STAFF MEMO

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In this paper, we analyse the appropriate capital adequacy ratio for banks from a socio-economic perspective. More equity capital in banks can contribute to financial stability by reducing the risk of costly banking crises, but lending may become more expensive if banks are required finance their assets with more equity. When assessing optimal capital adequacy ratios, the economic costs of more expensive credit must therefore be weighed against the benefits of fewer and less costly banking crises. Our calculations take into account recent changes in bank capital regulation. The results indicate that Norwegian banks should have a Common Equity Tier 1 (CET1) ratio of between 12 and 19 percent. The current CET1 ratio of around 18 percent is in line with this. Our estimates are consistent with results from international studies, but estimates vary considerably with changes in uncertain assumptions. However, banks' capital needs during the banking crisis in the beginning of the 1990s show that such estimates are not unreasonable.

Key words: banks, capital adequacy ratio, capital requirements, MREL

1. Introduction

Banking crises have substantial economic costs. This is because banks play an essential role in the economy. Banks provide funding, facilitate savings, execute payments and redistribute risk. These services are decisive for economic activity. The provision of banking services is often impaired during crises.

When banks' equity capital increases, they improve their loss-absorbing capacity. This reduces the risk of banking crises, but banks' funding costs may rise when equity capital increases. If banks pass on higher costs to loan customers, interest rates on loans will, in isolation, increase. In isolation, higher interest rates put a drag on economic activity. When assessing banks' capital adequacy ratios, the economic costs of more expensive credit must be weighed against the benefits of fewer costly banking crises.

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The authorities set requirements for banks' loss-absorbing capital. The regulation contains three categories of capital requirements that banks must meet simultaneously:

- Risk-weighted capital adequacy requirements are intended to ensure that banks' capital is adequate in relation to their risk of loss.
- The leverage ratio requirement is intended to ensure that banks finance lending and other assets with a sufficient share of Tier 1 capital, regardless of risk of loss and how it is calculated.
- Minimum Required Eligible Liabilities and Own Funds (MREL) requirements are intended to ensure effective crisis management of banks without the use of public funds.

Risk-weighted capital ratios are banks' capital as a percentage of risk-weighted assets. The denominator in the capital adequacy ratio, risk-weighted assets, is calculated by risk-weighting banks' exposures. The higher the risk of losses on an exposure, the higher the risk weight should be and the more capital the bank must hold behind the exposure. The largest Norwegian banks have been granted permission by Finanstilsynet (Financial Supervisory Authority of Norway) to calculate risk weights using their own models (the internal ratings based (IRB) approach), while the smaller banks use more general and standardised risk weights (standardised approach).

The numerator in the capital adequacy ratio, ie the capital, may consist of capital of various quality. The authorities set capital adequacy requirements measured using CET1 capital, Tier 1 capital and subordinated capital. Even if all the requirements must be met, it is most common to compute and report capital ratios using CET1 capital, which is equity deducted by specified items. CET1 capital is the first to absorb any losses. We therefore focus on the CET1 ratio in this paper.

Without capital regulation banks would probably have financed their assets with less equity than that which is economically optimal. There are several reasons for this. Banks' internal decisions can entail risks for other banks. This additional risk makes overall risk in the banking system greater than the sum of risks in each individual bank. Deposit guarantees and expectations of government support for banks facing problems may also contribute to banks holding less equity than what is economically optimal. A model-based analysis by Nordal et al (2016) also highlights that banks have an incentive to choose a capital adequacy ratio that is too low in the sense that owners do not find it profitable to recapitalise the bank if large losses are incurred. According to Nordal et al, a sufficiently high capital requirement will incentivise owners to recapitalise banks in such situations, because the owners want to avoid values accruing to creditors.[2] Overall, this indicates that individual banks will

[2] If the market value of the bank's equity is very low, an equity issue can increase the market value of the bank's debt. In such a situation, the market value of equity may increase less than the equity issue, increasing the market value of the bank's debt, ie values accrue to creditors, in particular if the expected return on equity is lower than the required rate of return. This debt-overhang issue is explained in more detail in Appendix 2 in Aronsen et al (2014).

normally want to hold less capital than the level best for society. The authorities therefore set requirements for loss-absorbing capital in banks. Combined with other regulations, this enables banks to absorb periods of higher losses without the use of public funds.

In 2012, Kragh-Sørensen (2012) conducted an analysis of the optimal capital adequacy ratio for Norwegian banks. The analysis indicated that the optimal CET1 ratio ranged between 13 and 23 percent.

An update of the analysis from 2012 is appropriate given a number of developments. Since 2012, Norwegian banks' CET1 ratio has increased from just over 11 percent to just over 18 percent, but parts of the increase in banks' capital ratios are due to regulatory changes and not to additional equity. In isolation, this indicates that capital ratios measured by the current rules should be higher than when using the rules that applied in 2012. On the other hand**,** systemically critical banks have been required to have subordinated capital and debt that can be swiftly written down or converted into new equity, so-called internal recapitalisation (MREL). Such debt can both reduce the risk of crises and reduce crisis costs. In isolation, the introduction of MREL may imply a lower need for capital adequacy. The Ministry of Finance has also introduced a leverage ratio requirement and liquidity requirements that may contribute to a lower optimal capital adequacy ratio.

Since 2012, we have also gained more experience regarding the costs of increasing banks' capital adequacy ratios. Moreover, further research has been published that can help increase the accuracy of optimal capital adequacy ratio calculations.

In this paper, we present new calculations of an economically optimal capital adequacy ratio for the Norwegian banking sector. Section 2 explains the calculation method, while Sections 3 and 4 describe the literature and changes in banking regulation. Section 5 describes our data set, and Section 6 discusses experiences with the recapitalisation of Norwegian banks. Section 7 calculates optimal capital adequacy ratios and Section 8 concludes.

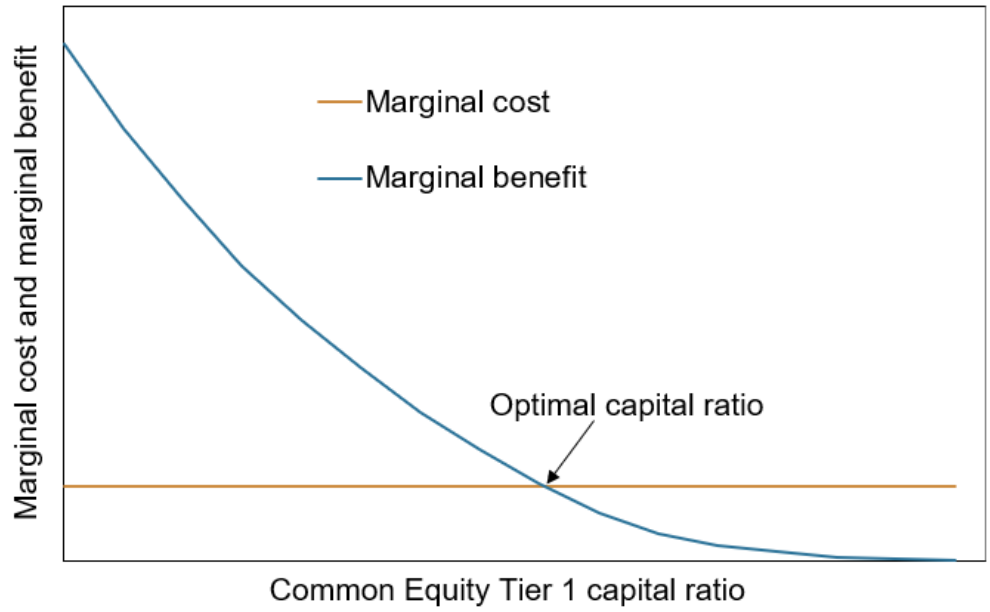
2. Calculation method for the analysis

The optimal capital adequacy level is derived by weighing the marginal costs of increasing the capital adequacy ratio against the marginal benefits (Chart 1). Benefits and costs are measured in terms of economic activity, ie gross domestic product (GDP).

The benefit of increasing capital adequacy ratios is that the risk of banking crises decreases. The marginal benefit is therefore estimated by multiplying estimated crisis costs by the estimated decrease in crisis probability when the capital adequacy ratio is increased. Most studies find that the marginal benefits are greatest when the capital adequacy ratio is increased from a low level, ie the benefits of increasing the capital adequacy ratio is decreasing.

When the capital adequacy ratio increases, the probability of a banking crisis decreases, and eventually the probability becomes so low that a further increase has no particular effect.

Chart 1 Analytical framework. Marginal benefits and marginal costs of increasing the CET1 ratio from different capital adequacy ratios. Percent of GDP.



Source: Norges Bank

The marginal cost of increasing the capital adequacy ratio is that banks' lending rates increase when a larger share of equity is needed for funding, curbing growth in economic activity. To prevent the return on equity from falling when equity increases, banks must increase earnings. That can be done by increasing lending rates. In isolation, higher interest rates dampen on economic activity. Marginal costs are therefore calculated on assumptions about how changes in capital adequacy affect the required rate of return on banks' equity and other funding costs, as well as how higher funding costs affect lending rates and GDP. Empirical studies normally assume that these costs are proportional to increases in CET1 ratios.[3]

The net benefits of increasing the capital adequacy ratio (k) are thus:

$$[\textit{Decline in crisis probability } (k) \textit{ x Crisis cost}] - \textit{Lower economic growth } (k)$$

As long as the marginal benefits of increasing the capital adequacy ratio exceed the marginal costs, ie the net benefit is positive, increased capital

[3] The relationship between costs and increases in the capital adequacy ratio is not necessarily proportional for all capital adequacy levels. Sharp increases in banks' capital ratios can, for example, crowd out the supply of capital for profitable projects in other parts of the economy, which can weaken economic activity. The Modigliani-Miller effect may also diminish with high capital ratios because the risk of loss for shareholders and creditors gradually becomes so low that further recapitalisations result in less reduction in required rates of return and debt interest. Our calculations indicate that the potential for further reductions in crisis probability (loss risk) is limited when the CET1 ratio exceeds 20 percent (Chart 10). According to our calculations, however, the optimal ratio is below this level (see Section 7.3).

adequacy ratios will generate economic benefits. With an optimal capital adequacy ratio (*k**), there are no net benefits from further increasing the ratio. If the ratio exceeds *k**, the marginal costs exceed the marginal benefits.

3. Literature

In 2010, the Basel Committee conducted a comprehensive analysis of the optimal capital adequacy ratio for banks in its 28 member countries. The study concluded that the optimal level was 9-15 percent, see Basel Committee (2010). Several studies use the same methods and assumptions as the Basel Committee, and a number of them build on partial results of the Basel Committee study. However, most studies conclude that the optimal ratio is somewhat higher than that of the Basel Committee, see Table 1. For example, the Federal Reserve Bank of Minneapolis (2017) found an optimal level for US banks of 23.5 percent and Almenberg et al (2017) an optimal level for banks in Sweden of 10-24 percent. Among studies for Norwegian banks, Kragh-Sørensen (2012) discovered an optimal level of 13-23 percent, while an analysis by Kockerols et al (2021) indicated an optimal level of just above 18 percent.

Table 1. Assumptions and results of selected studies

	Marginal benefit					
	Crisis cost[1]		Marginal crisis			
Study	Temporary	Permanent	probability[2]	Marginal cost[3]	Optimal level[4]	Sample
Almenberg et al (2017)	180		0.7	0.09-0.13	10-24	Sweden
Basel Committee (2010)	19	158	0.1-2.6	0.09	9-15	BCBS member countries
Fender and Lewrick (2016)	63 and 100		1.3	0.12	10-11	BCBS member countries
Barth and Miller (2018)	47		1.7	0.16	25	US
Federal Reserve Bank of Minneapolis (2017)		158	0.8	0.06	23.5	US
Firestone et al (2019)	41	99	0.6-1.7	0.04-0.07	13-26	US
Brooke et al (2015)		43	0-0.1	0.01-0.05	10-14	UK
Miles et al (2011)	140		0-0.5	0.02	16-20	UK
Boyd et al (2005)	63	302				23 countries
Haugh et al (2009)	21					6 OECD countries
Hoggarth et al (2002)	16					47 countries
Norway						
Basel Committee (2021)			0.03[5]	0.08		Norway
Boyd et al (2005)	86	314				Norway
Haugh et al (2009)	35					Norway
Hoggarth et al (2002)	10 - 27					Norway
Kockerols et al (2021)					18	Norway
Kragh-Sørensen (2012)	30 and 60		0-7.0	0.01-0.09	13-23	Norway
Schwierz (2004)	7-22					Norway

1) Crisis cost measured as a share of annual GDP. Estimates of crisis costs in Almenberg et al, Fender and Lewrick (2016), Kragh-Sørensen and Miles et al built on a combination of temporary and permanent effects. The method of the Basel Committee (2021) differs from the rest of the literature. The Basel Committee used the macro model NEMO and calculated crisis costs by comparing GDP in long-term equilibrium without crises with average GDP in simulations with endogenous crises.

2) Fall in annual crisis probability in the event of an increase in the capital adequacy ratio of 1 percentage point. The estimates are highly sensitive to the capital ratio from which the marginal effect is calculated.

3) Cost of increasing the capital adequacy ratio by 1 percentage point as a share of annual GDP. Firestone et al (2019) and Miles et al looked at the effect of increasing the Tier 1 capital ratio, while the Federal Reserve Board (2017) calculated the effect of increasing the Common Equity Tier 1 capital ratio. The Basel Committee (2021) found a marginal cost of 0.21 percent of

increasing the total capital ratio by 2.5 percentage points, which corresponds to about 0.08 percent per percentage point increase in the capital adequacy ratio.

4) Almenberg et al calculated the optimal equity ratio at 5-12 percent. Brooke et al calculated the optimal level of Tier 1 capital ratio. The Basel Committee (2010) calculated the optimal level of investors' equity (paid-in and retained earnings) less intangible assets and goodwill (Tangible Common Equity - TCE) as a share of risk-weighted assets. According to the Basel Committee, the TCE of euro area banks was on average about 25 percent less than the Tier 1 capital in 2010.

5) According to the Basel Committee (2021), a total capital ratio increase of 2.5 percentage points reduces the annual crisis probability by 0.07 percent, which corresponds to about 0.03 percent per percentage point increase in the capital adequacy ratio.

Sources: Basel Committee (2021), Birn et al (2020), Boyd et al (2005), Firestone et al (2019), Kockerols et al (2021), Kragh-Sørensen (2012), Hoggart et al (2002), Haugh et al (2009) and Schwierz (2004).

The subsequent literature review first discusses analyses of the marginal benefits of increasing the capital adequacy ratio and then analyses marginal costs.

3.1. Marginal benefits of increasing the capital adequacy ratio

The marginal benefits of increasing the capital adequacy ratio are that the risk of banking crises falls. In addition, increased capital adequacy ratios can reduce crisis costs. Our calculations do not include this type of benefit. The marginal benefits are therefore estimated by multiplying the crisis costs by the reduction in crisis probability that society achieves by increasing capital adequacy ratios.

3.1.1. Crisis probability at different capital adequacy ratios

The literature uses two overarching methods for calculating how capital adequacy ratios affect crisis probability: a top-down method and a bottom-up method, see Birn et al (2020). The top-down method uses country-level data to estimate relationships between crisis probability and the banking sectors' capital levels, and the studies typically control for other factors in the economy that may affect crisis probability.[4] The bottom-up method estimates relationships between capital and crisis in individual banks and extrapolates the results to relationships between banking sectors and crises. Both the Basel Committee (2010) and Kragh-Sørensen (2012) used both of these methods.

The Basel Committee (2010) used six different calculations to estimate the relationship between crisis probability and capital adequacy ratio. In three of the calculations**,** the Basel Committee used the top-down method to analyse how the frequency of banking crises in a large sample of countries has varied in line with capital adequacy ratios of banking sectors in the different

[4] The banking sector's liquidity, credit as a share of GDP, volatility targets (VIX), house prices and trade balances.

countries. In the three other calculations, the Basel Committee used the bottom-up method, in which crisis probability was estimated for individual banks at different capital adequacy ratios.

Kragh-Sørensen (2012) calculated crisis probabilities for the Norwegian banking sector using a bottom-up method. Kragh-Sørensen defined a banking crisis as a situation where at least two of the six largest Norwegian banks breach the minimum CET1 ratio requirement of 4.5 percent. He assumed that Norwegian banks' problem loans were exponentially distributed. This resulted in a continuous distribution that was used to simulate the problem loans. First, Kragh-Sørensen drew random observations from the continuous distribution. He then let the problem loans follow the average historical process. This provided estimates of how much banks may lose in different situations. The crisis probability was then estimated by estimating how the crisis frequency varied with the starting capital adequacy ratio. Kragh-Sørensen also used crisis probability estimates from both the Basel Committee (2010) and Miles et al (2011).

Miles et al (2011) used a bottom-up method that differs from methods employed in the rest of the literature. Miles et al discovered a positive one-to-one relationship between the fall in GDP and the fall in banks' capital adequacy ratios. Then they defined a crisis as a situation in which the capital ratio of the banking sector is zero or negative. With this crisis definition, they could assume that the crisis probability of a given capital ratio is equal to the probability of a GDP fall that is greater or equal to the capital ratio. Thus, Miles et al could use GDP figures from 31 countries covering a period of 200 years to calculate the annual crisis probability at different capital ratios. Since this method is based on a fall in GDP, it only captures financial crises that have occurred simultaneously with a sharp decline in economic activity. The method does not capture crises with a fall in GDP that is less significant than capital ratios in the banking sector. The study may thus underestimate the probability of a crisis.

Almenberg et al (2017) calculated crisis probabilities using two different bottom-up methods. In one calculation, Almenberg et al used a standard option price model and data on share prices, share capital, liabilities and assets of the four largest Swedish banks. In this calculation, Almenberg et al assumed that a banking crisis occurs when at least one of the four banks' equity ratios fall below respectively 3, 1.5 and 0 percent. In the second calculation, Almenberg et al used similar crisis thresholds for the Swedish banking sector as well as a model at reduced form and data for the Swedish banking sector's loan losses, assets and capital. The estimated crisis probabilities varied greatly with regard to both crisis threshold and methodology.

Birn et al (2020) conducted a literature review that showed considerable variation in the calculated effects on crises probabilities of changes in banks' capital adequacy ratios. The literature review also highlighted that the estimates depend heavily on the capital ratio used to calculate the marginal

effects. The marginal effects are clearly greatest when capital adequacy ratios are increased from low capital adequacy ratios, ie the benefits of increasing capital adequacy ratios are declining. When capital adequacy ratios increase, the probability of a banking crisis decreases. For example, the estimates of the Basel Committee (2010) show that the annual crisis probability is reduced by 2.6 percentage points when the CET1 ratio is increased from 7.8 to 9.1 percent, while the crisis probability is reduced by only 0.1 percentage point when the CET1 ratio is increased from 18.3 to 19.6 percent.

The Basel Committee (2021) used a DSGE model (NEMO[5]) with a banking sector and regime change to assess the effects of Basel III on the Norwegian economy. In NEMO both crisis probability and crisis severity are determined by households' total real credit growth over the past five years. An increase in capital requirements pulls up banks' funding costs, and banks adjust by increasing the lending margin. This dampens credit growth and reduces crisis probability. According to the calculations**,** the annual crisis probability falls by 7 basis points when the capital ratio requirement increases by 2.5 percentage points. The Basel Committee (2021) calculated the annual crisis probability in Norway at 3.38 percent with a capital ratio requirement of 16.3 percent.

3.1.2. Costs of banking crises

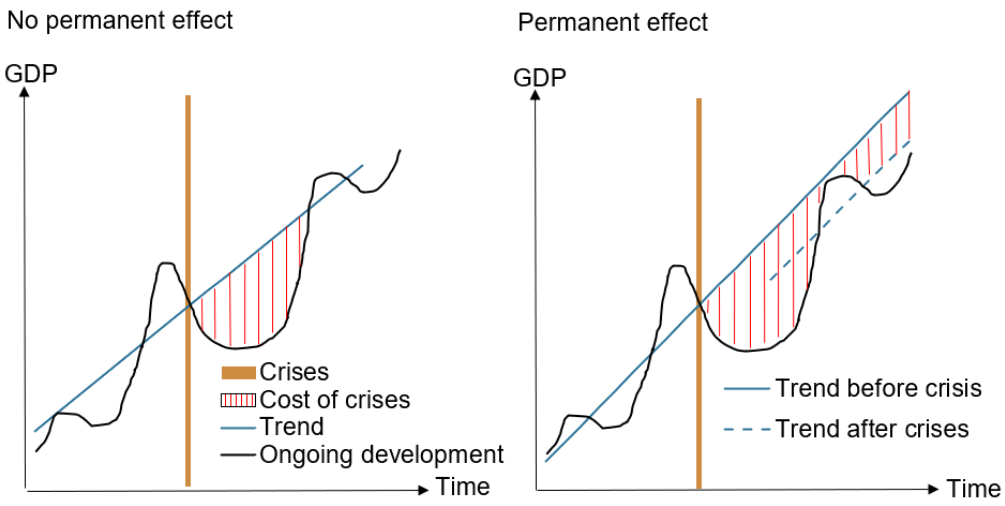
The benefits of avoiding a banking crisis depend on the economic cost of a crisis. Banking crises are normally costly for society. Banks offer services that are crucial for economic growth, including loans to firms and private individuals. The provision of such services is often impaired during banking crises. In difficult times, for example, banks may be forced to tighten lending in order to improve their capital adequacy ratios. Reduced credit supply may amplify the fall in investment and consumption, resulting in a sharper fall in economic activity than if banks had been able to meet credit demand. Some studies, including Haugh et al (2009), compare banking crises with other recessions. They show that recessions coupled with banking crises are about five times more severe than other recessions.

A number of studies calculate crisis cost in the form of output loss, ie GDP. Often, the studies exclude the cost of government measures. There is considerable variation in the projections, partly because the studies are based on different countries, different crises and different start and end dates for the same crisis. However, the most significant explanation for variations in estimates is the difficulty in assessing how GDP would have developed without a crisis. In the absence of an alternative GDP development**,** the studies estimate hypothetical GDP trajectories and compare these with actual GDP developments during and after crises. Certain studies are based on hypothetical GDP given that no crisis had occurred, while others calculate losses relative to potential GDP.

[5] NEMO is Norges Bank's model for monetary policy analyses and forecasts, see a detailed description of the model in Kravik et al (2019).

The estimated cost of banking crises depends in particular on whether banking crises are assumed to permanently weaken economic activity.[6] For example, banking crises can weaken the level of investment, contribute to capital misallocation or permanently lower employment.[7] In this case, crises can have permanent effects. Chart 2 illustrates the difference between temporary and permanent effects on GDP. In Chart 2, left panel, the banking crisis produces only temporary effects because GDP returns to the pre-crisis trend and remains close to that level. In the panel on the right, the banking crisis has permanent effects on GDP, ie GDP never reaches the long-term trend prevailing before the crisis. The trend will remain permanently lower, but it is assumed that trend GDP *growth* will be the same as before. The difference between the old and the new lower trend results in the annual permanent effect. Since the new trend never reaches the former level, the crisis cost must be estimated over an infinite horizon and all future losses must be discounted, see Basel Committee (2010). In this context, the sum of discounted annual costs becomes a finite size (not infinite), but total crisis costs will be significantly higher than in the case of only temporary effects, see shaded area in Chart 2.[8] Crises can also have permanent effects that pull up the trend, for example post-crisis reforms that yield efficiency gains. In the following, we refer to total cumulative costs as a percentage of annual GDP.

Chart 2 Illustration of crises costs



Source: Basel Committee (2010)

In a recent study, the IMF finds signs that the global financial crisis in 2008 had permanent effects on GDP, see IMF (2018). According to the analysis,

[6] See, eg Cecchetti et al (2009), Haugh et al (2009), Hoggarth et al (2002) and Laeven and Valencia (2008) for crises without permanent effects. For permanent effects, see, eg, Abiad et al (2009), Barrel et al (2010), Cerra and Saxena (2008), Furceri and Mourougane (2012), Furceri and Zdzienicka (2012) and Turrini et al (2010). Some studies calculate cumulative losses directly, see Boyd et al (2005) and Haldane (2010).
[7] Permanent effects of banking crises can be partly explained by hysteresis effects in the labour market, see Ellingsen and Galaasen (2021).
[8] Estimated costs also depend on the discount factor applied.

particularly weak investment developments produced permanent effects from the financial crisis. According to the study, countries with strong public finances public finances and flexible exchange rates suffered lower crisis costs than other countries. The IMF's explanation for this is that flexible exchange rates function as an automatic stabiliser or buffer, which to some extent shields the economy from terms-of trade changes, while strong public finances enable governments to mitigate crises by means of fiscal accommodation.

The average estimated crisis cost in the analysis of the Basel Committee (2010) was 106 percent of GDP**,** which is close to the average estimate in recent studies discussed in Birn et al (98 percent of GDP). The studies in our literature review that assume permanent effects of crises find generally higher crisis costs (43 to 302 percent of GDP) than the studies that only assume temporary effects (16 to 63 percent of GDP). For example**,** Firestone et al (2019) find that crises in the US cost up to 99 percent of GDP if they assume permanent effects, while the estimated crisis cost falls to 41 percent of GDP if they only assume temporary effects.

Few studies take into account that factors other than banking crises may weaken trend GDP growth, such as lower productivity growth or population ageing. This may result in excessive cost estimates. A banking crisis can also have positive effects on long-term trend growth if the crisis induces[9] the authorities to implement necessary structural reforms**,** see, eg OECD (2007). Economic crises can also stimulate innovation and cost-cutting in the private sector. Calculations that assess losses in relation to potential output take greater account of the possibility that factors other than the banking crisis itself may affect GDP. Such studies therefore generally arrive at somewhat lower cost estimates than other studies, see for example Barrel et al (2010), Furceri and Mourougane (2012) and Turrini et al (2010). However, estimating potential output is associated with substantial uncertainty.

The projections for the Norwegian banking crisis at the beginning of the 1990s also vary considerably (see Table 1). Boyd et al (2005) estimated costs at 314 percent of GDP under assumptions of permanent effects, while assumptions that the effects only occurred up to and including 1998 resulted in a cost estimate of 86 percent of GDP. Other cost calculations for the Norwegian banking crisis have not assumed permanent effects.[10] Haugh et al (2009)**,** Hoggarth et al (2002) and Schwierz (2004) only considered deviations from trend up to the end of the banking crisis, ie up to and including 1993. Hoggarth et al estimated that the Norwegian banking crisis cost between 10 and 27 percent of GDP. The lowest cost estimate in this study was calculated in relation to potential output. Haugh et al also calculated the costs in relation to

[9] Studies that incorporate that banking crises may be caused by economic downturns nevertheless document substantial costs (Bordo et al., 2001; Haugh m. fl., 2009; Hoggarth et al, 2002; Cerra and Saxena, 2008; IMF, 2009; Claessens, Kose and Terrones, 2008). In addition, Alfaro and Drehmann (2009) find that banking crises usually do not occur after a period of declining GDP.
[10] Different dating of the Norwegian banking crisis may also explain some of the difference between cost estimates.

potential output, but their study indicated higher costs (35 percent) than Hoggarth et al. Schwierz's study found lower costs than the other studies, in which the lowest cost estimate (7 percent) included the benefits of GDP running above trend during the pre-crisis years. It is unusual to include such benefits and they are not included in the other studies. The above-mentioned studies estimate on average that the cost of the Norwegian banking crisis came to 59 percent of GDP.

Almenberg et al used the results of Boyd et al in their assumptions about the cost of the banking crises in Sweden. Almenberg et al used the average of cost estimates in Boyd et al without permanent effects (101 percent) and with permanent effects (257 percent) in their assumption that banking crises in Sweden cost 180 percent of GDP. Using the same method, the cost of banking crises in Norway is 212 percent.

Kragh-Sørensen (2012) took into account the considerable uncertainty surrounding crisis costs by applying two different estimates, 30 and 60 percent of GDP respectively. This was in the lower half of the estimates in the international literature and on par with most cost estimates for the Norwegian banking crisis. Kragh-Sørensen assumed that crisis costs are independent of banks' capital adequacy ratios. But he pointed out that increased capital adequacy ratios can curb banks' need to tighten credit standards during crises, which will reduce the need for costly government bailouts. In isolation, the benefits of increasing capital adequacy ratios may therefore be higher.

Jorda et al (2021) concluded that more capital in banks can reduce the cost of banking crises rather than the probability of a crisis. They analysed data dating back to 1870 for 17 advanced economies and found no relationship between capital adequacy ratios and crisis probability. However, the analyses revealed that crises weaken economic activity over a shorter period in countries with well-capitalised banking sectors, ie high capital adequacy ratios result in lower banking crisis costs. The explanation for this offered by Jorda et al is that the supply of credit normalises more rapidly if the banking sector has good loss-bearing capacity. Such advantages were not included in the Basel Committee (2010). A simple calculation by Aikman et al (2018) indicates that the optimal capital adequacy ratio will be about two percentage points higher when the calculations assume that increased capital adequacy ratios result in lower banking crisis costs.

Kockerols et al (2021) used NEMO to analyse the macroeconomic effects of changes in capital requirements.[11] According to the analysis, increased capital requirements contribute both to reducing crisis severity and increasing the speed of post-crisis economic recovery. They concluded that the effect of increased capital requirements on crisis costs is greater than the effect on crisis probability.

[11] Kockerols et al used the same method as the Basel Committee in the calculations for Norway.

In the Basel Committee's calculations for Norway, increased capital requirements help reduce crisis costs (see Basel Committee (2021). This is explained by the fact that a given loss results in a smaller percentage reduction in the equity ratio than when banks have more equity.[12] A given loss will result in a lower need to increase lending margins if banks have a high equity ratio, and the cost of restoring the equity ratio will be lower. As a result, output will be more effectively maintained during crises. Measured as a share of GDP, crisis costs fall by 1-2 percent when capital adequacy requirements increase by 2.5 percentage points.

3.2. Marginal costs of increasing capital adequacy ratios

Increasing capital adequacy ratios entail marginal costs, ie banks' lending rates increase when a larger share of equity is used for bank funding, which puts a drag on economic activity. Stronger capital requirements can increase banks' funding costs because a larger share of assets must be financed with equity. The increase in funding costs is determined by the difference between the required return on equity, debt interest and the extent of increase in the equity ratio.

Equity owners take on greater risk than creditors. First, equity owners are the last to receive payments in the event of bankruptcy. Moreover, the return on equity, as opposed to the interest paid on the debt, will vary with the performance of banks. Equity owners therefore require higher return than creditors.

Nevertheless, it is not obvious that higher capital adequacy ratios result in higher funding costs for banks. The Modigliani-Miller theorem states that the cost of financing should not depend on the structure of financing, see Modigliani and Miller (1958). Additional equity reduces both return on equity volatility and creditor risk. Thus, both the required return on equity and debt interest fall when the equity ratio increases, so that the weighted sum of funding costs is in theory unaffected. However, international studies indicate that the theorem is invalid in practice, implying that banks' total funding costs rise when capital adequacy ratios increase, see eg Clark et al (2018), European Central Bank (2011), Elliot et al (2012), Kashyap et al (2010), Miles et al and Toader (2015). According to the analyses, lower equity return requirements and debt interest will offset about half of the direct cost increase resulting from an increase in the equity ratio. Most studies therefore assume relationships between banks' funding costs and capital adequacy ratios that correspond to this, see Birn et al. But some studies stand out in this area as well. For example, the Basel Committee (2010) assumed that both the required rate of return on equity and debt interest are independent of capital

[12] A loss reduces both the numerator (equity) and the denominator (total assets) in the equity ratio. The reduction in total assets dampens the fall in the equity ratio. This dampening effect is greater when the equity ratio is high because a given reduction in the denominator in isolation increases the share more when the numerator is high.

adequacy ratios, ie the Modigliani-Miller theorem is invalid, while Admati et al (2013) assumed that the Modigliani-Miller theorem is entirely valid.

There are several reasons why the Modigliani-Miller theorem does not hold. Interest expense reduces banks' taxable profits. This is not the case for dividend on equity. A lower equity ratio may therefore reduce tax expenses, see Elliot et al (2012) and Elliot (2013). Most studies apart from the Basel Committee (2010) ignore this effect. In addition, the theorem assumes that creditors and owners bear all respective losses in case banks encounter serious problems. In this case, the interest rate on debt financing should be reduced when capital adequacy ratios increase because credit risk falls. But in practice, implicit and explicit government guarantees can reduce the risk of creditors having to bear losses. This may contribute to fairly low debt interest rates, even if the equity ratio is low. Banks largely rely on financing in the form of customer deposits secured by deposit guarantees. Depositors in Norwegian banks are secured against losses on deposits of up to NOK 2 million. Such deposit guarantees make deposit rates less dependent on banks' equity ratios. In addition, creditors may believe that large banks are in practice insured by the authorities. If creditors regard these guarantees as substantial banks' capital adequacy ratios may have little impact on debt interest rates. In that case, debt-financing will be less costly for banks. Higher capital adequacy ratios may therefore entail somewhat higher costs for banks.

Kragh-Sørensen calculated the marginal cost of increased capital adequacy ratios with estimated relationships between equity ratio and financing costs from Vale (2011) and an estimated relationship between lending rates and GDP from Hammersland and Træe (2012). The cost of increasing the capital adequacy ratio by 1 percentage point varied between 0.0 and 0.07 percent of GDP. In addition, Kragh-Sørensen calculated marginal costs with results from a model estimated by Akram (2012), in which an increase in the capital adequacy ratio of 1 percentage point resulted in annual marginal costs equivalent to 0.09 percent of GDP in the long term. This is consistent with the calculations of the Basel Committee (2021) for Norway showing that an increase in capital requirements of 1 percentage point drags down real GDP by about 0.08 percent.

The cost estimates for Norway are at about the same level as the cost estimates in the international literature (see Table 1). According to the median result of the Basel Committee (2010), an increase in the capital adequacy ratio of 1 percentage point will reduce GDP annually by 0.09 percent in the long term.[13] In comparison, Miles et al found that a 1 percentage point increase in UK banks' Tier 1 capital ratio reduces UK GDP annually by about 0.02 percent, while Brooke et al estimated the marginal cost of the same recapitalization at 0.01-0.05 percent annually. Firestone et al estimated that an increase in U.S. banks' capital ratio of 1 percentage point resulted in a GDP loss of 0.04-0.07 percent annually. The Federal Reserve Bank of Minneapolis

[13] According to Kragh-Sørensen, the median result of the Basel Committee indicated that an increase in the CET1 ratio of 1 percentage point reduces GDP annually by 0.07 percent in the long term.

(2017) discovered effects similar to Firestone et al, while Barth and Miller (2018) estimated over twice as high marginal costs for the United States. Almenberg et al found somewhat stronger effects for Sweden, where the cost of increasing the CET1 ratio by 1 percentage point was estimated at 0.11 percent of GDP per year.

4. Changes in banking regulation over the past decade

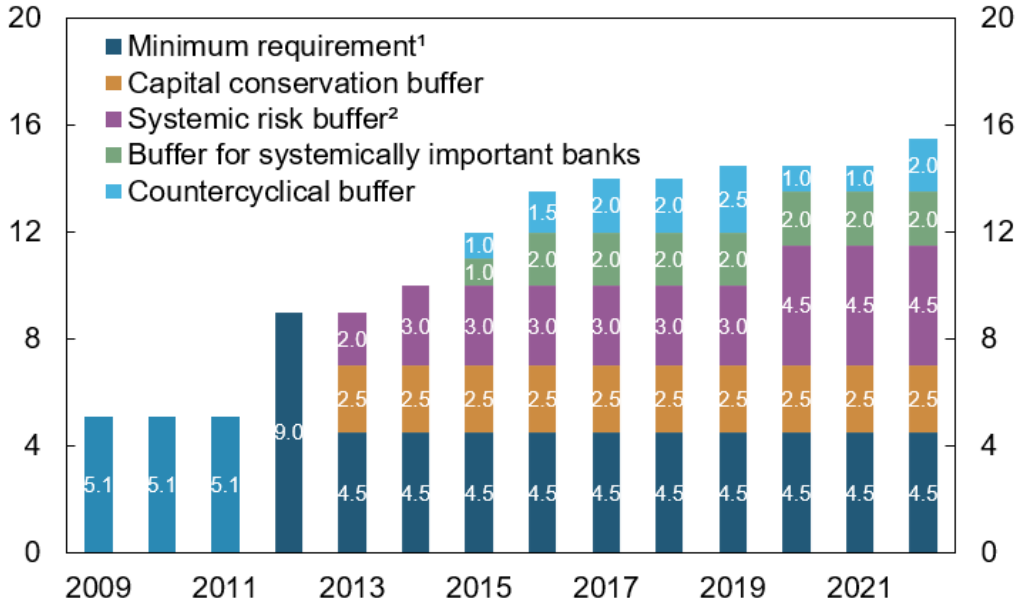
The 2008 global financial crisis triggered sweeping reforms of banking regulation. The crisis uncovered a swathe of regulatory weaknesses, with among other things a need for requirements to increase banks' resilience to losses. In 2010, the Basel Committee therefore presented Basel III – a comprehensive proposal for a new capital and liquidity framework, and in 2011 the Financial Stability Board (FSB) presented proposals for new principles for crisis resolution of banks. These proposals led to a significant reform of banking regulation a few years later. But already in autumn of 2011, the EU adopted a temporary requirement that the largest banks' CET1 ratio should be at least 9 percent by summer 2012. Finanstilsynet (Financial Supervisory Authority of Norway) imposed the same requirement on Norwegian banks.

In the summer of 2013, agreement was reached in the EU to introduce Basel III in EU rules (CRR/CRD IV). These regulatory changes, which were phased into Norwegian law from summer 2013, included a new minimum CET1 ratio requirement of 4.5 percent and several buffer requirements exceeding the minimum requirement. The introduction of these requirements substantially increased the overall CET1 ratio requirements for Norwegian banks (Chart 3).

The buffer requirements and the minimum capital adequacy requirements described above are so-called Pillar 1 requirements. In addition, there are Pillar 2 requirements to cover risks that are not sufficiently covered by the other requirements.

In this paper, we focus on the average capital adequacy ratio of the Norwegian banking sector. In practice, capital requirements vary across banks. Systemically important banks are to hold an additional capital buffer because problems in such banks can have greater negative economic consequences than similar problems in other banks. In addition, the Pillar 2 requirements are individual and depend on Finanstilsynet’s risk assessment of the bank concerned.

Chart 3 Pillar 1 CET1 requirements for Norwegian banks. Percent. 2009 – 2022



1) Prior to Basel III, the capital adequacy rules did not set out an explicit minimum CET1 requirement. Since the minimum Tier 1 capital requirement was 4 percent, and up to 50 percent of Tier 1 capital could consist of hybrid capital, the international regulations set out an implicit minimum requirement of a CET1 ratio of 2 percent. However, in Norway, the CET1 ratio requirement was in reality 5.1 percent. Kredittilsynet's (former name of Finanstilsynet) Circular 14/2001 required a Tier 1 capital ratio of at least 6 percent in order to issue time-limited subordinated loan capital. From 2002, preferred capital securities (hybrid capital) could account for up to 15 percent of Tier 1 capital, see Section 13.2 of Proposition No. 1 to the Odelsting (2001-2002). This entailed a CET1 requirement of: 6.0 * (1 – 0.15) = 5.1 percent.

2) Banks applying the standardised approach and the foundation IRB approach are required to satisfy the current systemic risk buffer requirement of 3 percent for all exposures up to 31 December 2022.

Source: Finanstilsynet

In 2018, the EBA (European Banking Authority) published guidelines requiring supervisory authorities to set a capital margin requirement for banks (see European Banking Authority (2018)). In recent years, Finanstilsynet has set a capital margin requirement (Pillar 2 guidance) of about 1 percent for Norwegian banks. Finanstilsynet follows up banks that do not have sufficient capital margins and will consider increased Pillar 2 requirements for such banks, see Finanstilsynet (2019). Most Norwegian banks adapt by holding a buffer above the capital margin requirement, to ensure capital adequacy ratios are above the total capital requirements.

Basel III allowed contingent convertibles (CoCos) to qualify as Tier 1 capital under certain conditions. CoCos are bonds issued by banks that are contractually written down or converted into equity if the capital adequacy ratio falls below a predefined level. Under Basel III, CoCos only qualify as Tier 1 capital if they are converted to equity with a CET1 ratio of at least 5.125 percent. If a bank has issued CoCos and its capital adequacy ratio falls below the predefined level, bondholders may be forced to take losses before equity is fully written down. This can improve banks' loss-bearing capacity.

Basel III also included a leverage ratio requirement to ensure that banks finance their assets with a minimum of Tier 1 capital, regardless of the calculated risk of the assets. In 2017, the Ministry of Finance introduced the unweighted requirement in Norway. This requirement serves as a security mechanism for the risk-weighted requirement. The leverage requirement is independent of banks' risk assessments and is a relatively transparent measure of solvency. Meeting the leverage requirement may therefore improve market confidence that banks are sufficiently capitalised. The leverage requirement has not been binding on Norwegian banks.

After the financial crisis, some regulatory changes have also reduced risk-weighted assets, ie the denominator in the capital adequacy ratio, and increased capital adequacy ratios without reflecting improved solvency. In isolation, this suggests that the capital adequacy ratio measured under the current rules should be higher than in the past. The CET1 ratio increased particularly in 2019 when the Ministry of Finance introduced the EU's fully harmonised capital adequacy rules (CRR) in Norway. As a result**,** among other elements, the Basel I floor[14] was removed and a reduction in risk-weighted assets for calculating loans to small and medium-sized enterprises, the so-called SME discount, was introduced. This contributed to an increase in the CET1 ratio by 1.5 percentage points. In summer of 2022, the Ministry of Finance introduced amendments to the EU's capital adequacy rules (CRR 2), which included an extension of the SME discount. This contributed to an increase in Norwegian banks' capital adequacy ratio by 0.3-0.5 percentage points (see Finanstilsynet (2022)). These changes to the rules did not affect loss-absorbing capacity, and the leverage ratio has remained approximately unchanged since 2018.

The financial crisis also highlighted the importance of maintaining core functions in systemically critical banks without the use of public funds.**[15]** Banks' shareholders and creditors are risk takers in banks. They must therefore bear the losses if banks are struck by a crisis. For distressed banks that are considered systemically critical, the regulations require that the bank's creditors provide new equity during crisis management, so that systemically critical banks are recapitalised, and their core functions are maintained. Hence, the authorities have introduced a requirement for systemically critical banks to have sufficient subordinated capital and debt that can be quickly written down or converted into new equity, so-called internal recapitalisation. The minimum requirement for such capital and debt is called MREL in Europe. Norwegian authorities introduced MREL in Norway in 2019.[16] In summer 2022, the Ministry of Finance issued new regulations on MREL following a new EU directive (BRRD 2).

[14] The Basel I floor ensured that the IRB banks' risk-weighted assets were not lower than 80 percent of risk-weighted assets in the former Basel I rules.
[15] A bank is considered systemically critical if the bank when in crisis constitutes a systemic.
[16] These rules built on an EU directive from 2014 (BRRD) and a Commission regulation from 2016

MREL is based on a Total Loss-Absorbing Capacity (TLAC) standard in globally systemically important banks published by the FSB in 2015. The purpose of the standard is to enable banks and authorities to prevent and manage crises effectively and at an early stage without taxpayers having to bear losses. Early intervention is intended to ensure that important banks can be managed in a crisis without operational disruption. MREL and TLAC reduce the risk that the public sector will have to cover the losses (bail-out) and increase the possibility of internal recapitalisation (bail-in). According to the model-based analysis by Nordal et al (2016), this reduces owners' incentive to keep capital adequacy ratios low. Debt that can be used for internal recapitalisation (senior non-preferred debt) also increases banks' loss-bearing capacity. However, internal recapitalisation with debt shall only be carried out after Finanstilsynet has assessed a bank as in crisis and all subordinated capital has been written down.[17] A bank will therefore already be in crisis when internal recapitalisation is implemented.

There are several reasons why MREL and TLAC may pull down optimal capital adequacy ratios. The FSB (2015) estimates that TLAC, through better market discipline and reduced risk-taking in banks, can reduce the probability of a crisis by about 30 percent. Brooke et al (2015) arrive at a similar effect of TLAC on the crisis probability for British banks. The BIS (2015) also highlights increased market discipline and reduced crisis probability as the greatest benefit of internal recapitalisation. Both the BIS and the FSB also point out that MREL will provide a better framework for crisis management. According to the FSB's calculations, MREL can reduce the cost of a crisis by more than 5 percentage points, partly because MREL reduces the need for government borrowing and improves the government's ability to stimulate the economy. According to Firestone et al (2019), TLAC can reduce the duration of crises, and expected crisis costs may fall by up to 4 percent. Brooke et al (2015) conclude that TLAC can provide more effective crisis management and reduce the costs of UK banking crises by more than 60 percent. This reduces the optimal capital adequacy ratio by about 5 percentage points.

MREL is likely to have less of an effect on crisis costs in Norway than in other countries. Norway had a relatively well-functioning framework for crisis management already during the banking crisis in the early 1990s. For example, the Norwegian banking crisis is included in a sample of 13 crises that, according to Brooke et al, was managed quickly and efficiently, and the estimate of Brooke et al that TLAC can reduce UK crisis costs by over 60 percent is calculated on the assumption that UK crisis costs fall to the same level as the average cost of the 13 crises. In addition, Norway has solid public finances. Fiscal space and government borrowing costs may therefore be less affected by MREL in Norway than in other countries.

[17] See § 20-15, § 20-20 first paragraph and § 20-26 third paragraph of the Financial Institutions Act. The Financial Institutions Act allows subordinated loans to be converted into equity before all Tier 1 capital is lost. However, Norwegian banks have a low share of subordinated loans, and subordinated loans can only be converted when a bank "is or must be expected in the near future to be in crisis".

Basel III also included new liquidity requirements that may have an impact on the optimal capital adequacy ratio. Liquidity Coverage Ratio (LCR) requirements were introduced in Norway at the end of 2015, and the Net Stable Funding Ratio (NSFR) was introduced in the summer of 2022. The LCR is intended to ensure that banks have sufficient liquid assets to withstand 30 days without access to new funding in the presence of severe funding market stress and a significant loss of customer deposits. The NSFR is intended to ensure that banks finance illiquid assets with long-term funding. The two liquidity requirements make banks less vulnerable to reduced access to funding, for example in a context of uncertainty about banks' solvency. This, in turn, can reduce the need for fire sales of illiquid assets. Solvency problems in banks are often amplified by liquidity problems and fire sales. LCR and NSFR can therefore reduce crisis probability, see Firestone et al (2019). This suggests that the LCR and NSFR may reduce the optimal capital adequacy ratio. On the other hand, Firestone et al only find an effect of liquidity requirements on optimal capital adequacy ratios if capital adequacy ratios are low. For the levels of optimal capital adequacy ratios observed in our analysis, it is reasonable to assume limited effects of LCR and NSFR.

5. Dataset

We use several data sources in our analyses of the optimal capital adequacy ratio. The bank statistics[18] contain data on banks' profitability, loan losses and equity dating back to 1987. We use data from this source to calculate the crisis probability in Norway at different capital adequacy ratios. In addition, we use data from Banking Statistics to analyse how banks' profitability has been affected by recapitalisation. We also use Banking Statistics data to calculate banks' capital needs during the Norwegian banking crisis.

We analyse the recapitalisation of Norwegian banks using capital adequacy data and return on equity targets from banks' own reports. In addition, we use data on risk premiums on banks' wholesale funding from Nordic Bond Pricing and data on banks' interest margins from Statistics Norway. We also use information on Pillar 2 requirements and data on Norwegian banks' total capital adequacy ratio from Finanstilsynet.

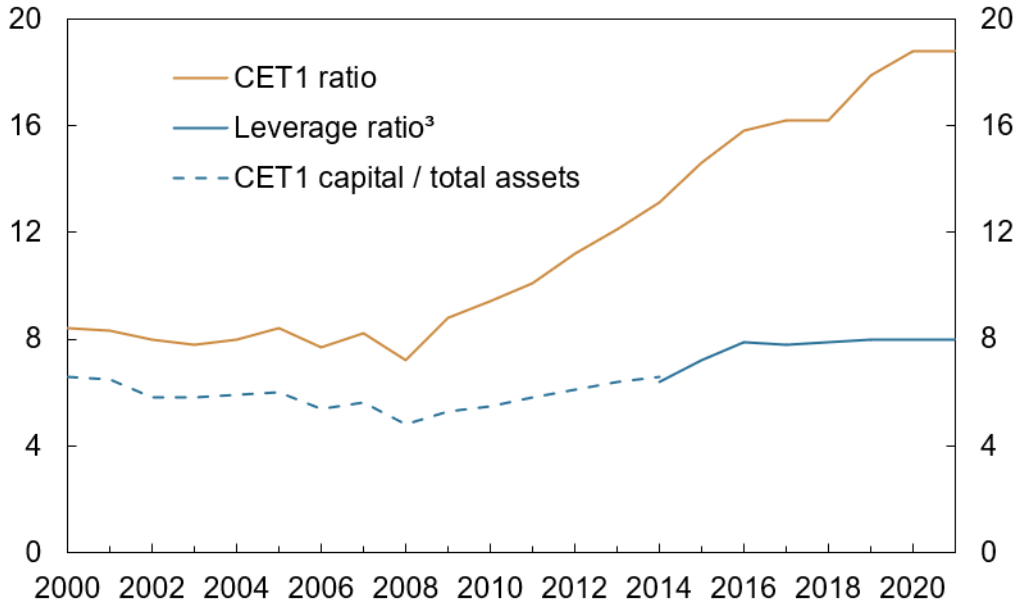
6. Experiences of recapitalisation of Norwegian banks

Since 2009, Norwegian banks have more than doubled their CET1 ratio, see Chart 4. The increase is partly due to regulatory changes that have reduced banks' risk-weighted assets, but banks have also increased their equity ratio.

[18] Public financial reporting by banks and finance companies (ORBOF).

The average leverage ratio increased from about 5 percent in 2009 to 8 percent in 2021.

Chart 4 CET1 ratio, leverage ratio and CET1 as a share of total assets in Norwegian banks[2]. Percent. 2000 – 2021



1) With the Basel I floor in the period 2007-2019.

2) All Norwegian banks.

3) Banks did not report leverage ratios prior to 2014. Consequently, the chart shows CET1/total assets up to and including 2014 and leverage ratios from 2014. Both measure unweighted capital adequacy and were approximately the same in 2014.

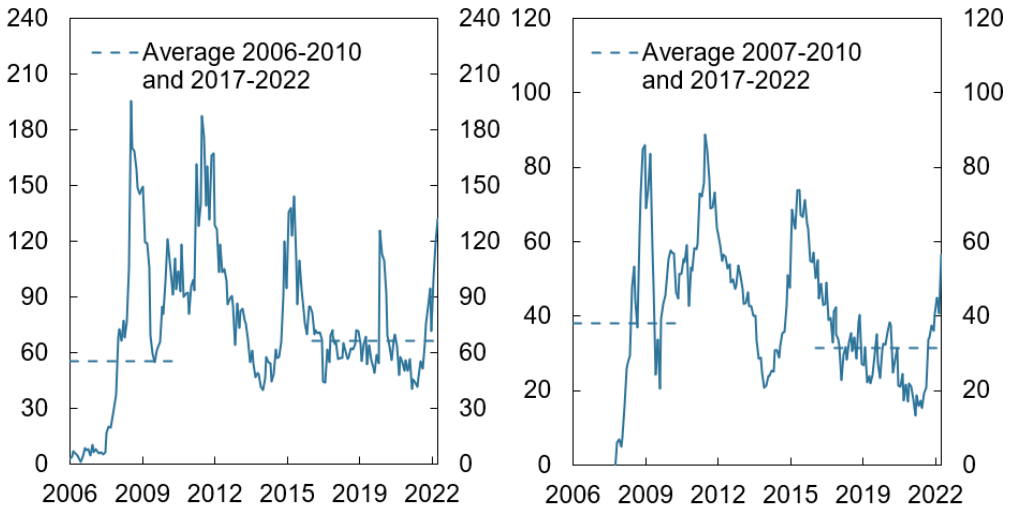
Source: Finanstilsynet

Experiences of the recapitalisation may provide information about the costs of increasing capital requirements. In the following, we compare indicator values before the authorities announced increased capital requirements in 2011 with the levels from 2017 when most of the recapitalisation had been completed.

Developments in Norwegian banks' wholesale funding do not provide any clear indication that the recapitalisation has reduced the price of bank debt. This is consistent with the assumption in Kragh-Sørensen (2012) that the interest rate on banks' debt is independent of capital adequacy ratios. The average risk premium on senior bank bonds is higher after 2016 than before 2011, while the premium on covered bonds has fallen (Chart 5). However, there are a number of factors other than banks' capital adequacy ratio that affect the price of wholesale funding, such as market liquidity. The increase in risk premiums on senior bank bonds may be due to the fact that banks have transferred an increasing share of mortgages with low credit risk to mortgage companies. In isolation, this weakens the quality of the bank's remaining collateral. In addition, the introduction of MREL may have weakened implicit

government guarantees. This may have contributed to holding up the price of senior bank bonds in recent years.[19]

Chart 5 Risk premiums on senior bank bonds (left) and covered bonds (right).[1] 5-year maturity. Basis points over 3-month Nibor. January 2006 – October 2022[2]



1) Premiums on bonds issued by large banks and mortgage companies in the Norwegian market.

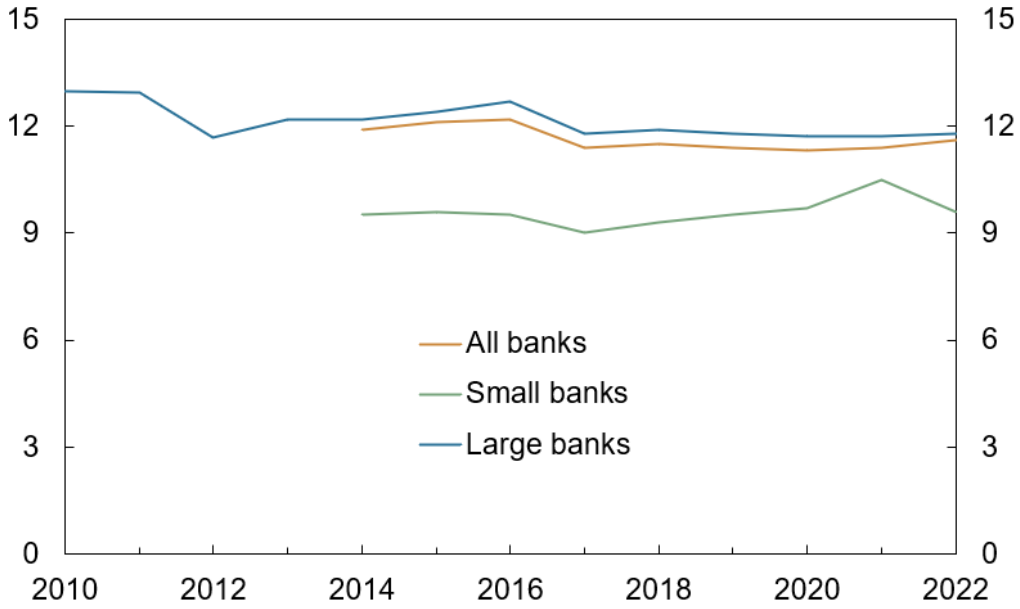
2) July 2007 – October 2022 for covered bonds.

Source: Nordic Bond Pricing

Developments in return on equity and corresponding return targets do not provide any clear indication that the recapitalisation has reduced the required rate of return on equity. In the long term**,** banks' return on equity should correspond to investors' required rate of return, see Aronsen et al (2014). In 2022, the return on equity has been close to the[20] average for the past decade, and Norges Bank expects banks to maintain profitability over the next four years, see Norges Bank (2022d). In addition, results from a survey conducted by DNB Markets of the 50 largest Norwegian banks show that Norwegian banks have largely maintained their return targets (Chart 6). This indicates that the recapitalisation has not substantially reduced the required rate of return. This is consistent with the naïve method used in Kragh-Sørensen (2012) and Vale (2011) which applied the assumption that the required rate of return on equity is independent of capital adequacy ratios. In that case, the Modigliani-Miller theorem does not hold, and the costs of increasing capital adequacy ratios are in the upper part of the interval assumed in Kragh-Sørensen (2012).

[19] If MREL reduces implicit government guarantees, price developments in banks' wholesale funding overestimate the costs of increased capital requirements. On the other hand, the benefits of increased capital requirements may become smaller if MREL reduces expected government support. Hence, it is unclear how changes in implicit government guarantees affect optimal capital adequacy ratios.
[20] Aronsen et al (2014) concluded that Norwegian banks' return on equity is about 12 percent in a long-term equilibrium, while investors' required rate of return on Norwegian banks' equity is about 10 percent. This corresponds to a long-term market value as a share of banks' book value (price/book) of 1.2. Banks' return on equity and return targets will accordingly correlate with developments in investors' required rate of return in the long term.

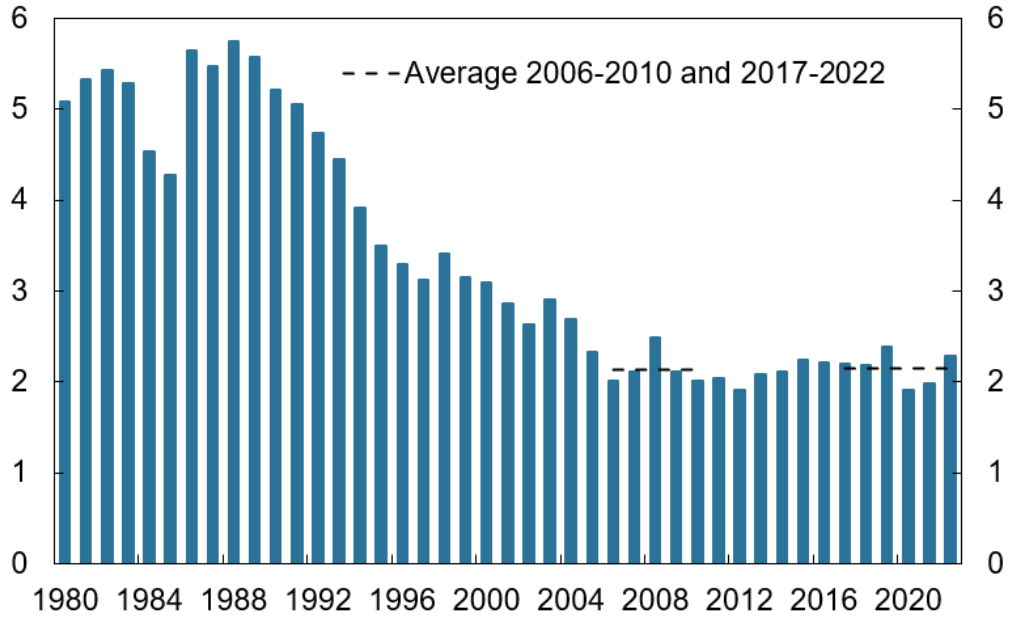
Chart 6 Norwegian banks' long-term return-on-equity targets. Weighted average. Percent. 2010 – 2022[1]



1) Averages before 2014 are calculated using figures for DNB, SpareBank 1 SMN, Sparebank 1 Nord-Norge, Sparebanken Vest (from 2012) and SpareBank 1 SR-Bank (from 2013). The average since 2014 is for banks that participated in DNB Markets' survey.

Sources: Banks' reports and DNB Markets

Chart 7 Interest margin for the Norwegian banking sector[1]. Percent. 1980 – 2022[2]



1) All banks in Norway before 2002. All banks and mortgage companies as of 2002.

2) Interest margin for 2022 as of Q3.

Source: Statistics Norway

Developments in interest margins may indicate that banks have partly adapted to higher costs of recapitalisation by reducing costs. The average interest margin after 2016 is at about the same level as before 2011 (Chart 7). At the same time, Norwegian banks have reduced operating costs considerably, both in relation to income and assets**,** see Andersen (2020). This may have enabled the banks to keep the interest margin down, even with an increased equity ratio.

7. Calculations

7.1. Marginal benefit of increasing capital adequacy

We estimate the marginal benefit by multiplying estimated crisis costs by estimated reduction in crisis probability, which is achieved for the overall economy by increasing capital adequacy levels.

7.1.1. Crisis probability at different capital adequacy ratios

In order to calculate crisis probabilities, we must first determine the capital adequacy levels corresponding to banking crises. In principle, a bank will be insolvent when the value of assets is lower than the debt of the bank, ie all the equity is lost. However, historical experience shows that banking crises usually occur long before equity is lost and the capital adequacy ratio is zero, for example in the event of a breach of capital adequacy requirements.

The capital adequacy rules enable banks to use capital buffers in periods of high losses. The buffer requirements are therefore placed above other requirements. This means that banks will breach the buffer requirements before they breach the Pillar 2 and the minimum requirements.[21] The consequences of breaching buffer requirements are also intended to be milder than the consequences of breaching minimum requirements and Pillar 2 requirements.[22]

We calculate crisis probabilities using different crisis definitions. In most calculations, we assume that a banking crisis occurs if the banking sector as a whole breaches the Pillar 2 requirement for CET1 ratios. The Pillar 2 requirement is on average almost 2 percent for the largest Norwegian banks.[23] We therefore assume that a banking crisis occurs when the banking sector's CET1 ratio falls below 6.5 percent. This means that banks can breach the

[21] Banks with capital adequacy ratios will draw on their capital margin before breaching the capital requirements.
[22] Breaches of buffer requirements, Pillar 2 requirements and minimum requirements allow Finanstilsynet to impose various restrictions, eg limit bonus payments of bonuses, dividends and interest on capital. Finanstilsynet may also require changes in operations. In addition, the capital adequacy rules allow Finanstilsynet to revoke licenses for banks that breach capital requirements.
[23] In September 2022, Finanstilsynet amended the requirement for the capital banks can use to satisfy the Pillar 2 requirement. Previously, the entire Pillar 2 requirement had to be met with CET 1 capital. Following the change, Finanstilsynet requires banks to use at least 56.25 percent of CET1 capital to satisfy the requirement. However, Finanstilsynet will update the Pillar 2 requirements.

buffer requirements without the occurrence of a banking crisis.[24] This crisis definition does not take into account that a banking crisis may occur before banks breach the Pillar 2 requirement.

Our crisis definition differs from the crisis definition of Kragh-Sørensen (2012). Our crisis definition requires that the banking sector as a whole breaches the crisis threshold, while Kragh-Sørensen only required a crisis in two of the six largest Norwegian banks. Since crises affect banks differently, capital adequacy ratios for the most vulnerable banks are usually subject to a steeper decline than the banking sector as a whole. This indicates that our crisis definition results in lower crisis probabilities than Kragh-Sørensen's crisis definition. On the other hand, our crisis threshold of 6.5 percent is higher than Kragh-Sørensen's threshold of 4.5 percent. This pushes up our crisis probabilities compared to Kragh-Sørensen's crisis probability.

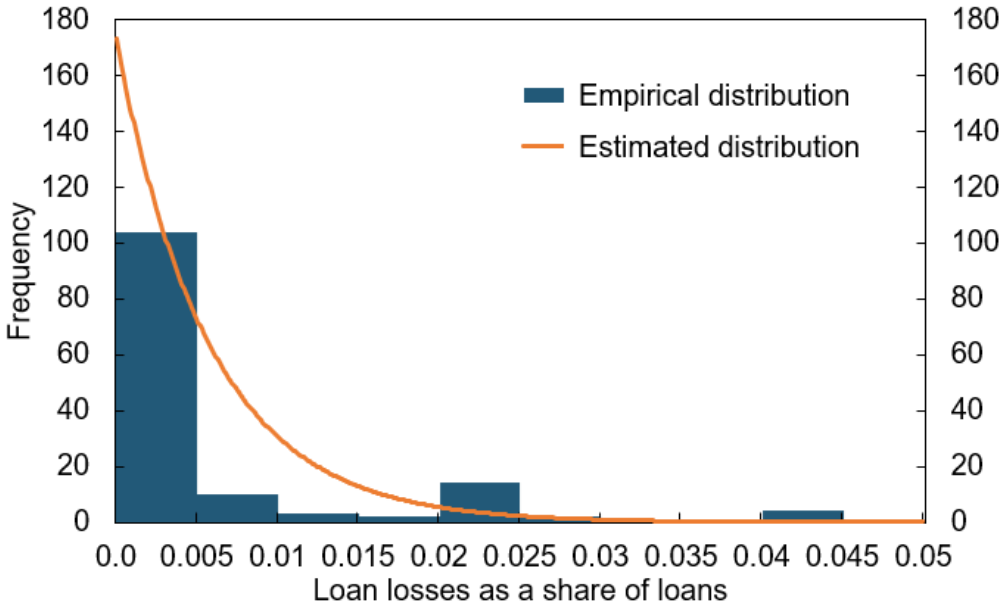
We use the crisis definition together with data on historical losses to calculate the marginal crisis probability at different capital adequacy ratios. Our starting point is the observed distribution of loan loss shares for Norwegian banks from the first quarter of 1987 to the third quarter of 2021 (Chart 8). We adapt an exponential distribution to the observed loss distribution. We then use the estimated loss distribution to simulate losses. For a given simulated loss, we calculate how much the banking sector's equity falls.[25] We assume that the composition of the banking sector's assets remains unchanged from the end of 2021 and converts equity falls into falls in the CET1 ratio. For a given starting capital adequacy ratio, we do this simulation 100 million times and calculate the relative frequency of cases where the CET1 ratio falls below the crisis threshold. This gives us the crisis probability for a given capital adequacy ratio. We find the *marginal* crisis probability by looking at how the crisis probability changes when we change the starting capital adequacy ratio.[26]

Lastly, we adjust estimated crisis probabilities downwards in accordance with the assumption that MREL's will improve market discipline and reduce banks' risk-taking. We only downgrade by half the effect (15 percent) of the FSB's estimate. This is due to our inexperience regarding MREL's mechanism during a crisis. In addition, there are few signs that MREL has contributed to reducing the risk assumed by Norwegian banks. For example, the Norwegian banking sector's exposures to various sectors and industries have hardly changed since the first Norwegian rules for MREL entered into force on 1 January

[24] With a crisis definition of 6.5 percent CoCos will not necessarily be converted to equity. According to Nordal and Stefano (2014), the majority of CoCos will be converted to equity if the CET1 ratio falls to around 5 percent.
[25] For a given loss shock, we calculate total losses by assuming that the losses follow an AR(1) process. The persistence of the AR(1) process is estimated using data on loss shares. We assume that earnings of 1.5 percent of total loans can be used to service losses before equity is written down.
[26] Simulations for individual banks with the assumptions in the stress test in Norges Bank (2022d), eg about banks' adjustments to lending and lending margins, result in marginal crisis probabilities at approximately the same level. The simulations assume approximately the same distribution and AR(1) process for losses.

2019, see Chart 9. Banks' internal credit risk measures are also little changed.[27]

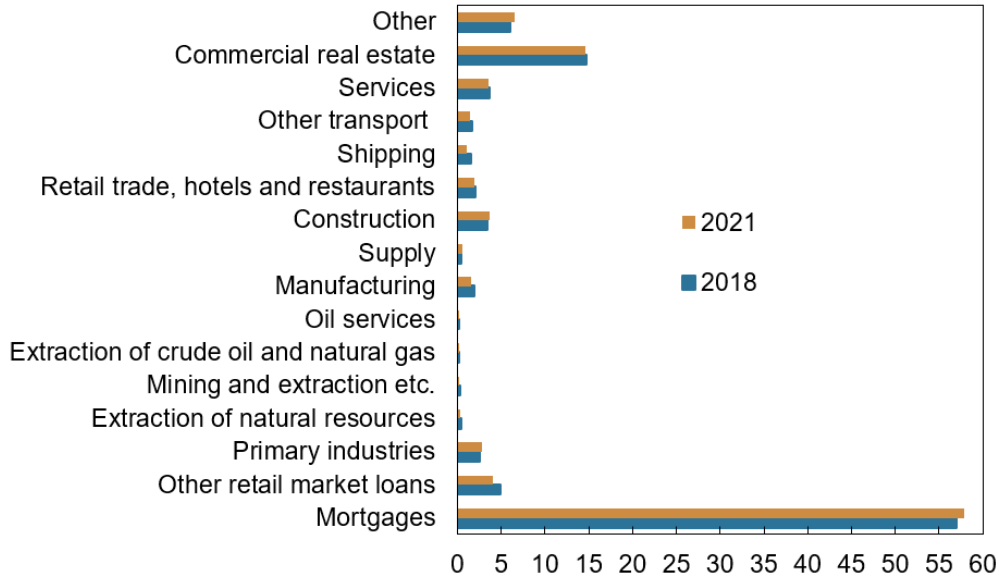
Chart 8 Banks'[1] loan losses as a share of loans and estimated loss distribution. Annualised. Percent. 1987 Q1 – 2021 Q4



1) All banks and credit companies.

Sources: Statistics Norway and own calculations

Chart 9 Loans from the Norwegian banking sector[1] broken down by sector and industry. Percent. At the end of 2018 and 2021



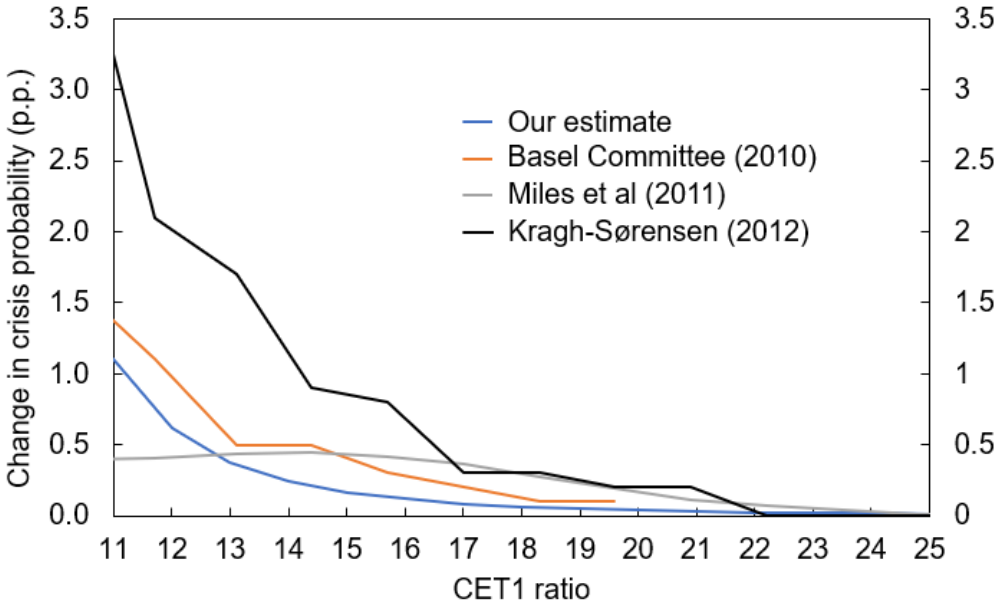
1) All banks and mortgage companies in Norway.

Source: Norges Bank

[27] According to Finanstilsynet's *Exposure Reporting*, the median probability of default (PD) across all business exposures was approximately unchanged after the introduction of MREL compared with 2018.

Our estimate of marginal crisis probability is considerably lower than previous estimates for Norway (Kragh-Sørensen, 2012) and slightly lower than the Basel Committee's estimate (2010), see Chart 10. The chart also illustrates that marginal crisis probability declines with increased CET1 ratios. If the CET1 ratio is around 20 percent, further increases in the capital adequacy ratio have a limited effect on marginal crisis probability.

Chart 10 Estimated marginal crisis probability



Sources: Basel Committee (2010), Kragh-Sørensen (2012), Miles et al (2011) and Norges Bank

There are several reasons why we arrive at a lower marginal crisis probability than in previous studies for Norway. First, we use a stricter definition of the capital adequacy levels corresponding to a banking crisis. Second, we adjust our estimated crisis probabilities downwards in line with MREL improving market discipline and reducing banks' risk-taking. Thirdly, loan losses have been low over the past decade. A larger proportion of observations with low losses reduces the probability of high losses in the calculation. Increased data acquisition, digitalisation and risk sensitivity in capital requirements, including the introduction of the IRB approach, are factors that may have contributed to improved risk management among Norwegian banks. This may have reduced the probability of a crisis in Norway. The low losses over the past decade can also be explained by historically low interest rates, low unemployment and solid real wage growth.

7.1.2. Cost of a banking crisis

The economic cost of a banking crisis in Norway may be higher than in other countries. The banking sector is important for the Norwegian economy and accounts for a larger share of corporate funding than in several other countries. All the major banks have substantial loan exposures to commercial property, and banks are closely interlinked, particularly through ownership of

covered bonds. This increases the risk of contagion, resulting in a broader banking crisis.[28] The Norwegian banking sector is also concentrated compared to other European countries.[29]

On the other hand, there are also factors suggesting that banking crises in Norway entail lower costs than in other countries. Norway has an effective framework for crisis management and a flexible exchange rate. In addition, Norway has solid public finances. This gives Norway considerable fiscal space.

Our assumptions about crisis costs incorporate that MREL has been introduced in Norway. Although Norway had a framework for crisis management before MREL was introduced in Norway, MREL requirements for recovery plans and crisis management plans can make crisis management more proactive, predictable and effective than during the Norwegian banking crisis, when crisis management rules were formulated during the crisis. MREL can also contribute to maintaining banks' recapitalisation capacity. In addition, MREL can create more predictability in financial markets about who will bear the losses in the event of a crisis. This may limit financial market turbulence and reduce banks' vulnerability to reduced access to funding. We therefore assume that MREL contributes to more effective crisis management in Norway, so that crisis costs are reduced in line with estimates from the Financial Stability Board (2015), ie by about 5 percentage points.

Since there is considerable uncertainty as to the cost of a banking crisis, different estimates of crisis costs are used. One calculation is based on a crisis cost of 60 percent before adjusting for MREL. This is in line with the median of a number of international studies of 63 percent (Basel Committee, 2010) and with the average of the calculations for the Norwegian banking crisis (59 percent), as well as the assumptions in Kragh-Sørensen (2012). We also use median estimates of crisis costs from the Basel Committee (2010) with assumptions of respectively temporary (19 percent) and permanent effects (159 percent). In addition, we include an alternative calculation, where the crisis cost depends on the banking sector's CET1 ratio. This is in line with Jorda et al (2021).

7.2. Marginal cost of increasing capital adequacy ratios

We use calculations from the Basel Committee (2021) to quantify the cost of increasing capital requirements. In these calculations the macro model NEMO is applied to quantify the benefits and costs of increasing capital adequacy ratios in the banking sector.[30] In the calculations, lending margins increase by

[28] See description of the vulnerabilities in Section 1 in Norges Bank (2022d).
[29] See Norges Bank (2022c).
[30] The NEMO-based effects of increased capital requirements are consistent with the conclusions of the Basel Committee (2010).

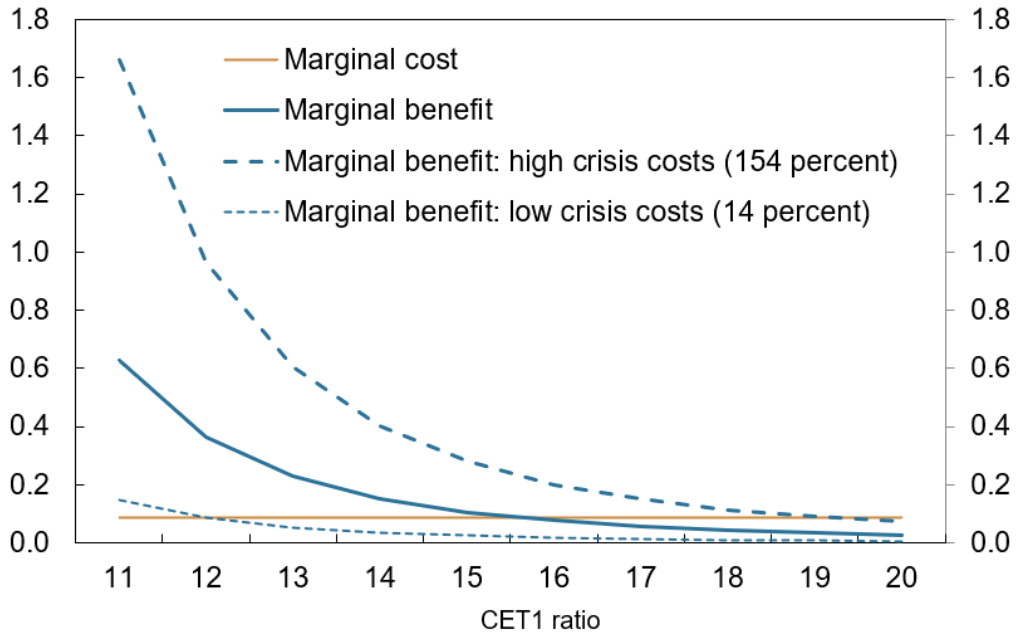
8–12 basis points if the capital requirement increases by one percentage point. This is in line with results of studies that assume or find a limited Modigliani-Miller effect, see Vale (2011) and Getz Wold and Juelsrud (2020). Like most studies, we assume that costs are proportional to increases in CET1 ratios.

We assume that long-term GDP will be reduced by about 0.08 percent per one percentage point increase in the capital requirement. This is consistent with the effects of NEMO. The method yields a marginal cost in the upper part of the interval used in Kragh-Sørensen's study (2012) and in several international studies (see Table 1). This is in line with the experiences of the recapitalisation of Norwegian banks after the financial crisis, see Section 6.

7.3. Optimal capital adequacy ratio for Norwegian banks

Finally, we use estimated marginal benefits and marginal costs to find the optimal capital adequacy ratio for Norwegian banks. Overall, the results indicate that Norwegian banks should have a CET1 ratio of between 12 and 19 percent, see Chart 11 and Table 2. Assuming that crises have only temporary effects on GDP, ie low crisis costs (14 percent of GDP), the optimal CET1 ratio is 12 percent. If crises have permanent effects, ie the crisis cost is high (154 percent of GDP), the optimal ratio is 19 percent. Under the assumption that the cost of a crisis is 55 percent of GDP, the optimal ratio is about 16 percent.

Chart 11 Marginal benefits and marginal costs of increasing the CET1 ratio by 1 percentage point. Percent of GDP



Source: Norges Bank

We also perform a calculation under the assumption that crisis costs depend on the CET1 ratio. In this calculation, we assume that a mild crisis occurs at a CET1 ratio of between 4.5 and 8 percent, while a severe crisis occurs when the CET1 ratio falls below 4.5 percent. The crisis costs of a mild and a severe crisis are assumed to reach 14 and 154 percent of GDP, respectively. Under these assumptions, the optimal ratio is 16 percent.

Table 2. Optimal capital adequacy ratio for different sets of assumptions

Crisis cost	55%	14%	154%	*Depending on capital ratio*
Crisis threshold	6.5%	6.5%	6.5%	4.5% and 8%
Cost of higher requirements	0.08%	0.08%	0.08%	0.08%
Optimal ratio	**16%**	**12%**	**19%**	**16%**

Source: Norges Bank

The results of our calculations are consistent with results from international studies (see Table 1). The results are also in line with Kragh-Sørensen (2012), but with a somewhat narrower interval.

There are several reasons why our calculations yield results that diverge from Kragh-Sørensen. We only consider different assumptions for crisis costs, while the assumptions concerning crisis probability and the cost of increasing capital requirements are held constant. It provides a more limited interval than in Kragh-Sørensen's study. We assume a relatively high marginal cost compared with Kragh-Sørensen, and the marginal crisis probability is lower in our calculations. In isolation, this pulls down our estimates compared with Kragh-Sørensen. We have assumed that MREL reduces both crisis probability and crisis costs. This reduces the optimal capital ratio by about one percentage point. On the other hand, we have incorporated changes in the capital adequacy rules over the past ten years, including the removal of the Basel I floor, the introduction of SME discounts and stricter IRB requirements, which overall pulls up the estimates. Our calculations also assume higher crisis costs than Kragh-Sørensen. In isolation, this pulls up our interval compared with Kragh-Sørensen.

Banks' capital needs during the banking crisis in the early 1990s show that our estimates are not unreasonable. During the banking crisis, the share capital of the three largest Norwegian banks, ie Den norske Bank (DnB), Christiania Bank og Kreditkasse and Fokus Bank, was written down to zero.[31] At today's average ratio between IRB banks' CET1 ratio and equity ratio, losses during the banking crisis correspond to a total fall in CET1 ratios of between 7 and 22 percentage points. At the same time, banks' risk of losses has probably changed somewhat since the banking crisis erupted in 1988. For example, a number of factors may have contributed to improved risk management in

[31] See a more detailed description of developments in the three banks in the box "Capital needs during the Norwegian banking crisis in the early 1990s" on page 22 of Financial Stability Report 2/09.

Norwegian banks (see Section 7.1.1). Risk-free assets such as cash and central bank deposits have also increased from 0.5 percent of the balance sheet in 1988 to 3.7 percent in 2021. In addition, the share of residential mortgage loans, which are empirically among the bank loans with the lowest risk, has increased from 21 percent in 1988 to 35 percent in 2021. On the other hand, Norwegian mortgage borrowers may have become more vulnerable. For example, Norwegian household debt has increased from 151 percent of disposable income in 1988 to 223 percent today.

The calculations provide an indication of how high the CET1 ratio of the banking sector as a whole should be in the long term. The calculations do not take into account that financial system vulnerabilities vary over time. The countercyclical capital buffer requirement is intended to reflect assessments of cyclical vulnerabilities[32], while the systemic risk buffer reflects assessments of structural vulnerabilities.[33] Changes in both cyclical and structural vulnerabilities suggest that capital adequacy ratios should deviate from calculations based on historical data. In addition, capital requirements vary across banks. Systemically important banks are required to hold an additional capital buffer because problems in systemically important banks can adversely affect the economy more so than comparable problems in other banks. The Pillar 2 requirements are also individual and depend on the Finanstilsynet's assessment of the risk in the bank concerned.

The calculations are associated with considerable uncertainty. Some factors may result in a higher optimal capital adequacy ratio. Crisis costs may be higher than assumed, in which case the marginal benefits of increasing capital adequacy ratios will be greater. For example, the cost estimates do not take into account that crises could have been more severe if they had not been mitigated by costly government measures. Nor have we incorporated that capital adequacy ratios may contribute to banks tightening lending less in bad times, thereby dampening fluctuations in the economy. The marginal cost of increasing capital adequacy ratios may also be lower than assumed, for example if banks pass on a smaller share of the increase in funding costs to loan customers or adapt by reducing costs. The same applies if higher capital ratios reduce banks' debt interest rates and required rate of return on equity more than we have assumed. A higher capital adequacy ratio would then be optimal.

On the other hand, there are other conditions that suggest lower optimal capital ratios. Capital adequacy levels may have less impact on the probability of crisis than assumed. Crisis costs may also be lower than expected, for example because crises stimulate innovation, cost cutting and other structural changes. In addition, the marginal cost of increasing capital adequacy ratios may be higher than assumed. High capital requirements may create barriers

[32] See Norges Bank (2022a).
[33] See Norges Bank (2022b).

that prevent entry of new banks. This can weaken competition and innovation, which in the long run contributes to higher prices. High capital requirements can also increase financial system vulnerabilities by shifting risk to institutions that are less transparent and less regulated than banks.

The results of the analysis show that banking crises have substantial economic costs and that the economic benefits of ensuring that banks are sufficiently resilient to absorb substantial losses. The benefit of increasing capital requirements is substantial when starting capital adequacy ratios are low, particularly if crises involve high costs (Chart 11). This means that the economic costs are higher if banks adapt with a too low rather than a too high capital adequacy ratio.

8. Conclusion

Banks offer services that are crucial to economic activity, including lending to firms and private individuals. The provision of those services is often impaired during banking crises. Banking crises therefore have an economic cost.

Increased bank equity can contribute to financial stability by reducing the risk of costly banking crises, but banks' funding costs may increase if they are required to finance their assets with a larger share of equity. If banks pass on higher funding costs to borrowers, lending rates will, in isolation, increase and put a drag on GDP growth. When assessing banks' capital adequacy ratios, the economic costs of more expensive credit must therefore be weighed against the benefits of fewer costly crises.

In this memo, we analyse the optimal level of capital adequacy for banks from a socio-economic perspective. Our calculations take into account recent changes in bank capital regulation. The results indicate that Norwegian banks should have a CET1 ratio of between 12 and 19 percent in the long term. This is in line with the current CET ratio of around 18 percent. Our estimates vary considerably with changes in uncertain assumptions. However, the estimates are consistent with results from international studies. Bank's capital needs during the Norwegian banking crisis in the beginning of the 1990s also show that such estimates are not unreasonable.

The results show that banking crises have substantial economic costs and that the society benefits from ensuring that banks are sufficiently resilient to absorb substantial losses. The benefits of increasing capital requirements are considerable when the starting capital adequacy ratio is low. This means that the economic costs are higher if banks adapt with a too low rather than a too high capital adequacy ratio.

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