QF609: Notes on Interest Rate Risk in Banking Book (IRRBB)

Tony Wong

January 17, 2024

IRRBB refers to the current or prospective risk to a bank's capital and earnings arising from adverse movements in interest rates that affect the bank's **banking book** positions. When interest rates change, the present value and timing of future cash flows change. This in turn changes the underlying value of a bank's assets, liabilities and off-balance sheet items and hence its economic value. Changes in interest rates also affect a bank's earnings by altering interest rate-sensitive income and expenses, affecting its net interest income (NII). Excessive IRRBB can pose a significant threat to a bank's current capital base and/or future earnings if not managed appropriately.

In April 2016, the Basel Committee on Banking Supervision finalized a new regulatory framework for IRRBB. It acknowledged that a previously proposed standardized approach under Pillar 1 (Minimum Capital Requirements) had raised wide concerns among industry participants, in particular on the complexities involved in formulating a standardized measure of IRRBB which would be both sufficiently accurate and risk-sensitive to allow it to act as a means of setting regulatory capital requirements. As a result, the Committee concluded that the heterogeneous nature of IRRBB would be more appropriately captured under a Pillar 2 approach.

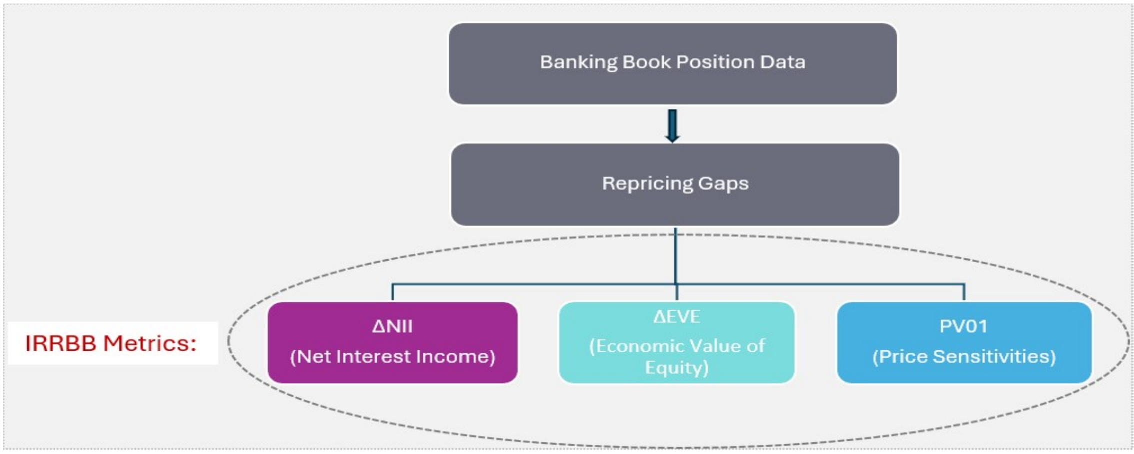
The finalized framework provides a set of revised IRR principles for defining supervisory expectations on the management of IRRBB. It also sets out the general guidelines for calculating the sensitivities of NII and economic value of equity (EVE) under a set of pre-defined interest rate shocks scenarios[1]. ΔNII and ΔEVE are the standard metrics for reporting IRRBB. The **repricing gaps**, extracted from the banking book positions, are the core inputs to the calculations of these IRRBB metrics.

There are three main sub-types of IRRBB are defined for the purposes, namely *gap risk*, *basis risk*, and *option risk*. Our focus is on gap risk. We shall provide an introduction to the basic concepts related to gap risk measurements for IRRBB:

- construction of repricing gaps for some representative banking book instruments
- methodologies for calculating ΔNII and ΔEVE

The general framework for calculating these IRRBB metrics in practice is illustrated by the following chart.

[1] EVE refers to the net present value of notional repricing cash flows for the whole banking book, excluding the bank's own equity capital.



1 The Repricing Gap Model

Within the contexts of IRRBB, **repricing** refers to the nearest future interest rate update/fixing event associated with a financial claim which can be a result of:

- a contractual interest rate fixing for an instrument payment
- a rollover/renewal of an expiring instrument or a partially retiring balance of an instrument

Interest rate repricing has an impact on a bank's future earnings as well as the economic value of a bank's assets and liabilities. To see this, simply consider a deposit sitting on a banking book which is expiring in one-year time. When the deposit expires and gets rolled over, the deposit rate applied to newly rolled-over deposit is likely to be updated if rates environment changes, i.e. the deposit gets repriced. A change in the deposit rate clearly will have impacts on the bank's future interest costs and hence its future earnings.

A repricing gap is charaterized by two important attributes, namely the repricing date and amount, whereby the repricing date is the nearest future date when the interest rate associated with an underlying instrument get refreshed and the amount is the notional exposure subject to repricing. It is worth noting the followings:

- the repricing amount for an asset (resp. liability) is expressed as a postive (resp. negative) number
- for some instruments such as mortgage, different portions of the principal amount may be repriced on different dates, the instrument in such cases is considered to have multiple repricing dates each of which is associated with a specific repricing amount

- if an instrument gets repriced periodically, with each repricing applying to the full notional amount, only the nearest next repricing date will be considered as its repricing date (we shall see one example in a later section)

Next, we shall look at how the repricing date and amount are determined for some representative banking book instruments.

1.1 Fixed Rate Deposit and Loan

Consider a 1-million fixed rate deposit expiring in 2Y with a contractual interest rate of 5%. We assume that the interest payments cover the interest amount only with the full deposit amount repaid at maturity. In this case, the deposit rate is fixed for two years and will only get repriced when the deposit expires and get rolled over. Therefore, the repricing date is 2Y and the amount is -1 million.

Similarly, consider a 1-million (interest-only) fixed rate loan expiring in 5Y with a contractual interest rate of 5%. We also assume that each periodic loan payment covers the interest amount only with the principal amount is repaid in full at maturity. In this case, the loan rate is fixed for 5Y. Hence, the repricing date is 5Y and the repricing amount is +1 million.

1.2 Floating Rate Deposit and Loan

Consider a 1-million deposit expiring in 2Y with the deposit rate being the 3M Libor rate. Interests are paid at the end of every 3M period based on the Libor rate fixed at the beginning of the period. In this case, the float rate, i.e. the Libor rate, for the first interest period is already fixed. The next interest rate fixing event occurs in 3M time. Therefore, the repricing date is 3M and the amount is -1 million.

This is a case where the instrument interest rate gets reset/repriced periodically, every 3M (on the full loan principal amount). Following our definition, the repricing date refers only to the nearest next interest rate reset date, which is 3M. There is a reason why the repricing date is defined this way in such cases. The reason is related to how the repricing date and amount are used in the calculations of IRRBB metrics (e.g. ΔNII and ΔEVE), which we shall see later.

The case of a floating rate loan is similar. Hence, we omit the details here.

1.3 Fixed Rate Mortage

While a fixed rate mortage is essentially a loan, its payment pattern is different from the fixed rate loan discussed above. More specifically, we consider a fixed rate mortgage with constant periodic loan repayments over the life of the mortgage. We further assume that there is no prepayment option. Hence, the mortgage is expected to stay on until its contractual maturity.

We have seen in the Excel example in class that the mortgage principal does not get repaid in full at one specific time. Instead, each loan payment consists of a certain amount of principal repayment. This is a case where the instrument has multiple repricing dates each of which is associated with a specific repricing amount (in this case, the repaid principal amount).

In this case, each loan payment date is a repricing date with the corresponding principal repayment amount being the associated repricing amount. The idea should be clear by noting that the principal repayment amount on any given loan payment date will need to be reinvested at an interest rate that will only be known on that payment date, i.e. subject to repricing at that point in time.

Some banks may approximate the repricing risk in such cases by considering all principal repayments being repriced on the mortgage maturity, and the repricing amount is the aggregated repayment amounts which is simply the full loan principal.

1.4 Interest Rate Swap (IRS)

We consider a standard single currency fixed-to-float IRS with no notional exchange. A typical example of this is a USD 3M Libor swap. It is clear that adding an notional payment to both legs at the maturity should not change the interest rate risk profile of the IRS. By adding the notional payments, however, we may consider the fixed leg as a fixed rate deposit or loan (depending on whether it's a pay or receive leg) and the float leg as a floating-rate deposit or loan. Then the repricng dates and amounts for the IRS can be determined accordingly.

1.5 Forward Starting Fixed Rate Loan

In the previous case of a fixed rate loan, an implicit assumption is that the initial funding instrument used to raise the initial loan principal for the borrower has already been accounted for by some instrument on the balance sheet whose repricing risk will be considered separately. As a result, the previous discussion focuses only on the repricing arising from the rollover of the loan.

Here, we consider a forward-starting loan whereby the expected amount is assumed to be known and the draw-down is expected to occur on some known future date. For example, a bank may have launched a 3Y fixed rate, say 5%, loan of which it expects to sell 50 millions with all draw-down occuring in 3M. In this example, there is a funding need in 3M to raises the initial 50 millions loan principal. The funding rate for the 50 millions will not be known until 3M time and hence is subject to repricing risk. As such, there are 2 repricing arising from this forward-starting loan:

- -50 million repriced in 3M
- +50 million repriced in 3Y3M.

The second repricing above simply accounts for the roll-over of the loan as it expires in 3Y3M.

1.6 Repricing Gap Report

An interest gap report produced by banks typically is a two-dimensional table with one axis representing a set of standardized time-to-repricing buckets over a selected planning horizon and the other axis representing the product category. In practice, a bank may also have IRRBB exposures across different currencies. In that case, some aggregation logic should apply. For simplicity, we shall consider the case of one exposure currency only.

For each banking book position, its repricing gap is slotted into one of the grids on the report based on its repricing date and product type, as shown in the following simplified example of a gap report.

time-to-repricing	loan	deposit	⋯	net gap
(0D,1M]	2	-10	⋯	-5
(1M, 2M]	3	-8	⋯	-15
(2M, 3M]	5	-20	⋯	5
(3M, 6M]	6	-25	⋯	15
(6M, 9M]	10	-10	⋯	-30
(9M, 1Y]	20	-5	⋯	-40
(1Y, 2Y]	⋯	⋯	⋯	⋯
(2Y, 3Y]	⋯	⋯	⋯	⋯
(3Y, 4Y]	⋯	⋯	⋯	⋯
(4Y, 5Y]	⋯	⋯	⋯	⋯
(5Y, 10Y]	⋯	⋯	⋯	⋯
Total	⋯	⋯	⋯	⋯

For each product column, each row entry corresponds to the sum of repricing amounts of all positions within that product category and with their repricing dates falling into the corresponding time-to-repricing bucket. For each time bucket, the repricing gaps are aggregated across all product categories which gives the net gap for that particular repricing time bucket.

It is worth noting that repricing risk arises not only from the imbalance between repricing asset and liability amounts but also the mismatching of repricing timing. To see the latter, consider again the example of a 2Y fixed rate deposit and a 5Y fixed rate loan, both with the same notional amounts. In this case, even though the total repricing amounts are zero, repricing risk still exists as the deposit will be repriced earlier and hence subject to risk of increasing funding costs in 2Y.

Once all positions of a banking book has been consolidated into an interest rate gap report, the report can be used to calculate the IRRBB metrics.

1.7 Limitations

While the repricing gap model appears to be simple and intuitive, it has some limitatons:

- It does not take into account repricing risks of interest payments. For example, the interests received from a loan (resp. paid to a depositor) are clearly subject to repricing risk due to reinvestment (resp. funding). Nevertheless, the repricing model effectively considers this as a second order risk and hence neglect it.
- Using standardized repricing buckets for a gap report can either understate or overstate the actual repricing risk.
- A gap report gives no indications of basis risk, i.e. items that appear to offest by virtue of having the same repricing date may not actually reprice by the same amount.
- behavioral assumptions need to be embedded into the repricing model to deal with contracts with balance amortization, prepayment, or early closure.

2 IRRBB Metrics

In what follows, we describe the calculation of the two commonly reported IRRBB metrics, *NII sensitivity (ΔNII)* and *EVE sensitivity (ΔEVE)*.

2.1 NII Sensitivity

NII Sensitivity is an earning-based measure which focus more on the sensitivities of a bank's short-term earnings to interest rate moves. To compute ΔNII, one needs to specify:

- an N-year time horizon (N is often chosen to be 1)
- a selected set of interest rate shock scenarios

For a given scenario s, we have

$$\Delta NII^s = \sum_{\{(T_i,A_i)\mid T\leq N\}} \Delta R_i^s \cdot A_i \cdot (N - T_i) \tag{1}$$

where T_i and A_i denote the time-to-repricing and the net repricing amount derived from the gap report. BCBS has specified two particular interest rate shock scenarios for ΔNII calculations. Once the sensitivities ΔNII^s under both scenarios are computed, a final reported number can be produced, e.g. the worst case ΔNII^s. When using the formula above, one typically applies a mid-point rule such that T_i is set to the mid-point of a time-to-repricing bucket.

It's worth noting that the NII sensitivity method assumes a constant balance sheet which means that:

- The total balance sheet size and shape are maintained by having like-for-like replacement of assets and liabilities as they run off. The maturing or repricing cash flows are replaced by new cash flows with identical features with regard to the amount, repricing period, and spread components.

2.2 EVE Sensitivity

The EVE sensitivity under a given interest rate scenario is calculated as the difference in the economic value of aggregated assets and libabilities between the base case and the scenario. Here, economic value of an instrument is given by the NPV of the repricing gap of the position under a specified discount curve. Therefore, we have:

$$\Delta EVE^s = EV_s - EV_0 \tag{2}$$

where

- EV_0: base EV of the banking book positions, given by the sum of all discounted interest rate gaps over all time buckets under a base discount curve.
- EV_s: scenario EV recalculated by applying the interest rate shock scenario s to the base discount curve.

BCBS has specified six interest rate shock scenarios for calculations of ΔEVE calculations which include both parallel and non-parallel yield curve shifts. Once the sensitivities ΔNII^s under all scenarios, a final reported number can be produced.

2.3 A Working Example

In the example below, we show the calculations of ΔEVE and ΔNII (assuming $N = 1$ for ΔNII). We also show the allocations of ΔNII over each time bucket. The results show that IRRBB still arises even if the total net gap is zero which is due to the mismatching of repricing timings.

NII sensitivity
scenario +200bp

bucket	(in year)	1y	gap	ΔNII_k
1M	0.0417	0.9583	-5.0000	-0.0958
2M	0.1250	0.8750	-15.0000	-0.2625
3M	0.2083	0.7917	5.0000	0.0792
6M	0.3750	0.6250	15.0000	0.1875
9M	0.6250	0.3750	-30.0000	-0.2250
1Y	0.8750	0.1250	-40.0000	-0.1000
			ΔNII (Total)	**-0.4167**

NII sensitivity allocation

		ΔNII Allocation					
bucket	ΔNII_k	[0M, 1M]	[1M, 2M]	[2M, 3M]	[3M, 6M]	[6M, 9M]	[9M, 1Y]
1M	-0.0958	-0.0042	-0.0083	-0.0083	-0.0250	-0.0250	-0.0250
2M	-0.2625		-0.0125	-0.0250	-0.0750	-0.0750	-0.0750
3M	0.0792			0.0042	0.0250	0.0250	0.0250
6M	0.1875				0.0375	0.0750	0.0750
9M	-0.2250					-0.0750	-0.1500
1Y	-0.1000						-0.1000
Total	**-0.4167**	**-0.0042**	**-0.0208**	**-0.0292**	**-0.0375**	**-0.0750**	**-0.2500**

		Discount Curve						EV	
			Tenor	Zero Rate		Discount Factor			
Bucket	Net Gap	Tenor	(in year)	base	parallel shift	base	scenario	base	scenario
1M	-5	1M	0.08	0.4330%	2.4330%	0.999639	0.997975	-5.00	-4.99
2M	-15	2M	0.17	0.5227%	2.5227%	0.999129	0.995804	-14.99	-14.94
3M	5	3M	0.25	0.5985%	2.5985%	0.998505	0.993525	4.99	4.97
6M	15	6M	0.50	0.7817%	2.7817%	0.996099	0.986188	14.94	14.79
9M	-30	9M	0.75	0.9289%	2.9289%	0.993058	0.978273	-29.79	-29.35
1Y	-40	1Y	1.00	1.0554%	3.0554%	0.989501	0.969908	-39.58	-38.80
2Y	5	2Y	2.00	1.4548%	3.4548%	0.971323	0.933237	4.86	4.67
3Y	10	3Y	3.00	1.7419%	3.7419%	0.949084	0.893814	9.49	8.94
4Y	5	4Y	4.00	2.0088%	4.0088%	0.922792	0.851845	4.61	4.26
5Y	20	5Y	5.00	2.2626%	4.2626%	0.893036	0.808053	17.86	16.16
6Y	5	6Y	6.00	2.4738%	4.4738%	0.862063	0.764581	4.31	3.82
7Y	15	7Y	7.00	2.6683%	4.6683%	0.829624	0.721240	12.44	10.82
8Y	0	8Y	8.00	2.8496%	4.8496%	0.796149	0.678434	0.00	0.00
9Y	5	9Y	9.00	3.0200%	5.0200%	0.762006	0.636481	3.81	3.18
10Y	5	10Y	10.00	3.1682%	5.1682%	0.728463	0.596415	3.64	2.98
Total	**0**								

EV_0	-8.39
EV_s	-13.48
EVE sensitivity	**-5.09**

2.4 Reconciling ΔEVE and ΔNII

While ΔNII differs from ΔEVE in that it focuses on IRRBB from an earning perspective within a pre-defined short-term horizon, we shall show that the two concepts can be reconcilled and interpreted similarly using a simple example where the balance sheet simply consists of the following two positions:

- a \$100 5-year fixed rate loan paying 5% annually
- a \$100 1-year fixed rate deposit to fund the loan which pays 5% annually

The gap report will look like below:

time-to-reprice bucket	deposit	loan	net gap
1Y	-100	0	-100
2Y	0	0	0
3Y	0	0	0
4Y	0	0	0
5Y	0	100	100
Total	-100	100	0

Furthermore, we assume:

- The base discount curve is 5% flat for all maturities. Here, we assume the 5% is an effective annually compounded rate, i.e. for any maturity t (expressed in years), the discount factor is given by $(1 + 5\%)^{-t}$.
- The scenario is a +200bps parallel shift to the base curve.
- For ΔNII, the planning horizon is $N = 5$. For this example, we use the exact time-to-reprice for T in the calculations (instead of applying the mid-point rule).

Following the above, we should obtain:

$$\begin{aligned}
\Delta EVE &= \left[\frac{100}{1.07^5} + \frac{-100}{1.07}\right] - \left[\frac{100}{1.05^5} + \frac{-100}{1.05}\right] = -5.27, \\
\Delta NII &= -100 \cdot 4 \cdot 0.02 = -8.
\end{aligned}$$

Hence, the two measures agree in sign but not in value.

To reconcile the two, we further take into account the below for ΔEVE calculations:

- repricing risk of the interest payments associated with the deposit and the loan
- impacts of the interest rate shock on deposit interest payments occurring after its repricing date

With this in mind, we will have two gap reports under the base case and the scenario for the ΔEVE calculation:

time-to-reprice bucket	Base: 5% flat deposit	loan	net gap	Scenario: parallel shift +200bps deposit	loan	net gap
1Y	-5	5	0	-5	5	0
2Y	-5	5	0	-7	5	-2
3Y	-5	5	0	-7	5	-2
4Y	-5	5	0	-7	5	-2
5Y	-105	105	0	-107	105	-2
Total	-125	125	0	-133	125	-8

Using the net gaps in the base case and the scenario case, we have:

$$\Delta EVE = \sum_{i=2}^{5} \frac{-2}{1.07^i} = -6.33.$$

To reconcile the above ΔEVE with ΔNII, we take into account discounting effect on the NII assuming the interest rate scenario is realized now:

$$\Delta NII = \sum_{i=2}^{5} \frac{-100 * 0.02}{1.07^i} = -6.33.$$

In this case, the ΔNII can be interpreted as the additional funding cost/surplus as of today if the scenario becomes realized today and holds valid until the relevant repricing dates.