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Capital Review Background Paper:

An outline of the analysis supporting the risk appetite framework

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Contents

Overview

The likelihood a bank will remain solvent when subject to unexpected losses reflects, in part, the amount of capital funding provided to the bank by shareholders.[1] When considering the level of capital to invest, shareholders do not take the societal impacts of bank failure into account and thus banks have insufficient capital from a societal perspective. Placing minimum capital requirements on banks is a tool used by bank regulators to address this issue.

The consequences of banks having low levels of capital relative to the risks they face were made clear during the Global Financial Crisis ('GFC'). During the GFC the failure of large, systemically important banks in advanced economies had severe economic impacts in those economies, and globally, and burdened taxpayers in some countries with significant bank bail-out costs.

In December 2018 the Reserve Bank proposed increasing the Tier 1 capital required of systemically important banks to 16 percent of risk weighted assets ('RWA'), with 6 percent of this a regulatory minimum and the remaining 10 percent a prudential capital buffer.[2] The purpose of this report is to outline in more detail than has been provided thus far, the information and analysis that informed the December 2018 proposal to increase Tier 1 capital requirements.

This paper does not provide a cost-benefit assessment of the proposal to increase bank capital, but has been prepared in order to provide further information to those who wish to provide feedback during the consultation process which ends on 3 May 2019.

The Reserve Bank will carry out a full cost-benefit assessment for a Regulatory Impact Statement to help inform and describe final decisions in the review. The concepts discussed in this Background Note will be an important component of that cost-benefit assessment. The full assessment will also consider any submissions received during the consultation period, as well as looking at alternative scenarios to look at risks around estimates of costs and benefits.

The setting of minimum capital requirements relies on the exercise of judgement. This is because banks are required to have capital in anticipation of large unexpected shocks, and the nature, timing, scale and impact of future shocks is unknown.

Given the inherent uncertainty involved, the Reserve Bank considers a wide range of information and analysis prior to setting minimum capital requirements. While the consultation document set out the rationale, broad information set and analysis relied upon in the proposals, this Paper expands the description of the underlying information set, the analytical framework and the quantitative analysis that was undertaken in forming the proposals.

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[1] 'Capital' in this context means shareholder equity invested in the bank.
[2] 'Tier 1' capital refers to equity provided by shareholders and 'equity-like' debt funding. For the purposes of this paper we consider Tier 1 to be made up solely of shareholder equity.

Introduction

Regulatory capital requirements are periodically reviewed and revised. Major reforms occurred in New Zealand in 2012, prompted by the Basel Committee of Banking Supervision's ('BCBS') introduction of new international regulatory capital standards (known as 'Basel III'). More recently, a comprehensive review of bank capital regulation was announced by the Reserve Bank in March 2017 and remains ongoing.

As part of the current review, in December 2018 the Reserve Bank proposed increasing the Tier 1 capital required of systemically important banks to 16 percent of risk weighted assets ('RWA'), with 6 percent of this a regulatory minimum and the remaining 10 percent a regulatory capital buffer.[3] Currently the weighted average ratio of Tier 1 capital to RWA in the banking system is 12.2 percent, which is significantly above the current regulatory requirement of 8.5 percent.[4]

The purpose of this report is to outline in detail the information and analysis that informed the December 2018 proposal to increase Tier 1 capital requirements. This information and analysis can be broadly described as follows:

Findings from the theoretical and empirical literature.[5]

- There is a large body of capital policy literature that is global in scope and explores relevant issues in considerable depth. This literature has played a pivotal role, underpinning the proposals announced as part of the current Capital Review and the earlier 2012 capital policy decisions.
- The international literature is particularly important in New Zealand's case because New Zealand has limited experience of severe banking stress. There is limited crisis-related information in New Zealand's historical economic data and no local case studies of banks' experiences during a systemic crisis upon which to draw. [6]
- The international literature has contributed to the policy design in a myriad of areas:
  - o It establishes a theoretical framework for thinking about capital policy. This framework has at its core three relationships relating to capital. These are the impact of capital on the probability of bank failure; the impact of a crisis on output; and the impact of capital on lending rates and thus equilibrium output.
  - o The Reserve Bank's policy goal follows directly from this framework;
  - o The literature provides high level theoretical and empirical findings about the amount of capital needed to achieve given policy goals (for example, empirical estimates of the amount of capital that would have been sufficient to prevent historical bank failures with a given probability). This body of work provides a valuable benchmark for more detailed, issue-specific analysis;

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[3] The proposed minimum Tier requirement for banks that are not deemed to be systemically important is 15 percent of RWA.
[4] These estimates of the Tier 1 capital held currently are based on RWA values that incorporate proposed changes to the RWA calculation made by the large four banks (the 'output floor and scaler' proposal). For remaining banks the estimate refers to reported Tier 1 ratios.
[5] Refer the references in this paper and see Appendix A for supplementary material. For example, Brooke et al (2015); Cline (2016); Firestone et al (2017); Schanz (2011).
[6] Some New Zealand banks experienced large losses in the early 1990s but this is not considered a systemic crisis by those who have developed comprehensive criteria to identify banking crises. Refer for example Laeven and Valencia (2012 and 2018).

- o The literature supplies a variety of methodologies to use to derive quantitative estimates of the three key relationships;
- o These methodologies range from collating historical loss data in order to estimate capital needs, undertaking regression analysis using cross-sectional or time series data and using models to undertake sensitivity analysis (for example, measuring the impact of different assumptions about shareholder return objectives to derive estimates of the impact of capital increases on lending rates); and
- o Quantitative estimates of the key relationships are provided in the literature.

Results from stress tests

- The Reserve Bank periodically undertakes stress testing exercise with locally incorporated banks. The Reserve Bank creates a hypothetical stress scenario and works with banks to determine how the event would impact on their balance sheets.[7] [8] The findings from the exercise relate to the likelihood a given bank will emerge from the scenario as a going concern.
- The results of the stress tests are dependent on the assumptions that form the basis of the stress scenario, and assumptions about how the banks respond during the stress event (for example, do they maintain interest margins during the stress event).

Findings from quantitative modelling

- Regulators must consider the local context, when feasible, when considering possible capital settings.
- One way to incorporate the local context is to consider, at a high level, relevant structural aspects of the banking system and the implications of these. An example would be the foreign dominance of the New Zealand banking sector and the implications of this in the event of bank failure (does foreign dominance complicate bank resolution, for example).
- Where feasible, local context can also be considered by undertaking quantitative analysis relating to the three key relationships that underpin capital policy. This includes regression analysis and/or using stylised models of the banking sector.
- The potential relevance of regression analysis for capital policy setting is limited in New Zealand because of the absence of a systemic banking crisis in New Zealand's post-war economic record. Unlike other countries, the data set cannot provide information about important issues such as the degree to which the correlation of loan defaults across asset classes, for example, changes during systemic crises.
- However quantitative modelling remains a valid option in the New Zealand context. Modelling involves using stylised tools to explore the level of capital that might be required to achieve a given policy goal. Model-based analysis involves creating a simple set of relationships to represent the issues of interest. By varying model inputs, within set ranges, analysts can conduct sensitivity tests. The model outputs vary with changes in input values and the relative frequency of different outputs can be compared.

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[7] Reserve Bank (2018).
[8] Dunstan A (2018); Lilly, C. (2018) .

- In the case of capital policy setting in New Zealand, modelling has been used to explore the relationship between capital and the probability of a banking crisis, the relationship between capital and lending rates, and, synthesising these, the relationship between financial stability and expected output.
- Model-based analysis allows for the incorporation of overseas experience, when deemed appropriate. For example, input value ranges can be informed by local data and views, as well as overseas findings, and model outputs can be contrasted with results from overseas.
- Model-based analysis informed the 2012 capital policy decisions and the December 2018 capital ratio proposals built on this earlier modelling work. The same stylised model was used in both cases to represent the relationship between capital and the probability of a crisis, for example. However the December 2018 analysis used different input values for this model, reflecting new information (including overseas findings). Moreover (unlike in 2012), most recently, detailed analysis was done to explore the relationship between capital and lending rates in New Zealand.
- In both 2012 and 2018 explicit consideration was given to risk aversion by the Reserve Bank. In 2012 this led to a weighting regime being assigned to the output benefits of capital. In contrast, in the recent case, an alternative approach was taken with the policy goal incorporating a cap on the probability of a crisis (capital has to be sufficient to meet an unexpected loss as large as that which might arise once every 200 years).

Information from each of these sources – the international literature, stress testing and quantitative modelling - was considered when designing the capital proposals released for consultation in December 2018.

The purpose of this paper is to outline the analytical framework that underpins capital policy setting in the literature; show how this framework leads directly to the policy objective that has been defined by the Reserve Bank; and describe the information and analysis that has been considered by the Reserve Bank in the context of the recent capital proposal.

This paper is not intended to provide a cost-benefit assessment of the proposal. The Reserve Bank will carry out a full cost benefit assessment for a Regulatory Impact Statement to help inform and describe final decisions in the review. The concepts discussed in this Background Note will be an important component of that cost benefit assessment. The full assessment will also consider any submissions received during the consultation period, as well as looking at alternative scenarios to look at risks around estimates of costs and benefits.

A large volume of material drawn from the international literature has contributed to the Reserve Bank's thinking on capital matters. It is not possible, in this paper, to discuss in depth each and every report or dataset that has contributed to the recent proposal. However, key sources and articles are signalled in the main text of the paper and a list of supplementary reports, information sources and articles relevant for the December 2018 proposal is given in Appendix A.

As well, the December 2018 consultation paper and associated background papers released in January 2019 provide detailed information about the overseas findings relevant for important issues such as the impact of capital on the probability of a banking crisis and the impact of capital increases on lending rates.

The modelling work that was done to inform the December 2018 capital ratio proposal is outlined in some depth in this paper because this aspect, thus far, has been outlined only in disparate papers and not brought together in one place.[9] However the relative coverage in this paper of the quantitative modelling work, the theoretical and empirical literature and stress testing should not be taken as indicative of the relative role of each type of information in leading to the December 2018 capital proposal. In particular, high level considerations, informed by the international literature, played a significant role.

The purpose of the report is to:

• Section 1: Outline the basis for the framework used to arrive at the capital ratio proposal announced in Dec 2018 (the 'risk appetite' framework); and

• Section 2: Describe the various threads of analysis used to inform the capital ratio proposal.

Throughout this paper we use bank 'capital' to refer to the equity invested in banks by their owners.

Section 1: The conceptual framework

The conceptual framework used by the Reserve Bank to consider the capital policy issue (the 'risk appetite framework') builds on, and is consistent with, the conventional treatment of bank capital policy in the literature. [10]

In the literature there are three key relationships that underpin capital policy setting. One of these is the relationship is between bank capital and the likelihood of a banking crisis – the more capital there is in the system, the lower the likelihood of a banking crisis.[11]

The other two relationships relate to output. One of these is the impact of a crisis on output. While the evidence suggests banking crises trigger or exacerbate severe recessions, the extent of the harm done is debated in the literature. By reducing the probability of a banking crisis, increasing capital generates an 'output benefit' which is the output losses that have been averted.

The remaining relationship relates to the impact of capital on output, mediated by lending rates. An increase in capital may prompt an increase in lending rates that reduces output by way of an impact on the volume of lending (this is the 'output cost' of capital).

There are other impacts of bank capital too, such as impacts on tax revenues. Where a tax regime treats interest payments by banks as a tax deductible expense (as New Zealand's does), the more a bank substitutes debt funding for capital funding, the less tax it pays (all else equal). While an increased tax payment would be an expense to the bank, from a societal perspective it is simply a transfer and not a cost (the only cost of capital from a societal perspective is the output impact of higher lending rates).

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[9] See Reserve Bank 2018a, 2018b and 2019
[10] Refer the references in this paper and see Appendix A for supplementary material. For example, Brooke et al (2015); Cline (2016); Firestone et al (2017); Schanz (2011).
[11] What constitutes a 'banking crisis' or a 'financial crisis' has been defined in the literature. For example see Romer and Romer (2015) and Laeven and Valencia (2012 and 2018)

As will be outlined later in the paper, findings in the literature suggest that up to relatively high levels of capital the benefits of increasing capital are expected to outweigh the costs.

The three key relationships that underpin capital policy are discussed in depth throughout this Paper.

1.1 Three underlying relationships

The three underlying relationships related to bank capital that need to be considered when setting capital policy are:

- The impact of bank capital on the probability of a banking crisis
- The impact of a banking crisis on output
- The impact of bank capital on lending rates and thus equilibrium output.

Conventions have emerged in the literature as to the nature of these relationships.[12] For example, the relationship between bank capital and the probability of a banking crisis is thought to be convex and the relationship between bank capital and equilibrium output is thought to be reasonably approximated by a linear function. [13]

The interaction of these three relationships provides important context for the setting of regulatory capital requirements. These interactions are outlined below, firstly using a simple intuition aided by graphs, then mathematically.

The intuitive description

The more capital there is in the banking system, the less likely it is there will be bank failures and a banking crisis. Reducing the probability of a crisis is beneficial for society because crises cause economic disruption (conventionally measured by a loss of output).

A common assumption is that the more capital there is in the system, the smaller this positive contribution derived from additional capital. In particular, the decline in the probability of a crisis due to marginally increasing capital, gets smaller and smaller the more capital you have. For simplicity it can be assumed that the size of the loss itself that occurs in a crisis is unrelated to the level of capital.[14]

The positive contribution to society that arises with an increase in capital, from a given level, is plotted as the 'marginal benefit' in Figure 1 below.

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[12] Refer the references in this paper and see Appendix A for supplementary material. For example, Brooke et al (2015); Cline (2016); Firestone et al (2017); Schanz (2011).

[13] For example, Miles et al (2012)

[14] The assumption about crisis losses can be varied so that it reflects the level of capital, but this does not change the underlying intuition.

Figure 1: Marginal costs and benefits of capital
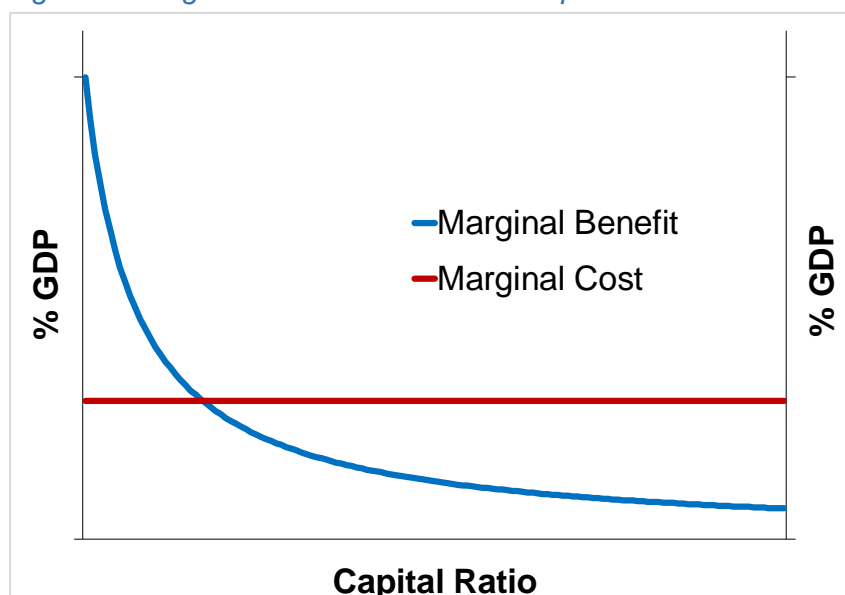
Increasing capital has another effect too, which is not beneficial. It can have the effect of increasing the average cost of funding for banks and thus has the potential to lead to an increase in lending rates. Higher lending rates means less investment and hence less potential output.[15] It appears to be commonly assumed that potential output and capital have a simple negative linear relationship.[16] Hence the 'marginal cost' of capital – the reduction in potential output due to a marginal increase in capital - is represented in the above chart as a horizontal line.

Capital thus affects output in two opposing, directions. On the one hand increasing capital reduces the probability that crises-related losses will arise. On the other hand, increasing capital may reduce potential output.

Information about the marginal benefit and marginal cost of capital can be used to infer a relationship between capital and output. For low levels of capital the net marginal impact (marginal benefit less marginal cost) is positive and large. Given this marginal impact is the change in output for a small change in capital, it suggests a curve relating output to capital is steeply upward-sloping at this point. At higher levels of capital, the marginal impact is still positive but much smaller. At even higher levels the curve becomes flat and then has a negative slope. This inferred curve thus reaches a peak. The inferred curve is the solid line in Figure 2 below (the marginal net impact at different capital ratios, is as indicated by the dashed line in Figure 2).

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[15] Some authors interpret potential output as meaning growth according to past trends, others adopt a long-run steady-state interpretation.
[16] For example, Miles et al (2012); Firestone et al (2017).
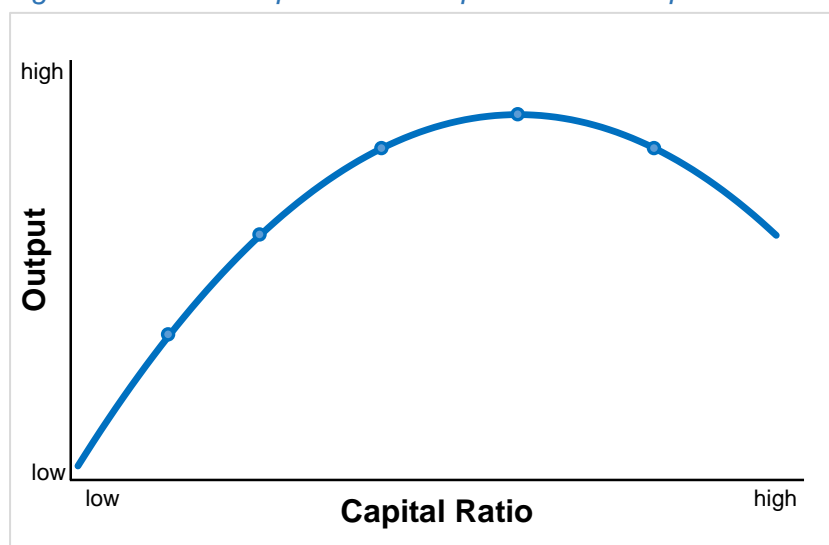
It is not easy intuitively to interpret 'output', derived in this way. As the mathematical exposition given below illustrates, output can be interpreted as "expected output".

Figure 2 is silent on the issue of stability. However, increasing capital can be reasonably expected to reduce the probability of a crisis in all but the most exceptional circumstances. In other words, there is a simple relationship between capital and financial stability. If we interpret 'stability' to mean the probability the banking system will remain solvent when subject to a shock (i.e. the probability a crisis will not occur), the more capital there is in the system, the more likely it is that stability will be achieved.

The relationship between capital, output and stability can be shown simply, by plotting output against stability, rather than capital as was done in Figure 2. This is how we prefer to illustrate the complex relationships between capital, output and stability.[17]

Figure 3: Relationship between expected output and stability

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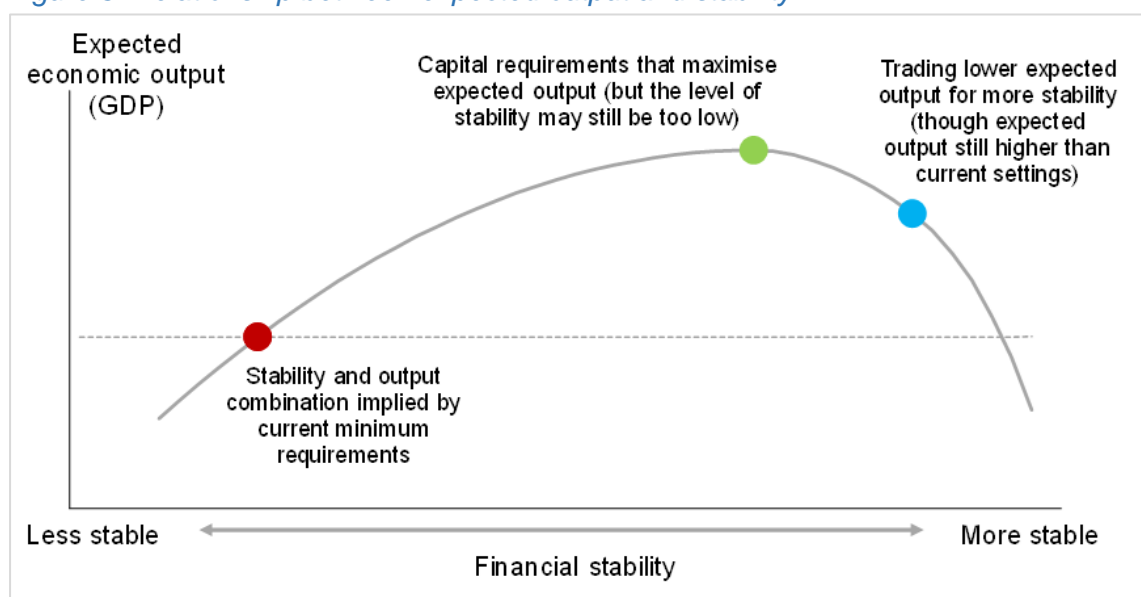
[17] In Figure 3 stability = 1 less the probability of a crisis and thus takes a value between 0 and 1.

Each point on the curve in Figure 3 represents a unique capital ratio. The horizontal axis represents the probability of stability (measured as 1 less the probability of a crisis 'p'). The vertical axis measures expected output.

Some outcomes are clearly inferior to others (for example the outcome indicated by the red marker). For some outcomes, having more capital would make more sense – both from a soundness perspective (stability will increase) and an output perspective (expected output would increase). In fact, any point to the north east of the red marker would be preferable to the red marker.

Expected output is highest at the green marker. Capital associated with the blue marker delivers more stability than capital associated with the green marker but less expected output. There are studies that suggest people are willing to forfeit output (income) to avoid uncertainty and/or abrupt disruption, and thus capital levels that go beyond the expected output maximising level are a potentially valid option if the public's attitude to risk is considered (we return to this issue below).[18]

We have opted to illustrate the policy problem as outlined in Figure 3 for several reasons:

- We believe it is more accessible to non-specialist audiences than the conventional marginal-based exposition. We wanted to have a genuine conversation with the public about capital policy, so we can reflect their risk preferences, and this required an accessible description of the policy problem.
- This illustration shows a wider range of what believe are potentially justifiable outcomes than the conventional treatment. It becomes clear that having capital beyond the expected output maximising level would deliver more stability and this may ultimately be preferable (it depends on society's attitude towards risk). Given the evidence available, it seems reasonable to assume that people value both stability and output (this issue is discussed in detail later in the paper).

A mathematical exposition of the key relationships

The three key relationships are:

- The impact of bank capital on the probability of a banking crisis
- The impact of a banking crisis on output
- The impact of bank capital on lending rates and thus equilibrium output.

In this section we use a static model with an output-stability trade-off governed by bank capital policy to illustrate the policy trade-off that is being considered. We consider a world with two possible outcomes – crisis and non-crisis. A crisis occurs when the representative bank runs out of capital and hence defaults. This crisis has real effects that lead to a decline in output.

The interaction of the three key relationships that underpin capital policy setting can be captured mathematically.

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[18] See for example, Barro (2009), and O'Donogue and Somerville (2018) for a more general summary of the risk aversion literature.

$$Qe = (1 - p)(1 - L_r) + p(1 - L_r - L_c) \qquad (1)$$

Equation (1) can be rearranged as follows:

$$Q_e = (1 - p) \cdot 1 + (1 - p + p)(-L_r) + p \cdot (1 - L_c)$$

$$= 1 - p + p - p \cdot L_c - L_r$$
$$= 1 - p \cdot L_c - L_r$$
$$= 1 - p \cdot L_c - \left(b(K - \phi)\right)$$
$$= 1 - p \cdot L_c - bK + b\phi$$

K = the capital ratio (the policy variable).

$\overline{Q}$ = potential output, n, consistent with current capital requirements (and thus lending rates and investment levels). $\overline{Q}$ is a constant.

ϕ = the current capital ratio, associated with potential output $\overline{Q}$ =, and is a constant.

p = the probability of a crisis, $p = P(k)$.

L_c = the present value of the cumulative output lost in a crisis, percentage of $\overline{Q}$. Assume L_c to be a constant.

L_r = the present value of cumulative output lost due to changing lending rates, percentage of $\overline{Q}$. We assume $L_r = b \times (K - \phi)$.

Q_e = expected output, expressed as a percentage of $\overline{Q}$.

If $K = \phi$, expected output is a weighted average of output states with and without a crisis (i.e. Lr is zero and expected output = potential output less the output lost in a crisis with some probability).

If $K > \phi$, expected output is a weighted average of output states with and without a crisis, but the potential output in each state is less than $\overline{Q}$.

The analysis reported in this paper applies Equation 1 throughout. However, for completeness, the marginal expression of the policy problem, as illustrated in Figure 1, is derived from Equation 1 as explained below.

Taking the first derivative of Equation 1 with respect to the capital ratio K:

$$\Delta Qe / \Delta K = [- p'(K) Lc] \quad - \quad b \qquad (2)$$

Marginal benefit   Marginal cost

- The first part of the right hand side of Equation 2 is the marginal benefit of capital (the change in the probability of a crisis multiplied by the loss that arises in a crisis).

- The second part is the marginal cost of capital (the potential output lost due to moving to the new level of lending rates).

1.2 The policy goal

While conventions have established around the key relationships underpinning capital policy, the policy problem is described in a variety of ways in the literature.[19] Some authors define the policy problem solely in terms of maximising output.[20] Others take the view that output might not be the only factor that matters – society may have an attitude towards uncertainty that should be reflected in the capital policy decision.[21] In this context 'uncertainty' has a broad meaning that includes instability and 'risk'.

We use 'society's risk tolerance' and 'society's risk appetite' interchangeably to refer to the public's attitude towards uncertainty. A related term is 'risk aversion' which refers to a particular attitude towards risk (one of dislike).[22] An established assumption in economics, and in specific fields such as insurance and finance, is that people are risk averse.[23]

> "..*risk aversion* is part of the intrinsic make-up of the investor. It is a parameter that our theoretical priors suggest should not change markedly, or frequently, over time."[24]

Evidence that people are risk averse arises in many fields. For example, the insurance industry is predicated on people being willing to pay more in premiums than the actuarial value of the likely loss they face.[25] Some studies have attempted to measure risk aversion using financial market data.[26] In one case, the conclusion was that "society would be willing to lower real GDP by as much as 20% each year to eliminate the small chance of major economic collapses."[27]

Risk aversion has typically been explained in economics using utility theory. The key assumption made is that people derive more utility from wealth the less they have, and so a marginal loss of wealth matters more to them (leads to a greater decline in utility) than a marginal gain.[28] This leads to the finding that people will willingly forfeit some expected gains in wealth to avoid a potential loss.[29] However there are other theoretical models (not based on utility theory) which also deliver a finding of risk aversion (for example, loss aversion theory).[30]

In practical terms, society's risk appetite is relevant for the capital policy decision because, as Figure 3 above shows, there is a potential trade-off between expected output and

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[19] Refer the references in this paper and see Appendix A for supplementary material. For example, Brooke et al (2015); Cline (2016); Firestone et al (2017); Schanz (2011).
[20] For example, Miles et al (2012), Aikman (2018)
[21] For example, Firestone et al (2017)
[22] For a discussion of these terms refer Bank of England (2004)
[23] O'Donoghue et al (2018)
[24] Bank of England (2004)
[25] O'Donoghue et al (2018)
[26] Gai and Vause (2006)
[27] Barro (2009)
[28] O'Donoghue et al (2018)
[29] Barro (2009)
[30] O'Donoghue et al (2018)

stability. If given the option of a capital policy that, compared to an alternative, delivers more stability but less expected output, what would the public choose?

Incorporating risk aversion in the analysis via utility curves requires making assumptions about what value people place on avoiding a loss rather than making a gain. The evidence that might inform this assumption can be quite conflicting.[31]

Some authors are sceptical of the utility curve approach, preferring simply to be guided by the scale of historical crisis losses when setting capital policy.[32]

> "In practice, however, estimating the optimal level of bank capital is likely an impossible task ex-ante. It requires defining a social welfare function and estimating the effect of bank capital on the cost and availability of credit, the probability and severity of banking crises, and the impact of credit availability and banking crises on output and output volatility. Such an exercise would require several simplifying and perhaps undesirable assumptions, and its results would necessarily be too model-, bank-, and sample-specific to provide convincing policy guidance."[33]

In the majority of the capital policy studies we reviewed the policy goal was defined solely in terms of maximising expected output, with no role for risk aversion.[34] Some authors, while not incorporating assumptions about society's attitude towards risk, nevertheless acknowledge the potential importance of risk aversion for capital policy.[35]

The risk preferences are of New Zealanders cannot be known with great precision. However the Reserve Bank is an agency with delegated authority (and obligations) to make such decisions on behalf of the public.

We adopted a pragmatic position, acknowledging the importance of risk aversion but not adopting the utility curve approach. On the one hand, the evidence strongly suggests that society is not indifferent to risk, so it seems important to accommodate the possibility that society may prefer capital levels that deliver a great deal of stability even if it means some sacrifice of expected output. On the other hand, we accept the point that any modelled representation of society's preferences depends on assumptions (the accuracy of which may be impossible to verify ex ante) and the results will be very sensitive to the assumptions made.

The approach adopted by the Reserve Bank incorporates society's risk tolerance in a simple way. We represent the costs and benefits of capital objectively (without any weightings) and incorporate risk aversion by aiming to cap the probability of a crisis at some predetermined level.

How risk aversion has been incorporated in the most recent capital review will be explained in detail below, and contrasted with the 2012 approach (which also incorporated risk aversion).

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[31] O'Donoghue et al (2018)
[32] Dagher et al (2016)
[33] Dagher et al (2016)
[34] For example, Aikman et al (2018); Firestone et al (2017); Miles et al (2012)
[35] Firestone et al (2017)

1.3 The Reserve Bank's policy goal

For the present review we have opted to incorporate society's attitude towards risk explicitly in the policy goal (which is an innovation compared to the 2012 analysis). In our view the approach is transparent, simple, pragmatic and consistent with the risk aversion literature. [36]

The approach is to set a two-part policy goal. The first element of the policy goal is to set bank capital requirements with the aim of achieving a banking system that retains the market's confidence in the face of large unexpected shocks (delivering 'soundness'). At a minimum, maintaining the market's confidence means the banking system remains solvent.

Implicit in this objective is an acceptance of some risk (some losses will be so very large that no banking sector can be expected to have the capital needed to absorb them). This first part of the policy goal thus equates to aiming to cap the probability of a crisis to some predetermined level. By aiming to cap the probability of a crisis we are incorporating society's risk aversion explicitly in the policy goal.

The second element of the policy goal relates to 'efficiency'. If, at the level of bank capital implied by the soundness objective, stability can be increased further with no loss of expected output, then bank capital can be increased beyond what society's risk tolerance would require. This second 'leg' of the policy goal is akin to delivering a constrained maximisation of expected output - expected output is being maximised but this is conditional on achieving the stability objective. [37]

Our two-step policy goal lends itself to a two-step decision rule:

i.   Set capital so as to cap the probability of a crisis at a specified low level (step 1).
ii.   If, at that level of capital, it seems likely that, by increasing capital beyond what society's risk tolerance requires, expected output would increase then capital should be increased so as to maximise expected output (step 2).

The policy goal can be described with reference to Figure 3 which is reproduced below.

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[36] O'Donoghue et al (2018)

[37] If soundness dictates a level of capital less than the output-maximising bank capital level, capital should be increased to the output-maximising level. If the soundness objective dictates a level of bank capital that is higher than the output maximising level, the soundness objective dictates the level of capital that will be required of banks.

Relationship between expected output and stability
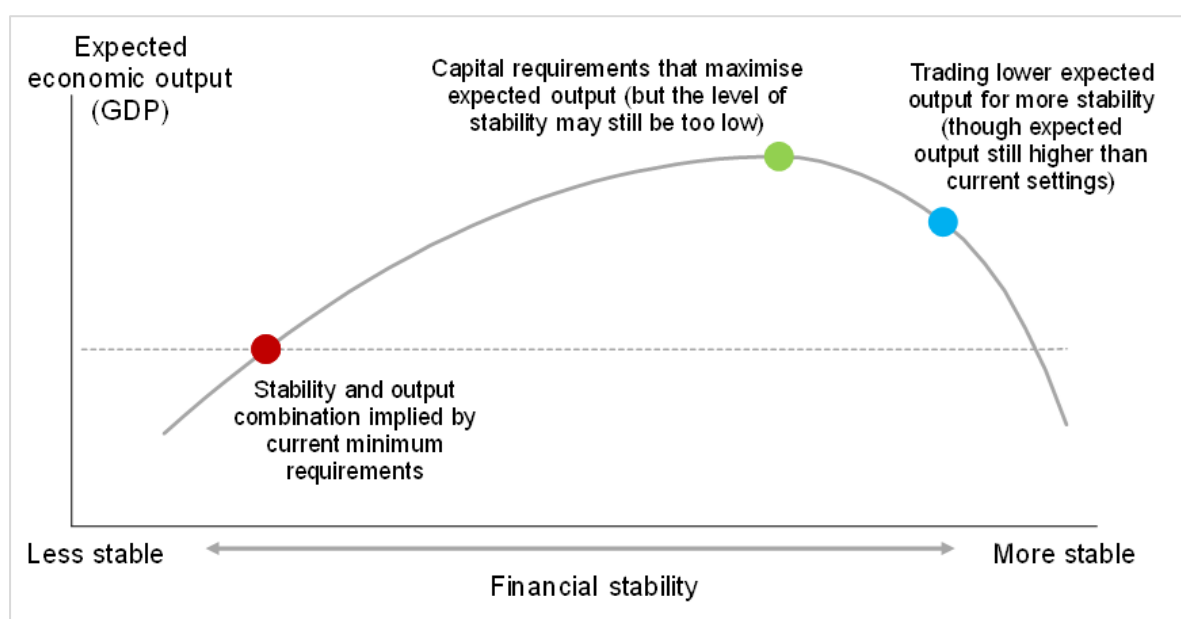
The soundness objective implies identifying a stability target (a position on the horizontal axis). If, at this level of stability, it appears that expected output will be less than the maximum, require more bank capital (increasing stability to the level that is consistent with maximum expected output). If, in contrast, the soundness objective implies a level of stability that exceeds the output maximising level, settle upon the level of capital that meets the soundness objective.

We adopted the two-part policy goal for several reasons:

- We find the evidence that people value both stability and output, and are risk averse, compelling. To assume society is not risk averse seems, to us, to be an extreme and unrealistic position. We wanted to find a simple way to incorporate society's risk tolerance in our policy goal. This is achieved by step 1.
- The Reserve Bank Act 1989 mandates the Reserve Bank to promote the maintenance of a sound and efficient financial system. We have to consider efficiency (interpreted in this context as expected output maximisation) but also soundness.
- We wanted to be as transparent and accountable as possible. This meant describing the policy problem in terms that non-specialists can understand.
- We believe it is not feasible to accurately map ex ante the public's preferences (for example, using the utility curve construct so common in economics). However, by articulating a simple decision rule and seeking feedback we hope to engage with and learn about the public's preferences with respect to stability and output, meaning we can meaningfully reflect these preferences in our capital policies. [38]

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[38] Note too, however, that the Reserve Bank has used the Tuatara model, which incorporates assumptions about society's risk tolerance via value-based weights, as part of the analysis used to arrive at the recent capital proposals. We did take into consideration, when using this model, the sensitivity involved in these types of studies. Hence, it was only one input of many in our final policy decision.

Risk aversion received a different treatment in the analysis undertaken by the Reserve Bank in 2012. Rather than incorporate risk aversion in the policy goal explicitly, a weighting regime was applied to the output benefits of capital (but not the output costs). For "large shocks that enhanced capital ratios are designed to provide protection against" a weight "in excess of two" was used.[39]

The impact of a weighting regime such as this is to base the decision on a subjective relationship between stability and value-weighted output, not a relationship between stability and expected output. The goal is still to maximise 'output' but the calculation of output is amended to include value-based weights.

As a result of applying value-based weights (that exceed 1) to the output benefits of capital, the level of capital (and thus stability) deemed 'output maximising' is higher than it would be if no weights had been applied. In other words, applying value-based weights with a value above 1 to the output benefits of capital imposes some forfeit on an expected output basis. This is illustrated in Figure 4. The unweighted curve reaches a peak at a lower level of stability than the weighted curve.

Figure 4: Comparison of Expected Output and Weighted Output (adjusted for risk aversion)[40]
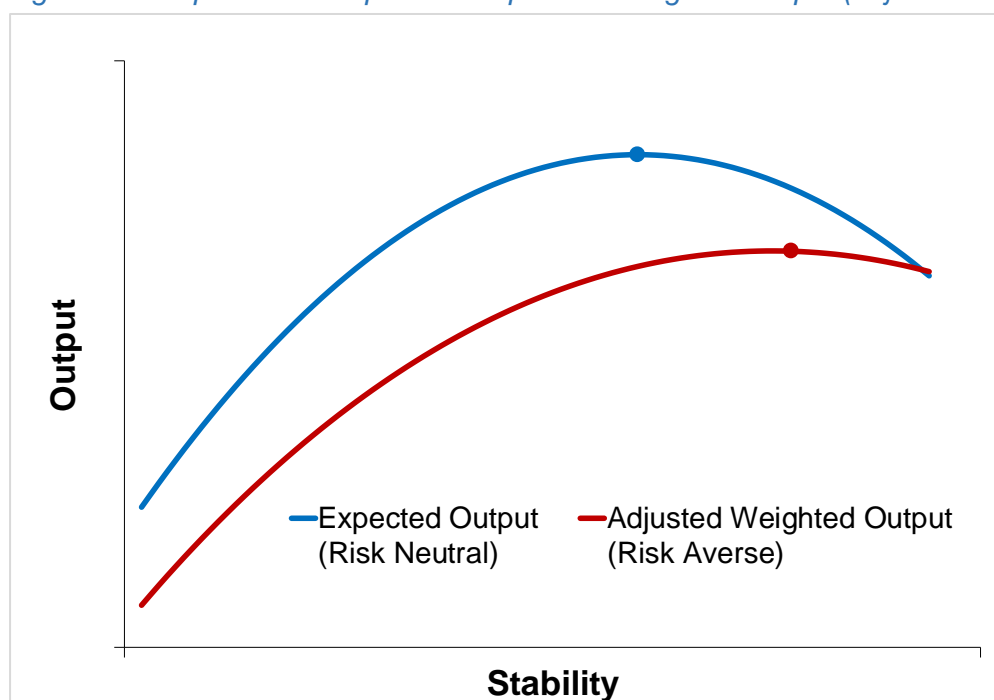
Our preference is to be transparent and thus accountable when deciding on capital requirements. Our view is that incorporating risk aversion explicitly in the policy goal – by aiming to cap the probability of a crisis at 1/200 – achieves this.

It is also important to note that a comparative exercise was undertaken in order to assess the impact of incorporating risk aversion in the policy goal. This was a review of the high

[39] Reserve Bank of New Zealand (2012).
[40] Stability is defined as one less the probability of a banking crisis occuring. Expected output is defined as a weighted average of the crisis and non-crisis states using the respective probabilities of each state. Weighted output is the weighted average of the crisis and non-crisis states, where the weighting for the crisis state is greater than the probability of a crisis occurring, and a greater weighting is attached for more severe losses.

level findings in the literature where the policy goal was defined simply in terms of maximising expected output. A summary of the findings is provided in Section 2.4 below.

These findings provided a valuable comparator, enabling us to see the potential impact of our approach to risk aversion. The conclusion from this work was that a similar minimum capital requirement would be appropriate even if the policy goal was defined solely in terms of maximising expected output. Adopting the risk appetite framework remains appropriate, however, as it ensures capital settings can accommodate any assumption about societal risk aversion, including less tolerance for banking crises than we have assumed.

1.4 The 1/200 representation of society's risk tolerance

In the interests of transparency and clarity, we expressed our soundness objective in terms of the probability of a banking crisis. The decision was made to define the policy goal as the banking system having sufficient capital to retain the confidence of the market when faced with losses as large as (but not larger than) losses that might arise once every 200 years.[41]

We don't have evidence about New Zealanders' tolerance for banking crises, and we hope that as a result of the consultative process we might become better informed. However for the purposes of arriving at a capital proposal we needed a starting assumption, and that became 1/200.

'Failure' probability rates are a common device in similar regulatory frameworks. For example, internationally, some insurance regulators administer solvency standards that specify a probability of 'ruin' that is not greater than 1/200 years.[42] In New Zealand, non-life insurers are subject to a solvency requirement of 1/1000 years in relation to earthquake risks and 1/250 for other non-life catastrophes. [43] In the US, in 2017, analysts at the Federal Deposit Insurance Corporation used a risk tolerance of 1/500 years in their modelling work related to setting the reserve ratio for the U.S. deposit insurance fund. [44] A risk tolerance is also embedded in the capital equation specified in the Basel III standards and used by banks permitted to model their risk weights. A 'confidence level' of 99.9% is specified (this translates to a risk tolerance of 1/1000 years). [45] [46]

There are thus a range of risk tolerances evident in financial sector regulation around the world and in New Zealand. The risk tolerances used in other areas of financial regulation provided context for the decision to adopt 1/200 when setting minimum bank capital requirements.

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[41] The 1/200 relates to likelihood a loss of a given magnitude will be exceeded. 1/200 in this context means sufficient capital will be held to absorb a loss that is so large it might arise only once every 200 years. Implicit in this is that losses that are even larger, and therefore less likely, would exceed banking system capital. As will be explained later in the paper, the distribution of bank losses can be represented by a probability density function where the area under the curve is equal to 100% and the area beyond a given loss rate represents the probability that loss will be exceeded. This function is not normally distributed. Refer BCBS (2005).

[42] European Insurance and Occupational Pensions Authority. 'Solvency II' .

[43] Reserve Bank Solvency Standards for Non-life Insurance Business. 2014

[44] O'Keefe et al (2017).

[45] BCBS (2005).

[46] Because of inherent data weakness and other uncertainties arising from risk modelling per se, the Reserve Bank's view is that the IRB models cannot, in fact, be assumed to deliver capital sufficient to match unexpected losses that have a probability of 1/1000 years.

More fundamentally, though, in order to set a risk tolerance for policy purposes it was necessary to consider the adverse economic and social impacts of banking crises. Acting as an agent for society, how tolerant should the Reserve Bank be of the risk of a banking crisis, given the available evidence about the impacts of such a crisis?

While the Reserve Bank's explicit mandate does not make reference to societal well-being, the social impacts of crises are a relevant consideration for society and society's attitudes towards the risk of harm from crises that we seek to represent in our capital policy. The idea that economic policies (and by association, financial regulations) should be set after considering outcomes in the broadest sense is not novel.

> "It is essential that Governments take into account the likely social implications of their economic policies. It has been shown, time and again, that economic policies considered in isolation from their social outcomes can have dire consequences for poverty, employment, nutrition, health and education, which in turn, adversely affect long-term sustainable development."[47]

There is a large literature about the economic and social impacts of deep and prolonged recessions (such as are likely to arise in the event of a banking crises). A common theme in the literature is the harm to mental and physical health, family cohesion and community connectedness caused by the economic stress induced by a severe downturn – through unemployment, falling incomes, reduced savings and/or declining asset values. There is evidence of these impacts in both developed and developing countries although local circumstances can act to mitigate the effects.[48]

> "Although systemic data are not available, there is growing evidence that the crisis is indeed having significant impacts on individuals, families and communities in terms of wellness, cohesion and conflict. In many countries, rates of mental illness, substance abuse and suicides have increased. Family cohesion is increasingly being jeopardised by divorce and domestic violence, as well as by abandonment, neglect and abuse of children. Some communities are seeing increased outbreaks of conflicts and protests." [49]

It is worth considering examples of the available evidence in some detail, as this can provide insights into why agencies such as the World Health Organisation, the World Bank and the United Nations see the societal impacts of financial crises as being long-lived. [50] The break-up of families, ill-health, reduced spending on healthcare and nutrition and societal unrest can all be expected to have enduring effects on society as a whole.

Impacts on physical health:

- Public health impacts from prolonged recessions – such as increased mortality due to heart disease and illnesses such as liver cirrhosis related to increased alcoholism - have been long documented. [51]

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[47] UN (2011)
[48] For example, the extent to which there is fiscal room to expand social support programmes in response to the crisis. Refer World Bank (2013).
[49] UN (2011)
[50] World Bank (2013)
[51] UN (2011)

- "Adverse health effects are mostly found among the "lower socio-economic classes" without economic security. The lack of economic security is often stressful: social and family structures break down and habits harmful to health are adopted. These effects may be manifested in a psychopathological event, such as suicide, or, after a time lag of a few years, in chronic diseases." [52]

Impacts on mental health:

- "A recent study of 26 countries in the European Union found that for every one percent increase in unemployment, the suicide rate for people under 65 years of age went up by 0.8 percent." [53]
- "During the Asian crisis, overall poverty rose from 11 percent to 18 percent in Indonesia, and urban poverty doubled to 18 percent in Korea. Previous studies also point to increased inequality associated with financial crises in a panel of advanced and emerging market countries during 1988-2010, with the impact rising along with severity of recessions. Research also shows that the average rise in income inequality during recessions tends to be larger than the fall during booms, suggesting that the poor tend to get a bigger share of the pain than the prosperity." [54]
- "Economic crises also coincide with a deterioration in social cohesion. During the Great Depression in 1929-32, for example, there was a 40 percent increase in suicide rates and a 10 percent increase in deaths from all causes in the United States. Similarly, there was a 39 percent increase in suicide rates among males in Japan during the Asian crisis, a 44 percent increase in Hong Kong SAR, China, and a 45 percent rise in Korea and Thailand." [55]

Impacts on family cohesion:

- "Economic stress is a major source of family tension and a leading cause of family breakups. A study of housing prices and marital dissolution in the United Kingdom in the period 1991 to 2004 found that a 10 percent fall in housing prices was associated with an additional 5 percent of couples breaking up." [56]
- "Although data are scarce, some countries have seen an increase in cases of domestic violence linked to the crisis. For instance, a survey of 630 domestic violence shelters in the United States reported a 75 percent increase in the number of requests for services since the onset of the crisis…The survey also found that abuse had become more severe…"[57]

Impacts on the wellbeing of children and youth:

- "Recent reports by UNICEF, for example, point to a significant deterioration in child well-being in a number of advanced countries, based on measures of material well-being, health and safety, education, behaviours and risks, and housing and environment….Similarly, the UN composite Human Development Index, computed as a function of measures of life expectancy at birth, access to knowledge, and a decent

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[52] UN (2011)
[53] UN (2011)
[54] World Bank (2013)
[55] World Bank (2013)
[56] UN (2011)
[57] UN (2011)

standard of living, declined between 2007 and 2012 for a number of middle and high income countries in the Middle East and Europe as well as for small island states." [58]

- "The youth have been particularly hit hard by the crisis….The jump in the youth unemployment rate has been most pronounced in advanced economies, rising from 12.5 percent in 2007 to an estimated average of 17.9 percent in 2012. The rate has reached alarming levels in the peripheral Euro Area countries, to 59 percent in Greece and 56 percent in Spain, compared with an average rate for the Euro Area at 24 percent in mid-2013 and 7.5 percent in Germany." [59]

Impacts on community connectedness:

- "We study the implications of the Great Recession for voting for anti-establishment parties, as well as for general trust and political attitudes, using regional data across Europe... We compare the regions that greatly suffered from the crisis with those that weathered the crisis relatively well – controlling or pan-European and country-specific time trends... We show that the differential [regional] impact of the crisis explains the rise of anti-establishment, often populist, parties, and also the respective drop in trust towards political parties and the European Union…." [60]
- "The World Health Organisation has recently highlighted the negative psychological effects of financial crises as well as the increase in crime that these typically bring." [61]

Impact on vulnerable people.

"While everyone is vulnerable to their adverse consequences, financial crises hurt disproportionately the poor, as with natural disasters, contagious diseases, or climate change, given that the poor have limited capacity and instruments to insulate themselves from the shock and recover from the impact of the crisis….In any given country, crises hit particularly hard the most vulnerable – the young, the old, women and the ill. A severe financial crisis can morph into a social crisis if it is poorly handled…" [62]

We believe these impacts are likely to lead society to be relatively intolerant of banking crises. However, one aim of the consultation is to generate a public conversation, and prompt feedback, about this important issue.

An additional factor in the decision to adopt 1/200 was the preliminary finding from the early modelling work. This indicated that, for the range of input values being considered, adopting a risk tolerance of 1/100 would typically lead to an inefficient result (i.e. adopting a lower risk tolerance than 1/100 would likely lead to both greater stability and increased expected output). [63] In those cases where this was not the case (for example, when we adopted the lowest value in our range for L_c - the output cost of crises), the modelling results suggested the adverse output impact of adopting 1/200 would be small. This early work also suggested

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[58] World Bank (2013)
[59] World Bank (2013)
[60] By "Great Recession" the authors are referring to the period since 2007. Algan et al (2017)
[61] Calvo (2013)
[62] World Bank (2013)
[63] The issue of whether 1/100 would lead to an inefficient outcome was debated at the steering group level. Reference to this debate can be found in Reserve Bank (2018a) Footnote 2. Material about the capital impact of adopting 1/100 and 1/200 can be found in Reserve Bank 2018a Appendix 4.

adopting a risk tolerance above 1/200 would leave some room for further efficiency gains under some scenarios.

This analysis is illustrated in Figure 5 with three different assumed values for L_c (20 percent, 40 percent and 63 percent).[64]

Figure 5: Expected output and stability, with varying assumptions on cost of crises
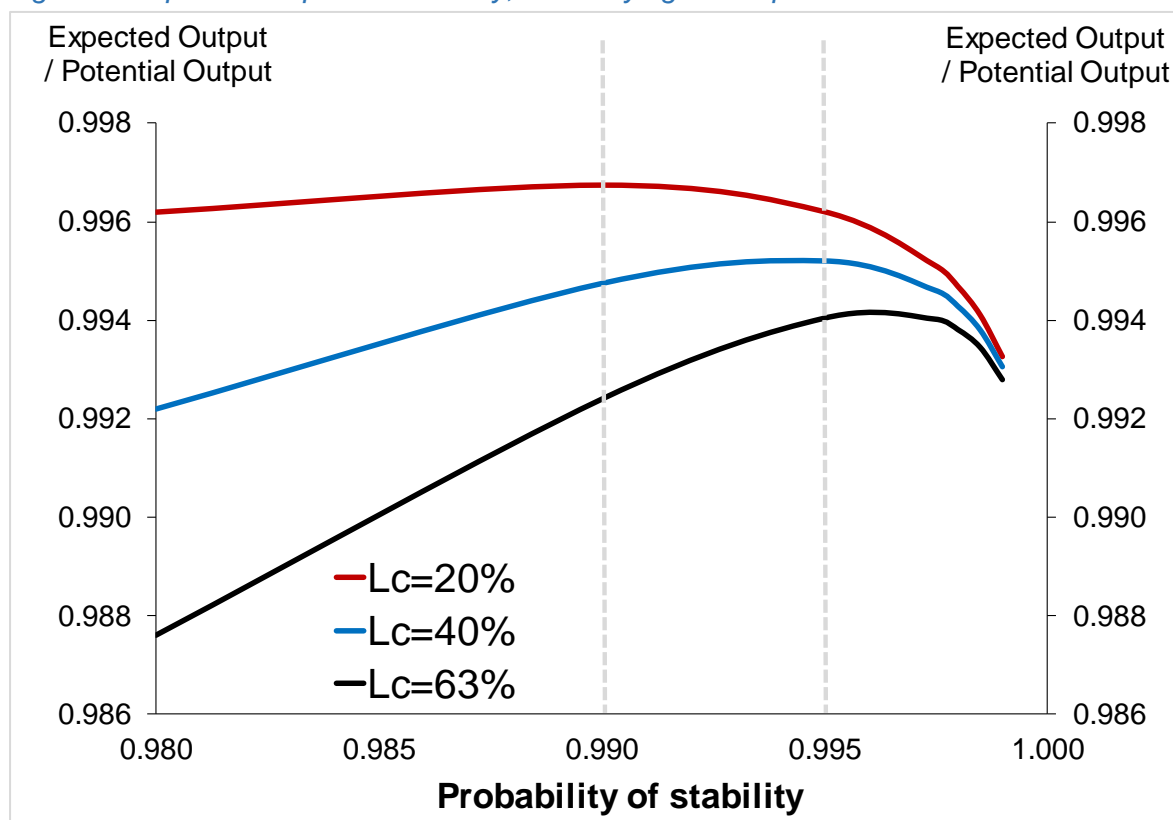
Weighing up all of these considerations 1/200 was accepted as being a reasonable approximation, in the absence of any information to the contrary, as to what society might consider an appropriate risk tolerance.

Section 2: The Reserve Bank's analysis

The purpose of this Section is to describe the analysis that was considered in the proposal to increase the Tier 1 capital required of systemic banks to 16 percent of RWA.

As was described in Section 1, various types of information was considered as part of the policy-making process – findings from the literature, stress test results and quantitative modelling.

The quantitative modelling work that was done to inform the December 2018 capital ratio proposal is outlined in some depth in this paper because thus far it has not been brought together in any one public document. However, the relative coverage in this paper of the modelling work, the theoretical and empirical literature and stress testing should not be taken

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[64] In all three cases 'b' was assumed to be 8.1 basis points, and assumptions about the relationship between capital and the probability of a crisis were based on the ASRF model using inputs for PD, LGD and R of 2.25%, 40% and 0.3 respectively.

as indicative of the relative role of each type of information in leading to the December 2018 capital proposal.

With the exception of information that informed the setting of the risk tolerance, the information that was considered and the analysis that was done can be usefully categorised in relation to the key components of Equation 1 from Section 1, which is reproduced below. Equation 1, it will be recalled, encapsulates the three key relationships that underpin bank capital policy setting:

- The relationship between capital and the probability of a banking crisis ('p' in Equation 1);
- The impact of a crisis on output ('L_c' in Equation 1); and
- The impact of capital on lending rates and thus equilibrium output ('L_r' in Equation 1).

$$Qe = (1 - p)(1 - L_r) + p(1 - L_r - L_c) \tag{1}$$

Note that Equation 1 represents the three key underlying relationships and is silent on the policy goal. In our case, as explained earlier, a two-part policy goal – and accompanying two-step decision rule – was adopted. First, set capital so as to cap the probability of a crisis at 1/200 years. Secondly, explore whether stability and expected output can be increased by adopting a higher capital requirement than soundness considerations would imply.

Equation 1 continues to apply even when, as others have done, an alternative policy goal is adopted.

In this Section the material and analysis relating to the proposal to increase capital is grouped with respect to Equation I's inputs – p, L_c and L_r. Each input discussion will follow a common structure:

- First, the key issue(s) identified in the literature with respect to the relationship represented by this input will be briefly outlined;
- Secondly findings in the literature related to this relationship will be outlined;
- Thirdly any quantitative modelling done by the Reserve Bank in order to arrive at a range of values for this input will be outlined (if no quantitative modelling was done by the Reserve Bank the range of input values used reflected findings in the literature); and
- Fourthly, the value range settled upon for the input will be presented (in the case of 'p', this will be presented as a range of probabilities of crisis for a given capital ratio).

Once ranges for inputs p, L_c and L_r were established sensitivity tests that were done with respect to the policy goal. Sensitivity testing was essential given capital policy has to set under conditions of uncertainty.

2.1 The relationship between capital and the probability of a crisis ('p')

The issue

The key factor that underpins this relationship is the scale of unexpected future bank losses. If future unexpected losses are large enough to overwhelm the available capital in the banking system, or to be perceived as overwhelming the banking system's capital, the banking system will lose the confidence of the market and a banking crisis may occur.

Inevitably, however, the nature and timing of future shocks, and the scale and impact of future bank losses, are unknowable so the relationship between capital and the probability of a crisis can never be known with any certainty.

The evidence available in the literature

Various approaches have been adopted in the literature in order to estimate the relationship between capital and the probability of a crisis. These include collating evidence about the scale of losses experienced by banks historically, using historical losses as a guide to future losses.[65] Estimating the relationship between capital and bank failure directly, using cross-sectional regression analysis, is one alternative. [66] Another option is to use a stylised model of the banking system to generate hypothetical loss distributions for bank credit portfolios.[67] Finally, while serving multiple purposes and not used specifically to explore this relationship, stress tests, as described in Section 1, provide a window into potential future credit losses during stress events.

The relationship between capital and the probability of a crisis was addressed at some length in the consultation paper released in December 2018 and in the background papers released in January 2019, so the coverage here will, in the interests of space, be relatively brief. [68] [69]

Beginning with historical losses, it is difficult to estimate the losses incurred in banks during crises because the losses can be removed from the banks' balance sheets during resolution, realised only many years later or averted through a government-funded bailout. Nevertheless, there are some estimates available.

For example, using losses expressed relative to RWA, in 2010 the Bank of International Settlements reported losses ranging from under 5 percent in Japan (1997) and the United States (GFC), to between 10 percent and 15 percent for Finland (1991) and almost 25 percent for Korea (1997).[70]

In a related vein, focusing on the capital that would have been sufficient to match historical losses, a study published by the IMF in 2016 found that "[equity] capital in the range of 15-23 percent of risk weighted assets would have been sufficient to absorb losses in the majority of past banking crises (at least in advanced economies)." [71]

Moving onto regression analysis, in 2017 economists at the Federal Reserve used regression analysis to estimate the probability of a financial crisis given a banking system's capital and liquidity levels, and controlling for factors other than capital that might make the banking system vulnerable. This approach suggested Tier 1 capital of 8 percent of RWA generates a probability of crisis in excess of 4 percent. The top down approach found a Tier 1 ratio of 17 percent associated with a probability of crisis ranging from 0.5 percent to 3.5 percent.[72]

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[65] For example, see Laeven and Valencia (2012 and 2018), Dagher et al (2016)
[66] Firestone et al (2017)
[67] Studies of this nature were reviewed in BCBS (2010)
[68] Reserve Bank (2018b).
[69] Reserve Bank (2018a)
[70] BIS (2010)
[71] Dagher et al (2016)
[72] Firestone et al (2017).

In terms of stress test results, there are findings from New Zealand available. The tests were conducted in 2015 and 2017 and one finding was that the banking system can maintain significant capital buffers above current minimum requirements (for example Tier 1 capital equal to 8.5 percent of RWA) during a severe downturn. During the 2017 stress test, the capital ratios of major banks fell to around 125 basis points above minimum requirements, for example.[73] In other words the banks not only remained solvent but had sufficient capital to meet the minimum requirements. Stress test results are sensitive to assumptions on the scale and timing of credit losses, and on the ability of banks to generate underlying profits when subject to shocks. An important assumption in the results reported here was that banks continued to enjoy positive lending margins during the stress event, for example. [74]

Finally, in terms of modelling credit-related losses, a variety of approaches have been adopted in the literature and some of these were summarised in reports released by the Basel Committee in 2010, in advance of the adoption of Basel III. [75]

Table 1 summarises research findings that relate to the relationship between capital and the probability of a crisis – and specifically, the capital required to limit the probability of a crisis to 1/200.[76]

Table 1: Summary of research findings on capital needed to limit the probability of a crisis to 0.5 percent

Study	Capital needed to cap the probability of a crisis at 0.5%	
	Ratio measurement	Required amount
BCBS (2010)	CET1 (Equity) / RWA[77]	10% to 13% (Bank of England restated as 16%+ Tier 1 Ratio)
Brooke et al. (2015)	Tier 1 Capital / RWA	14% to 16%
Firestone et al. (2017)	Tier 1 Capital / RWA	17%+
Dagher et al. (2016)	Equity / RWA	15% to 23% required to avoid 85% of the banking crises during the GFC

The Reserve Bank's use of modelling to estimate the relationship

There is an established precedent at the Reserve Bank of using quantitative modelling to inform capital policy. A stylised model of the banking system, known at the Reserve Bank as the "Tuatara Model", was available to inform the 2012 capital policy reforms. The Tuatara

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[73] Dunstan (2018) and Lilly (2018)
[74] Dunstan (2018) and Lilly (2018)
[75] BCBS (2010)
[76] Note that the measure of CET1 used in the BCBS (2010) study was a pre-Basel III definition.
[77] This is based on a pre-Basel III definition of CET1.

Model is not discussed in great detail in this paper but is the subject of background papers released by the Reserve Bank in January 2019.[78]

The conventional assumption (that we share) is that the relationship between capital and the probability of a crisis is convex.[79] This means that the more capital there is already, the smaller the impact on the probability of crisis due to a marginal increase in capital. In order to explore this important relationship we needed a tool that had an underlying economic rationale and delivered a relationship that satisfied this assumption of convexity.

Two options were available to us: regression-based modelling and portfolio loss modelling. We opted for the latter in the recent work. This reflected the fact that New Zealand has limited experience of severe banking system stress (and while the stress has been experienced was severe, it does not qualify in the literature as constituting a systemic banking crisis). In our view, New Zealand's limited experience of severe banking system stress severely constrains the potential for regression-based applications in the New Zealand context.[80] We thus undertook model-based analysis.

We followed the precedent established by the Tuatara model and modelled the New Zealand banking system as a single bank with a banking crisis defined as the bank losing the confidence of the market (which means, at a minimum, that it is viewed as being insolvent).

This precedent seems reasonable in the New Zealand context given four large banks dominate the market and the failure of any one of these banks would impact on such a large proportion of economic activity that it would constitute a systemic crisis. In other words, we do not believe we need to share the modelling challenges of overseas regulators who have to estimate complex inter-bank linkages in order to relate bank capital to the probability of a banking crisis.

Again, following the precedent set by the Tuatara model, we used an asymptotic single factor risk ('ASRF') model to explore the potential relationship between capital and the probability of a crisis in New Zealand. The ASRF is one example of a Value-at-Risk portfolio loss model (VaR).

We used the ASRF model to derive multiple hypothetical distributions of future credit-related losses. Banks, however, are also required to have capital for operational and market risks. We adopted the assumption that the current quantum of capital held against operational and market risks is appropriate going forward, and thus focused, in the quantitative modelling, solely on credit-related losses.[81]

The ASRF model generates a convex relationship between capital and the probability of insolvency. The model generates a hypothetical distribution of bank losses. From the loss distribution it is possible to estimate the scale of loss that will be exceeded with a given probability (for example 1/200). Capital is set at the level needed to ensure that unexpected

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[78] Reserve Bank background papers released in January 2019.
[79] Refer the references in this paper and see Appendix A for supplementary material. For example, Brooke et al (2015); Cline (2016); Firestone et al (2017); Schanz (2011).
[80] We used the regressions estimated by Firestone et al (2017), as a sense-check on our analysis.
[81] In practice, this meant for any model-generated unweighted capital ratio output, we added 0.6 percentage points to reflect the capital needed in total (i.e. the model generated the capital needed to meet hypothetical credit losses with some probability and additional capital equal to 0.6% of unweighted assets reflected remaining risks).

losses will exceed capital (i.e. the bank will become insolvent) with this predetermined probability (and not more often).[82]

The amount of capital that is required is the total loss that will be exceeded with a given probability (drawn from the hypothetical distribution and known as the 'Value at Risk' or 'VaR' at this probability), less annual provisions for losses. Provisions for losses are assumed to equal expected losses. [83]

The relationship between the hypothetical distribution of losses, generated by the model, provisions for losses and capital is illustrated in Figure 6 (this illustration is reproduced from a 2005 Basel Committee publication).[84] The probability capital will be exceeded by shock losses – i.e. the bank will become insolvent - is given by the shaded region of Figure 6 (the area under the entire curve has a value of 1).

Figure 6: Value at Risk, unexpected losses and the probability of a crisis
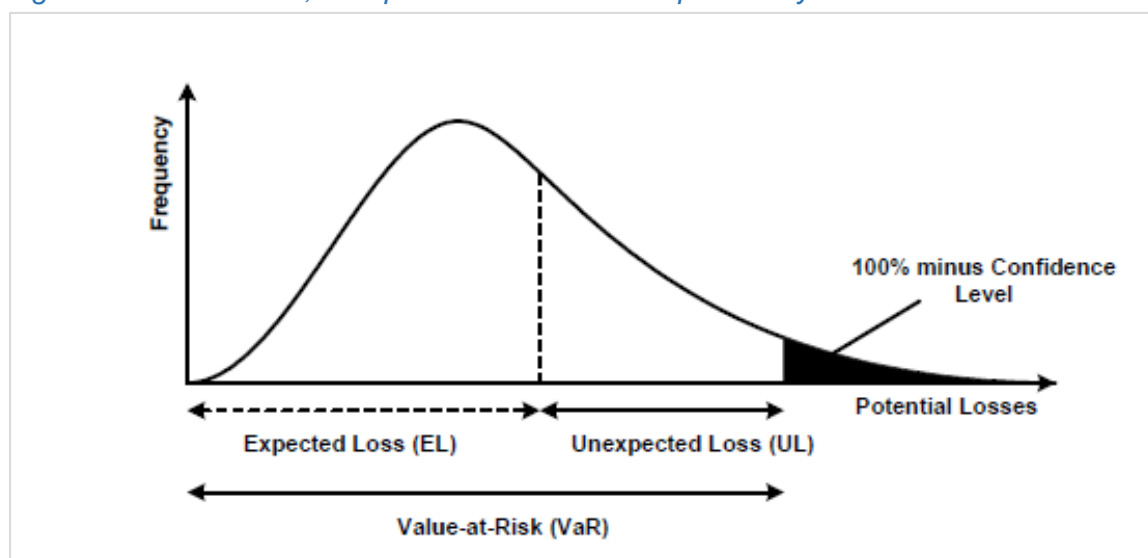
Source: BCBS (2005)

The ASRF has a number of simplifying assumptions. These enable the capital required to cap the probability of insolvency to a predetermined level to be generated from just three inputs (as well as a pre-determined confidence level): the 'probability of default' ('PD'), the 'loss given default' ('LGD') and correlation R: [85]

- 'PD' represents the proportion of borrowers that default in a year. 'PD' is an average concept, with the average drawn from all states of the economy including crisis conditions.
- 'LGD' represents the percentage of the loan exposure the bank would lose if the borrower defaults.

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[82] Refer BCBS (2005) for further information
[83] BCBs (2005)
[84] BCBs (2005)
[85] BCBs (2005)

- Correlation R measures the extent to which 'PD' varies with the state of a systemic risk factor.

Note that 'PD' multiplied by 'LGD' gives an estimate of expected losses, which are assumed to be matched by provisions.

The ASRF model assumes that PD depends on the state of the systemic risk factor (typically assumed to be economic output), and is thus conditional. At low points in the economic cycle, the 'conditional PD' will be higher than at other points in the business cycle. Correlation R captures the sensitivity of PD to the systemic risk factor. The greater is R, the wider the distribution of conditional PDs. The relationship between conditional PD and the systemic risk factor is illustrated in Figure 7.

Figure 7: Default Rates and the Economy – stylised illustration of ASRF model
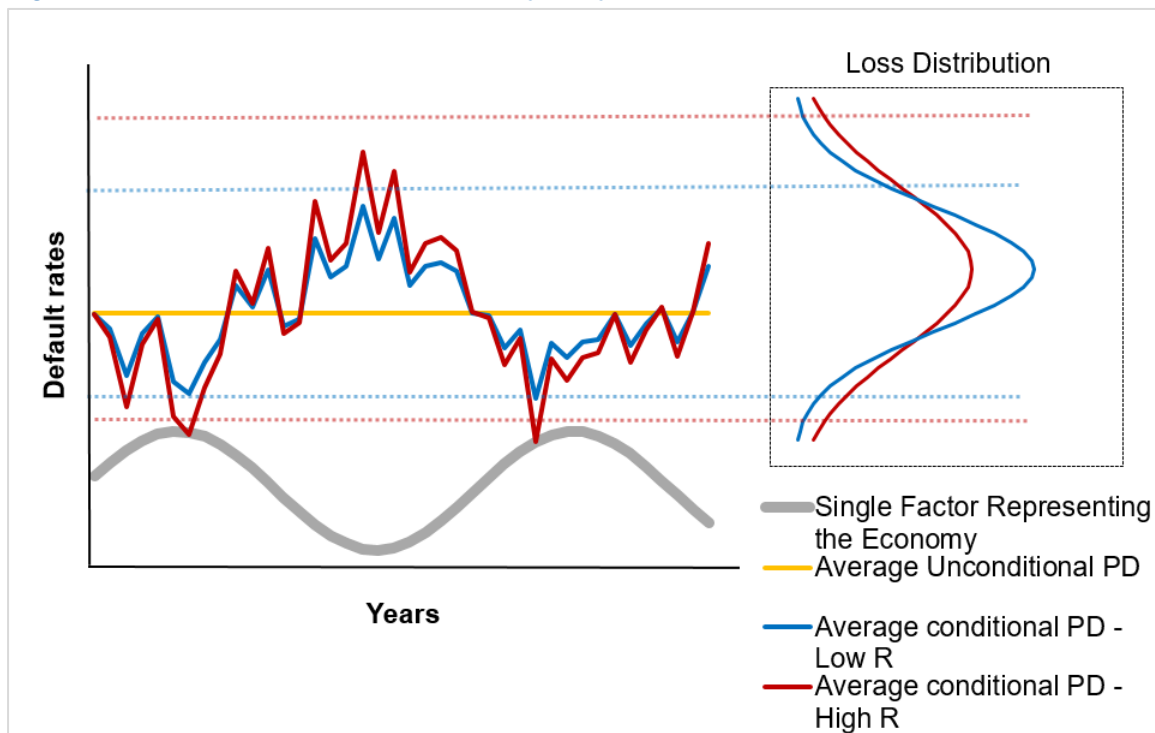
Risk models like the ASRF are highly stylised with relatively few inputs. Risk models have well-known weaknesses but, because they require few inputs and can be adapted for many purposes, they appear to be widely used in many financial applications. [86] [87]

It is important to note that we were not using the ASRF model to derive a single point estimate of the most suitable capital ratio to achieve our soundness objective (this would be an unsound approach, given the uncertainty around future losses). Instead we were using it to explore the implications for capital requirements of differing possible distributions of future system-wide loan losses.

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[86] Tarashev et al (2008)
[87] Danielsson (2002)

The ASRF model we used is identical in almost all respects to the model specified in the Basel III standards for use by IRB banks when estimating portfolio risk weights.[88] We omit the Basel standard's scaler for borrower size and we inputted assumed values for the correlation variable (R), rather than allowing it to be determined by the value assumed for PD (as the Basel standards allow for some types of loan portfolios).

The ASRF model we used is as follows:[89]

$$Capital\ K = LGD \times N\left[\frac{1}{\sqrt{(1-R)}} \times G(PD) + \sqrt{\left(\frac{R}{1+R}\right)} \times G(confidence\ level)\right] - PD \times LGD \quad (4)$$

$\underbrace{\qquad\qquad\qquad\qquad\qquad\qquad\qquad}_{VaR} \quad \underbrace{\qquad\qquad}_{expected\ losses}$

- N refers to the standard normal distribution applied to the single risk factor (the single risk factor has a mean value of 0 and a standard deviation of 1)
- G refers to the inverse of the standard normal distribution, applied to PD
- The confidence level reflects risk aversion - we seek protection from losses up to the level implied by the confidence level, but not beyond.
- Provisions are assumed to equal expected losses. Capital is required to fill the gap between the total loss and provisions.

In order to apply the ASRF model we needed to make judgements in several areas. These were:

- What indicators will be used to generate a range of assumed values for unconditional PD?
- What, if any, New Zealand banks would be omitted from any historical sample used for this purpose?
- Given New Zealand has not experienced a banking crisis in the modern era, what use will be made of other countries' loss experiences?
- What information will be relied on for LGD and R assumptions?
- Should strict insolvency be the test for bank failure, or should failure be deemed to have occurred with some positive level of capital?

In order to ensure we our results were not overly dependent on these judgements, we explored the implications of varying these judgements. For example, one stream of work defined 'failure' as strict insolvency (all capital was eroded by the loss), and combined this with assumptions about PD that were informed by simple averages of New Zealand data (not simply results from the large four banks) and overseas information. In contrast, another stream interpreted 'failure' to mean a loss of confidence that occurred when there was some

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[88] The IRB banks calculate the capital needed for a given portfolio using the ASRF model, then convert the capital to a RWA value (which when compared with unweighted assets generates a risk weight).

[89] BCBS (2005). This can be calculated in Excel by using the NORMSDIST and NORMSINV functions for the *N* and *G* distribution functions respectively.

reported capital remaining in the banks, but used a lower range for the PD input.[90] The findings in both cases were similar – i.e. both indicated capital in the vicinity of 9 percent to 10 percent of unweighted assets (or, equivalently, 14.5 percent to 16 percent of RWA) would be sufficient to cap the probability of a crisis at 1/200.[91]

The modelling results illustrated in this paper reflect:

- Failure defined as strict insolvency;
- PD in the range of 1.5% to 3.0%;
- LGD in the range of 35% to 50%;
- Correlation R in the range of 0.2 to 0.4; and
- 60 bps of Tier 1 capital assumed for market and operational risk requirements, which was added onto the unweighted capital ratio output.

It is important to reiterate that other input assumptions were used and the model implications explored, but the conclusions drawn in terms of the implications for capital requirements were ultimately similar.

A given relationship between capital and the probability of a crisis emerges from the ASRF model once assumptions are made about PD, LGD and R. Varying the inputs provides a range of estimates for this relationship. Figure 8 provides illustrative outputs.

Figure 8: Leverage ratio and the probability of insolvency[92]
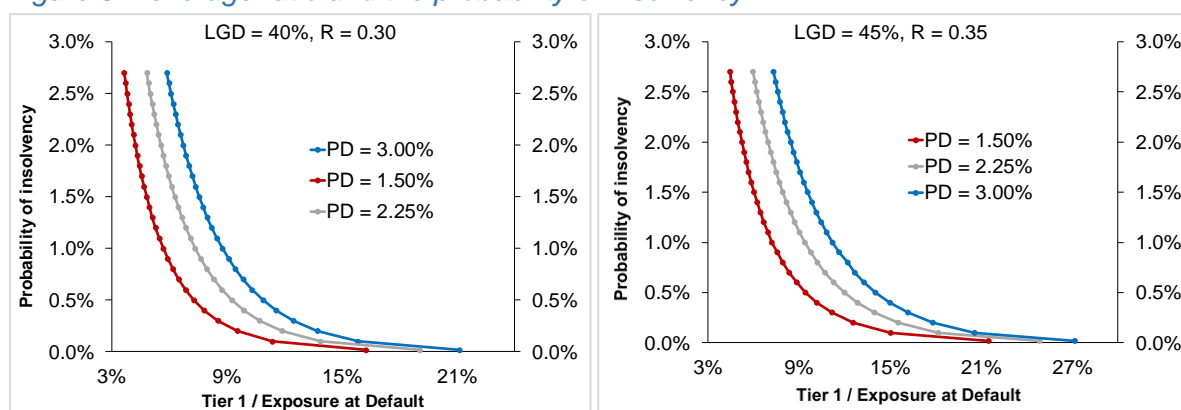
The data underpinning Figure 8 are presented in Table 2. Table 2 shows, for example, that with a PD input value of 2.25 percent, an LGD value of 40 percent and R of 0.3, capital equal to 9.26 percent of unweighted assets would deliver bank solvency in the face of losses that have a probability of 1/200 or less). In contrast, with a higher LGD and R value, a ratio of 11.98 percent of unweighted assets would be required.

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[90] Reserve Bank (2019)
[91] Reserve Bank (2019)
[92] Leverage ratio is defined as Tier 1 capital / Exposure at Default.

*Table 2: Leverage ratio needed to cap probability of insolvency*

Confidence	Probability of insolvency	PD = 1.5%	PD = 2.25%	PD = 3.0%	PD = 1.5%	PD = 2.25%	PD = 3.0%
		LGD = 40%; R = 0.30			LGD = 45%; R = 0.35		
		Leverage Ratio (Tier 1 capital / Exposure at Default)					
97.5%	1 in 40 years	3.8%	5.0%	6.1%	4.7%	6.2%	7.6%
98.0%	1 in 50 years	4.2%	5.6%	6.7%	5.2%	7.0%	8.5%
98.5%	1 in 67 years	4.8%	6.3%	7.6%	6.0%	7.9%	9.6%
99.0%	1 in 100 years	5.7%	7.4%	8.8%	7.2%	9.4%	11.2%
99.5%	**1 in 200 years**	**7.3%**	**9.3%**	**10.9%**	**9.4%**	**12.0%**	**14.1%**
99.9%	1 in 1000 years	11.4%	13.9%	15.8%	15.0%	18.2%	20.6%

Our approach was not to derive a single 'best estimate' of the relationship between capital and the probability of a crisis – and, in particular, the capital needed to cap the probability of a crisis at 1/200 - but to identify a range of reasonable estimates. We thus needed to do many repeat iterations of the ASRF model, generating each time a new array of data relating capital to the probability of crisis. Rather than try and attempt this manually, Monte Carlo simulations were used. The question the Monte Carlo analysis sought to answer was: which capital ratios emerge most often as being sufficient to cap the probability of a crisis at 1/200?

Monte Carlo analysis using the input ranges detailed above, and a risk tolerance of 1/200 produces a frequency distribution of unweighted capital ratios (refer Figure 9). For comparison purposes, the unweighted capital ratios that emerged as preferred from the overall policy assessment (not just the quantitative analysis) are shown here in red. As can be seen, the range of ratio that eventually emerged as preferred – 9 percent to 10 percent of unweighted assets – are marginally higher than those that emerged as most frequent from the Monte Carlo analysis applied to the ASRF model.

Figure 9: Frequency of leverage ratios arising from Monte Carlo analysis
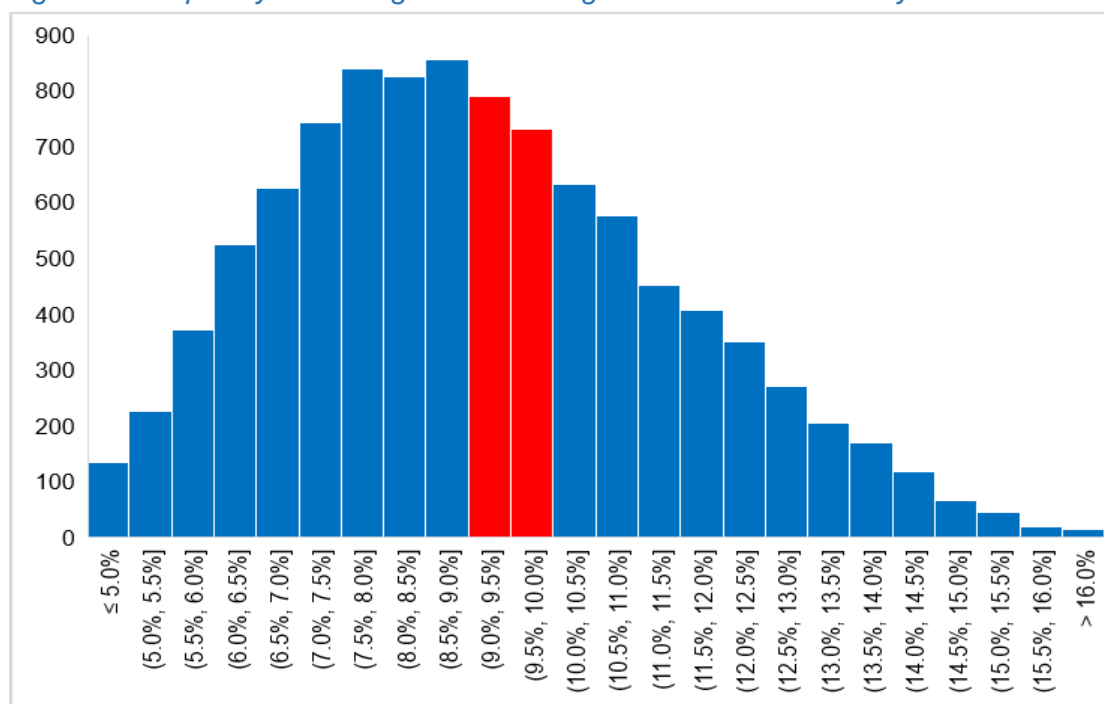
The input range

The probability-related work was important for three reasons.

- Firstly, it enabled us to explore the implications of different risk tolerances (as explained earlier).
- Secondly, it informed the issue about the capital needed to cap the probability of a crisis at 1/200. In this regard, the findings from this work complemented the findings from the literature (and the findings also aligned with those from the literature).
- Thirdly, it provide the probability input needed to estimate expected output, which is required in order to deliver the 'efficiency' component of the policy goal.

By pushing to their extremes the inputs used in the ASRF model it is possible to identify an upper and lower limits for the estimated probability of a crisis associated with a given capital ratio. This means when considering whether to increase capital from 9.8 percent of unweighted assets to 10 percent, for example, we do not need to rely on a point estimate but can consider a range.

The upper and lower limits for the probability of a crisis when the capital ratio is 9.8 percent to 10 percent of unweighted assets, for given LGD and R inputs and PD within the established range, are given in Table 3 below.

Table 3: Estimated probability of a crisis for a given leverage ratio

		Estimated probability of a crisis		
Tier 1 Capital / EAD		**9.6%**	**9.8%**	**10.0%**
LGD = 40%; R = 0.30	PD = 1.50%	0.20%	0.18%	0.17%
	PD = 2.25%	0.44%	0.41%	0.39%
	PD = 3.00%	0.76%	0.71%	0.67%

2.2 The impact of a crisis on output ('Lc')

The key issue

An important issue that is discussed in the literature is whether or not the output impact of a crisis can be assumed to be permanent. If the effect is permanent, it means even though the economy returns to growth at some point, growth is from a permanently lower base. Hence, in this case, the estimated output effects are high.

Another potentially relevant issue relates to what basis the loss is measured from. If it is the most recent level of output, and that was unsustainable (for example, fuelled by under-priced credit), the loss may be over-estimated. This is acknowledged in our framing of the policy problem as we have chosen potential output (which we interpret to mean non-inflationary steady state output) given current interest rates (not actual output) as the benchmark against which to measure the output impacts of capital.

A third issue relates to what, if any, of the output loss would have occurred even in the absence of a financial crisis. This issue is addressed in the literature by using statistical techniques to separate out the effects of many factors on realised output.[93]

It is also necessary, when estimating the output impact of a crisis, to decide the "time-varying effects" of the crisis (if any) for the duration of the crisis, and to calculate the net present value of all identified effects (if there is no permanent effect, only short and near term effects will need to be estimated).[94]

The evidence available

There is a considerable body of literature that aims to measure the output impacts of banking crisis.[95] Researchers have devised criteria to define banking crises, enabling crises to be distinguished from what are simply deep, prolonged recessions.[96] Such classifications enable the use of statistical tests to identify the causal factors driving output levels during and after the onset of banking crises, and the scale of the impacts.

We share the view of the authors of the following quote, namely that the empirical results appear to suggest the output effects are long-lasting.

> "Other studies leave the duration of a crises' effects open as an empirical question, and generally find support for long lasting effects. Furceri and Mourougane (2012), analyze OECD countries and compare actual output after a crisis with a measure of potential input. They estimate autoregressive equations and the implied impulse response functions, finding an average permanent reduction in GDP of 2 percent. Cerra and Saxena (2008), analyzing data from over 120 countries, find evidence that effects of a financial crisis on GDP are barely reduced by one percentage point after ten years, remaining at a level of six percent. These studies provide evidence for robust long-lasting effects. We assume that financial crises have persistent effects in the rest of the analysis."[97]

Overseas studies each have to apply a discount rate. These tend to be lower than what is currently required of public projects (other than accommodation and office buildings) by the

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[93] For example Romer and Romer (2015).
[94] Firestone e al (2017)
[95] For example, see Romer and Romer (2015)
[96] For example, Laeven and Valencia (2012 and 2018), and Romer and Romer (2015)
[97] Firestone et al (2017)

NZ Treasury, for example.[98] This suggests that the output cost of a crisis reported in these studies would be less if the costs had been discounted using the rate currently prescribed by the NZ Treasury.

A further complicating factor is that these impact estimates are invariant with the level of capital. In the theoretical literature there are some studies that suggest the output impacts of a crisis will be smaller the more capital is held in the system at the time of the crisis (in other words, it is not just the probability of a crisis that is related in a non-linear way to capital, the output impacts of a crisis are too).

The use of modelling by the Reserve Bank

We did not undertake independent analysis related to L_c. We referred to the findings in the range of studies presented in Table 4.

New Zealand has limited experience of severe banking stress. There is limited crisis-related information in New Zealand's historical economic data and no local case studies of banks' experiences during a systemic crisis upon which to draw. In our view this makes it difficult to credibly model the output cost of crises in New Zealand (historical New Zealand data would not be particularly informative). [99]

Table 4: Estimated cumulative present value of output lost due to financial crisis

Study	Duration of impact on economy	Discount rate used	Net present value (NPV) as a percentage of GDP
Federal Reserve (2017)	Long-lasting and varying	2.7%	41% to 99%
BCBS LEI (2010)	No permanent effect	5.0%	19%
BCBS LEI (2010)	Moderate permanent effect	5.0%	63%
BCBS LEI (2010)	Large permanent effect	5.0%	158%
Bank of England (2015)	Permanent effect	3.5%	43%

The input range

We drew our range of values for L_c from the overseas estimates presented in Table 5, settling on a L_c input value range of 20 percent to 90 percent for the sensitivity analysis, and using the BCBS's 'moderate effect' 63 percent as a central case for illustrative purposes.

2.3 The relationship between capital, lending rates and equilibrium output ('L_r')

There are two components in this relationship:

- the impact of increased capital on lending rates; and
- the impact of lending rate changes on equilibrium output.

Each of these subcomponents will be considered in turn.

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[98] Refer NZ Treasury discount rates
[99] In other areas of policy the Reserve Bank has used a central assumption of a 20 percent loss of output as a result of a crisis. Refer Reserve Bank (2017)

The impact of capital on lending rates

The key issue

Investors in a bank's capital, such as its shareholders, typically require a higher return on their investment than debt investors, such as depositors. This is because investors in a bank's capital bear more of a bank's risk. More capital may imply that a bank's average funding costs (the 'weighted average cost of capital') should increase to reflect a greater reliance on this costlier funding source. Hence, increasing the capital required of a bank has the potential to increase the bank's average cost of funding, and this can be expected to flow through (to some degree) to the interest rate charged to borrowers.

However the impact of higher capital requirements on banks' average cost of funding, and therefore the lending rates it charges borrowers, will depend on how the banks' investors respond. If the bank's capital has increased it is able to withstand greater losses and shareholder risk has thus reduced. This may lead to a reduction in the return on equity required by shareholders.[100]

An important theorem in economics identifies conditions under which an increase in the proportion of funding provided by capital will not lead to an increase in a bank's average cost of funding.[101] The degree to which shareholders absorb the potential cost increase due to higher capital is known as the Modigliani and Miller 'offset' (or the 'MM offset'). The greater the MM offset, the smaller the impact on lending rates from a given increase in the reliance on capital funding.

A related issue is whether borrowing costs might decline if bank capital increases. There is evidence globally that this may be the case.[102] [103]

Another potential area of uncertainty is whether banks will attempt to recover costs through increasing rates for all types of loans, or just some (for example, mortgages). This aspect will depend on the context, as competitive pressures will limit what can be achieved by banks in different sectors.

The evidence

There is considerable debate in the literature about the appropriate assumption to use for the MM offset. Empirical evidence about the offset was summarised in the 2017 report prepared by economists at the Federal Reserve. They conclude "the body of empirical evidence strongly supports a partial Modigliani-Miller offset".[104] Studies they reported, plus the assumptions they made in their own analysis, are presented in Table 5.

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[100] Miles et al (2012)
[101] The theorem extends to all corporations, not simply banks. Refer Modigliani and Miller (1958)
[102] Brooke et al (2015),
[103] Gambacorta and Shin (2016)
[104] Firestone et al (2017)

Study	Geography of Sample	MM Offset
Firestone et al (2017)	US	50%
Clark, Jones, and Malmquist (2015)	US	65% -100%
Toader (2015)	Europe	42%
Junge and Kugler (2013)	Switzerland	36%
Miles et al. (2013)	UK	45%
ECB (2011)	International	41% - 73%

While merely illustrative, New Zealand's recent past (as mapped in Figure 10) shows higher capital levels being accompanied by largely unchanging (and, if anything, declining) interest margins (lending rates less borrowing costs), suggesting higher capital does not necessarily translate to higher lending margins.

Figure 10: Historical NZ lending spreads compared with ratio of equity to assets
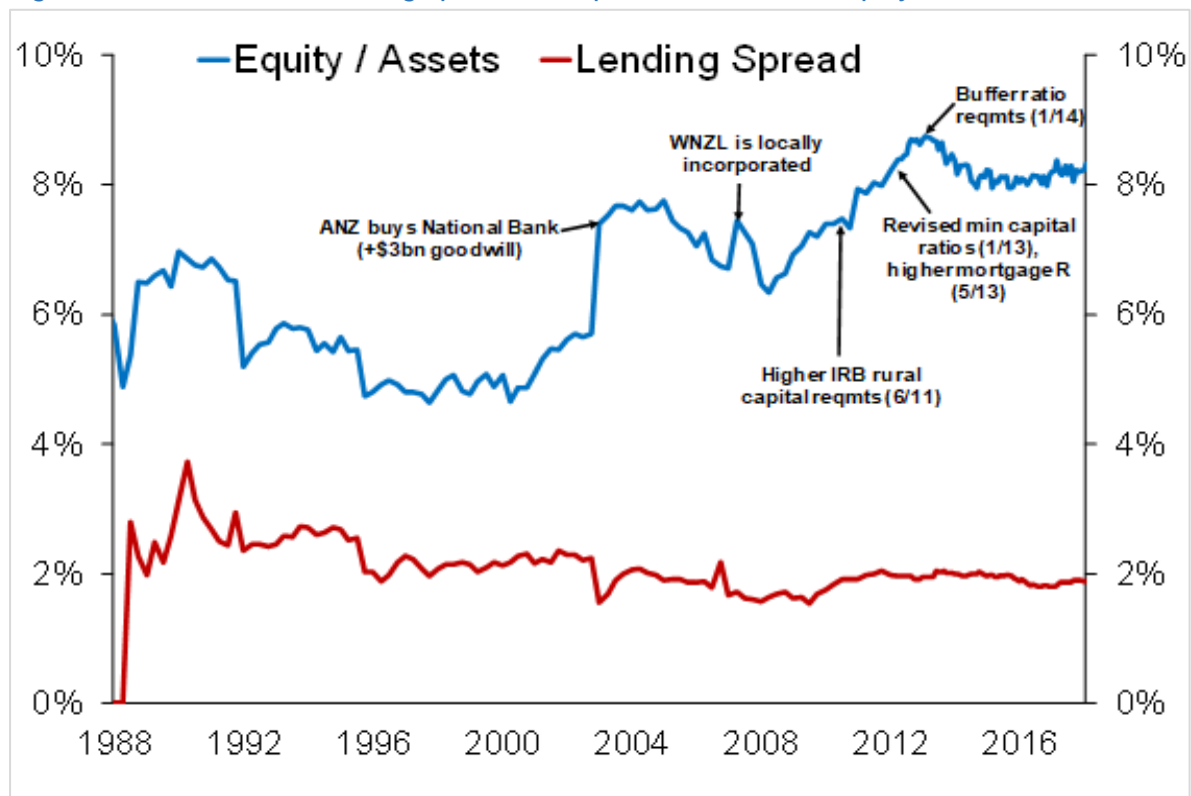
Source: Disclosure statements of locally-incorporated banks, RBNZ

In order to form a view about L_r it is necessary to form a view about the impact of lending rates on equilibrium output. In the absence of an adequately specified generally equilibrium

model, we relied on overseas estimates for this factor. [105] We will thus turn to this issue before outlining the quantitative modelling done by the Reserve Bank in relation to L_r.

ii)   The impact of lending rates on equilibrium output
The key issue
Investment in physical assets such as housing and plant and equipment, and human capital, is considered sensitive to lending rates. If lending rates increase, this would imply there will be less investment, which will reduce potential future output (which can be thought of as long run equilibrium GDP). L_r represents this loss of future potential GDP, measured on a cumulative, present value basis and expressed relative to prevailing potential GDP (which reflects prevailing lending rates).

The evidence
A range of views and approaches are evident in the literature. Regulators that have access to long term general equilibrium models that incorporate banks can use these to estimate the new output level following an interest rate shock.[106] Another avenue is to use theoretical modelling and/or regression analysis to explore the impact of higher capital on output.[107]

The results from a range of studies reviewed in a paper published by the Federal Reserve in 2017 (and the findings from the paper itself) are presented in Table 6.[108]

What is relevant here about the data in Table 6 is not the impact of capital on lending rates but the relationship between the increase in lending rates and potential output ('long run equilibrium GDP'). The Basel Committee Study from 2010, for example (line 2 in Table 6) reports the finding that a 13 basis point increase in lending rates may lead to a decline of 9 basis points in long run equilibrium GDP. This relationship between lending rates and output is something we refer to as the 'output multiple' later in the paper.

Table 6: Estimated cumulative impact of 100 bps increase in Tier 1 capital ratio on lending rates and output

Study	Effect on lending rates (basis points)	Effect on long run equilibrium GDP (present value, basis points)
Firestone, Lorenc and Ranish (2017)	3.4 to 6.9	-3.7 to -7.4
Fed Reserve of Minneapolis (2016)	5.7	-5.7
RBNZ meta-study (2016)	5 to 8	-1 to -5
Bank of England (2015)	5 to 10	-1 to -5
BCBS (2010)	13	-9

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[105] However near term analysis of the impact of lending rates on output was done in order to inform monetary policy settings. The conclusion that was reached was that the capital proposal would have a modest impact on lending rates, no greater than what would be typically considered 'noise' for monetary policy setting purposes. Refer Reserve Bank (2019) Monetary Policy Statement February 2019, Box E.
[106] BCBS (2010)
[107] For example, Miles et al (2012)
[108] Firestone et al (2017)

The use of modelling by the Reserve Bank

We now turn to the quantitative analysis done by the Reserve Bank with respect to L_r.

We estimated the impact of a 100 basis point increase in Tier 1 capital relative to unweighted assets, then used an 'output multiple', based on findings from the literature, to convert the increase in capital to a change in equilibrium output (delivering '*b*' in the equation defining L_r).

Not with-standing the debate about the MM offset, estimating the impact of a 100 basis point increase in the capital ratio can be done in a relatively straightforward way. Given the returns on equity achieved in New Zealand appear relatively high globally, and tax rates vary globally, it is important to estimate the impact using local data.[109]

We used the methodology of Firestone et al (2017). This approach incorporates the return on equity capital and debt, the local corporate tax rate, and an assumption about the degree to which higher equity capital reduces the returns required by shareholders (the 'Modigliani-Miller' or 'MM' offset). The MM offset is the proportion of the increase in a banks' weighted average cost of capital (due to an increased share of equity funding) that would otherwise arise, but does not arise because the cost of equity declines in response to the increased reliance on equity funding.[110]

The impact on lending rates of a 1 percentage point increase in the ratio of equity capital to risk-weighted assets is as follows: [111]

$$change\ in\ lending\ rates = 0.01 * \frac{RWA}{Assets} * [(1 - MM) * (RoE - RoD) + RoD * tax\ rate] \quad (3)$$

Note, that if the impact of an increase in the *unweighted* capital ratio (i.e. the ratio of Tier 1 capital to unweighted assets) is being considered, the 'RWA/assets' input in this formula takes a value of 1. This is relevant because the modelling work described above, to arrive at estimates of the probability of a crisis for a given level of capital, was done on an unweighted assets basis.

Table 7 shows the results of using Equation 3 to estimate the lending rate impact of a 1 percentage point increase in the ratio of equity capital to unweighted assets. The estimated impact is an increase in lending rates of 8.1 basis points. Our calculation assumes all of the increase in average funding costs is captured in lending rates, with no impact on borrowing costs. We view this as a conservative approach, as we believe some impact on borrowing costs is likely. [112] [113]

Table 7 can be considered a 'central' estimate in the sense it is based on a central estimate of the MM offset (50 percent, drawn from a range of 25 percent to 75 percent). When the

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[109] This is a change compared to the 2012 analysis done in New Zealand. At that time, no specific estimates of the interest rate impacts made. Refer RBNZ (2012).
[110] Modigliani and Miller (1958)
[111] Firestone et al (2017)
[112] Brooke et al (2015),
[113] Gambacorta and Shin (2016)

MM offset is set to 25 percent or 75 percent (rather than 50, as in Table 7), the estimated lending rate impact is 11.8 percent or 4.5 percent respectively.

Table 7: Estimated impact of 100 bps increase in leverage ratio on output[114]

	NZ
Impact of an increase in equity capital:	
- tax rate	28.0%
- return on equity capital, per annum	14.0%
- return on debt, per annum	2.3%
- assumption about MM offset	**50.0%**
- impact on returns from assets	0.06%
Impact of 1% change in capital ratio:	
- assumed risk weight	**1.0**
- impact of 1% change in capital ratio	0.06%
Impact on lending rates:	
- ratio of loans / total assets	**80.0%**
- impact on lending rates	0.08%
Cumulative impact on lending rates:	
- total proposed increase in leverage ratio (Tier 1 / EAD), percentage points	**4.0**
- cumulative impact on lending rates	0.32%
Impact on long run equilibrium GDP	
- factor to convert lending rate change to change in equilibrium GDP (PV)	**1.0**
- impact on GDP of 1% change in leverage ratio	0.08%
- cumulative impact on GDP	0.32%

Table 7 also shows the expected cumulative impact of the December 2018 proposals. As will be explained later in the paper, the proposal equates to an increase of 400 basis points in the ratio of capital to unweighted assets. The total impact of this on lending rates, given the assumptions in Table 7, is thus an increase (in this case) of 32 basis points (4 times 8.1). If the MM offset is 75 percent, the total impact would be 18 basis points (4 times 4.5). If the MM offset is 25 basis, the total impact is 47.2 (4 times 11.8).

The impact of varying the conservative assumption that only lending rates were impacted by the proposal was explored using sensitivity analysis. When lending rates and borrowing

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[114] Estimates were derived using Firestone et al (2017) approach. Key assumptions are emphasised in the table.

costs were allowed to vary in response to the increase in bank capital, and shareholders absorbed half of the cost increase (equivalent to a 50 percent MM offset), the cumulative impact of the capital proposals was an increase in lending *margins* of 20 to 40 basis points.

Figure 11 shows that if all of the impact occurred entirely through lending rates, the cumulative impact of the proposals would be an increase in lending rate of around 40 basis points (this compares with 32 in Table 7, the differences being due to differing assumptions about starting value borrowing costs). This result is shown by the top line in Figure 11, with the result corresponding to a value of 50 percent on the horizontal axis. If, in contrast, half of the increase in lending margins was due to declining borrowing costs, again with a 50 percent shareholder pass through, the total impact of the proposal would be a 20 basis point increase in lending rates. [115]

Figure 11: Impact on lending rates of 400 bps increase in Leverage Ratio (Tier 1 capital to EAD)
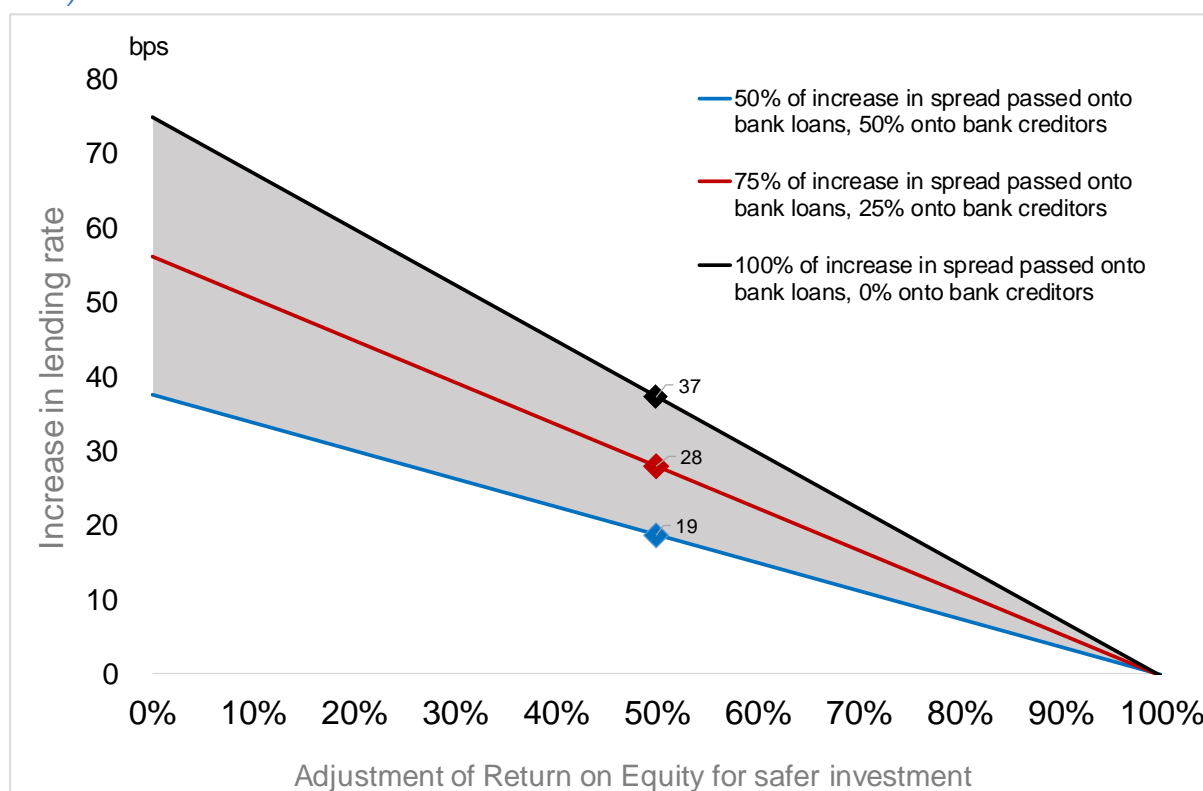
When asked for an estimate of the lending rate impact of the December 2018 proposals we have responded with an increase in lending margin of 20 to 40 basis points, which is the central result in the sensitivity analysis described above.

We do not consider an interest rate impact of this scale to be particularly onerous for the economy. A one-off 20 to 40 basis point increase in lending rates appears to sit easily within the usual range of short term movements in New Zealand lending rates (refer Figure 12).

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[115] The '50% of increase in spread passed onto bank loans' refers to 50% of the required increase in net interest (interest income less interest expense) being achieved through changing bank lending rates.

Figure 12: Advertised 2 year fixed mortgage rate, average for the Big 4 banks, Jan 2017 to Jan 2019
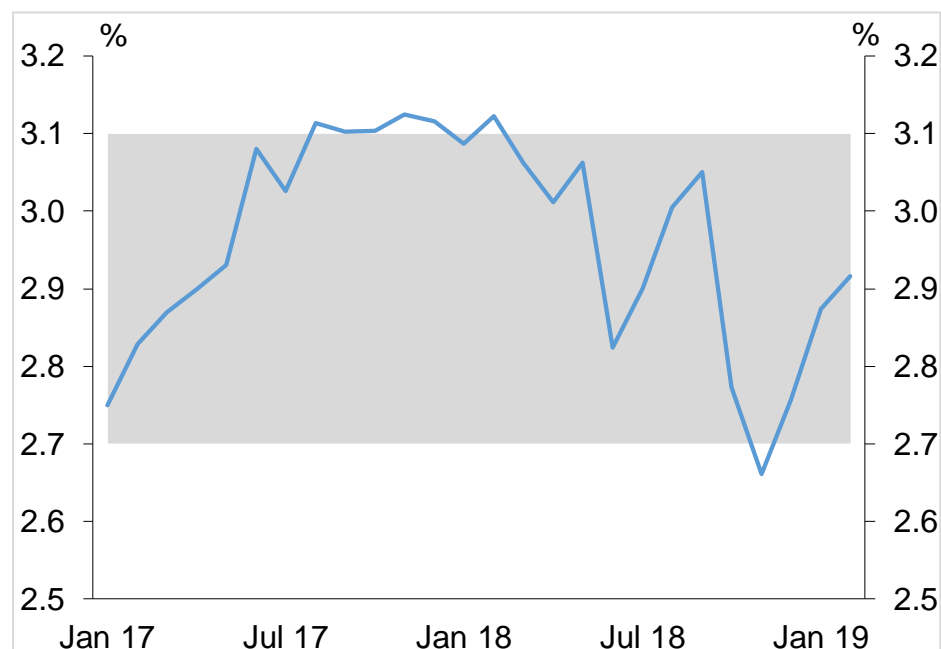
Source: RBNZ

Having estimated, for a given set of assumptions, the lending rate impact, it is necessary to estimate the present value of the cumulative output impact of the lending rate increase - the 'output multiple'. This is necessary in order to estimate L_r. We based our assumptions about the value of the output multiple on findings in the international literature summarised in Section 2.3 above).

Table 8 shows the impact of assuming an output multiple of 1 (drawn from a range of 0.8 to 1.2). The 8.1 basis point increase in lending rates leads to a 8.1 basis point reduction in potential output. This latter estimate – the change in potential output due to a 100 basis point increase in the unweighted capital ratio – is the 'b' coefficient in the definition of L_r.

Again this result can be considered a central estimate in that it is based on the mid-point of the range used for the MM offset, as well as the output multiple (a value of 1 was used for the later, drawn from the range 0.8 to 1.2).

Table 8: Impact of 100 bps increase in leverage ratio using different 'Modigliani-Miller offset' and 'Output multiple' assumptions

		Output multiple		
		0.8	**1.0**	**1.2**
Modigliani-Miller Offset	**25%**	9.4	11.8	14.1
	50%	6.5	8.1	9.7
	75%	3.6	4.5	5.4

The input range

The input range used for 'b' in Equation was 3.6 to 14.1, as per Table 8. Just to reiterate an earlier point, we view this as a conservative range as it is based on the assumption that all only lending rates are impacted by the increase in capital, not borrowing costs.

2.4 Bringing it all together

In this section, we explain how the findings relating to the three key relationships were brought together to arrive at a proposed capital setting. However, an important point made earlier must be reiterated here. Quantitative modelling was only part of the analysis that was considered before arriving at the capital proposal. The theoretical and empirical literature and findings from local stress tests also played a role. In particular, high level considerations, informed by the international literature, played an important role in arriving at final proposals. Before moving on to illustrate how the various findings from the quantitative analysis were brought together it is important to consider these high level findings.

As well as providing information about the three key relationships that are central to capital policy setting, the international literature provides high level findings about what constitutes an appropriate capital level. There was an extensive discussion of these findings in the consultation paper released in December 2018, which won't be repeated here. However that Paper's high level summary of the findings from a literature review is reproduced as Table 9.

Table 9: Findings from 'Optimal capital' literature

Study	Range of risk-weighted Basel III common equity ('CET1') ratios (unless otherwise noted)
BCBS (2010)	10% (if crises have no permanent effect on output, uses tangible common equity for CET1)
	13% (if crises have moderate permanent effect on output, tangible common equity for CET1)
Schanz et al (2011)	10% to 15% (pre-Basel III definition of capital)
Miles et al (2013)	18% to 20% (if crises have permanent effect on output)
	16% to 18% (if crises have no permanent effect on output)
Yan et al (2012)	10%
Junge and Kugler (2012)	Up to twice the Basel minima
Mendecino et al (2015)	12% to 16% (Total Capital ratio)
Brooke et al (2015)	10% to 14% (baseline result)
	7% to 11% (if costs of crises are temporary, or if transition to higher capital is moderately costly)

	15% to 19% (if improved resolution and other reforms are ineffective)
Cline (2016)	7% to 8% leverage ratio
	12% to 14% (Tier 1 ratio)
Firestone et al (2017)	13% to 26% (Tier 1 ratio)

With the qualification that the quantitative modelling was only a subset of the material considered, the focus of the remainder of this section is explaining how the quantitative analysis was brought together to arrive at a capital ratio proposal. Here we illustrate how, having considered and quantified (with ranges) the three key relationships related to capital, the ultimate issue - what capital ratios might deliver soundness and efficiency – was addressed.

Figure 13 is a stylised representation of all the factors which were considered together in the quantitative analysis.

Figure 13: Illustrating the flow of information and analysis
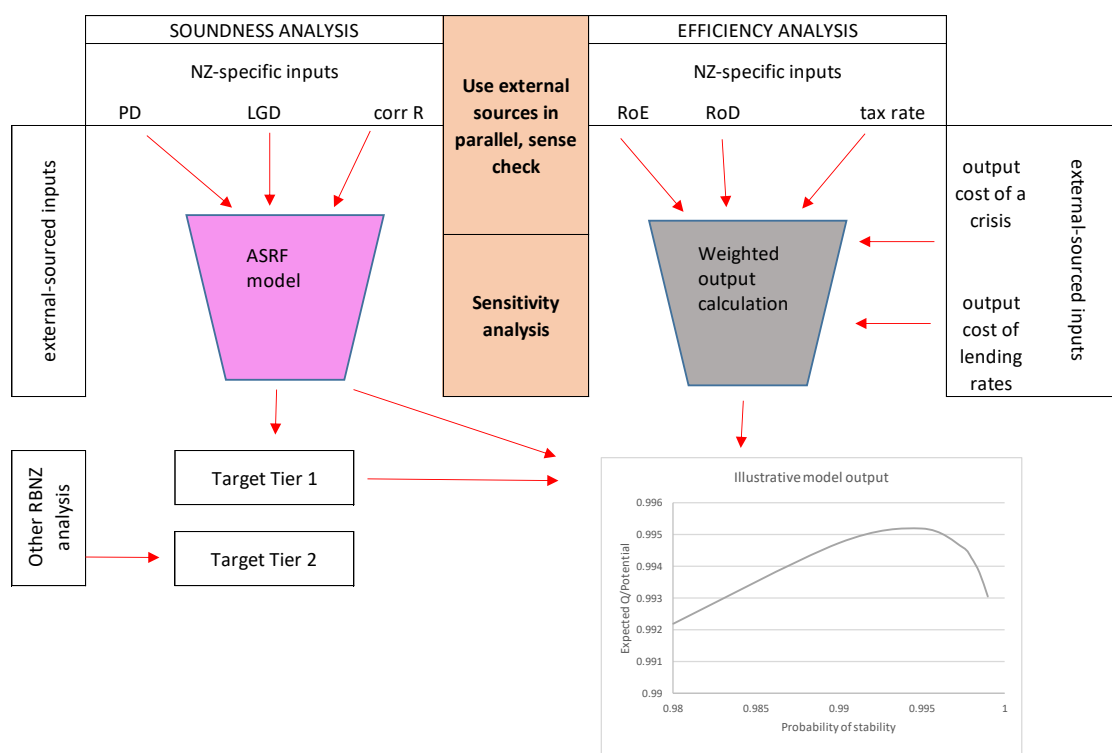
The key to identifying capital ratios able to deliver soundness and efficiency is relating stability to expected output, via capital, as is achieved in Equation 1, which is reproduced below.

$$Qe = (1-p)(1-L_r) + p(1-L_r-L_c) \qquad (1)$$

Equation 1 was used in three ways:

- An early use was to calculate expected output curves repeatedly using differing input values from within the agreed ranges for *Lc, Lr, PD*, LGD and R (the latter three delivering '*p*' in Equation I and selected from within the settled ranges). From these curves conclusions could be drawn about the output implications of adopting a given risk tolerance – would, for example, 1/200 mean a large loss of expected output very often? As explained earlier in the Paper, this analysis suggested 1/100 would be inefficient in most cases (and therefore ultimately not binding on the decision, which would then be driven by efficiency considerations). In contrast, 1/200 appeared to deliver a level of stability that was close to the output maximising level. This analysis informed the setting of the risk tolerance.
- A second application of Equation 1 was estimating the expected output implications of capital requirements equal to 9 percent or 10 percent of unweighted assets, the ratios eventually identified as being suitable given the soundness objective. The finding here was that, for central scenarios, no reduction in expected output was implied, and in those cases where expected output peaked at a level of capital below 9 or 10 percent, the reduction in expected output due to adopting a capital requirement of 9 or 10 percent was only modest (less than 0.5 percent of GDP measured on a present value, cumulative basis). Analysis of this nature is ongoing, as it is an important part of the cost benefit assessment that will be released once all submissions have been received and considered.
- The third application of Equation I was to see whether there were efficiency opportunities remaining if capital requirements were set at the proposed level of 9 to 10 percent of unweighted assets.

After adopting a risk tolerance of 1/200, weighing up the available evidence and considering soundness and efficiency as outlined in Section 1.3, the decision was made to propose an increase in minimum Tier 1 capital requirements such that the minimum requirement would exceed current Tier 1 system-wide capital by $20bn.

The final proposal was expressed as capital relative to RWA, not unweighted assets (and reflected proposed changes to the calculation of RWA by the large four banks). However, the quantitative analysis reported here was done on an unweighted basis, so for consistency, will continued to be reported on this basis.

The final proposal equates to capital equal to 9.3 percent of unweighted assets (measured as total exposure at default or 'EAD'). This is shown in Table 10. Assuming banks hold a voluntary buffer of 0.5 percent of EAD means the proposal will deliver capital equal to 9.8 percent of unweighted assets. For simplicity, we have assumed in Table 10 that the Tier 1 requirement will be met solely with common equity capital.

Table 10: CET1 Capital as % of Exposure at Default, as at 31 March 2018

All locally-incorporated banks, as at 31 March 2018	$bn	As % of Exposure at Default (EAD)
Current required CET1	20.2	3.6%
Current actual CET1	32.5	5.8%
Current actual shareholder equity	40.2	7.1%
Proposed required CET1 (assumes all Tier 1 is CET1)	52.5	9.3%
Estimated actual CET1 (assuming a voluntary buffer of 0.5% of EAD)	55.5	9.8%
Shareholder equity after proposal is implemented (add back deductions for CET1)	60.0	10.6%
Exposure at Default (EAD)	565.0	

Source: RBNZ Quantitative Impact Study, RBNZ Capital Satellite

In terms of the third application of Equation 1, this is illustrated in Tables 11 and 12. With expected capital at 9.8 percent of unweighted assets, Equation 1 was used to explore whether what, if any, efficiency 'headroom' remained with capital at this level.

In Table 11, efficiency headroom remains. With Lc assumed to be 63 percent and 'b' assumed to be 8.1 basis points, capital equal to 9.8 percent of unweighted assets is close to the output maximising capital ratio. Moving to a 10 percent ratio would generate more stability with no loss of expected output. 'Output' in Table 11 refers to potential output at current interest rates and the value given is notional and for illustrative purposes only.

Table 11: Assessment of whether 9.8 percent leverage ratio is 'efficient'

Change in expected output, given leverage ratio increases from 9.8 to 10%		$bn
Potential GDP	1	300
Initial leverage ratio	9.8	
Cost of crisis	0.63	
Impact on output of 1 percentage point increase in ratio ('b')	0.081%	
Probability of crisis at the old ratio (9.8% leverage ratio)	0.412%	
Probability of crisis at the new ratio (10% leverage ratio)	0.385%	
New leverage ratio	10	
Expected output (current)	0.99740	299.2
Expected output (new)	0.99741	299.2
Change in expected output	0.00%	0.0

It is important to note that the probabilities assumed in Table 11 are *derived from the ASRF model for a given range of inputs*. The changes in the probability of a crisis, accompanying the change in the capital ratio, reflect the input assumptions used (in this case, a PD of 2.25 percent, LGD of 40 percent and R of 0.3). Varying these assumptions, within the established ranges, as well as Lc and Lr, was an important part of the sensitivity analysis.

The ASRF model can be used to generate a *range of probabilities of crisis* for a given capital ratio. Using the lowest accepted value for PD for example, (keeping LGD and R constant, for the current purpose) produces a lower bound on the probability of crisis for the a given capital ratio, and similarly, using the highest accepted PD input values produces an upper estimate.

If we combine the lowest estimate of the probability of a crisis emerging from the ASRF model for the current ratio and the lowest estimate of the output cost of a crisis (from the literature we reviewed) we arrive at a conservative benchmark for measuring the output impacts of an increase in the capital ratio.

We can contrast this benchmark with the expected output arising from the new ratio, assuming the worst case scenario for the output cost of capital ('b' equal to 14.1 percent from Table 8), and the highest (i.e. worst case) ASRF-derived value for the probability of a crisis associated with the new capital ratio (in this case the highest PD value).

The results of this exercise are presented in Table 12. There is a small adverse impact on expected output as a result of increasing the capital ratio from 9.8 percent to 10 percent of unweighted assets - a cumulative effect measured in present value terms equal to 0.1 percent of potential GDP.

Table 12: Assessment of whether 10 percent leverage ratio is 'efficient', given lower cost of crisis

Change in expected output, given leverage ratio increases from 9.8 to 10%		$bn
Potential GDP	1	300
Initial leverage ratio	5.8	
Cost of crisis	0.2	
Impact on output of 1 percentage point increase in ratio ('b')	0.08%	
Probability of crisis at the old ratio (9.8% leverage ratio)	0.95%	
Probability of crisis at the new ratio (10% leverage ratio)	0.84%	
New leverage ratio	9.8	
Expected output (current)	0.99810	299.4
Expected output (new)	0.99512	298.5
Change in expected output	-0.30%	-0.9

On balance, given the worst case analysis illustrated above, it was concluded that there was little justification on efficiency grounds to increase capital significantly above 9.8 percent of unweighted assets.

Conclusion

The purpose of this paper was to provide, in more detail than has been released thus far, an outline of the information and analysis that helped support the proposal announced in December 2018 to increase bank equity capital to 16 percent of RWA.

The information and analysis that was considered includes findings from the international literature, the results of bank stress tests and the results of quantitative modelling. The relative coverage in this paper of the quantitative modelling work, the theoretical and empirical literature and stress testing should not be taken as indicative of the relative role of each type of information in leading to the December 2018 capital proposal. In particular, high level considerations, informed by the international literature, played a significant role.

This document should not be read in isolation but in conjunction with the consultation paper that was released in December 2018 and background papers released in January 2019.[116]

The Reserve Bank will carry out a full cost benefit assessment for a Regulatory Impact Statement to help inform and describe final decisions in the review. The concepts discussed in this Background Note will be an important component of that cost benefit assessment. The full assessment will also consider any submissions received during the consultation period, as well as looking at alternative scenarios to look at risks around estimates of costs and benefits.

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[116] Reserve Bank (2018b), January 2019 release of background documents.

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Appendix B: Key judgements and the ranges used for model inputs 'PD', LGD and R

Key judgements dictated the range of assumed input values for 'PD' LGD and correlation R used in much of the quantitative analysis. As explained, the impact of these key judgements was assessed by doing parallel model runs using differing input ranges. [117]

The key judgements were as follows:

- Basing the 'PD' input on NPL ratios and/or impairment rates;
- Using a simple average of New Zealand bank impairment data, not a value weighted average;
- Referencing overseas experience when reviewing possible 'PD' input values; and
- Reflecting observed relationships between house values and output, and contrasting New Zealand with overseas countries, when setting a range of values for correlation R.

These decisions led directly to the input ranges assumed for 'PD' and correlation R. The ranges used for PD, LGD and R, used to generate the outputs that illustrate this paper, are compared to some statistical sources in Box 1.

Box 1: Input ranges compared to statistical sources

'PD' input: (1.5% to 3%)
- Simple average all registered NZ banks, impairment ratio 1988 to 2018, was 3.2% (average halved and actual = 1.6% to 3.2%)
- The average NPL ratio in med-high income countries that have had crises (1998+ data) – excluding Greece and Cyprus – was 3.8% (average halved and actual = 1.9% to 3.8%). Median was 2.9% to 3.3%.

LGD input: (35% to 50%)
- NZ stress test results 31% and 37% (2015 and 2017 respectively)
- Minimum prescribed LGD in current BS2B (not less than 42.5% for high LVR rural loans)

Correlation R: (0.2 to 0.4)
- Observed correlation between NZ house values and GDP (63% simple correlation estimate, converted to R input value of 0.4)
- NZ's results seem high compared to other countries

Probability of Default

Basing the 'PD' input values on NPL ratios and impairment rates

The risk associated with a loan reflects two things: the probability the loan will go bad in some way and the loss that will arise if the loan goes bad. In the Basel capital equation loss

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[117] Reserve Bank (2019)

is measured in the context of loan default (i.e. the assumed probability of default is multiplied by the assumed loss given default in down turn conditions to arrive at expected losses).

However the probability of default is not the only indicator of the risk a loan will go bad. The ratio of non-performing loans to total loans is another indicator of potential risk (the 'NPL' ratio).

Unlike the PD measure, which tries to capture how a given loan will perform over time, and is thus a flow measure, the NPL ratio provides a snapshot in time, showing the relative frequency of bad loans at a point in time. In the absence of any information other than a loan belongs in a particular sub-class, for example, the NPL ratio for that sub-class indicates the risk such a loan will be non-performing.

To analyse risk using the ASRF we needed an input value that captures the risk a loan will go bad (we labelled the input 'PD'). The 'PD' input conceptually is an average value representing a sample that includes periods of crises. If an historical average is being used to generate the 'PD' input, for example, the historical era must include a crisis in order for the conditional loss distributions, generated by the ASRF model, to be meaningful for capital policy. If this is not the case, the conditional loss distributions generated by the ASRF model will not be sufficiently comprehensive, they will not be able to represent both crisis and non-crisis futures.

Given a potential role for overseas experience in our modelling work it was decided base the 'PD' input value on annual NPL data – whether historical New Zealand NPL ratios (or similar) or overseas data. In other words, if asked "what is the probability a loan will go bad in a given year?" our response would have been based on the annual average NPL ratio (or similar).

We are aware that the NPL ratio may overstate the likelihood a loan will go bad in a given year – because a loan may sit unresolved for more than a year and thus count twice. We responded to this problem by using, at the top of our range of 'PD' input values, the average historical NPL or impairment ratio (based on whatever series we were looking at) and, for the bottom of the range, 50% of the historical average (this would be appropriate if all loans classified as non-performing took two years to resolve, rather than one). We believe this is a conservative assumption, because similarly some loans may enter and leave the NPL pool within the year.

New Zealand historical impairment rates

New Zealand NPL ratio data only goes back to 1996. We thus do not have NPL data for a crucial period – the early 1990s when many New Zealand banks experienced losses on par with losses experienced elsewhere during the GFC. We do, however, have impairment data going back to 1988.

Large samples provide more reliable information than small samples. Given that the risks we are trying to capture in the modelling impact on small banks as well as large, a simple average was calculated of the annual impairment rate of all New Zealand banks over the period 1988 to 2018 (had a value weighted average been calculated we would have in effect removed all small banks from the sample).

The average impairment ratio of New Zealand banks (1988 to 2017) was 3.2%.

Figure A shows the relative frequency of annual impairment ratios.

Figure 14: Relative frequency of annual impaired loans ratio (all NZ banks, 1998 to 2017)
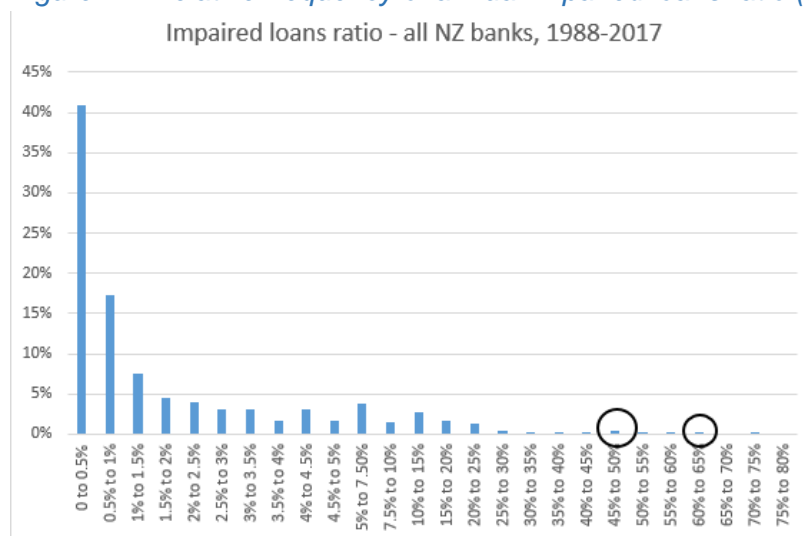
Source: Reserve Bank data

The impaired loan data shown in Figure A includes stresses experienced by the Bank of New Zealand (BNZ) in 1992. At the time BNZ was New Zealand's largest bank by a considerable margin. Five large banks dominated the banking sector and, among them, BNZ had 40% market share. In 1992 BNZ had an impairment ratio of 25%. It was state-owned and received substantial capital injections before being sold. Despite the size and systemic importance of the bank, and the need for capital injections, the BNZ episode is not considered to constitute a 'crisis'. This appears to be because the fiscal injections were relatively modest relative to GDP and there was limited contagion to other banks (BNZ's losses did not appear to cause systemic problems, although some other small banks incurred large losses around this time).
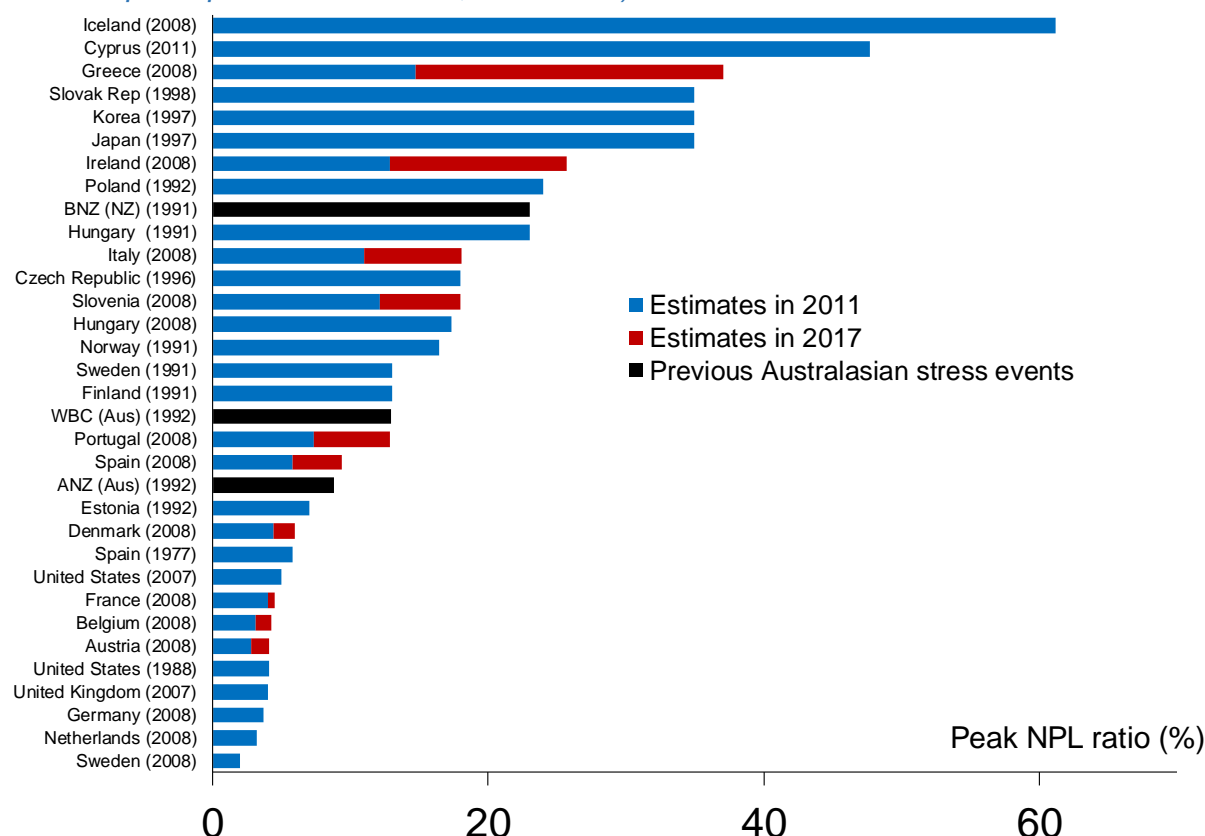
Source: Laeven and Valencia (2012, 2018), annual reports of BNZ, WBC, ANZ.

The peak impairment rates for the BNZ and two stressed Australian banks are included in Figure B for comparison purposes. The impairment experience of these banks was on par with the average experience (indicated by peak NPL ratios) of banks in countries that have experienced crises. The impairment data for New Zealand banks is thus a suitable data set to use for model inputs.

Using simple averages of New Zealand bank data

Given New Zealand is a banking system that has long been dominated by just four or five banks, it might be tempting to confine the historical sample to simply the large banks. Small banks, it could be said, have had very different portfolios than large banks and therefore their loss experience is of little relevance when assessing the capital needs of systemic banks.

Firstly, there is the obvious point. We are setting capital policy for the long term and for an unknown future. Portfolio composition among the large banks today is not necessarily a reliable guide to the portfolios that will be held in the distant future.

Secondly, many factors impact on loan performance, not simply loan type. Governance qualities, macroeconomic vulnerabilities and correlations between borrowers are relevant for all banks. These factors impact on all banks and thus, in order to best capture the effects of these factors, it seems reasonable to include small banks in any sample.

Thirdly, it is important to use large samples wherever possible. Omitting small banks would, to our view, have meant relying too much on a sample of effectively four banks.

Using data from countries that have experienced banking crises

The absence of a banking crisis in New Zealand's history makes the issue of settling on a range of values for the 'PD' input particularly problematic. We had to be open to using data drawn from other countries' histories.

While every accounting measure can be assumed to have had varying definitions through time and across jurisdictions the definition of 'non-performing' appears to be quite comparable across countries and to have been relatively stable through time. In contrast, the real-world meaning of 'default' could potentially vary more widely, making PDs a less reliable loss indicator in a cross-country context. There are precedents for using cross-country NPL ratios to derive loan loss rates (the NPL ratio is multiplied by an assumed LGD value to arrive at a loss estimate). A recent example is a report published by the IMF in 2016.[118]

Table A below shows historical average NPL ratios for countries with GNI per capita above US$15,000 in 2017 (a Reserve Bank criteria for comparability with New Zealand) that have been identified by the IMF as having experienced banking crises. Omitting Greece and Cyprus, the median NPL ratio sits between 2.9 percent and 3.3 percent and the average is 3.8 percent.

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[118] Dagher et al (2016)

Table A: Average annual NPL ratios; 1998 to 2017

Jurisdiction	Average NPL ratio	Notes
Luxembourg	0.4%	
Finland	0.7%	data missing 2013
Canada	0.9%	
Australia	1.0%	
Sweden	1.1%	
Norway	1.2%	
Estonia	1.6%	
USA	1.9%	
Rep. of South Korea	2.1%	series ends 2014
Denmark	2.2%	
UK	2.3%	
Austria	2.6%	
Belgium	2.9%	
Japan	3.3%	
Spain	3.5%	
Germany	3.6%	
France	4.1%	
Iceland	4.2%	data discrepancies
Uruguay	5.9%	
Portugal	6.0%	
Slovenia	6.5%	
Slovak Rep.	7.7%	
Ireland	7.9%	
Czech Republic	8.0%	
Italy	10.5%	2008 to 2016
Median	2.9%	
Average	3.7%	
Cyprus	46.2%	
Greece	16.4%	

Source: Data is prepared for the IMF Global Outlook, data was sourced from Federal Reserve of St Louis Economic Database and the World Bank.

The overseas NPL data suggested a PD range similar to that arising from the taking a simple average of historical impairment rates for all New Zealand banks.

LGD input values

Previous analysis by the Reserve Bank has led to prescribed LGD values for different types of loans within the capital framework.[119] The minimum prescribed value (which applies to high LVR farm loans) is 42.5 percent. In our view this analysis is supportive of LGD inputs in the vicinity of 40 percent.

Supporting this view are the results from the stress tests, held with the big four banks, in 2015 and 2017. The 2017 large bank stress test outcomes for asset class losses give us some information which can be used to arrive at a range for the LGD input. Based on the aggregate loan exposure of the four large banks, the weighted average LGD rate arising in the stress test was 31 percent (4.3/13.8). The estimate from 2014 was slightly higher, at 37 percent (5/13.7). These results are shown in Table B.

Table B: Stress-testing outcomes

Portfolio	Exposure at Default ($b, 2017)	Cumulative default rate (%)		Cumulative loss rate (%)	
		2014 test	2017 test	2014 test	2017 test
Residential mortgage	226.8	10.3	12	2.9	2.2
Of which: investment	96	-	12.8	-	2.3
Of which: owner-occupier	130.7	-	11.5	-	2.2
Corporate (large)	47.5	12.6	7.6	5.4	4.2
Corporate (SME)	30.9	24.9	19.7	7.8	7.7
Commercial property	32	30.6	27.2	7.8	7.5
Farm lending	51.1	17.1	25.1	6	8.7
Financial institutions & Sovereign	53.1	2.1	4.8	1.1	2.8
Credit cards	14	21.7	14	19.5	11.4
Other consumer	3.4	36.8	27.1	27.3	23.8
SME retail	10.7	31.8	19.8	9.9	4.7
Other	18.9	3.3	6.7	3.4	2.3
Total	488.3	13.7	13.8	5	4.3

Source: Lilly, C. (2018)

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[119] Reserve Bank, Banking Supervision Handbook (chapter 2B)

One area that was of particular interest is correlation R.

The ASRF model has been applied as part of the Basel III standards, providing the basis for risk weight calculations by banks permitted to model risk weights ('internal ratings based' or 'IRB' banks). In the Basel III application R relates to the correlation between borrowers' income and GDP. Borrowers' income is, in the Basel III case, assumed to be the determinant of the likelihood of borrower default.

However, equally, the value of the borrowers' assets could be a driver of default. Based on the limited data available, the correlation between asset values and output in New Zealand seems relatively high. The ASRF model allows the capital implications of high correlation between asset values and GDP to be explored.

In New Zealand there is a paucity of asset value data. One area where there is asset value information is housing.

In New Zealand house prices and GDP appear to be highly correlated. Figure C presents a simple plotting of the annual percentage change in GDP (real, relative to trend) against the annual percent change in house prices (relative to trend). The statistical correlation between the two series is 0.63. The statistical correlation does not translate directly into the 'R' input needed for an ASRF model, but an approximation to R can be achieved by squaring the statistical correlation (i.e. this data generates an R input value of 0.39).[120]

Figure C16: NZ House Price Index and Real GDP, 1990-2018
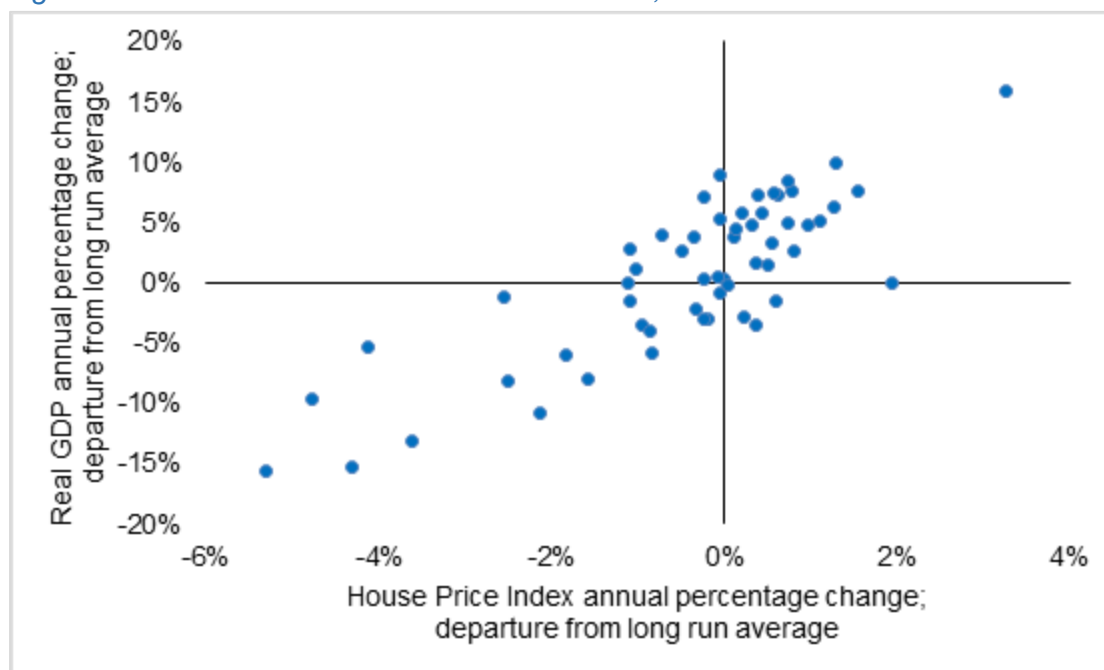
Source: Stats NZ, RBNZ

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[120] This assumes that the standardised asset returns are defined as $y_{i,t} = \alpha_i + \beta_i * S + e_{i,t}$, where $S \sim N(0,1)$ represents the systemic risk factor and $y_{i,t} \sim N(\alpha_i, 1)$. This assumes that the error terms of individual house price returns are independent and identically distributed. Hamerle et al. (2003) and Martin (2013) also provide guidance on potential ways to estimate R factors. The data used in this calculation is quarterly observations of 12-month changes.

Repeating this exercise for other countries, suggest the correlation between asset values and output in New Zealand might be particularly high. Some studies suggest that the correlation between asset values and output (and by inference, borrowers with each other) increases noticeably during crises.[121] Despite a banking crisis in the data, the correlation evident in New Zealand data is higher than in the UK and Ireland, for example, two countries that have experienced banking crises.

Table C: Correlation and 'R' estimates for NZ and other countries

Country	Statistical correlation estimates				Approximate 'R' value (square root of correlation)
	1990 to 2007	1990 to 2017	Full sample available	Full sample result	
New Zealand	0.52	0.63	1990 to 2017	0.63	0.39
UK	0.37	0.62	1976 to 2018	0.47	0.22
Canada	0.24	0.26	1971 to 2018	0.31	0.10
Norway	0.40*	0.44*	1993 to 2018	0.44	0.19
Ireland	N/A	N/A	2006 to 2018	0.44	0.19

Source: Federal Reserve of St Louis Economic Database, RBNZ

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[121] Danielsson (2002)