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A Macroprudential Stress Testing Framework

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STAFF MEMO

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NORGES BANK

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A macroprudential stress testing framework*

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Abstract

We present a macroprudential stress testing framework. While traditional stress testing assesses the level of banks' capital adequacy relative to regulatory requirements through a hypothetical crisis, macroprudential stress testing assesses macroeconomic consequences of the impact of banks' adjustments to capital requirements. The outcome of such testing depends on the capital requirements and on banks' capital targets. The primary focus is not on whether or not banks "pass" the test, but on how macroprudential policy tools can prevent a deterioration of macroeconomic developments. Such analyses will be included in Norges Bank's decision basis for the countercyclical capital buffer. This framework was used to conduct the stress test in *Financial Stability Report 2018*.

*Views and conclusions expressed in this publication are those of the authors and should not be taken to represent the views of Norges Bank.

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1 Introduction

The financial crisis in 2008-09 showed that bank capital shortfalls can lead to a sharp tightening of credit standards, further weakening the economy. This has, in the post-crisis period, contributed to a broad focus on macroprudential policy, as a supplement to both traditional banking regulation and macroeconomic stabilisation policy.

While traditional banking supervision is intended to set limits on the risk an individual bank may take, macroprudential supervision is aimed at managing the risks to the rest of the economy posed by the financial system and to dampen the financial system's contributions to economic volatility. The countercyclical capital buffer requirement is a key macroprudential policy tool, and Norges Bank advises the Ministry of Finance on the level of this buffer each quarter.

Stress testing of banks is currently being used actively by the authorities in many jurisdictions to assess whether individual banks have adequate capital, but stress testing can also be used as a tool for assessing the calibration of macroprudential instruments. Stress tests are based on a pronounced, but conceivable, downturn and assess the impact of such an event.

The focus of a stress test should depend on its purpose. Norges Bank has conducted annual stress tests since 2004 for its financial stability reports. Traditionally, these stress tests can be characterised as *solvency tests*, where the most important question has been whether or not banks “pass” the test. The basis of a *macroprudential stress test* should be the ability of banks to meet credit demand and conduct other normal business, even in the event of a pronounced economic shock. This requires resilient banks that are both solvent and liquid before negative shocks occur. It may also require that some capital requirements vary over time.

In this article, we present a macroprudential stress testing framework. We set four requirements for its design. *First*, a connection must be established between the level of financial imbalances and the severity of the stress scenario. *Second*, the impact of the downturn on banks' capital ratios must be calculated. *Third*, we must estimate the implications for credit provision of banks' adjustments to the capital requirements. *Fourth*, the macroeconomic consequences of banks' credit provision must be quantified. Compared with traditional stress testing requirements, the third and fourth in particular apply to macroprudential stress testing. There is considerable uncertainty surrounding analyses of this type, since we are assessing situations that seldom arise. Results depend on the model. In this article, we describe how a macroprudential stress test can be conducted using models developed over time by Norges Bank.

This framework will constitute a part of the decision basis for Norges Bank's advice on the countercyclical capital buffer. This decision basis is broad-based and includes a number of indicators of financial imbalances.¹ The purpose of a macroprudential stress test is to link the analysis of financial imbalances to assessments of banks' resilience and adjustments to the capital adequacy rules. A stress test can thus be used to assess the impact on banks' credit provision and the macroeconomy of different levels of regulatory buffer requirements (see discussion in [Anderson et al. \(2018\)](#)). In particular, the stress test will analyse the effect of reducing the countercyclical buffer in a crisis. Consequently, the test

¹See quarterly updates in [Monetary Policy Report with financial stability assessment](#).

can also be used to indicate what the countercyclical buffer should be ahead of deep downturns: If imbalances are substantial, with a potential for a correspondingly pronounced downturn, the buffer should be higher than it would be otherwise. Nevertheless, stress tests cannot provide a satisfactory answer to the question of what the correct level of buffer requirements is, since they can only be used to analyse the benefits of different levels in a stress situation. A comprehensive analysis should also include the costs, for example, in the form of a lower level of economic activity in normal times owing to higher capital requirements.

Our point of departure for conducting macroprudential stress tests is Norges Bank's macroeconomic model, NEMO. It contains a banking sector that responds to various macroeconomic shocks by changing its credit standards. Furthermore, the model contains feedback effects whereby banks influence the economy, in line with estimated relationships in the Norwegian economy. In the model, assumptions must be made regarding other policy measures, including fiscal and monetary policy. We assume that banks should be sufficiently resilient to be able to maintain lending in a downturn without extraordinary fiscal or monetary policy measures. The assumption is therefore that the authorities do not implement such measures.

The framework we present in this article is an extension of the stress tests that Norges Bank has developed and improved over a number of years. We are not the first to use stress testing to assess the level of countercyclical capital requirements. In recent years, the Bank of England has had the same objective for its annual stress test (see [Bank of England \(2016\)](#)).² Moreover, our proposed model framework is very similar to the approach of the Banque de France (see [Bennani et al. \(2017\)](#)). The Federal Reserve³ also conducts cyclical stress tests by assuming that unemployment will rise to a particular level (10 percent). In good times with low unemployment, the magnitude of the macroeconomic shock will thus typically be more pronounced than in bad times.

The remainder of the article is organised as follows: The next section is a review of current capital adequacy rules and the role of stress testing in those rules. In Section 3, we show the elements of a macroprudential stress test, including the design of a cyclical scenario, extrapolation of banks' losses and capital ratios, banks' adjustments to the rules and macroeconomic effects of bank behaviour. We also show some examples of the application of the framework in connection with the stress test in Financial Stability Report 2018. Section 4 concludes.

2 The capital adequacy framework in brief

2.1 Common Equity Tier 1 (CET1) capital requirements

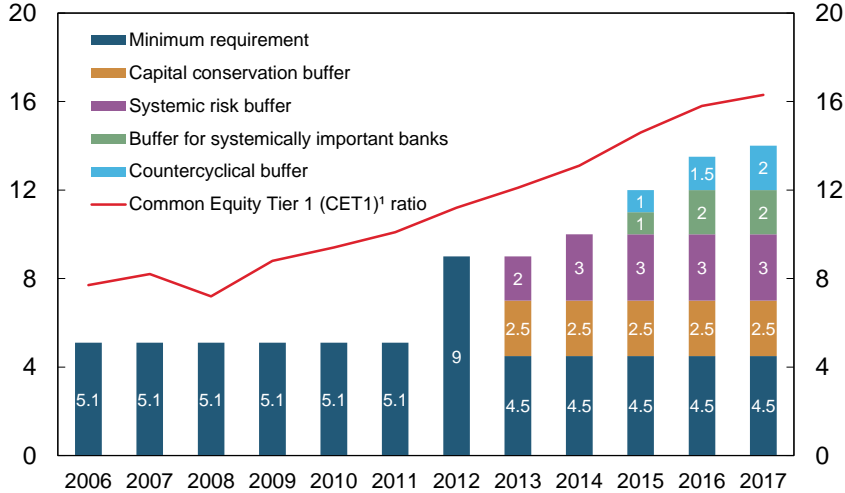
Since the financial crisis, the Norwegian authorities have tightened bank solvency requirements (Chart 1). Up until 2012, the real minimum Common Equity Tier 1 (CET1) capital

²See also [Dent et al. \(2016\)](#) for a historical overview of stress testing.

³See [Hirtle and Lehnert \(2015\)](#) for a review of the design of Federal Reserve stress tests and [Durdu et al. \(2017\)](#) for a description of the measurement of crisis depth.

requirement in Norway was a little over 5 percent.⁴ In autumn 2011, the EU approved a minimum CET1 capital requirement of 9 percent for the largest banks by summer 2012. Finanstilsynet (Financial Supervisory Authority of Norway) expected Norwegian banks to meet the same requirement. From summer 2013, capital requirements continued to rise as the rules in the new EU capital framework (CRD IV/CRR) were phased in.

Chart 1: Norwegian banks¹ CET1 capital ratios² and Pillar 1 CET1 capital requirements. Percent



1) All banking groups excluding branches of foreign banks in Norway. For banks that are financial groups, data for the financial group are used; for other banks, parent bank data are used. Nordea has been removed from the history owing to its conversion to a branch in 2017.

2) With transitional rule (Basel I floor).

Sources: Finanstilsynet, Ministry of Finance and Norges Bank

The new capital requirements are now fully implemented in Norway. The capital adequacy framework specifies minimum and buffer requirements for banks’ regulatory capital (Pillar 1). With the current buffer requirements, the total Pillar 1 CET1 capital requirement is up to 14 percent for systemically important banks and 12 percent for the remaining banks (see Chart 1), and will increase to 14.5 and 12.5 percent, respectively, from 31 December 2019. Banks must also meet Pillar 2 requirements from Finanstilsynet⁵ and a Tier 1 leverage ratio requirement.

Pillar 1 requirements comprise a minimum requirement of 4.5 percent and the following buffer requirements:

Capital conservation buffer: The capital conservation buffer requirement is 2.5 percent. Under CRD IV, banks shall hold a capital conservation buffer to be able to

⁴Kredittilsynet’s Circular 14/2001 required a minimum Tier 1 capital ratio of 6 percent to be able to issue time-limited subordinated debt capital. From 2002, up to 15 percent of Tier 1 capital could consist of hybrid capital instruments. This implies an implicit minimum CET1 capital requirement of 5.1 percent.

⁵Pillar 2 requirements are intended to cover risk not covered under Pillar 1 requirements. Pillar 2 requirements apply on an individual basis and depend on Finanstilsynet’s assessment of risk at the relevant bank. Pillar 2 requirements consist of a formal requirement that is based on an individual decision and in addition an assessment of the size of a margin in the form of CET1 above the total requirement. In 2018 Q3, the average Pillar 2 requirement for the banks in the stress test was 1.8 percent.

absorb losses in downturns.

Buffer for systemically important financial institutions (SIFIs): SIFIs in Norway shall hold an extra capital buffer of 2 percent. Two institutions are classified as systemically important: DNB ASA and Kommunalbanken AS. Both have total assets equivalent to more than 10 percent of GDP for mainland Norway and share of the lending market of over 5 percent.⁶

Systemic risk buffer: The Ministry of Finance has laid down a requirement for a systemic risk buffer of 3 percent. The level of the buffer is to be assessed every other year and reflects structural vulnerabilities in the Norwegian financial system.⁷ The Ministry highlights Norway's one-sided industry structure, relatively pronounced cyclical fluctuations, high household debt levels and a closely interconnected financial system dependent on foreign capital as vulnerabilities.

Countercyclical capital buffer: The current countercyclical capital buffer requirement is 2 percent. The Ministry of Finance has decided to increase the buffer to 2.5 percent from 31 December 2019. Norges Bank prepares a decision basis and advises the Ministry of Finance on the buffer rate each quarter. The buffer rate is to be raised when financial imbalances are building up or have built up. In the event of an economic downturn and large bank losses, the buffer rate is to be reduced.

2.2 The purpose of (time-varying) buffer requirements

The capital adequacy rules allow banks to draw on buffer capital in a downturn. The rules permit banks in breach of the buffer requirements to continue operating, while a bank in breach of the minimum requirement risks losing its licence.

The consequences of breaching the buffer requirements will be of importance for how banks adjust to a situation with large losses. If a bank breaches the buffer requirements, a capital plan to restore the buffers must be prepared within five working days. Among other things, the plan shall contain forecasts for the bank's earnings and balance sheet and a time frame for compliance. In addition, the capital adequacy rules set restrictions on dividend distributions by banks in breach of the buffer requirements. The size of these restrictions depend on the how low the CET1 capital ratio is relative to the combined buffer requirement (Chart 2).⁸ The rules set out four bands that specify the proportion of earnings that banks may distribute as dividends to shareholders. The lower the capital ratio is, the lower the permitted dividend payout ratio will be. If a bank meets more than 3/4 of the combined buffer requirements, it may distribute a maximum of 60 percent of profit in dividend. If it only meets between 1/2 and 3/4 of the combined buffer requirements, the permitted payout ratio fall to 40 percent. If the bank only meets 1/4 of

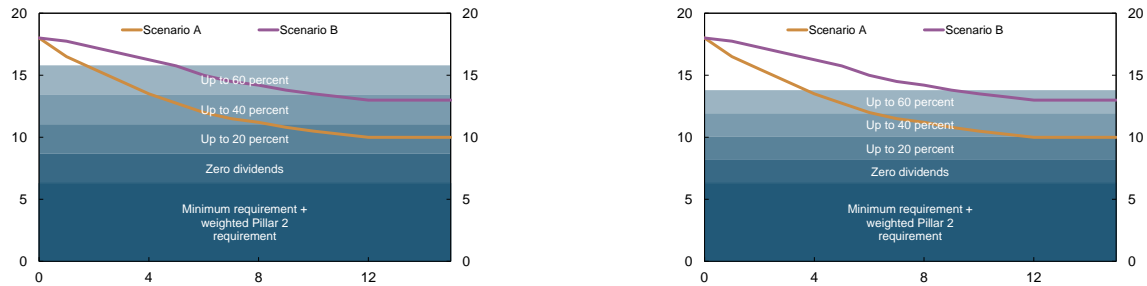
⁶See *Regulation on identifying systemically important financial institutions* (in Norwegian only) for a detailed description of the criteria. Finanstilsynet has proposed changes to the rules for identifying systemically important banks. Under the proposals, banks that have at least 10 percent of the corporate lending market in one or more regions, will be regarded as systemically important.

⁷See Chapter 3 of *the National Budget 2018* (in Norwegian only).

⁸The discussion of dividend restrictions assumes that the bank in question has a recapitalisation plan that shows that its capital ratio will exceed the total requirement within the time horizon set by Finanstilsynet. If this is not the case, the banks will not be allowed to distribute a dividend, regardless of how close to the total capital requirement its capital ratio is.

the combined buffer requirements, only 20 percent may be distributed, while no dividend distributions are permitted if the capital buffer ratio is lower than this.

Chart 2: Permitted dividend in event of a breach of the combined buffers¹. Percent



(a) Countercyclical capital buffer of 2 percent

(b) Countercyclical capital buffer reduced to zero

1) The combined buffer requirements include the capital conservation buffer, the systemic risk buffer, the countercyclical capital buffer and buffer for systemically important banks.

Sources: Finanstilsynet, Ministry of Finance and Norges Bank

Although the rules permit banks to breach the buffer requirements in a downturn, banks may nevertheless prefer to maintain their capital adequacy. Even if the consequences of breaching the combined requirements are less severe than for breaching the minimum, banks will prefer to avoid restrictions from Finanstilsynet. Banks in breach of buffer requirements may also risk higher funding costs, because investors will require a higher risk premium or prefer not to provide funding. Furthermore, owing to heightened uncertainty regarding developments ahead in a downturn, banks may prefer to hold larger capital buffers. If banks consider the consequences of breaching buffer requirements as costly or uncertain, they may show little willingness to draw on the buffers, even in the event of substantial losses. This is illustrated by two hypothetical paths for CET1 capital in Chart 2 (a). In scenario A, the bank’s capital ratio falls far below the total capital requirement, and the bank may not distribute more than 20 percent as a dividend. To avoid this, it must either increase CET1 capital or reduce risk-weighted assets. Scenario B shows a hypothetical path where the bank manages to raise its capital ratio by 3 percentage points, for example, by tightening credit. In this case, the bank may distribute up to 40 percent as a dividend and retains additional room for manoeuvre.

In the event of an economic downturn and large bank losses, the countercyclical capital buffer is to be lowered to mitigate the procyclical effects of tighter bank lending. In connection with a reduction in the buffer rate, the authorities are also required to estimate a period during which the buffer rate is highly unlikely to be increased. This creates predictability for banks, and may prevent a substantial deterioration in access to funding. The countercyclical capital buffer regulation thus enables banks to allow their capital ratios to fall. In principle, the systemic risk buffer requirement may also be lowered from the current level of 3 percent, but the Ministry of Finance has not published criteria for this. For reduced buffer requirements to have the desired effect, it is also important that market participants consider the capital requirements to be sufficiently high relative to banks’ level of risk and capital needs following a reduction of the buffer. This requires sufficiently high capital requirements in advance of a crisis.

Chart 2 (b) shows the effects of a reduced countercyclical capital buffer on the dividend restrictions in scenarios A and B. Reducing the buffer will result in a lower total capital requirement and in less restrictions from breaching the remaining buffer requirement, both of which may reduce banks' motivation to tighten lending.

2.3 Stress testing within the current framework

Banks regularly conduct stress tests to assess whether and to what extent they have adjusted their capital to their own level of risk. Under the Capital Requirements Regulation (CRR), banks are obliged to conduct stress tests at least once a year as part of ICAAP.⁹ Finanstilsynet sets requirements for this process. In addition, Finanstilsynet performs its own analyses of banks' risk levels and capital needs in order to lay down Pillar 2 requirements. This process is called SREP¹⁰ (see Finanstilsynet circular for further information).¹¹

The ICAAP process requires banks to assess all material risks that may affect their ability to fulfil their commitments. Banks must calculate how much capital they need to hold for credit risk, market risk and operational risk under Pillar 1. Banks must also comply with Pillar 2 requirements from Finanstilsynet, intended to cover risk not covered by Pillar 1 requirements, such as concentration risk, interest rate risk in the banking book and pension risk. According to the Finanstilsynet circular, banks shall develop a framework for stress testing that incorporates all material risks to which the banks might become exposed. The stress test scenario shall assume a serious macroeconomic downturn of at least three years' duration. The CET1 capital ratio in the stress test provides a point of departure for each bank's board of directors and Finanstilsynet for assessing the bank's capital needs. While ICAAP is a "bottom-up" stress test, Finanstilsynet also conducts annual "top-down" stress tests of the banking sector that are based on the authority's own models (see, for example, *Risk Outlook* 2018). Finanstilsynet uses these as a supplement to assessments of banks' capital needs.

3 Elements of the framework

In this section, we describe the elements comprising our macroprudential stress testing framework.

We set four requirements for this framework. *First*, a connection must be established between the level of financial imbalances and the severity of the stress scenario. *Second*, the impact of the downturn on banks' loan losses and capital adequacy must be estimated. *Third*, we must assess the implications for credit provision of banks' adjustments to the capital requirements. *Fourth*, the macroeconomic consequences of banks' credit provision must be quantified.

As our main model, we use Norges Bank's macroeconomic model, NEMO (Gerdrup et al., 2017). NEMO is a relatively large macro model that is estimated for the Norwegian

⁹ICAAP – Internal Capital Adequacy and Assessment Process

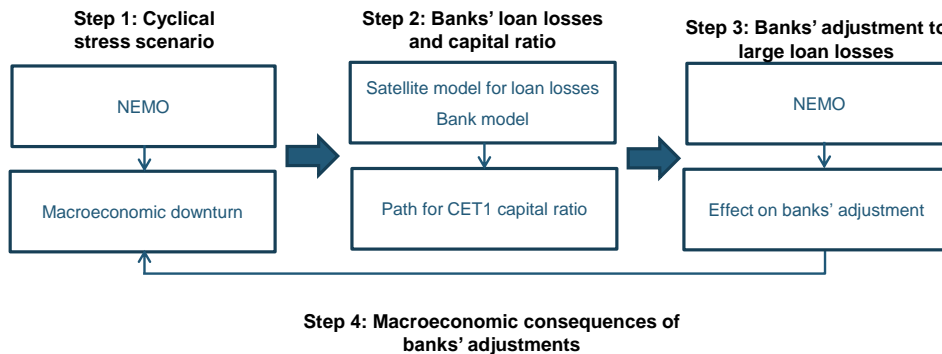
¹⁰SREP – Supervisory Review and Evaluation Process

¹¹Finanstilsynet Circular 12/2016, "Finanstilsynet's methodologies for assessing risk and capital needs."

economy. Nevertheless, the current version of the model does not meet all four of our framework requirements. NEMO contains a banking sector, but there is no linkage between macroeconomic developments and credit losses. Furthermore, the banking sector is highly simplified, on both the income and cost sides. We therefore enhance the estimates from NEMO using satellite and cross-check models. Thus, our macroprudential stress testing approach, like that of the Banque de France (Benmani et al., 2017), can be considered a hybrid strategy. Our objective is to further develop the banking sector in NEMO for future stress tests, but there will also be a need to use several models in future analyses as well.

The strategy we use to combine information from different models is illustrated in Chart 3. The strategy consists of four steps, each addressing one of our four requirements for a suitable framework.

Chart 3: Strategy for conducting the macroprudential stress tests



In step 1, we construct a cyclical stress scenario using NEMO by entering a series of negative macroeconomic shocks (see Section 3.1).

In step 2, we use satellite models for credit losses and banks' balance sheets (see Section 3.2) to estimate developments in the banking sector's CET1 capital and CET1 ratio, conditioned on the stress scenario from step 1.

In step 3, we use developments from the bank model to calibrate the magnitude of the shock to the banking sector in NEMO (see Section 3.3).¹² We define "passive" bank capital and "passive" capital adequacy as the levels of the banking sector's CET1 capital and CET1 ratio in NEMO when it is subjected to a shock, but where developments in the other variables are exactly as in step 1. The shocks are calibrated so that passive bank capital and capital adequacy follow the same path as CET1 capital and the CET1 ratio in the bank model, measured as a percentage deviation from estimated trend.

In step 4, the stress scenario is updated with the impact on the macroeconomy of the banking sector adjusting to the shocks from step 3 (see Section 3.4), resulting in a new path for the macro variables from NEMO. This can be used to return to step 2, and update the results for the banking sector's CET1 capital.

We repeat steps 2-4 several times. For each round, increasingly smaller adjustments of the shocks will be necessary for developments in NEMO to be consistent with those in

¹²The shocks used to ensure consistency between the bank model and NEMO are shocks to the banking sector's equity capital and average risk weight.

the bank model. In practice, a small number of iterations have been necessary to achieve sufficient convergence.

In what follows, the elements of the framework are described in more detail. We also provide some quantitative examples of its application from *Financial Stability Report 2018* (FSR 2018).

3.1 Designing a cyclical stress scenario

A stress test is based on a pronounced, but conceivable, downturn and assesses the impact of such an event. The design of the stress scenario depends on the questions the stress test is supposed to answer. It is customary to distinguish between thematic and cyclical stress tests. Thematic stress tests seek to elucidate vulnerabilities associated with specific developments, while cyclical stress tests are intended to shed light on vulnerabilities over time. If the stress test is to be included in the decision basis for the countercyclical capital buffer, it should reflect a scenario where the current financial imbalances materialise in a crisis. A cyclical stress test is suitable for this purpose.

The stress scenario is based on Norges Bank's risk assessment as published in *Monetary Policy Report* and *Financial Stability Report*. As a small, open economy, Norway is exposed to external shocks. Owing to domestic financial imbalances that have built up, the Norwegian economy may be more vulnerable to external shocks and the impact of a downturn amplified. Empirical analyses show that the impact of financial crises is more severe following a rapid rise in credit and asset prices (see [Jordà et al. \(2013\)](#)). The depth of the downturn should therefore vary with measures of financial imbalances.

The macroeconomic scenario is generated by entering a number of economic shocks into NEMO, such as to the global economy, oil prices, productivity and preferences. In FSR 2018 the magnitude of these shocks were calibrated so that developments in the global economy were broadly in line with those during the financial crisis and oil prices fell to a historically low level. At the same time, money market risk premiums were assumed to rise to levels observed during the financial crisis. Shocks to the banking sector were also included, as described in the strategy above. Since NEMO projects macroeconomic variables as deviations from trend (gaps), we need a procedure for transforming these variables into level variables that are used in the rule of thumb for credit losses and the bank model. The procedure for extrapolating the trend in the stress scenario is shown in [Appendix A](#).

In order to ensure a cyclical stress scenario, developments in GDP in the stress scenario are cross-checked against an estimate of the empirical relationship between financial imbalances and crisis depth, known as local projections ([Jordà, 2005](#)). This approach is based on the dependence of the depth and length of the fall in GDP on the level of the pre-crisis credit gap.¹³ The credit gap is measured as the deviation between the credit-to-GDP ratio and an estimated trend. Norges Bank has used this method as a tool to calibrate crisis depth since 2016. In the estimation, we use a panel of 20 OECD countries¹⁴ for the period 1975 Q1 to 2014 Q4. The data set and dating of financial crises are

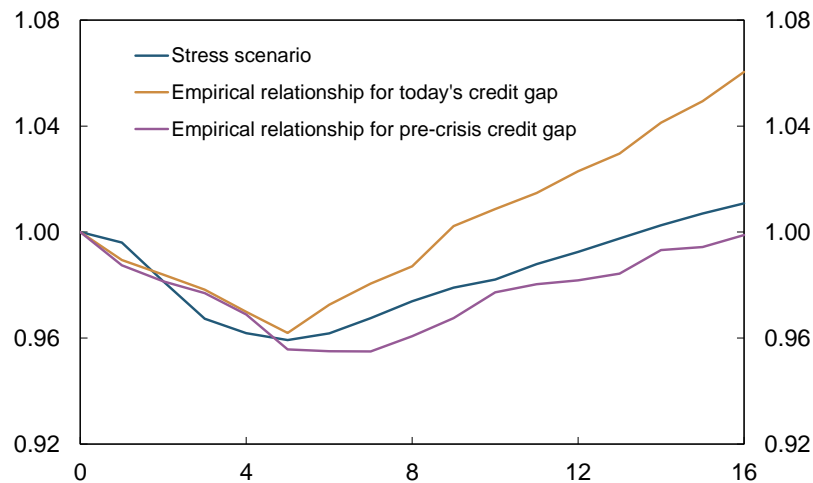
¹³See also [Hansen and Torstensen \(2016\)](#) for a description of the methodology and application on Norwegian data.

¹⁴Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Italy, Japan,

based on Anundsen et al. (2016) and include the crises in Spain (1978), Norway (1988), Finland (1991), Sweden (1990), Japan (1992) and the subsequent global financial crisis, which affected most of the countries in the sample.

As an example of such a cross-check, we show developments in mainland GDP in the stress scenario from FSR 2018 together with the crisis depth ensuing from the local projections for different levels of the credit gap in Chart 4.

Chart 4: Mainland GDP in the stress scenario and empirical relationship¹ for crisis depth. Index. Quarter before start of crisis = 1. Quarters into the stress period



1) The empirical relationship provides developments in GDP through a crisis as a function of the credit gap before the crisis begins.

Source: Norges Bank

Owing to the uncertainty surrounding the level of financial imbalances, we do not only compare the crisis depth with what ensues from the local projection based on the current credit gap. The local projection does not take into account the possibility that the relationship between financial imbalances and economic impacts will vary across countries and over time. Nor does the method control for the impact of fiscal, monetary, exchange rate or macroprudential policy on downturns. For example, banking crises in countries with a fixed exchange rate regime can be more severe than in countries with a floating exchange rate. For many of the OECD countries in our estimation, the exchange rate is fixed. Also for countries with their own currency, the magnitude of the downturn will depend on the monetary policy conducted and the effects of a lower bound for the policy rate. In our cross-check we therefore estimate a lower bound for GDP with an average credit gap for the five years prior to the financial crisis, while the upper bound is estimated using the current level. GDP in the stress scenario is required to be within this range, as shown in Chart 4.

Measuring systemic risk is highly uncertain, but is an area that is quickly evolving. Vulnerabilities can increase in many parts of the financial system, and the system can become more interwoven, without being reflected in individual indicators such as the credit gap.

Korea, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the UK and the US.

Norges Bank therefore uses a number of indicators and methodologies to obtain a more complete picture of systemic risk in *Monetary Policy Report* and *Financial Stability Report*.¹⁵ In the design of a stress scenario, the magnitude of the downturn will therefore be set on the basis of a broad set of indicators, methodologies and assessments.

3.2 Projections of banks' credit losses and earnings

3.2.1 Satellite model of credit losses

In stress tests of banks, higher credit losses are one of the key forces driving weaker earnings and capital adequacy. Projections of banks' credit losses in a crisis are very uncertain and vary both in methodology and underlying data. The underlying data for Norway cover long periods of solid economic growth and contain few periods of large credit losses, except for the banking crisis at the beginning of the 1990s. Developments in delinquent loans and other loans with a particularly high probability of default have shown cyclical variation (Galaasen and Johansen, 2016), but the relationship between macroeconomic developments and credit losses is probably non-linear. In a crisis, historical relationships can break down and lead to a marked decline in borrowers' ability and willingness to service their debts.

In order to estimate credit losses in the stress scenario in FSR 2018, a rule of thumb was used for developments in banks' credit losses estimated on international data. Hardy and Schmieder (2013) have identified simple rules for developments in banks' credit losses associated with economic shocks of varying severity. The rule of thumb indicates how much credit losses can increase in a stress scenario as a function of GDP growth. Appendix C shows how this rule was implemented in FS 2018.

Norges Bank has also developed other loan loss models. Using several models and techniques can produce more robust loss estimates. Among other things, Berge and Boye (2007) estimate relations for banks' delinquent loans and loans with a particularly high probability of default on Norwegian data. Lindquist et al. (2017) analyse household debt using microdata and identify vulnerable households on the basis of loan-to-value (LTV) and debt-to-income (DTI) ratios as well as debt-servicing capacity. Simple sensitivity analyses show how sensitive households' debt-servicing capacity is to shocks such as an interest rate increase or fall in house prices. Hjelseth and Raknerud (2016) assess the risk of losses on bank loans to non-financial enterprises on the basis of a bankruptcy probability model. The bankruptcy probabilities are estimated at sector level, and can uncover particularly vulnerable industries.

Earlier stress testing exercises have shown that Norges Bank's loss estimates are higher overall than the banks' own loss estimates (see International Monetary Fund (2015) and Havro et al. (2011)). Loss estimates across banks vary widely in response to the same economic shocks. This variability may be due to qualitative difference in banks' risk management and loan portfolios and to banks' use of different loss estimation techniques. Norges Bank's stress tests are based on published bank data and do not take into account detailed information beyond taking into account the breakdown between household and

¹⁵See also Norges Bank (2013) for a detailed description of the Bank's key indicators and Arbatli and Johansen (2017) for an overview of the heatmap for measuring systemic risk.

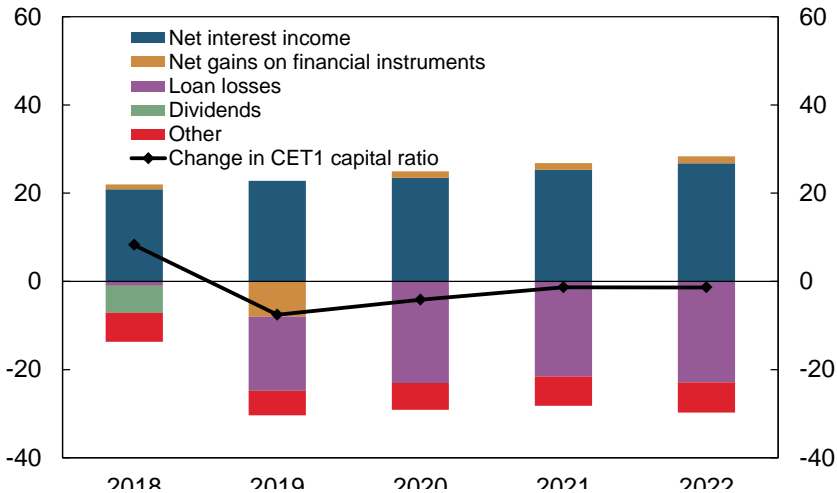
corporate loans. Norges Bank’s analyses will therefore underestimate differences in credit risk across banks. Even if individual banks have more detailed knowledge of their own loan portfolios, Norges Bank’s “top-down” approach will yield a more consistent assessment of the banking system as a whole. The objective of stress testing is not to provide the best possible estimate of banks’ credit losses and earnings in a crisis, but to illustrate what *might* happen.

3.2.2 The bank model

Norges Bank has developed a bank model to project the balance sheet and profit and loss items for nine large banks in Norway: DNB Bank, SpareBank 1 SR-Bank, Sparebanken Vest, SpareBank 1 SMN, Sparebanken Sør, SpareBank 1 Østlandet, SpareBank 1 Nord-Norge, Sbanken and Sparebanken Møre (see Syversten et al. (2015)). The results are then aggregated to a macro bank.

The most important profit and loss and balance sheet items are projected using developments in macroeconomic variables. Loans to the households and non-financial enterprises, respectively, are projected with the aid of credit growth in the stress scenario. Other assets are projected under an assumption that the balance sheet composition will remain unchanged. Moreover, conditions are imposed on bank behaviour in the stress scenario. In FSR 2018 it was assumed, for instance, that banks would limit their costs and also not distribute dividend as long as earnings are negative. Chart 5 shows developments in the stress scenario from FSR 2018 and contributions to the changes.

Chart 5: Change in CET1 capital and contributions from different components in FSR 2018. Percent



The most important drivers of banks’ earnings in FSR 2018 are developments in net interest income, credit losses and losses on financial instruments. Developments in banks’ interest-bearing assets, liabilities and interest rates determine banks’ net interest income.¹⁶

¹⁶Interest expense for wholesale funding is based on the increase in the premium in the money market rate and on the credit premium on covered bond and senior bond funding in the stress test, as well as data on the maturity structure of issued covered bond and senior bond debt from Stamdata and Bloomberg.

Credit losses follow from the rule of thumb. We have little detailed information on banking groups' financial instrument holdings. In FSR 2018 it was assumed that all banks incur substantial impairment losses on equity and fixed income instruments in the first quarter of the stress period.¹⁷

The CET1 capital ratio is CET1 capital as a proportion of risk-weighted assets. The change in CET1 capital is estimated by profit adjusted for any dividend distribution in each quarter. Total risk weights are the sum of the weights for credit risk, operational risk and market risk, adjusted for the transitional rule.¹⁸ Credit risk represents the decidedly largest portion of the total risk weights for Norwegian banks. The weights for credit risk take account of changes in banks' exposures and changes in risk weights owing to developments in the risk in banks' loan portfolios. The average risk weight is projected for each bank's total loan portfolio using changes in the estimated share of problem loans. The change in the average risk weight is assumed to be equal to the change in the share of problem loans, which in turn depends on the breakdown of the bank's loans between non-financial enterprises and households.

3.3 Banks' adjustment to the capital requirements

We use NEMO to assess bank behaviour in the stress scenario. NEMO contains a simple banking sector that responds to various shocks by adjusting interest margins and lending, in order to satisfy its capital target. In the model, banks build capital only by retaining earnings. In the event of higher losses, banks must therefore adjust lending to maintain their capital adequacy ratio. In the model, a reduction in the countercyclical capital buffer in response to a shock contributes to dampening the procyclical effects of tighter bank lending. The effect of reducing the buffer may be somewhat exaggerated in the model because banks are not permitted to issue equity capital. At the same time, it is precisely during crises that uncertainty is considerable and issuing equity capital is costly.

The banking sector in NEMO comprises many identical banks that lend to households and non-financial enterprises. Assets are funded by equity, deposits from Norwegian households and foreign wholesale funding. Banks' deposit and lending rates are set as in a monopolistic market. Deposits are set under an assumption of a "mark-down" of the money market rate (deposit margin), while lending rates to households and businesses are set as a "mark-up" (lending margin). Margins depend on the demand for loans and competition among banks. Banks incur costs when changing interest rates. This contributes to more realistic developments in lending and deposit rates.

Banks' capital targets depend on the capital requirements set by the authorities. This behaviour is modelled by assuming that banks incur costs when they deviate from their capital target.¹⁹ The banks in NEMO will change credit standards along two dimensions when they deviate from their capital target:

¹⁷We assume losses in 2019 at the same level as during the financial crisis, ie 40 and 5 percent, respectively, of the equity and fixed income portfolios. The value of these securities is then kept unchanged.

¹⁸Norwegian IRB banks have been directed to use the transitional rule in calculating total risk-weighted assets. Under the transitional rule, total risk-weighted assets (with the transitional rule) must be at least 80 percent of the level that would have applied under Basel I.

¹⁹In the model, it is just as costly for banks' capital ratios to be above the capital target as below it. This is partially a simplification, but may also be motivated by banks' greater willingness to compete on price if they are well-capitalised.

1. *Lending margin*: Banks increase their lending margin if their capital ratio falls below the capital target, so that earnings and capital ratios rise.
2. *Collateral requirements*: In the model, both households' and non-financial enterprises' borrowing are constrained by the value of posted collateral. Banks are assumed to ration credit by raising collateral requirements when the Tier 1 capital ratio falls below the capital target. This improves the capital adequacy ratio and reduces the deviation from the capital target.

Chart 6: Effects of shocks to the banking sector in NEMO. Percent (percentage points for lending margin)

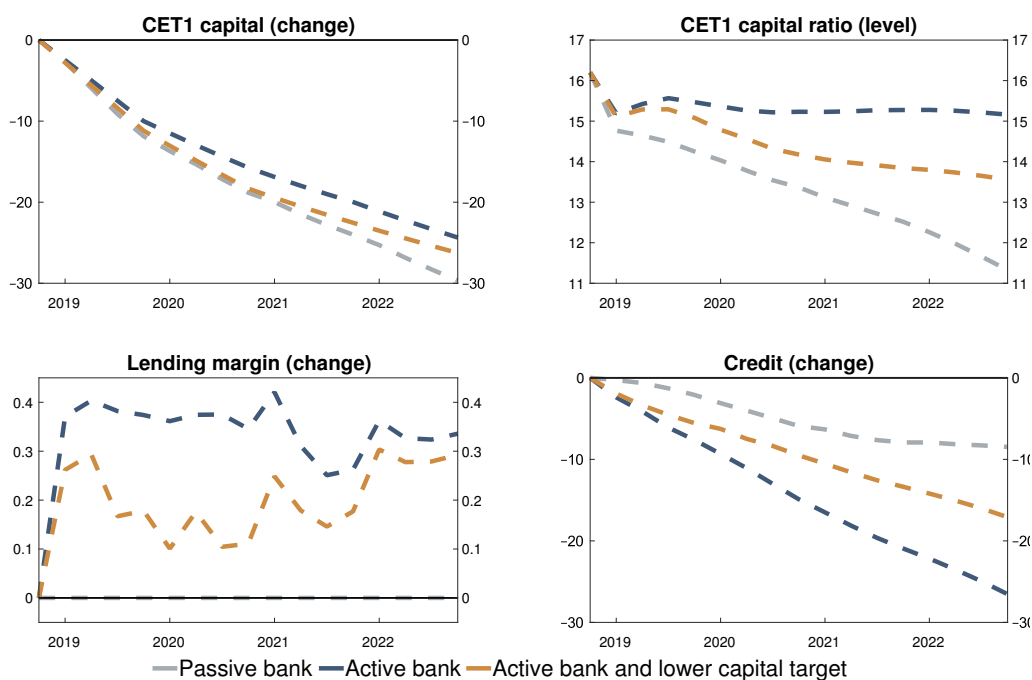


Chart 6 illustrates the adjustments made by the banks in NEMO in response to an abrupt fall in CET1 capital and higher risk weights²⁰. Here we have sketched in three scenarios. The first (passive bank) represents the effect of the shocks to the banking sector if the macro bank does not adjust. Lending and lending margins then remain at their long-term equilibrium values. In this case, the shocks reduce CET1 capital by almost 30 percent, while the CET1 capital ratio falls by close to 5 percentage points. The second scenario (active bank) shows developments when the macro bank adjusts to the shocks to reach its capital target. It will then increase lending margins and raise collateral requirements for new loans. Increased lending margins result in improved earnings and a somewhat less pronounced fall in CET1 capital. The combination of higher lending rates and stricter collateral requirements contribute to reducing credit provision. Therefore, overall, the CET1 capital ratio remains higher than in the case of a passive bank, and falls by only around 1 percentage point. The third scenario (active bank and reduced capital target) shows the adjustment of an active bank if we also assume a 2 percentage point fall in the

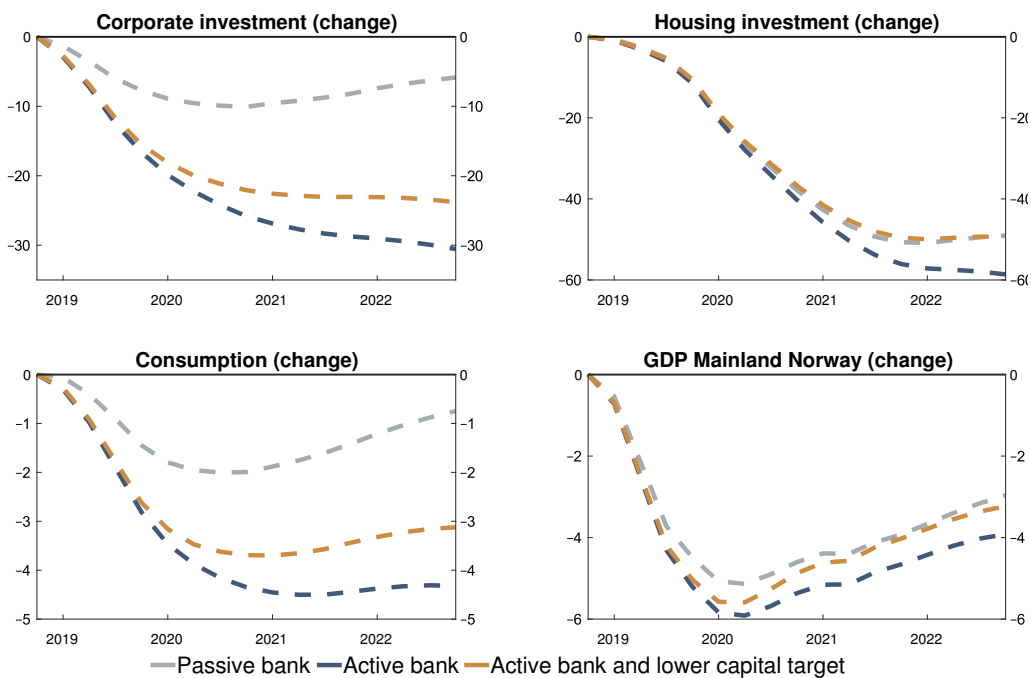
²⁰We have used a combination of shocks to CET1 capital and risk weights. The latter shock is used to take account of effects of increased credit risk on risk weights.

capital target. This may be due, for example, to a reduction in the countercyclical capital buffer rate.²¹ A lower capital target will weaken the macro bank’s incentive to tighten credit standards. The adjustment is more like in the case with a passive bank.

3.4 Macroeconomic effects of bank behaviour

In NEMO, shocks to the banking sector will not only affect bank behaviour, but also the rest of the economy. This is shown in Chart 7.

Chart 7: Effect of shocks to the banking sector in NEMO. Percent



Banks’ adjustments to an abrupt fall in equity capital and higher risk weights contribute to weakening economic developments. Owing to higher lending rates and reduced access to credit, households reduce growth in both consumption and housing investment. For enterprises, reduced demand growth, higher lending rates and tighter credit conditions lead to a decline in investment.

If the capital target is lowered at the same time as the shock to the banking sector occur, the fall in GDP and the other demand components is cushioned. This is because banks have less need to tighten credit standards. The feedback effects from the banking sector to the rest of the economy are thus partly neutralised.

The responses in NEMO are calibrated to ensure that the effects on mainland GDP, banks’ lending margins and credit developments from shocks to the capital requirement

²¹The case of an active bank and reduced capital target coincides with the stress scenario in FSR 2018. The case of an active bank and unchanged capital target coincides with the exercise in FSR 2018 that looked at the effect of not reducing the countercyclical buffer.

remain in line with a multi-country study by the [Basel Committee on Banking Supervision \(2010\)](#). The study suggests that increased capital requirements will result in higher lending margins because equity financing is perceived as more expensive than debt financing. This contributes to a near-term reduction in credit provision and overall economic output. [Akram \(2014\)](#) has analysed the effects of increased capital requirements using a macroeconomic model estimated for Norway. Akram finds somewhat weaker effects than the results from the [Basel Committee on Banking Supervision \(2010\)](#). A number of other empirical studies also support the view that banks' adjustments to capital requirements have an impact on the real economy. [Gropp et al. \(2018\)](#) find that the banks participating in the European Banking Authority (EBA) stress test in 2011 adjusted to higher capital requirements by reducing risk-weighted assets, not by increasing equity capital. For Switzerland, [Auer and Ongena \(2016\)](#) found that higher capital requirements for residential mortgages contributed to an increase in corporate lending by banks. A study for Norway by [Juelsrud and Wold \(2018\)](#) finds that banks adjust to higher capital requirements by tightening corporate lending. [Jiménez et al. \(2017\)](#) use evidence from dynamic loss provisioning in Spain to evaluate the effect of time-varying capital buffers. They find that banks that had accumulated more capital during good times, and could therefore draw on these buffers in periods of weak profitability, were better able to maintain lending during the financial crisis. This helped to tide over enterprises in a period when access to financing was poor.

4 Summary

In this article, we have presented a macroprudential stress testing framework. We set four requirements for its design. *First*, a connection must be established between the level of financial imbalances and the severity of the stress scenario. *Second*, the impact of the downturn on banks' capital adequacy must be estimated. *Third*, we must assess the implications for credit provision of banks' adjustments to the capital requirements. *Fourth*, the macroeconomic consequences of banks' credit provision must be quantified. A macroeconomic model with banks that actively adjust to meet capital requirements is key to the new framework. This permits two new elements in the stress testing analysis: The effect of losses on bank behaviour and the importance of changes in capital requirements on bank behaviour and macroeconomic developments.

The motivation for developing this framework is to make Norges Bank's stress tests useful for macroprudential policy. Time-varying capital requirements, including the counter-cyclical capital buffer, are important macroprudential policy tools. The new stress testing framework enables us to analyse the impacts of different calibrations of the time-varying capital requirements in the stress period. Instead of using stress testing to measure whether or not banks "pass" the tests, we seek to explore how macroprudential policy tools may prevent macroeconomic downturns from worsening. Nevertheless, stress tests cannot provide a satisfactory answer to the question of what the correct level of buffer requirements is, since they can only be used to analyse the benefits of different levels in a stress situation. A comprehensive analysis should also include the costs, for example, in the form of a lower level of economic activity in normal times owing to higher capital requirements.

The framework was first used in *Financial Stability Report 2018*. The results of the

stress tests will vary from year to year, owing to new assessments of the size of financial imbalances and to new assessments of economic relationships. The work to further develop Norges Bank's stress testing framework will continue. This pertains to all elements we have described in this article: methods for disciplining a cyclical stress scenario, the relationship between developments in the real economy and banks' credit losses, banks' adjustments to substantial credit losses and the effects on the macroeconomy of those adjustments.

References

- Akram, Q. F. (2014). Macro effects of capital requirements and macroprudential policy. *Economic Modelling* 42, 77 – 93.
- Anderson, R., J. Danielsson, C. Baba, U. S. Das, H. Kang, and M. A. S. Basurto (2018). Macroprudential Stress Tests and Policies: Searching for Robust and Implementable Frameworks. IMF Working Papers 18/197, IMF.
- Anundsen, A. K., K. Gerdrup, F. Hansen, and K. Kragh-Sørensen (2016). Bubbles and crises: The role of house prices and credit. *Journal of Applied Econometrics* 31(7), 1291–1311.
- Arbatli, E. and R. M. Johansen (2017). A Heatmap for Monitoring Systemic Risk in Norway. Staff Memo 10, Norges Bank.
- Auer, R. and S. Ongena (2016). An analytical framework to calibrate macroprudential policy. Working paper 593, Bank for International Settlements.
- Bank of England (2016). The Financial Policy Committee’s approach to setting the countercyclical capital buffer. A Policy Statement, Bank of England.
- Basel Committee on Banking Supervision (2010). Interim Report: Assessing the Macroeconomic Impact of the Transition to Stronger Capital and Liquidity Requirements. Technical report, Bank for International Settlements.
- Bennani, T., C. Couaillier, A. Devulder, S. Gabrieli, J. Idier, P. Lopez, T. Piquard, and V. Scalone (2017). An analytical framework to calibrate macroprudential policy. Working paper 648, Banque de France.
- Berge, T. O. and K. G. Boye (2007). An analysis of banks’ problem loans. *Economic Bulletin* 2/2007, 65-76, Norges Bank.
- Dent, K., B. Westwood, and M. Segoviano (2016). Stresstesting of banks: an introduction. *Bank of England Quarterly Bulletin* (2016 (Q3)).
- Durdu, B., R. Edge, and D. Schwindt (2017, May). Measuring the Severity of Stress-Test Scenarios. Feds notes, Board of Governors of the Federal Reserve System.
- Galaasen, S. M. and R. M. Johansen (2016). Cyclical Capital Regulation and Dynamic Bank Behaviour. Staff Memo 22, Norges Bank.
- Gerdrup, K. R., E. M. Kravik, K. S. Paulsen, and Ø. Robstad (2017). Documentation of NEMO - Norges Bank’s core model for monetary policy analysis av forecasting. Staff Memo 8, Norges Bank.
- Gropp, R., T. C. Mosk, S. Ongena, and C. Wix (2018). Bank response to higher capital requirements: Evidence from a quasi-natural experiment. SAFE Working Paper 156.
- Hansen, F. and K. N. Torstensen (2016). Gir høy gjeldsvekst i oppgangstider større konsumfall i nedgangstider? Aktuell kommentar 8/2016, Norges Bank.
- Hardy, D. C. and C. Schmieder (2013). Rules of Thumb for Bank Solvency Stress Test. Working Paper 232, International Monetary Fund.

- Havro, G. B., R. M. Johansen, J. Ruud, and C. B. Tr  e (2011). Norges Bank's stress test in Financial Stability 2/10 compared with banks' projections. *Economic Bulletin* 2, Norges Bank.
- Hirtle, B. and A. Lehnert (2015). Supervisory stress tests. *Annual Review of Financial Economics* 7(1), 339–355.
- Hjelseth, I. N. and A. Raknerud (2016). A model of credit risk in the corporate sector based on bankruptcy prediction. Staff Memo 20, Norges Bank.
- International Monetary Fund (2015). Norway. Financial Sector Assessment Program. Technical note - Stress testing the banking system. IMF Country Report 258, International Monetary Fund.
- Jim  nez, G., S. Ongena, J.-L. Peydr  , and J. Saurina (2017). Macroprudential policy, countercyclical bank capital buffers, and credit supply: Evidence from the spanish dynamic provisioning experiments. *Journal of Political Economy* 125(6), 2126–2177.
- Jord  , O. (2005, March). Estimation and inference of impulse responses by local projections. *American Economic Review* 95(1), 161–182.
- Jord  , O., M. Schularick, and A. Taylor (2013). When credit bites back. *Journal of Money, Credit and Banking* 45(s2), 3–28.
- Juelsrud, R. E. and E. G. Wold (2018). Risk-weighted capital requirements and portfolio rebalancing. *Journal of Financial Intermediation forthcoming*.
- Lindquist, K.-G., H. Solheim, and B. H. Vatne (2017). Husholdningenes gjeld og koplinger til boligmarkedet - konsekvenser for finansiell stabilitet. *Aktuell Kommentar* 17, Norges Bank.
- Norges Bank (2013). Kriterier for en god motsyklisk kapitalbuffer. Norges Bank Memo 1.
- Syversten, B. D., R. M. Johansen, O. A. Lind, H. Solheim, and N. Stefano (2015). The bank model and the stress test in the 2015 Financial Stability Report. Staff Memo 5/2015, Norges Bank.

Appendices

A Extrapolating trend growth in the stress scenario

The stress scenario from NEMO provides developments in main economic aggregates in gap form, ie as a percentage deviation from trend. To convert these to variables in level or growth form, one must make assumptions about trend growth for these variables.

It is common to use empirical, theoretical and judgement-based assessments to estimate trend growth. A fairly simple procedure was followed in FSR 2018. For a particular variable, let X_{t_0} be the variable in level form in the last period before the stress period, x_{t_0+h} be the variable in gap form h quarters into the stress period and $X_{t_0+h}^*$ be the trend value through the stress period. Assume constant trend growth and normalising the trend in period t_0 , the trend value can be expressed as $X_{t_0+h}^* = (1 + g)^h X_{t_0}$, where g is trend growth. To find the level values in the stress period, one must apply the relationship between the level, trend and gap, as given by:

$$\log X_{t_0+h} = \log X_{t_0} + gh + x_{t_0+h}$$

The question is how to choose g . The recipe used in FSR 2018 for this is as follows:

1. Start with an initial guess of g .
2. Calculate the level values through the stress period. Also find the level values in B periods after the stress period, where you assume that the level lies at trend.
3. Use a Hodrick-Prescott (HP) filter on a time series for X that includes both historical data, the stress period and the B additional periods at the end. This filter gives a time-varying trend growth rate. Find the lowest value for trend growth through the stress period, \hat{g} .
4. Update the estimation of g by setting $g = \hat{g}$.
5. Repeat steps 2-4 until convergence.

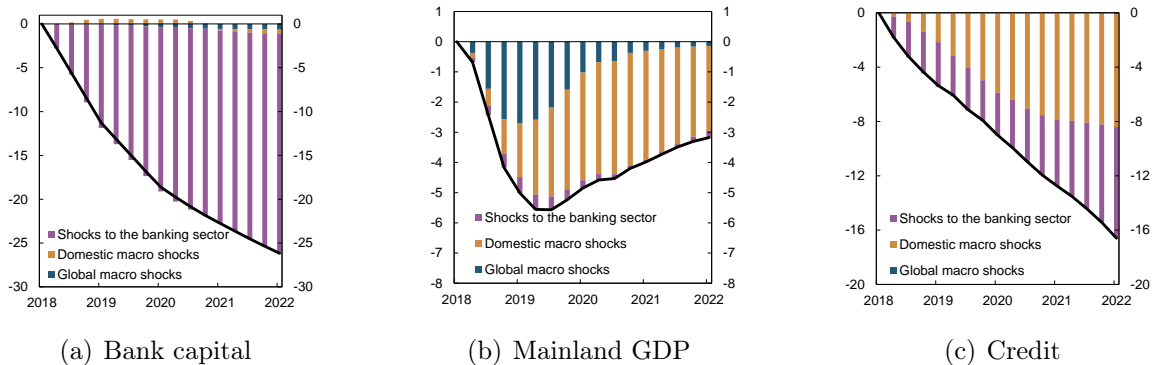
This method is simple and ensures identical treatment of all trend variables. Another useful attribute is that if one begins at level form, use an HP filter, extract the lowest trend growth in the stress scenario, \hat{g} , and then calculate the gaps under the assumption that trend growth through the stress period is constant and equal to \hat{g} , one will return to the same gap variables from NEMO that were used to begin with.

B Simple decomposition of shock contributions in the stress scenario

Chart 8 illustrates how different shocks affect developments in the mainland GDP, credit and bank capital gaps in the stress alternative in FSR 2018. The shocks have been divided into three categories: global macro shocks, domestic macro shocks and shocks to the banking sector. The last category represents the impact of shocks to the macro

bank’s equity capital and risk weights and of the reduced countercyclical buffer. Even though the countercyclical buffer is reduced to zero, banks will adjust to prevent capital adequacy from falling below the remaining capital requirement.

Chart 8: Decomposition of shock contributions¹ to different gaps in the stress scenario. Percent



1) The category “shocks to the banking sector” shows the net effect of shocks to banks’ equity capital and risk weights and shocks to the capital requirement (countercyclical capital buffer reduced to zero).

Bank capital is driven primarily by shocks to the banking sector because no linkage exists between the macroeconomic situation and banks’ credit losses in NEMO. Shocks to the banking sector are therefore used to generate developments in bank capital and the capital ratio that are consistent with the bank model. These shocks, however, will have a feedback effect on the macroeconomy, as shown in Charts 6-7.

In the first three quarters of the stress period, GDP is affected primarily by the global shocks, after which GDP is primarily affected by domestic macro shocks. But banking sector losses also result in higher lending rates and tighter credit standards, which weaken GDP.

Credit falls, owing to both negative domestic macro shocks and shocks to the banking sector. A weaker economy reduces demand for credit, while impaired banking sector solvency [reduces] the supply of credit. All together, the fall in the credit gap is fairly pronounced.

C A rule of thumb for credit losses

The rule of thumb for credit losses is inspired by [Hardy and Schmieder \(2013\)](#). They identify rules of thumb for developments in banks’ credit losses in connection with economic shocks of varying severity. In FSR 2018, it was used a sensitivity parameter set to -0.2 based on a median advanced economy bank during a severe crisis (Table 4 in [Hardy and Schmieder \(2013\)](#)). The rule of thumb expresses how much credit losses as a share of gross lending will increase in the stress scenario, as a function of GDP trajectories.

Let L_{t_0+h} be the increase in credit losses h quarters into the stress period. t_0 is the last period before the stress period begins. The rule of thumb gives

$$L_{t_0+h} = \alpha G_{t_0+h}$$

where α is the sensitivity parameter and G_t is derived from the level series for mainland GDP (Y_t). G_t is defined as the cumulative sum of the difference between growth in mainland GDP and estimated trend growth over the past five years (measured in percentage points):

$$G_t = 100 \sum_{i=0}^{19} \left(\frac{Y_{t-i} - Y_{t-1-i}}{Y_{t-1-i}} - \bar{g} \right)$$

where \bar{g} is quarterly trend growth. The values $\alpha = -0.2$ and $\bar{g} = 0.674\%$ were used for the stress test in FSR 2018