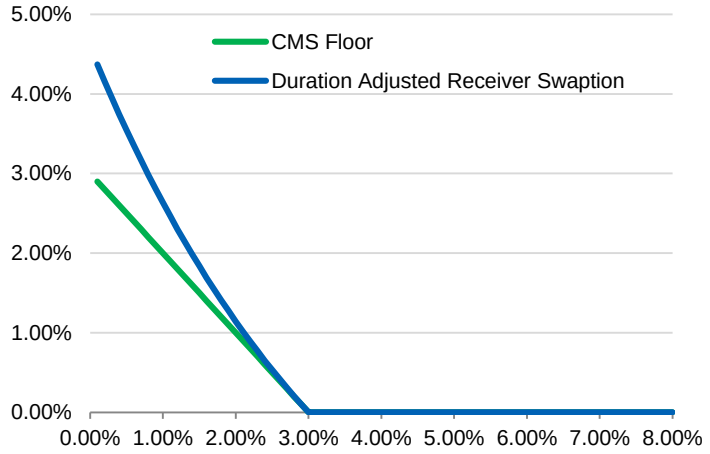
Receiver and Payer Swaptions

- Convex exposure at expiry, in line with natural duration exposure
- More liquid
- More expensive than CMS option on the downside exposure

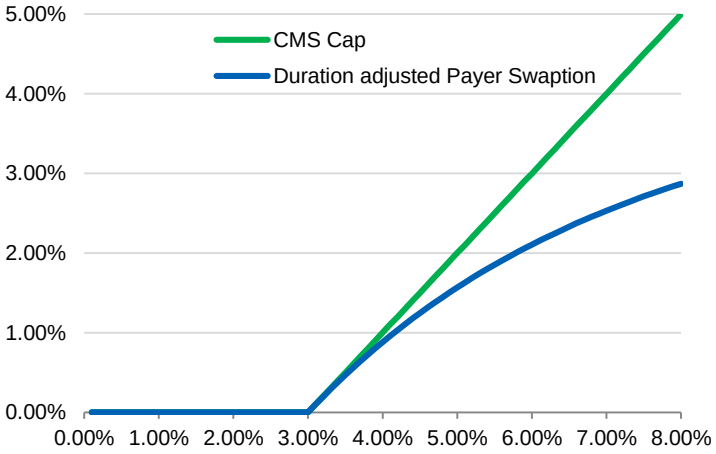
CMS Caps and Floors

- Linear exposure at expiry
- Less liquid
- Cheaper than Receiver Swaption on the downside exposure

Payoff profile at expiry of CMS Floorlet vs. duration adjusted receiver swaption



Payoff profile at expiry of CMS Caplet vs. duration adjusted payer swaption



- The usual strategy is to buy options on a 10Y underlying and wait for expiry of the option, or unwind the option after a significant rate movement. This strategy is costly and not optimal.
- **Monetization is an important consideration in the choice of strategy.**

KRW Swaption Volatility Matrix and determination of cheapest point for convexity hedging

ATM implied normal volatility matrix

Tenor/Expiry	1Y	2Y	5Y	10Y	15Y	20Y
3M	40.7	40.3	51.1	53.5	52.4	52.8
6M	41.0	42.2	48.4	51.6	50.9	51.5
1Y	40.8	43.6	44.3	46.6	46.3	46.8
2Y	46.1	44.8	43.8	44.3	44.4	44.6
3Y	45.9	45.2	43.7	43.4	42.8	42.6
4Y	44.7	45.0	43.5	42.8	41.9	41.5
5Y	42.6	42.7	43.2	42.1	41.8	41.4
7Y	41.9	41.7	42.1	41.4	41.4	41.2
10Y	41.0	41.0	40.8	40.7	40.7	40.6

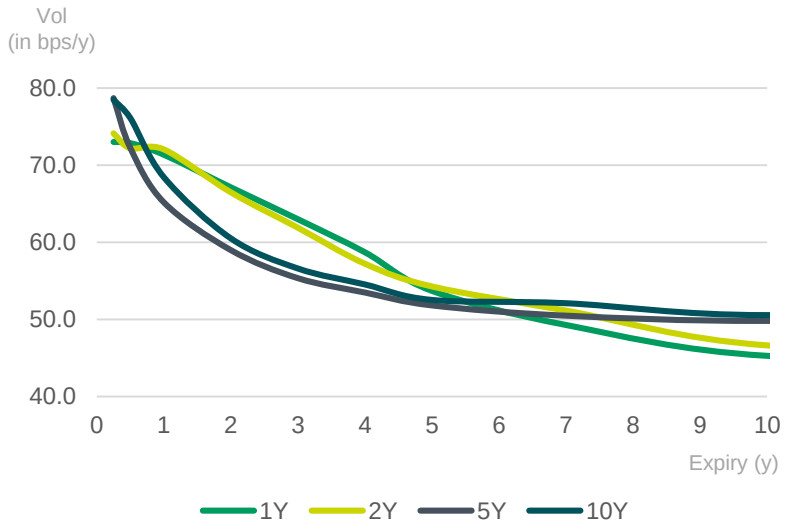
Hedge Funds (seller)

Korean Lifers (seller)
Exotic flows (buyer or seller)

Convexity hedgers (buyer)

Very low liquidity

Normal Volatility (bps/y) as of March 22, 2022



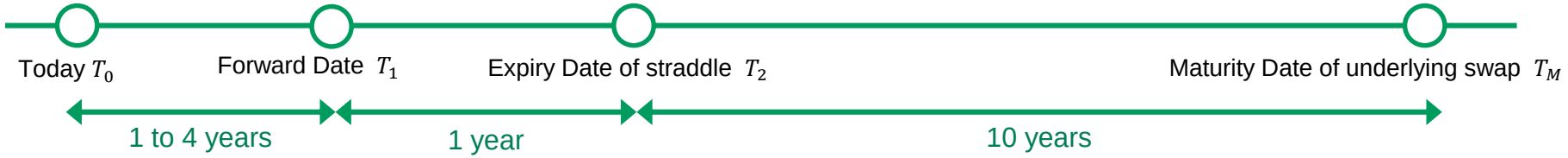
Typical market conditions for KRW plain vanilla swaption:

- **Volatilities are lower on longer tenors and expiries**
- Currently long tenor and short tenor are the most expensive (right top of the matrix)
- **Convexity hedgers** will usually prefer to **buy longer expiry swaptions** on 10 to 20Y underlying swap to benefit from the lower volatility (right bottom of the matrix)
- **Longer expiries and longer tenor** swaptions are not very liquid in the KRW swaption space. Maximum tenor with decent liquidity is 10y.
- For long expiry swaptions on 10y tenor, monetization of the convexity can be problematic, as this would happen when the option is deep in the money hence less liquid to be unwound.
- Swaption hedging strategies can be **costly and only partially effective** though, since they need to be re-striked or restructured on a regular basis, which implies **risk and uncertainty** on liquidity, market condition and cost whenever this needs to be done.

Convexity Hedging Solution:
Strip of Forward Volatility Agreement

Convexity Hedging: Strip of Forward Volatility Agreements (in KRW)

- To address the shortfalls of a swaption-based hedging strategy, Crédit Agricole CIB proposes a strip of Forward Volatility Agreements as the next-generation solution.
- A **Forward Volatility Agreement** ("**FVA**") is a **swaption straddle** where the **strike** will be determined at the then **prevailing ATM strike on a future date** T_1, with an expiry date in the future $T_2 > T_1$ and a maturity date of the underlying swap $T_M > T_2$



- The **strip** of FVAs consists of a **spot start** 1y10y, **1y**1y10y, **2y**1y10y, **3y**1y10y and **4y**1y10y **straddles**

1	**Expiry of Straddle: 1y**	• **Short Expiry** of swaption allow to **maximize the convexity** thanks to a low time value. • **Consistent** with annual balance sheet valuation.
2	**Underlying Swap Tenor: 10y**	• **Longer tenor** tend to have higher volatility under stressed market conditions from an historical perspective. • This is because market participants tend to put in place flattener strategies during such periods. • Longer tenor higher volatility **increases the potential performance** of the strategy • Low liquidity on the KRW swaption market prevents to use tenor higher than 10 years
3	**Forward Strike and Swaption roll**	• **Forward volatility is structurally lower** than spot volatility in today's KRW market, which lowers swaption costs. • The spirit of using a strip of FVA is to **purchase very short dated options** with the objective of **collecting intrinsic value** by letting expiring or unwinding the front end swaption of the strip only. • Pricing is sensitive only to volatility of the longest future expiry. This allows investor to **buy short term swaptions at the price of long term volatility** (usually cheaper than short term volatility).

Comparative Study: Vanilla Swaption and Bermudan Swaption

Assumptions

- Hedging 1st order and 2nd order interest risk allows to put in place a management of the duration gap generated not only by a mismatch of asset/liabilities duration but also option and guaranties on the liability side
- First order duration hedges are assumed to be already in place to reduce the duration gap between Asset and Liabilities
- Convexity hedge program to be established for the next 5 years, allowing to generate a positive income in case of important interest rate movement to cover the costs of re-establishing the first order duration hedges

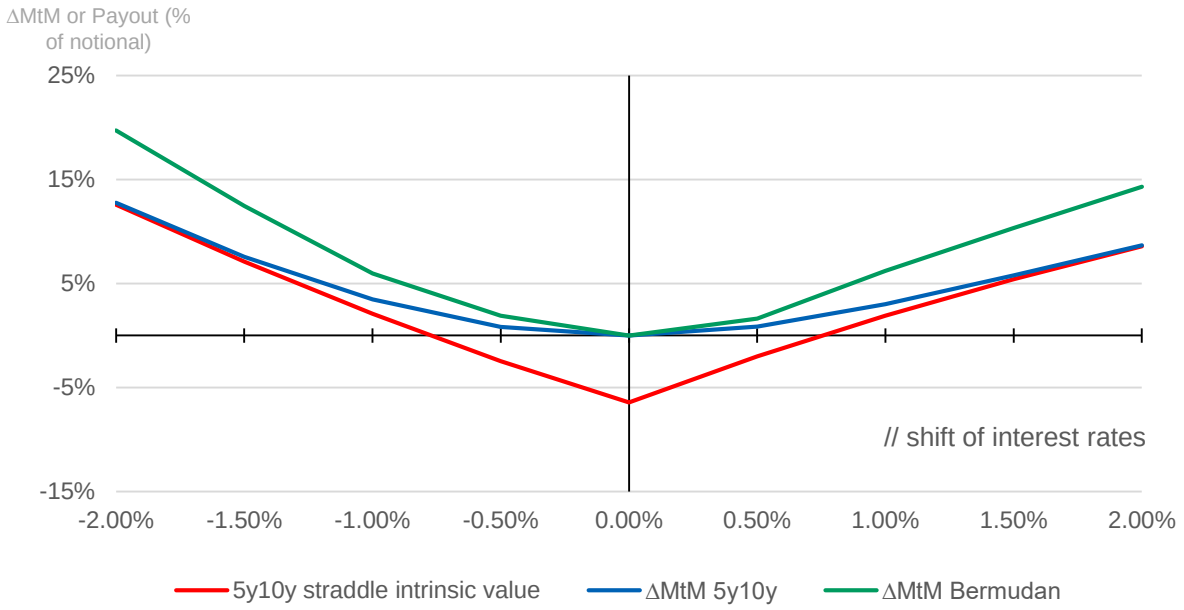
Objective of the Hedging Strategy

- Get a long exposure on rate convexity
- Monetize the convexity when needed or at least on a regular basis
- Cover the cost of rebalancing of first order duration hedges with the convexity hedging program
- We start with two base scenario: vanilla straddle and Bermudan straddle:

Base Scenario 1: 5y10y Vanilla Straddle	
Notional	KRW 50B
Buyer	Investor
Swaption type	European Straddle
Strike	ATMF
Expiry	5Y
Underlying Swap	10Y, fixed rate paid on quarterly basis Act/365
Premium	**0.75%** p.a., paid on a running basis, same dates as payment dates of the fixed rate of the underlying swap

Base Scenario 2: 15y yearly callable up to 5y expiry Bermuda Straddle	
Notional	KRW 50B
Buyer	Investor
Swaption type	Bermudan Straddle
Strike	ATMF of 5y10y
Expiry	1y, 2y, 3y,4y or 5y
Underlying Swap	14y swap if exercised on y1 13y swap if exercised on y2 […] 10y swap if exercised on y5 With fixed rate paid on quarterly basis Act/365
Premium	**0.98%** paid on a running basis, same dates as payment dates of the fixed rate of the forward start 5y10y swap

Comparative Study: Vanilla Swaption and Bermudan Swaption



Indicative Pricing

Product	Running	Upfront
5y10y straddle	0.75 % p.a.	627 bps
Bermudan	0.98% p.a.	824 bps

Analysis

- The payment of the premium on a running basis allows to **reduce the directional exposure to rates** due to the discounting effect. First order duration hedges are assumed to be already in place to reduce the duration gap between Asset and Liabilities.
- After a parallel shock on the interest rate curve, the MtM variation of the 5y10y straddle (blue) and of the Bermudan straddle (green), including the payment of premium on a running basis, is compared to the vanilla 5y10y straddle intrinsic value (red)
- Both strategies **provide some convexity**, however **not significant**
- **High break even** of +/- 75bps for the strategy of the 5y10y vanilla straddle
- For the vanilla swaption, any early termination to monetize the convexity is likely to happen then the straddle is deep in the money, in stressed market conditions where liquidity is poor
- The Bermudan strategy provide more flexibility but **can be exercised only one time** and is expensive

Comparative Study: Strip of FVA

Assumptions

- Hedging 1st order and 2nd order interest risk allows to put in place a management of the duration gap generated not only by a mismatch of asset/liabilities duration but also option and guaranties on the liability side
- First order duration hedges are assumed to be already in place to reduce the duration gap between Asset and Liabilities
- Convexity hedge program to be established for the next 5 years, allowing to generate a positive income in case of important interest rate movement to cover the costs of re-establishing the first order duration hedges

Objective of the Hedging Strategy

- Get a long exposure on rate convexity
- Monetize the convexity when needed or at least on a regular basis
- Cover the cost of rebalancing of first order duration hedges with the convexity hedging program
- We now use the strip of FVA:

Strip of FVA	
Notional	KRW 50B
Buyer	Investor
Swaption type	Strip of forward start Straddle
Strike	ATMF of then prevailing 1y10y straddle
Forward Strike	Spot, 1y, 2y, 3y and 4y (altogether 1 spot straddle and 4 forwards start straddle)
Expiry	1y from the Forward Strike date
Underlying Swap	10y swap With fixed rate paid on quarterly basis Act/365
Premium	**0.32%** paid on a running basis, same dates as payment dates of the fixed rate of all the forward start 1y10y swap for each straddle (need to pay this premium of over a notional of 5 times the notional of the strip) Overall cost is around **1.62% p.a.** for the notional of the strategy

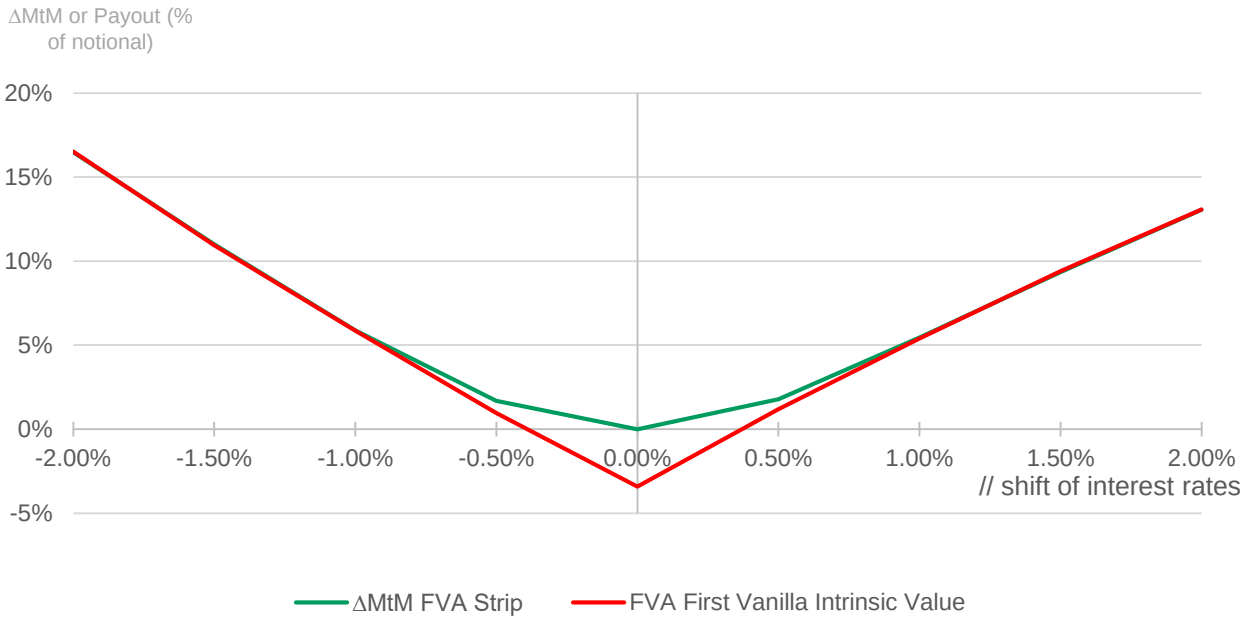
Benefits

- Uses straddle as a building block (i.e. vanilla product)
- Automatic monetization on a yearly basis during 5 years vs. only one time monetization for 5y10y straddle or Bermudan straddle
- Cheaper cost relative to 5y10y straddle

Considerations

- Forward strike feature may generate some hurdle in term of booking and valuation on investor side

Comparative Study: Strip of FVA



Indicative Pricing

Product	Running	Upfront
5y10y straddle	0.75 % p.a.	627 bps
Strip of FVA	1.62% p.a.	1405 bps
Strip of FVA average cost by straddle	0.32% p.a.	281 bps
Strip of spot straddle (1y10 … 5y10) for comparison	2.95% p.a.	2541 bps
Strip of spot straddle (1y10 … 5y10) average cost per straddle for comparison	0.59% p.a.	508 bps

Analysis

- The payment of the premium on a running basis allows to **reduce the directional exposure to rates** due to the discounting effect. First order duration hedges are assumed to be already in place to reduce the duration gap between Asset and Liabilities.
- After a parallel shock on the interest rate curve, the MtM variation of the strip of FVA (green), including the payment of premium on a running basis, is compared to the vanilla 1y10y straddle intrinsic value (red). This 1y10y vanilla option is the first option of the strip of FVA.
- The forward striking straddle of the FVA strip have **no sensitivity to any interest rate move**
- The FVA strip **provides the same convexity**, as a vanilla 1y10y swaption, at a lower cost.
- **Low break even** of +/- 40bps for the strip of FVA
- **Automatic monetization** of the convexity every year after the vanilla 1y10y expires
- In term of cost, this strategy provides five times the payout of a vanilla straddle and each individual straddle is cheaper compared to a spot start vanilla straddle

Solvency Capital treatment of Swaptions

K-ICS Framework

- K-ICS **allows use of Bond Forward** to reduce the solvency capital charge on the interest rate risk module
- Usage of Bond forward should however satisfy the following requirements:
  - Physical settlement at maturity
  - Application of hedge accounting to the bond forward transaction
- Swaptions are **not explicitely mentioned** as an authorized hedging tool to reduce the interest rate risk module

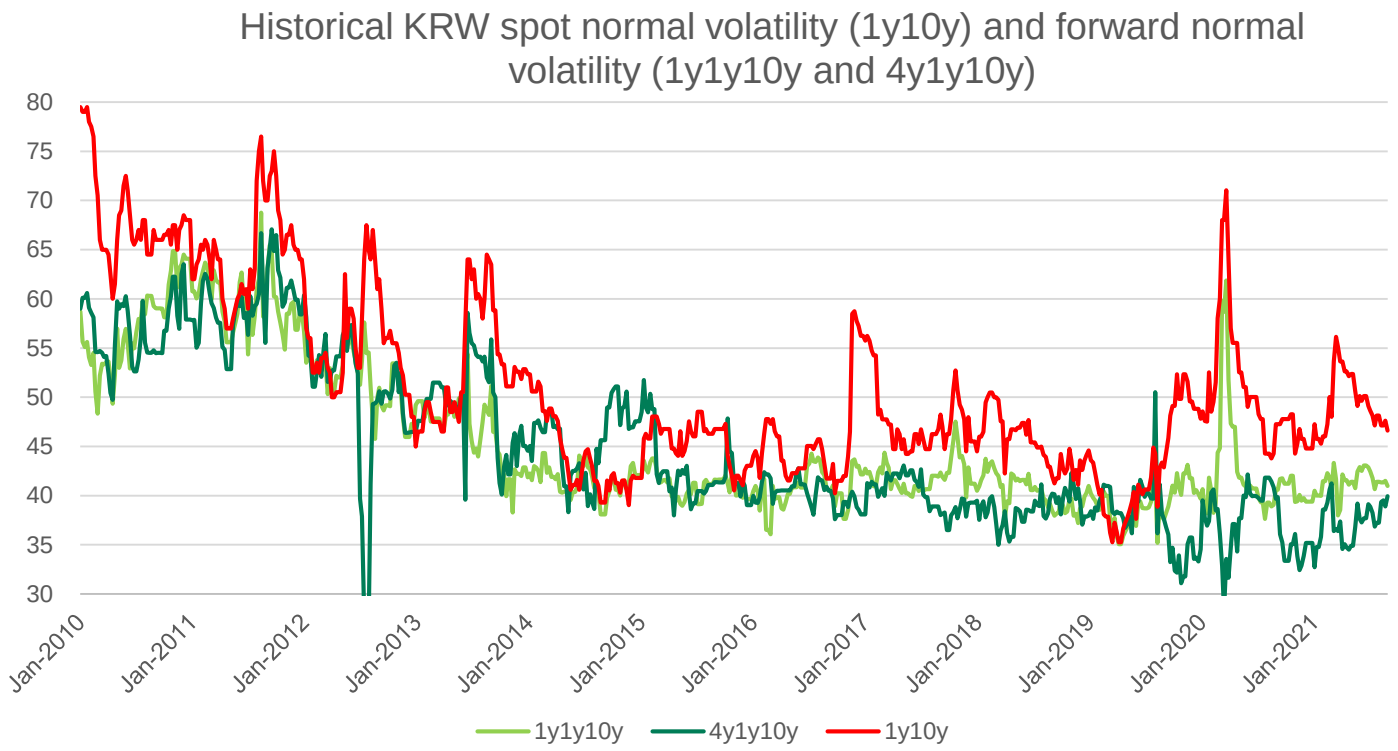
Europe Solvency II Framework

- **All interest rates derivatives are allowed** to be used to mitigate any interest risk of the balance sheet of Life Insurance companies
- Recognition in the interest rate risk module is done through calculating **the market value of derivative before and after** the interest rate shocks applied to the interest rate curve.
- This framework allows insurance companies to **use various derivative tools to reduce** significantly the **interest rate risk**

Singapore RBC2 Framework

- Interest Rate Swaps, futures, swaptions and futures are **allowed** in the calculation of the interest rate risk module
- These **derivative** should be **converted into equivalent cash position**:
  - E.g. for a receiver interest rate swap, convert to a long fixed rate bond position and a short floating rate bond position
  - E.g. for a swaption, convert to a long position or short position in a fixed rate bond, and apply adjustment for out of the money swaptions

Backtesting



Analysis

- Historically, forward volatility (green) is consistently cheaper than spot volatility (red) due to the properties volatility term structure in normal markets.
- This particular property gives a positive volatility carry to forward start volatility products
- Some rare market conditions make forward volatility more expensive than spot volatility, typically when shorter tenor swaptions become more expensive compared to longer tenor and when shorter expiries become cheaper than longer expiries
- In KRW market this was often related to central bank policy change which is impacting shorter tenors volatility

Short review of Convexity Solutions

Exposure	Long term Bond or IRS Receiver	Long/Short Bond or IRS	Swaption or Strangle	Vol Bond	Strip of FVA
Convexity	High	High	High	Linear exposure	High
Duration at inception	High	Neutral	High/Neutral	Low	Low
Rates Directional	Yes	Yes	Yes/No	No	No
Fixed Strike	N/A	N/A	Yes	No	No
Rates Slope	Yes	Yes	Yes	No	No
Potential loss	Bond Purchase Price	Unlimited	Swaption premium	Option premium	FVA premium
Systematic Monetization	No	No	No	Yes	Yes
Carry	Positive	Negative	Negative	Negative	Negative

Disclaimer

***Note on graphs / historical simulations:**
Data used in the graphs are sourced from Crédit Agricole Corporate and Investment Bank and/or Bloomberg.
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