Explanatory note on portfolio risk modelling in the New Zealand context

1. This note provides background information on some of the modelling the Reserve Bank undertook as part of the Capital Review, as detailed in paragraphs 50 to 61 of the Consultation Paper "Capital Review Paper 4: How much capital is enough?".

2. One approach to assessing the minimum quantum of capital required to ensure a bank's solvency is to quantitatively model the probability and extent of potential credit losses. A common approach is called "Value-at-Risk" (VaR), using an estimated loss distribution to calculate the amount of capital required to limit the likelihood of a bank's insolvency to a specified probability.

3. The VaR concept lies behind the internal-ratings based (IRB) approach to credit risk introduced in Basel II in 2006. In the IRB approach banks combine their own estimates of parameters for their credit exposures (PD, EAD, LGD) with supervisory-specified inputs (CL, R) and a supervisory-specified equation (Table 1).[1] Given these inputs and the supervisory equation, the bank derives a regulatory capital requirement. The sum of these values represents the bank's minimum regulatory capital requirements for credit risk.

4. We used a variant of the Basel IRB model to supplement our other analysis in coming to a view on the appropriate level of capital for New Zealand banks. Rather than modelling a portfolio of individual loans, we took a highly stylised, top-down approach that models the New Zealand banking system as a single credit exposure. Conceptually, we are modelling the capital that creditors of New Zealand banks would require to protect themselves from loss with a given probability, taking into account the risk profile of New Zealand banks' assets.

Table 1: Inputs to the Basel IRB model

Probability of default (PD)	The likelihood that a credit exposure will default, averaged over a range of economic conditions. Expressed as an annual rate.
Exposure at default (EAD)	The expected notional value of a credit exposure at the point of default.
Loss given default (LGD)	The proportion of EAD expected to be lost following default, calibrated to economic downturn conditions.
Confidence level (CL)	The probability that, over a one year horizon, unexpected losses on a portfolio of credit exposures will not exceed the amount of capital. In the Basel IRB approach, this is set at 99.9 percent.
Asset correlation (R)	The degree to which the default of a credit exposure is related to the systematic risk factor in the model. Represents how strongly linked defaults in a credit portfolio are to general economic conditions, as opposed to idiosyncratic factors. In the Basel IRB approach this is set between 0.03 and 0.3 depending on the type of credit exposure, and, in some cases, PD and the size of the counterparty's business.

[1] Note there also is a parameter for some asset classes which incorporates the increasing credit risk of exposures with longer maturities, which we have not included in this analysis.

5. The theoretical model underlying the Basel IRB approach has a number of simplifying assumptions that were seen by the Basel Committee as a necessary compromise to make the framework computationally tractable for banks and supervisors, and applicable to a diverse range of bank business models and credit portfolio compositions (a property known as portfolio invariance). Model uncertainty and estimation errors mean that in practice the IRB approach is likely to deliver a lower level of solvency than implied by the notional 99.9 percent confidence level chosen by the Basel Committee.[2]

6. Implied solvency is also likely to be lower when applying the Basel IRB model to less diversified banks. While the choice of a single risk factor structure for the model leads to the desired portfolio invariance outcome, the Basel Committee calibrated the model (through CL and R) to the perceived capital needs of a group of large, internationally active banks. The calibration of the Basel IRB framework therefore implicitly assumes a degree of portfolio and geographic diversification that is unlikely to be present in banks with narrower business model focusses, such as those operating in New Zealand. All else being equal, this means that the capital requirements determined by applying the Basel IRB framework to less diversified institutions will deliver a lower level of solvency than the notional 99.9 percent chosen by the Basel Committee.

7. A further point is that the 'failure threshold' in the Basel IRB model, i.e. the level of capital at which the bank is deemed insolvent, is implicitly set at a capital ratio of 0 percent. In our view it is likely that a bank would reach a point of non-viability (inability to retain creditor confidence) sooner than the point of reaching zero capital. It therefore seems reasonable when using the Basel IRB model to assess minimum capital requirements to deem failure to occur at some small, positive capital ratio.[3]

8. We see the primary role of the Basel IRB model as being a useful tool for assessing the relative levels of risk in different credit portfolios and across banks. The limitations of the underlying model discussed above suggest a significant degree of caution should be exercised in using it as an analytical tool for calculating the minimum level of capital needed to deliver a particular solvency outcome for the banking system as a whole (the focus of the Reserve Bank's analysis in the Capital Review). The notional solvency outcomes that the Basel IRB model produces (e.g. 99.9 percent) should not be taken at face value.

9. With these limitations in mind, we still consider that exploratory analysis using the model can be a useful complement or sense check on the other material considered as part of the Capital Review (such as international literature on the relationship between capital and banking crises, stress testing, and modelling of 'optimal capital').

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[2] For example, over long time series economic variables rarely exhibit the normal distribution that the model assumes for firms' asset returns. For further discussion, see for example Thomas, H. and Wang, Z. (2005), "Interpreting the internal ratings-based capital requirements in Basel II", *Journal of Banking Regulation* 6(3), Tarashev, N. and Zhu, H. (2008), "Specification and Calibration Errors in Measures of Portfolio Credit Risk: The Case of the ASRF Model", *International Journal of Central Banking* 4(2) and BCBS (2005), "An Explanatory Note on the Basel II IRB Risk Weight Functions", https://www.bis.org/bcbs/irbriskweight.pdf.

[3] Expected shortfall or other risk measures that focus on the expected losses in the tail region of a credit loss distribution may be more useful in assessing residual capital following the realisation of a large shock.

Applying the model to New Zealand data

10. A key constraint to credit risk modelling in New Zealand is the relatively limited availability of detailed credit performance data covering a range of economic conditions, including an economic downturn, for estimation of the inputs required by the Basel IRB model. For example, the Reserve Bank's view is that the 2008-2009 recession in New Zealand is not, on its own, a sufficiently severe event for the estimation of appropriately calibrated PD, LGD and EAD inputs for the Basel IRB model. That is, while the Global Financial Crisis was a significant historical crisis by global standards, the downturn in New Zealand was relatively less significant.

11. Data on credit losses during the early 1990s would provide a more reliable basis for estimation of the inputs needed for the Basel IRB model than the GFC period. However this data was not readily available at granular levels (e.g. segmented by types of lending), in the correct form (flow measures of credit impairment rather than stocks), or at high enough quality. Moreover, the lending composition of New Zealand banks' balance sheets has changed materially over the subsequent decades, potentially lessening the historical data's relevance.

12. As a result, when using the Basel IRB model to assess the capital needs of a representative New Zealand bank balance sheet we drew on a range of sources to form a view of appropriate model inputs:
    - historical New Zealand credit loss data, where available;
    - outputs of IRB models currently in use by New Zealand banks;
    - outcomes from stress tests of New Zealand banks; and
    - our own judgement.

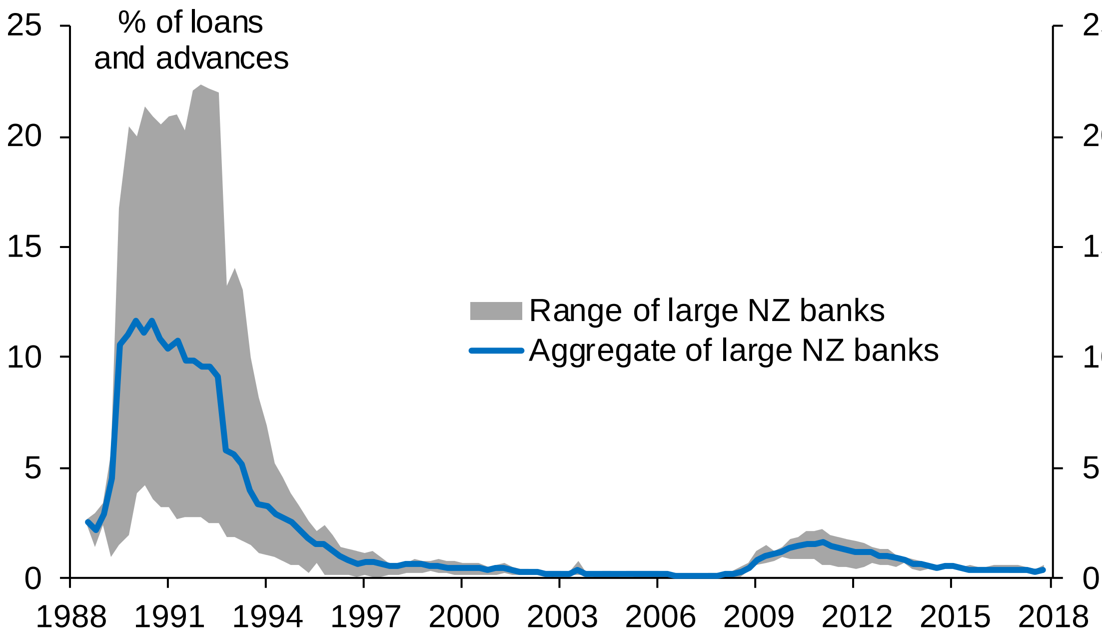
13. Table 2 summarises the data sources considered when determining a modelling range for the PD input. As context for the historical New Zealand data, figures 1 and 2 plot the ratio of impaired assets to loans and advances, and impaired asset expense to loans and advances, for the five large New Zealand banks in the data sample (1988Q3 to 2017Q4). For our modelling we settled on a range of 1-3 percent for the PD input, taking into account the difficulties noted in the table in translating the available data to a PD that is conceptually consistent with the Basel IRB framework.

Table 2: Inputs for a long run average PD of New Zealand bank portfolios

Information source	Outcomes	Notes	Limitations
Impaired assets to loans and advances ratio	0.8-3.6% (range of 5 large banks) 2% (aggregate of 5 large banks) 2.1% (simple average of all banks with >2% of total system assets at observation date) 3.1% (simple average of all banks)	Average of quarterly observations from 1988Q3 to 2017Q4.	Impaired asset ratio measures the stock of non-performing credit exposures. This needs to be divided by an assumed average workout period (e.g. 1.5 years) to convert to an annual PD estimate. Does not include past due (but not yet impaired) assets.
Impaired asset expense plus extraordinary items to loans and advances ratio	0.2-0.5% (range of 5 large banks) 0.4% (aggregate of 5 large banks) 0.4% (simple average of all banks with >2% of total system assets at observation date) 0.3% (simple average of all banks)	Average of quarterly observations 1989Q2 to 2017Q4 (12 month rolling). Includes extraordinary items to capture credit-related restructuring costs incurred by some banks in the early 1990s data.	Impaired asset expense measures flows of net credit losses. This needs to be divided by an assumed average loss given default (e.g. 20%) to convert to a PD estimate. Does not include past due (but not yet impaired) assets.
Impaired and past due assets to total assets ratio	1.4% (aggregate of all banks)	Average of quarterly observations 1989Q2 to 2017Q4. Includes past due (but not yet impaired) assets only after 1996.	Impaired asset ratio measures the stock of non-performing credit exposures. This needs to be divided by an assumed average workout period (e.g. 1.5 years) to convert to an annual PD estimate. Includes assets in the denominator of the ratio that do not bear credit risk.
IRB model outcomes	1.4% (September 2010) 1.1% (March 2018)	Exposure-weighted average values across the aggregate credit portfolios of four IRB banks.	IRB model outcomes at a point in time can reflect cyclical rather than long run risk factors.
Stress tests	2.7% (2014 test) 2.8% (2017 test)	Average annual default rate over 5 year stress scenario, from RBNZ industry stress tests.[4]	Reflects a simulated economic downturn, not a full range of economic conditions.

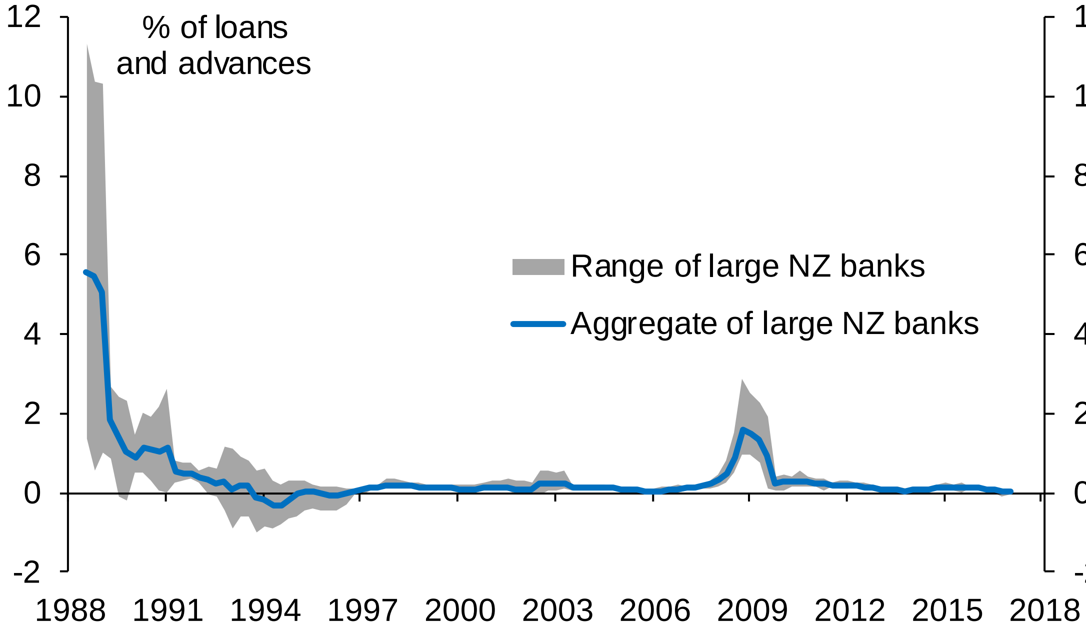
[4] See Lilly, C. (2018), 'Outcomes from the 2017 stress test of major banks.' *Reserve Bank of New Zealand Bulletin* 81(9).

Figure 1: Impaired assets as a share of gross loans and advances, large New Zealand banks



Note: “large NZ banks” includes ANZ, ASB, BNZ, National Bank, and Westpac.

Figure 2: Impaired asset expense and extraordinary items (12 month rolling total) as a share of gross loans and advances, large New Zealand banks



Note: data begins from the year to June 1989.

14. The LGD input for the Basel IRB model should reflect the loss in economic value of banks' defaulting credit exposures in economic downturn conditions. The need to calibrate LGDs to downturn conditions accentuates the issue discussed earlier of having limited detailed data available on downturn credit losses in New Zealand. The two primary sources of information we used to determine the range of LGDs for our modelling were the IRB models currently used by New Zealand banks and outcomes from recent Reserve Bank industry stress tests.

15. Table 3 provides a summary of New Zealand IRB model outcomes by portfolio as at March 2018. In some cases (farm lending and residential mortgages), banks' LGD estimates are prescribed by the Reserve Bank, which were informed by modelling work we undertook when implementing the IRB approach in New Zealand. Reflecting the relatively high weighting of New Zealand banks' portfolios towards lending collateralised by real estate, as at March 2018 the weighted average LGD estimate was 29 percent.

Table 3: New Zealand IRB model estimates (average of four IRB banks, March 2018)

IRB asset class	Average PD (%)	Average LGD (%)	% of total EAD
Sovereign	0.02	14	5
Banks and PSEs	0.04	53	5
Corporate (large)	0.62	47	10
Corporate (small)	1.68	35	6
Corporate (farm lending)	2.27	32	10
Commercial property	1.08	22	7
Residential mortgage	0.89	20	47
Retail – SME	2.14	41	2
Retail – credit cards	1.27	77	3
Retail – other	4.91	88	1
Weighted average	1.1	29	

Source: RBNZ Quantitative Impact Study (2018)

16. To supplement banks' LGD estimates we considered outcomes from recent Reserve Bank stress tests, which typically feature significant declines in asset prices. Over the 5 year scenarios assessed in the 2014 and 2017 tests banks' weighted average LGD was 37 percent and 31 percent respectively.

17. For the asset correlation parameter (R) we firstly considered the current calibrations in the Basel IRB model (e.g. 0.12 to 0.24 for corporate exposures). Taking into account the genesis of these calibrations by the Basel Committee and their

applicability to New Zealand banks, discussed above, we adopted a benchmark range of 0.16 to 0.4 for the correlation input in our analysis.[5]

Modelling approach

18. We considered two broad approaches to modelling capital using the Basel IRB model: sensitivity analysis of a range of specific calibrations of the model, and a Monte Carlo-type approach. Given the limitations of what can be achieved using the model for assessing the minimum capital needed to deliver a particular solvency outcome, and that we do not know the true underlying values of the various risk inputs to the model, it would be erroneous to think one could use the model to arrive at a definitive calibration and minimum capital outcome. Instead, our aim was to explore how a range of plausible calibrations of the model, and variations to those calibrations, affect the conclusions one can draw about appropriate minimum capital requirements.

19. Our analysis focussed only on capital requirements for credit risk. Capital for operational and market risks, which are also subject to their own requirements in the current framework, is assumed to be unchanged from current levels. This amounted to adding one percentage point to the resulting capital ratio from the Basel IRB model.

20. The output of the Basel IRB model is a capital amount as a proportion of EAD. We convert this to a capital ratio by dividing by the average IRB risk weight (RWA/EAD) expected after our proposed changes to the calibration of the IRB approach, 52 percent.

21. Our notional target is for bank failure to occur no more frequently than once every 200 years. Naively, this would imply setting the value for the confidence level in the Basel IRB model at a value of 0.995. However, for the reasons noted earlier, significant modelling uncertainties such as the effect of the normality assumption would suggest a higher confidence level is appropriate in the model to produce an outcome consistent with a 0.5 percent solvency target in practice. We considered the range of 99.5 to 99.9 percent for the model's confidence level, though it is open for debate whether an even higher confidence level would be more appropriate.

22. Furthermore, we needed to form a view on the appropriate failure threshold, that is, the capital ratio at which a bank would no longer be able to maintain creditors' confidence. The starting point for this in our modelling was 0 percent, consistent with the Basel IRB framework where failure occurs at the point capital is fully exhausted. However, to be more realistic we also considered a failure point of a capital ratio of 2 to 4 percent.

23. Table 4 shows the results of sensitivity analysis of one illustrative calibration of the model. From the initial outcome of 15.5 percent, more (less) conservative settings for each input tend to increase (decrease) the resulting outcome by around 2.5 (2) percentage points.

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[5] Although the role of the asset correlation parameter in the modelling was slightly different, we adopted a similar range in our modelling of optimal capital for New Zealand banks in 2016, and as part of the 2012 RIS analysis for the adoption of Basel III (a range of 0.2-0.4).

Table 4: Sensitivity analysis of an illustrative calibration

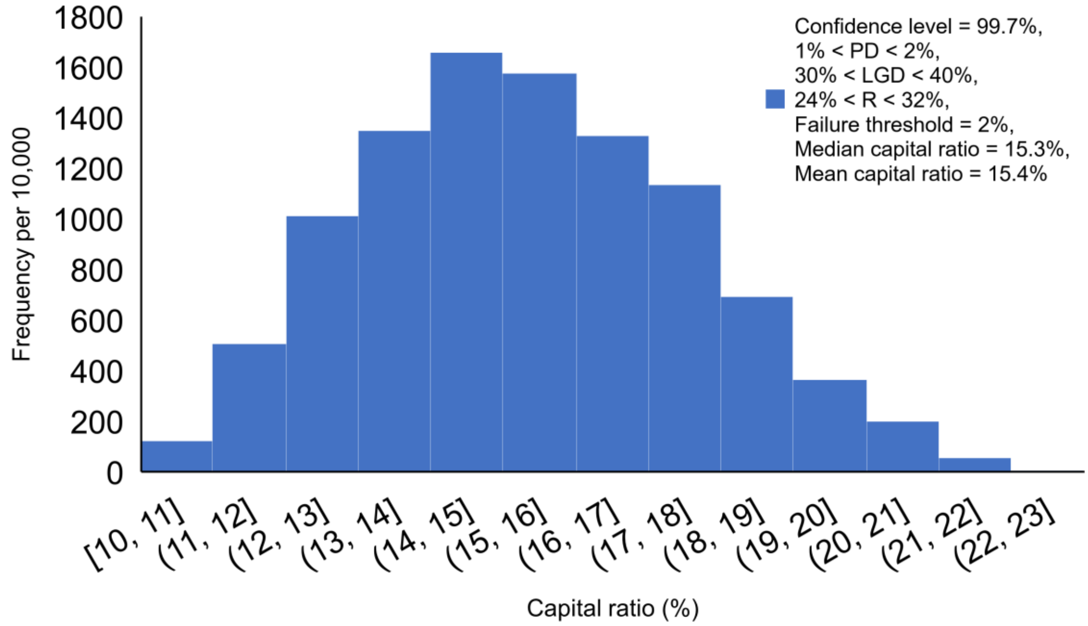
Model input	Initial setting	Lower PD	Lower LGD	Lower R	Lower CL	Higher PD	Higher LGD	Higher R	Higher CL
PD (%)	1.5	1.2	1.5	1.5	1.5	2.0	1.5	1.5	1.5
LGD (%)	35	35	30	35	35	35	40	35	35
R (%)	28	28	28	24	28	28	28	32	28
Confidence level (%)	99.7	99.7	99.7	99.7	99.5	99.7	99.7	99.7	99.9
Failure threshold (%)	2	2	2	2	2	2	2	2	2
Capital ratio (%)	15.5	13.9	13.7	13.7	13.6	17.9	17.3	17.5	19.9

24. A complementary approach we considered is Monte Carlo analysis, where we do not specify the settings of each model input, rather we set ranges from which values are randomly drawn. This allows us to see the shape of the distribution of capital ratio outcomes for different input settings. The intuition behind taking this approach is that given the uncertainty involved, we are more confident in setting a range for the various model inputs than setting precise values.

25. In the Monte Carlo analysis, PD, LGD and R in the Basel IRB model were randomly drawn 10,000 times from uniform distributions that we specified. We did not impose any correlation structure across the three inputs. The Monte Carlo analysis is analogous to assessing the capital requirements for a bank with 10,000 equally sized loans with IRB inputs drawn randomly from the specified ranges.

26. Figure 3 is a histogram plotting the 10,000 outcomes from applying the same ranges for PD, LGD and R considered in the illustrative calibration in Table 4. The mean capital ratio outcome approximately matches the base case outcome, since we assume a uniform distribution.

Figure 3: Monte Carlo analysis (PD 1-2%, LGD 30-40%, R 24-32%)



27. In Figure 4 we widen the range of the R input, from 24-32 percent to 16-40 percent. While the expected value of R is the same, the result is an increase in the right tail of the capital ratio distribution as the increased number of scenarios with very high asset correlations leads to an increase in the number of large tail loss outcomes. As a result, the mean capital ratio across 10,000 draws increases from 15.4 percent to 15.6 percent. Taking similar approaches for the other inputs to the Basel IRB model, we used the Monte Carlo analysis to explore the implications of different levels of confidence we had in the appropriate values for each of the model inputs.

Figure 4: Monte Carlo analysis (PD 1-2%, LGD 30-40%, R 16-40%)