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Norwegian banks' net interest income and macroeconomic developments over the past 30 years

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Abstract

Banks' profitability is their first line of defence against losses, and net interest income is banks' main source of revenue. Since the policy rate hikes began in 2021, net interest income has increased substantially relative to assets, strengthening banks' loss-absorbing capacity. We use a VAR model to analyse what has affected Norwegian banks' net interest income relative to assets over the past 30 years. Historically, a higher policy rate has typically pulled up net interest income, while heightened market uncertainty has pulled down net interest income. In addition to the policy rate, cost-efficiency improvements help explain the substantial reduction in net interest income relative to assets observed since the 1990s. The increase during 2022 is largely caused by policy rate hikes from a low level during the pandemic. The increase reflects in part the fact that banks have more interest-bearing assets than interest-bearing debt and other factors such as developments in banks' interest margins. Using the VAR model, we show that banks' net interest income is procyclical, which supports the use of time-varying capital requirements.

1 Introduction and summary

Norwegian banks' net interest income has increased substantially over the past year. Combined with low losses, developments have boosted banks' profitability. Net interest income as a percentage

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of average total assets (hereinafter assets) has increased in pace with the policy rate hikes that started in 2021, and the current level of interest income has not been observed since before the financial crisis. In the period ahead, interest income is expected to remain high (see Financial Stability Report 2023 H1). At the same time, a number of large banks have revised up their long-term return on equity targets.[1] This *Staff Memo* analyses what has affected developments in banks' net interest income, based on close to 30 years of data.

There are several reasons why a better understanding of banks' net interest income is useful. First, net interest income is banks' main source of revenue, and higher earnings strengthen their first line of defence against losses. High current earnings may cover losses, ensuring that banks do not operate at a loss and need to draw on capital in downturns. This reduces both the risk that banks will tighten credit standards to maintain capital adequacy and the risk that banks will amplify a downturn (see Andersen et al. (2019)). For example, the results of the European Banking Authority's stress test for 2023 show that in a high interest rate scenario, adequate net interest income could partly compensate for higher losses (see EBA (2023)). However, high losses can occur just as often in the event of severe downturns when interest rates are reduced, and it is not clear whether net interest income will then be as adequate. It is therefore useful for financial stability reasons to ascertain how banks' net interest income is typically changed based on macroeconomic conditions.

Second, the effect of the policy rate on net interest income affects the pass through of monetary policy.[2] Floating rate loans amplify the impact on lending rates and will, in the event of a rate hike, reduce customers' disposable income and dampen credit demand but could also increase banks' earnings and potential credit supply. According to findings by Altunok et al. (2023), US banks that lend to a great extent at floating rates earn higher interest income and increase credit supply when the policy rate is raised. Higher credit supply may dampen the impact of higher lending rates on the economy. The effect may be symmetric and also dampen the impact of a lower policy rate. Focusing on expansionary monetary policy, a range of studies point out that very low or negative interest rates do not necessarily contribute to higher lending activity by banks because banks' earnings are then weaker (see Brunnermeier and Koby (2023) and Eggertsson et al. (2023)).

Third, improved insight into drivers of net interest income may strengthen the understanding of banks' capacity to adjust to time-varying capital requirements in different cyclical situations and thus improve Norges Bank's decision basis for setting the countercyclical capital buffer (see Norges Bank (2022)).

Our empirical approach is to look at how aggregated income statement items for the large Norwegian banks have developed together with macroeconomic developments. To take into account

[1] In the course of winter 2022/23 a number of large bank groups revised up their long-term return on equity targets by 1 percentage point (see DNB Bank, SpareBank 1 SMN , SpareBank 1 Nord-Norge, SpareBank 1 SR-Bank and Sparebanken Vest (2023 Q1)).

[2] There is extensive literature on the impact of monetary policy through banks' balance sheets (see eg Drechsler et al. (2017)). In this paper, we are interested in effects through net interest income.

the fact that net interest income affects and is affected by developments in the macroeconomy and other bank variables, we have included net interest income as a percentage of assets in a Vector Auto Regression (VAR) model for the Norwegian economy and the Norwegian banking sector. We describe what has historically affected net interest income as a percentage of assets and examine how net interest income as a percentage of assets responds to changes in the macroeconomy and banks' other income statement items. The estimated VAR model includes the macro variables output, inflation, policy rate, exchange rates and an indicator of market uncertainty, the Volatility Index (VIX), as well as the banking variables: total assets, operating expenses, credit losses and net interest income. To simplify the comparison of banks' income and costs over time, the income statement items are normalised by calculating them as a percentage of assets.

By using a new data set[3] with time series for the large Norwegian banks'[4] income items as far back as 1994, we can study developments in the earnings of the large Norwegian banks over several economic cycles. The financial statements of Norwegian banks are not only affected by macroeconomic developments but also by institutional changes. To filter out the effects of key institutional changes, the time series for banks' accounting variables have largely been break-adjusted for changes such as mergers and transfers of loans to covered bond mortgage companies.

Our analysis shows that policy rate hikes, irrespective of cause, will typically lead to higher net interest income as a percentage of assets. We find that a 1 percentage point rise in the policy rate results in approximately 0.1 percentage point higher net interest income as a percentage of assets. In isolation, this corresponds to approximately 1 percentage point higher return on equity. It is reasonable that return on equity increases somewhat when the nominal interest rate level and yields in general rise in the economy. A simple calculation indicates that close to half of the effect of the rate hike may be due to the fact that banks have more interest-bearing assets than interest-bearing debt. However, other indicators than the policy rate also affect net interest income: We find that heightened market uncertainty tends to push down banks' net interest income as a percentage of assets, and one possible reason is that wholesale funding in such situations is more costly. We also find that banks let cost reductions be reflected in lower net interest income, but not in a 1:1 relationship. It follows that profitability increases somewhat when costs fall.

Furthermore, we present our interpretation of what has driven net interest income as a percentage of assets in recent years, based on the VAR model. The model shows that macroeconomic conditions (largely through the policy rate) pulled down net interest income as a percentage of assets when the Covid-19 pandemic started. The rise in net interest income relative to assets from mid-2021 can be explained by a reversal of macroeconomic conditions, increased inflationary pressures and somewhat slower growth in banks' assets measured relative to nominal mainland GDP. We also show that net interest income as a percentage of assets was slightly higher than the

[3] Galaasen and Johansen (2016) apply an earlier version of the data set and study developments in banks' balance sheet items over the business cycle.

[4] The large Norwegian banks are DNB Bank, SpareBank 1 SR-Bank, Sparebanken Vest, SpareBank 1 SMN, Sparebanken Sør, SpareBank 1 Østlandet and SpareBank 1 Nord-Norge.

model's expectation in 2022 Q4. However, in the model, the upside surprise was not greater than other historical surprises for net interest income.

The remainder of this paper is structured as follows: Section 2 justifies the choice of variables in the VAR model in light of literature and theory, and discusses what we can expect from interaction between the variables. Section 3 describes the empirical approach and criteria for choice of specification. Section 4 describes the data set. In Section 5, we show the results of the analysis and illustrate in a policy exercise how procyclical net interest income supports the use of time-varying capital requirements. Section 6 provides concluding comments.

2 What drives developments in net interest income? A glance at the literature

This section provides a selective overview of theoretical and empirical literature that describes key drivers of net interest income as a percentage of assets. This overview provides the rationale for the choice of variables in our empirical model in Section 3.

Banks receive net interest income as the interest rates they charge on their interest-bearing assets are higher than on their interest-bearing liabilities. The total average interest margin (average interest on interest-bearing assets less average interest on interest-bearing liabilities) is therefore important for banks' net interest income (see also **Definitions** on page 5). Many considerations play a role when banks set interest rates, such as macroeconomic conditions, the policy rate and market interest rates, terms and conditions for deposits and loans, banks' costs and the competitive situation.[5]

In addition to developments in interest margins, the composition of banks' balance sheets will affect developments in net interest income.

[5]For an overview of Norwegian banks' margins and conditions that affect margins (see Erard (2014)).

Definitions Observable accounting variables are marked in blue. Net interest income is primarily interest income on lending less interest expenses, such as interest on deposits and wholesale funding.

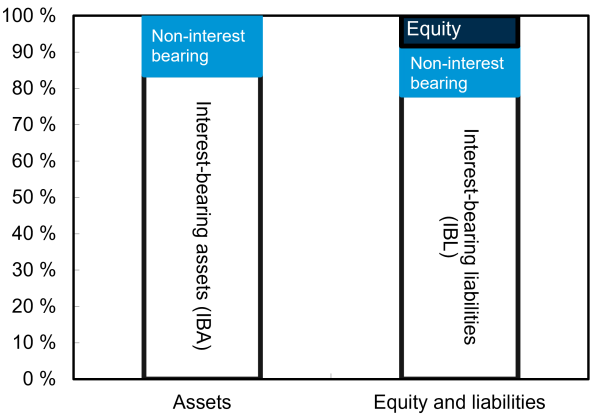


Chart 1: *The large banks' overall balance sheet. 2022.* Distinction between interest-bearing and non-interest-bearing balance sheet items is based on a rough categorisation of banks' balance sheet items.

Average total assets (assets):

$$\text{AA(t)} = \frac{\text{Assets(t)}+\text{Assets(t-1)}}{2}$$

Average interest-bearing assets:

$$\text{AIBA(t)} = \frac{\text{IBA(t)}+\text{IBA(t-1)}}{2}$$

Average interest-bearing debt:

$$\text{AIBL(t)} = \frac{\text{IBL(t)}+\text{IBL(t-1)}}{2}$$

Average interest on interest-bearing assets and interest-bearing liabilities:

$$r_i(t) = \frac{\text{Interest income(t)}}{\text{AIBA(t)}} \qquad r_e(t) = \frac{\text{Interest expenses(t)}}{\text{AIBL(t)}}$$

Net interest income as a share of average total assets:

$$\frac{\text{Net interest income(t)}}{\text{AA(t)}} = \frac{r_i(t)\cdot\text{AIBA(t)} - r_e(t)\cdot\text{AIBL(t)}}{\text{AA(t)}}$$

Net interest income as a share of interest-bearing assets:

$$\text{NIM(t)} = \frac{\text{Net interest income(t)}}{\text{AIBA(t)}} = \frac{r_i(t)\cdot\text{AIBA(t)} - r_e(t)\cdot\text{AIBL(t)}}{\text{AIBA(t)}}$$

$$\text{Total average interest margin(t)} = r_i(t) - r_e(t)$$

$$\text{Return on equity(t)} = \text{After-tax profits(t)} / \frac{Equity(t) + Equity(t-1)}{2}$$

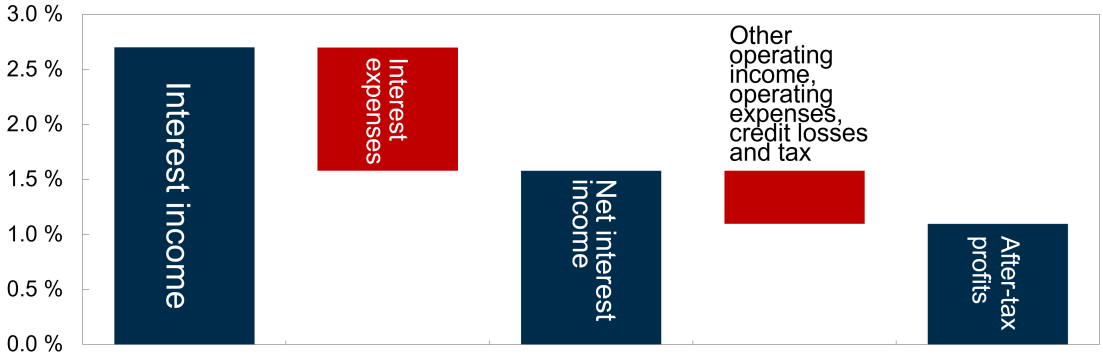


Chart 2: *The large banks' overall profits. As a percentage of assets. 2022*
Sources: S&P Capital IQ and Norges Bank

2.1 Effect of macroeconomic developments

Positive macroeconomic developments may contribute to higher net interest income owing to higher lending and deposit activity. To achieve a positive effect of net interest income as a percentage of assets, the rise in net interest income must be larger than the rise in total assets. Albertazzi and Gambacorta (2009) look at net interest income and find a historical positive correlation with GDP when they study international banks in the period prior to the financial crisis.[6] They interpret the results as showing that positive macroeconomic conditions boost household and corporate credit demand and improve borrowers' financial conditions. Buncic et al. (2019) focus on net interest income as a share of total assets and find a positive effect of higher inflation and GDP growth for Swedish banks. They interpret the results as showing that macroeconomic conditions boost demand and credit supply, which results in an expansion of banks' interest-bearing business opportunities.

In addition, macroeconomic developments may have more indirect effects on banks' net interest income as a percentage of assets. Higher inflation and demand may for example trigger a rate hike that in turn pulls up net interest income as a percentage of assets (see Section 2.2). Macroeconomic developments may also affect banks' costs that in turn affect net interest income as a percentage of assets (see Section 2.3). Andersen (2020) finds that higher economic activity results in a lower cost-to-assets ratio. The results are interpreted to mean that banks can exploit economies of scale in times of higher growth or that banks adjust to bad times by restructuring, which in the near term results in additional restructuring costs for banks.

In the sections below, we discuss further indirect effects of macroeconomic developments on net interest income as a percentage of assets, such as the effects of changes to the policy rate, costs and market stress.

2.2 Effect of policy rate and market rates

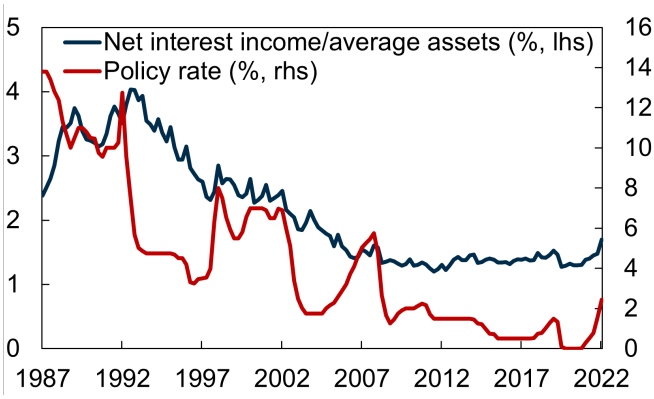
In Norway, the policy rate showed a declining trend in the wake of the banking crisis and up to 2010 (Chart 3a). In the same period, banks' deposit margins also showed a declining trend, while lending margins edged up (see Erard (2014)). In total, banks' interest margins (the gap between lending and deposit rates) and net interest income as a percentage of assets narrowed gradually in the period to 2010 (Chart 3a).

Developments in banks' interest margins received considerable attention after policy rates were reduced to very low levels following the financial crisis and more recently during the current tightening cycle. In an analysis of data covering 17 countries over 145 years, Zimmermann (2019) finds that the difference between lending and deposit rates increases when monetary policy is tightened.

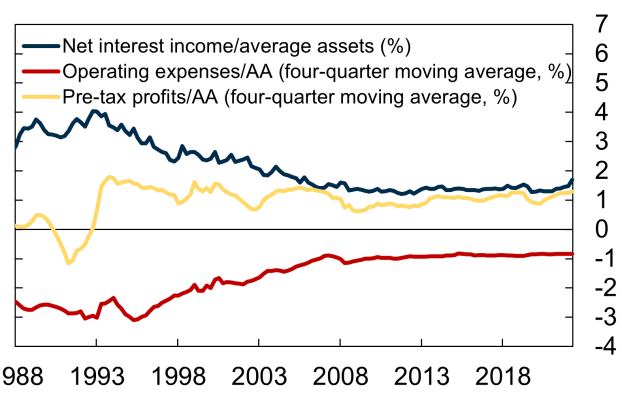
[6] Albertazzi and Gambacorta (2009) appear to estimate the effect on net interest income that is not normalised by dividing by total assets.

Chart 3: *Net interest income has fallen in pace with the policy rate and operating expenses*

(a) *Net interest income* and the policy rate*



(b) *Net interest income* and operating expenses**



**Annualised and break-adjusted time series for the sum of seven large Norwegian banks. For more detail, see Appendix A.*
Expenses are reported with a negative sign.
Sources: S&P Capital IQ, Statistics Norway and Norges Bank

Nominal deposit rates can in principle be negative, but when deposit rates are below zero, banks' customers have incentives to withdraw their deposits as cash or invest them in funds and other savings products. Given that banks typically set deposit rates lower than the policy rate, deposit margins are put under pressure when the policy rate approaches zero. A number of studies refer to a positive relationship between net interest income relative to assets and the level of short-term interest rates (see Brunnermeier and Koby (2023), Eggertsson et al. (2023) and Windsor et al. (2023)). Borio et al. (2017) take an empirical non-linear approach based on data on large international banks and find that the effect of higher rates on net interest income fades, because the pressure on deposit margins eases as the policy rate moves away from the zero lower bound.

Lags in the adjustment of deposit and lending rates in response to policy rate changes usually result in a temporary effect on net interest income. In Norway, banks have a notification requirement of a number of weeks[7] to raise mortgage lending rates and to reduce deposit rates, while corporate lending rates[8] and the interest rate on banks' wholesale funding are more closely linked to developments in market interest rates such as Nibor. Juelsrud et al. (2020) finds that for Norwegian banks, the historical pass-through from changes in the policy rate in subsequent quarters varies over time and is different for customers' deposit rates and lending rates. This means that banks' overall interest margin (the gap between lending rates and deposit rates) and net interest income are affected by changes in the policy rate. In general, they find that the pass-through to interest rates varies with the direction of the policy rate change and is more pronounced when unfavourable for customers, i.e. a stronger pass-through to lending rates when the policy rate is raised and a stronger pass-through to deposit rates when the policy rate is reduced.

[7] See section 3-13 on changes to contractual terms and conditions in the Financial Contracts Act.
[8] See How important are premiums above the policy rate for corporate interest rates?

A number of international studies emphasise that developments in the difference between long-term and short-term market rates (the slope of the yield curve) result in higher net interest income relative to assets (see Alessandri and Nelson (2015), Borio et al. (2017), English (2002) and Marques et al. (2022)). In such analyses, banks' business models usually include lending at a fixed (long-term) interest rate.[9] Norwegian banks primarily offer loans at floating interest rates (short-term) and are funded at floating rates.[10] Thus, long-term interest rates and the slope of the yield curve likely have little effect on net interest income as a percentage of assets. Buncic et al. (2019) find for Swedish banks (with similar business models to Norwegian banks) that the historical relationship between the slope of the yield curve and banks' interest margins is negative.

The composition of banks' balance sheets also affects what happens to banks' net interest income as a percentage of assets when the policy rate is raised.[11] An equity effect arises because banks do not have interest expenses linked to equity (see also description in Borio et al. (2015), Hack and Nicholls (2021) and Windsor et al. (2023)). As interest-bearing assets are larger than interest-bearing liabilities (Chart 1), this means in isolation that a higher policy rate that passes fully through to average interest rates pulls up net interest income. Since the introduction of Basel III[12] and the phasing-in of capital and buffer requirements[13] in Norway in 2013, Norwegian banks' equity ratios have increased and the equity effect has likely become larger.

The composition of customer deposits is also of importance. Customer deposits can be divided into savings deposits and transaction deposits. Demand for transaction deposits is usually less sensitive to changes in deposit rates since customers always require a certain volume of such deposits to make payments. This means that deposit rates on transaction accounts can be kept low when the policy rate is raised. An effect corresponding to the equity effect may therefore apply to transaction deposits, but in the data this is shown as a lower pass-through to banks' average rates on interest-bearing liabilities (see **Definitions** on page 5). However, if there is adequate competition for these liquid deposits, deposit margins on transaction deposits are unlikely to be much larger than what it would cost the banks to provide transaction services, (see Section 2.3). Based on US data, Drechsler et al. (2017) show that the rise in deposit margins in response to policy rate hikes is linked to banks' market power.

Another type of balance-sheet effect is that wholesale funding can be more advantageous for

[9] Drechsler et al. (2023) point out that fixed-rate loans can be used by a bank to hedge interest rate risk if deposit margins rise (fall) when the policy rate is raised (lowered). When the policy rate is lowered, a fall in deposit margins is offset by gains on fixed-rate lending contracts that were entered into before the policy rate reduction.

[10] Norwegian banks provide credit and receive deposits largely at a floating nominal interest rate, in the sense that these interest rates can be adjusted by the bank after a notification period. In practice, these interest rates closely track the policy rate. Banks' corporate lending rates are often linked to a reference rate such as Nibor.

[11] There is substantial literature on the economic effect of monetary policy through banks' balance sheets (see eg Bernanke and Gertler (1995) and Drechsler et al. (2017)). In this paper, we are interested in the effects on net interest income.

[12] See Basel III: A global regulatory framework for more resilient banks and banking systems.

[13] The recommendations are implemented in the EU/EEA capital framework (CRD-IV and CRR) and in Norwegian law (Financial Institutions Act with regulations).

banks than deposit funding when interest rates are low, and banks with a high share of wholesale funding may therefore find that compared with other banks, lower interest rates do not pull down their net interest income to the same extent. The effect arises because the cost of wholesale funding is often linked to market rates such as Nibor and is therefore likely less limited by a possible zero lower bound on deposit rates (see Windsor et al. (2023)).

2.3 Effect of costs and competition

Banks usually have a return-on-equity target (see **Definitions** on page 5), and will adjust their operations to achieve this target over time. In addition to generating profit on lending activity, net interest income is the largest income item and is meant to also cover banks' operating expenses, credit losses and tax (Chart 2). If competition between banks is strong, banks' earnings should theoretically only result in normal return on equity, while earnings beyond this covers banks' costs. We can therefore expect (in a given competitive situation) that the level of banks' net interest income has a positive relationship with banks' operating expenses over time (when costs are measured with a positive sign).[14]

Banks' operating expenses have shown a declining trend since the banking crisis (Chart 3b). Net interest income fell in pace with operating expenses and contributed to return on equity remaining at approximately 12 percent. Andersen (2020) finds that Norwegian banks' cost-efficiency improvements can largely be explained by automation and digitalisation. Based on a larger sample of countries Le and Ngo (2020) also find that digitalisation measured as the number of ATMs and payment terminals is positive for banks' profit but contributes through both net interest income and reduced operating expenses. Increased digitalisation also provides banks with the opportunity to charge extra fees on card and digital transactions.[15]

Credit losses differ from banks' operating expenses in that loss expenses are considerably more volatile and the wide fluctuations clearly impact banks' earnings (Chart 4a). Banks likely charge a lower interest rate on loans with lower expected loss expenses. Risk weights, which should reflect how exposed banks are to losses, have fallen for the large banks since the capital adequacy framework (Basel II) was introduced in Norway in 2007 (see Andersen and Winje (2017)). Banks have also gradually shifted exposure to the retail market, which has lower risk weights and losses in international crises (see Kragh-Sørensen and Solheim (2014)). However, it is difficult to quantify credit risk precisely (see Andersen and Winje (2017)) and in particular developments over time and thus which historical effect credit risk developments have had on net interest income.

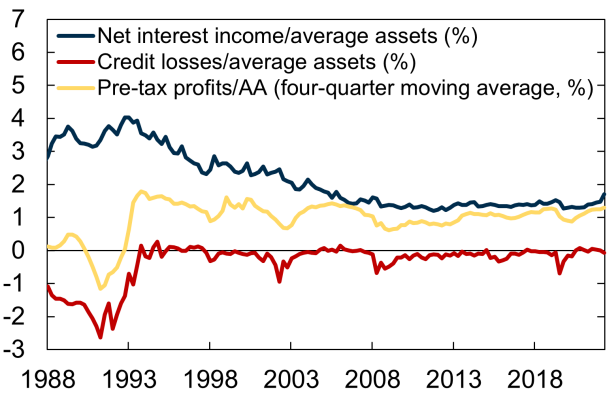
If banks' profitability comes under pressure, banks will adjust interest rates, earnings and

[14] In the charts and VAR model described in Section 3, costs are measured with a negative sign and we expect a negative relationship between net interest income and operating expenses with this reporting.

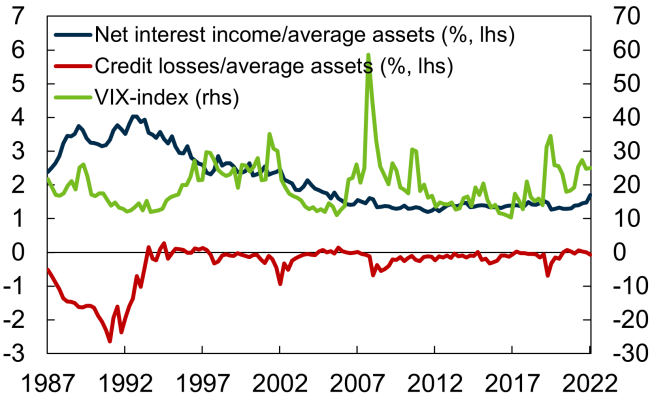
[15] In ORBOF bank statistics , income relating to payment services is included, such as cards and giros (payments made directly from a bank account) under commission and fee income and are not included in banks' interest income.

Chart 4: *Net interest income in the event of higher losses and market stress*

(a) *Credit losses* and earnings before tax**



(b) *Credit losses* and market stress*



**Annualised and break-adjusted times series for the sum of seven large Norwegian banks. For more detail, see Appendix A.*
Expenses are reported with a negative sign.
Sources: FRED, S&P Capital IQ, Statistics Norway and Norges Bank

balance sheets to stabilise return. Developments in banks' net interest income will thus affect and be affected by developments in the other earnings and balance sheet items. Goodhart and Kabiri (2019), Avignone et al. (2022) and IMF (2020) discuss banks' adjustments to improve profitability as a result of interest margins in the aftermath of the financial crisis. Banks can for example improve profitability by improving the cost-efficiency of banking operations or by lending to riskier customers. Such adjustments may have feedback effects on net interest income further out.

The degree of competition for deposits and loans will be important for net interest income and for the size of the return banks can expect to receive from these activities. Increased competition may push down lending margins (see Lian (2018) and Joaquim et al. (2023)). In addition, increased competition for customer deposits to prevent customers from changing banks may reduce deposit margins. This could for example be a key driver of bringing net interest income as a percentage of assets back down when income has increased as a result of a rate hike with a muted pass-through to banks' deposit rates (see Section 2.2). Similarly, Drechsler et al. (2017) emphasise that banks' market power makes it possible for banks to increase deposit margins in response to a policy rate hike. The competitive situation may also have more indirect effects because it may stimulate cost-efficiency improvements (see T. Nguyen and Nghiem (2017)), which then pulls down net interest income relative to assets.

Competition in the Norwegian banking sector is affected by several factors, including the number and size of banks, competition from branches and subsidiaries of foreign banks, and competition from the bond market (see Ulltveit-Moe et al. (2013)). Andersen (2020) looks at several measures of developments in the competitive situation for Norwegian banks and draws no clear conclusion on how competition has evolved.

2.4 Effect of uncertainty and market stress

Uncertainty affects banks through many channels, and there are different types of uncertainty.

Tran and C. Nguyen (2023) discuss how economic policy uncertainty influences banks and find that increased demand for safer investments in uncertain times gives banks increased access to deposit funding, which pulls down their funding costs. Juelsrud and Larsen (2023) find a significant negative effect of text-based measures of uncertainty on Norwegian banks' corporate lending.[16] These results indicate that the effect of uncertainty through banks' balance sheet composition may be important for net interest income as a percentage of assets.

Dang and H. C. Nguyen (2022) describe that uncertainty may affect banks' net interest income in different directions: On the one hand, uncertainty can lead to banks being more selective in their exposures (choosing only those with higher risk-adjusted return) and improve customer follow-up. This may result in higher net interest income as a percentage of assets, particularly if banks find that risk has increased and that lending margins should increase. However, on the other hand, heightened uncertainty may mean that banks let the asset side be more liquid than otherwise, that they seek funding at longer maturities and that they limit lending, which pulls down net interest income.

In our VAR analysis, we focus on uncertainty that is often closely related to market stress and higher interest rates on banks' funding. Wholesale funding[17] accounts for approximately 47 percent of the large Norwegian banks' funding. If uncertainty related to the financial sector increases and spreads, it could become more costly for Norwegian banks to obtain wholesale funding. This was partly the case for Norwegian banks during and in the wake of the financial crisis (see Molland and Erard (2012)).

In isolation, higher funding costs will pull down net interest income as a percentage of assets, and if banks' customers are also affected by or cause market stress, (Chart 4b, which shows that market stress and losses often occur at the same time) it may be difficult for banks to pass on these costs to customers through higher lending rates. However, in the light of literature, it is an empirical question whether the direct effect on banks of heightened uncertainty is increased or reduced net interest income as a percentage of assets.

Heightened uncertainty may also have an indirect effect on banks through macroeconomic effects. For example, whether the policy rate is changed when uncertainty increases will have a substantial impact on the overall effect of net interest income as a percentage of assets.

[16] The measures of uncertainty are time-series that show the occurrence of the word uncertainty (and its variants) in different types of newspaper articles over time. The newspaper articles are grouped using topic-based machine learning (such as macroeconomic uncertainty and monetary policy uncertainty), thus resulting in a time-series for each topic.

[17] Wholesale funding is defined as total liabilities less customer deposits.

2.5 Other conditions

Many other conditions affect banks' net interest income as a percentage of assets. For example, developments may be affected by regulatory changes, such as developments in banks' capital requirements. It became compulsory for banks to hold more capital in response to regulatory changes in the aftermath of the banking crisis and the financial crisis (see Haare et al. (2015)). Banks can increase their capital ratios by reducing risk-weighted assets or increasing Common Equity Tier 1 (CET1) capital. CET1 capital can be increased through equity issues, or by letting a larger share of banks' earnings be retained, or by increasing earnings (profitability) while the distribution of earnings remains unchanged. The latter will likely be reflected in temporary positive developments in net interest income as a percentage of assets. The other adjustment may likely be related to net interest income through more indirect channels. In addition, higher capital ratios (as a result of higher capital requirements) will in isolation pull down banks' return on equity if funding costs do not fall at the same time owing to lower risk (see for example Vale (2011)). To maintain return on equity, banks have further incentives to increase net interest income as a percentage of assets. Juelsrud and Wold (2020) find that higher lending margins follow after higher capital requirements in 2013, while Aronsen et al. (2014) find that the higher capital requirement was met with more retained earnings.

In addition, the Liquidity Coverage Ratio and the Net Stable Funding Ratio requirements have increased banks' total funding costs somewhat, relative to the policy rate and Nibor. As a result of the liquidity requirements, banks must hold larger liquid reserves that usually generate lower interest income than other interest-bearing assets, and the increase in the balance sheets pulls down net interest income further as a percentage of assets.

Another factor is that periods with particularly high or low growth in banks' lending (and assets) have historically led to or been accompanied by abrupt macroeconomic changes.[18] The effect such periods will have on banks' net interest income as a percentage of assets is uncertain, but historically periods preceding both banking and financial crises in Norway have been marked by high lending growth and low lending margins which may have reflected higher risk appetite (see Arbatli and Johansen (2017)). Rapid growth in banks' loans (and assets) also usually occurs through increased wholesale funding, and a higher wholesale funding ratio may pull down banks' profitability since wholesale funding is usually more costly than deposit funding.

[18] The impact of financial crises is often more severe when preceded by periods of particularly rapid credit growth (see Jordà et al. (2013)). The global financial crisis in the period between 2008 and 2009 showed that a sharp tightening of bank credit can amplify economic downturns.

3 Empirical method

Our core model is a VAR model with five lags that include the following seven variables in addition to net interest income as a percentage of assets: mainland GDP growth, CPI-ATE inflation (core inflation), the policy rate, the real exchange rate based on the I-44, banks' total assets as a percentage of nominal mainland GDP, credit losses as a percentage of assets and operating expenses as a percentage of assets. In the development of the model, our aim was to capture the effects discussed in Section 2 and we have therefore included key macroeconomic variables, components of banks' financial statements and a market stress indicator.

As an indicator of global uncertainty, we have included the natural logarithm of the VIX index. The VIX is a frequently used indicator of uncertainty with documented effect also beyond the US (see Miranda-Agrippino and Rey (2022)). The VIX can capture the fact that market stress usually leads to higher funding costs for banks. An alternative would be to directly include premiums on banks' money market funding, which we do in a robustness test (see Appendix E). To limit the number of endogenous variables in the model, which pull down the precision of the estimation, we have chosen the model where VIX is included exogenously as our core model.

The model structure has been chosen so that the first four variables in the VAR model can capture the dynamics in a typical simple New Keynesian macro model for a small open economy, inspired by Bjørnland (2009). Since our priority is to capture banks' adjustments and we need to limit the number of variables in the model, unlike Bjørnland (2009), we have not included foreign interest rates.

The last four variables[19] capture the mutual influence between banks' aggregate income, expenses and balance sheet. The model also captures the fact that banks affect and are affected by macro developments where we are particularly interested in identifying how macro developments affect net interest income as a percentage of assets.

Banks' income and expenses are normalised in the VAR model as we measure them as a percentage of assets. This means that a well-specified model should include variables that affect both income and expenses (the numerators) and assets (the denominator). For example, banks' increased liquidity reserve holdings after 2008 (see Section 2.5) may contribute in increasing banks' balance sheets and thus pull down net interest income as a percentage of assets.[20] A number of the variables likely affect cyclical developments in banks' assets, but particularly total assets as share of mainland GDP will likely capture structural changes that have affected the size of banks' balance sheets, but not net interest income.

We check for potential autocorrelation in the residual terms of our core model. Using five lags in the model and the VIX index as the exogenous variable, we find that we can retain the

[19]The last four variables are banks' total assets as a percentage of mainland GDP, credit losses as a percentage of assets, operating expenses as a percentage of assets and net interest income as a percentage of assets.

[20]Net interest income is affected to a lesser extent as it is difficult for banks to achieve a positive return on liquidity reserves.

null hypothesis of zero autocorrelation by an ample margin (see Table B.1 in Appendix B). Using less than five lags, we must at a 5 percent confidence level reject the null hypothesis of zero autocorrelation, and we therefore use five lags. The need for this large number of lagged quarters in the model is due to the tendency for economic activity to affect banks' growth and earnings with a lag.[21] We cross-check the selected structure using a number of tests for the number of lags (see Table B.2 in Appendix B).[22] For the alternative estimated models in Appendix E and Appendix F, where we remove or replace some variables or change which exogenous variables are included, we use the same specification for lagged variables as is used in the core model.

To assess the effect of a rate hike in different macroeconomic situations, we have also looked at some simple identified structural shocks using the Cholesky decomposition (see for example Bjørnland and Thorsrud (2015)). The sequence of the variables we have used with the Cholesky decomposition is the same as specified in the first paragraph in Section 3, and then finally with net interest income as a percentage of assets. This means, for example, that we assume that net interest income as a percentage of assets may be immediately affected by shocks (unexpected changes in the VAR model) to all the other variables since it is ordered last. As growth in mainland GDP comes first, we thus assume that it is not immediately affected by shocks to any other variables. By using the decomposition, we can distinguish between the different drivers of a rate hike and explore whether the reason for the rate hike is important for developments in net interest income as a percentage of assets.

In our core model, included data is expressed in levels, but mainland GDP and CPI-ATE are included as log differences over the past four quarters. Operating expenses as percentage of assets and total assets as share of mainland GDP are measured using a four-quarter moving average.

As a cross-check and to study the cyclical relationships, the model is also estimated based on data as a deviation from estimated trends (see Appendix F). The trends are estimated using a two-sided HP-filter[23] with $\lambda = 30\,000$. Classical specification tests indicate that it is also suitable to include five lags in the model with cyclical components.

4 Data

Data for banks' accounting variables cover the period between 1987 and 2022, but the core model is estimated on quarterly data for 1994 to 2022 (see Section 5 for an explanation of the estimation period).[24] Accounting data are obtained from ORBOF bank statistics[25] and S&P Capital IQ.

[21] In line with our results, Andersen (2020) finds that a well-specified model of banks' expenses requires lagged variables between one and two years.

[22] We have estimated and analysed the model using Matlab-based RISE, developed by Junior Maih (see Maih (2015)). We have used Eviews software to conduct classic specification tests.

[23] See Robert J. Hodrick (1997).

[24] The inclusion of lagged variables means that data from 1992 Q4 are effectively included in the estimation of the model.

[25] Banks' and financial undertakings' financial reporting to the Norwegian authorities (ORBOF)

For each accounting variable, the time series for the seven large Norwegian banks are aggregated to a time series that describes what we call the macro bank. The time series are adjusted for institutional conditions such as mergers and transfers of loans to covered bond mortgage companies.[26] The aim is for all institutions that are included in the current aggregated macro bank to be included back in time so that we can focus on the interaction between the macroeconomy and the aggregate of the large banks over time. The data set for banks' financial statements are described in detail in Appendix A.[27] Total assets measured relative to nominal mainland GDP is based on adjusted[28] total assets for all Norwegian banks and mortgage companies from ORBOF bank statistics.

To assess how macro developments affect net interest income as a percentage of assets, we use data from different sources. Macro indicators such as mainland GDP, CPI-ATE, the policy rate and exchange rates are obtained from Statistics Norway and Norges Bank. The VIX index is from FRED.[29]

To test robustness, we also assess the response of net interest income for a range of alternative models (see Appendix E and Appendix F). To take account of exogenous developments in the automation of banking services, we include the number of electronic payment transactions and developments in internet use as exogenous variables. The time series on electronic payment services is obtained from Norges Bank and developments in the share of the population that uses the internet is obtained from Statistics Norway. Projections for internet use in the period between 1994 and 1996 are obtained from Andersen (2020). To take into account the fact that banking regulation has become more resource-intensive, we use an indicator of the number of employees in Finanstilsynet (Financial Supervisory Authority of Norway). The indicator is the same as in Andersen (2020) and is obtained from Finanstilsynet and the Norwegian State Administration Database. We have also looked at alternative uncertainty indicators, such as a financial conditions index for Norway(see Bowe et al. (2023)), money market premiums obtained from Norges Bank and text-based measures for macroeconomic and monetary policy uncertainty (see Juelsrud and Larsen (2023)).

Our core model estimates are based on data from 1994 Q1, but we include as a robustness test an estimation of the model using data from 1987 Q4 (see Appendix C and Appendix F). For banks' income and expense items, quarterly figures in the period to 1992 have been estimated using linear interpolation of annual figures. The VIX index is chained in the period between 1987 and 1990 using historical data for the CBOE (Chicago Board Options Exchange) S&P 100 Volatility Index

[26] For more background information and how transfers of loans to covered bond mortgage companies affect banks' balance sheets (see Bakke et al. (2010)).

[27] There are a number of historical regulatory changes that may have contributed to changing the interaction between the macroeconomy and the observable bank variables (see, for example, the effect of liquidity requirements described in Section 2.5). Such regulatory changes and changes in accounting rules that have not been corrected for may add some noise to our results.

[28] The figures are adjusted for intercompany receivables and payables.

[29] See Federal Reserve Economic Data.

from FRED. In spring 1993, Norges Bank's liquidity management system was restructured, and from June 1993, the effective policy rate changed from being the D-loan rate to the sight deposit rate. The observation we have used for the policy rate for 1993 Q2 is a weighted average of the D-loan rate and the sight deposit rate in the quarter.[30]

5 Results

We start by presenting the effect on net interest income as a percentage of assets of three variables that we find have been particularly important for historical developments. The result is based on the VAR model in reduced form. This means that we do not impose any assumptions about causal relationships in the model and the reported results can be interpreted as what has typically occurred in the estimation period in the event of a persistent shift in the different variables. In the next step, we discuss whether a rate hike always results in higher net interest income as a percentage of assets. For this purpose, we use the Cholesky decomposition and thus impose a causal relationship in the short term, see Section 3 for more information. Based on the Cholesky decomposition, we explore the importance of different drivers of the rate hike. Finally, we describe what has recently driven developments in net interest income as a percentage of assets. We also present a policy exercise where we illustrate how procyclical net interest income may support the use of time-varying capital requirements.

We have chosen to focus on historical relationships in the period between 1994 and 2022. In this period, credit losses in the wake of the banking crisis in the early 1990s had stabilised (Chart 4a). Inflation had also stabilised, even though the inflation target was not introduced until 2001. If we include the banking crisis in the estimation period, the results are qualitatively the same, but size and duration vary somewhat (see Appendix C).

5.1 What affects developments in net interest income?

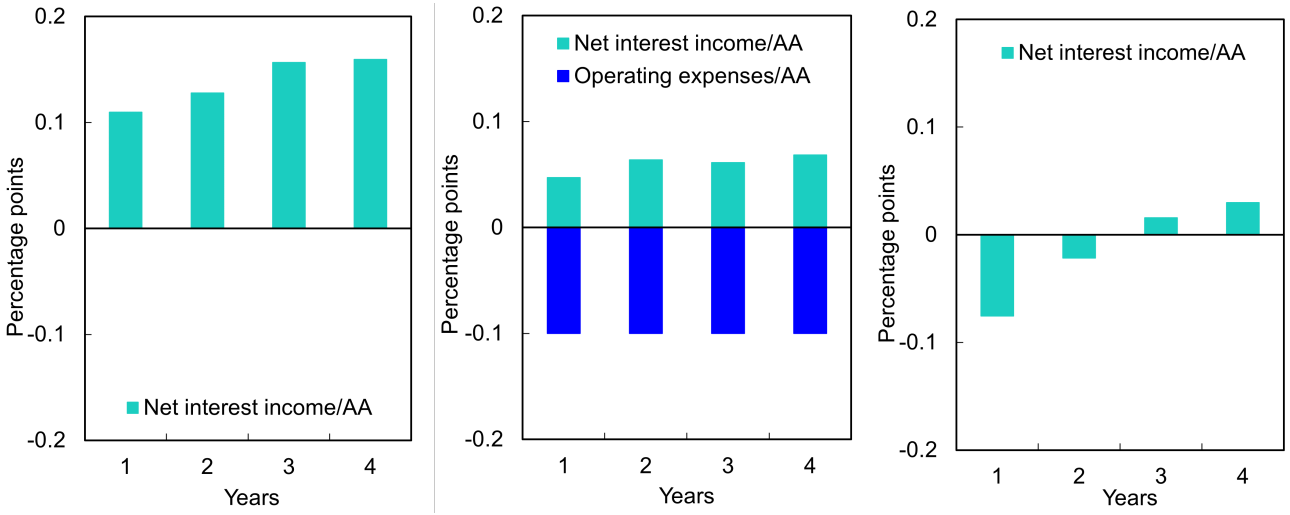
Based on the reduced-form VAR model, we document that net interest income as a percentage of assets has been sensitive to the developments of three of the variables in the model. According to the model, a higher policy rate and increased operating expenses have historically pulled up net interest income as a percentage of assets, while increased market stress has dampened net interest income as a percentage of assets.[31] In Appendix D, we show results from another type of exercise where we impose the criterion that the changes are unexpected in the VAR model, based on the Cholesky decomposition. The exercise shows that identified shocks in interest rate and operating

[30] See Explanation of the policy rate.

[31] Note that the model is symmetric. The result therefore implies that lower operating expenses also result in lower net interest income. Our linear model is a simplification that in our opinion generates transparent and qualitatively robust results in the analysis of net interest income, but the approach will not capture any asymmetry in the effect of changed operating expenses.

expenses result in significant effects on net interest income as a percentage of assets. An increase in market stress – captured by the variable VIX – reduces net interest income as a percentage of assets.[32]

Chart 5: *Effect on banks' net interest income of a persistent* [1] *shift in the policy rate, operating expenses and the VIX index based on reduced-form VAR model. Measured as a percentage point shift in net interest income as a percentage of average assets (AA)*



(a) *1 p.p. higher policy rate* (b) *0.1 p.p. higher expenses* (c) *Increased market stress*[2]

1 Persistent shift in the policy rate and operating expenses is based on a simulation covering 10 years.
2 Based on shifts in the VIX index from the average in the estimation period to developments during the financial crisis.
Expenses are reported with a negative sign. The estimation period is 1994 Q1 – 2022 Q4. Annual figures are calculated as the sum of the quarterly shares.
Source: Norges Bank

First, the model indicates that policy rate developments are important for net interest income as a percentage of assets (Chart 5a). Banks' net interest income as a percentage of assets increases by about 0.1 percentage point in the first year at a 1 percentage point persistently higher policy rate. In the longer term, net interest income increases by about 0.16 percentage point. The effect likely reflects a number of the interest rate effects described in Section 2.2, but a simple calculation of the non-interest equity effect[33] based on a rough classification of interest-bearing and non-interest-bearing balance sheet items indicates that it may have accounted for almost half of the increase in the first year.

[32] In the VAR model, the exogenous variable VIX has a significant and negative coefficient in the equation for net interest income as a percentage of assets.

[33] The calculation is based on the average equity ratio during the estimation period and an otherwise static balance corresponding to the classification in Chart 1. The exercise indicates that a 1 percentage point sustained policy rate hike with full pass-through to average interest rates on banks' interest-bearing assets and liabilities will result in close to 0.05 percentage point higher net interest income as a percentage of assets. The exercise is highly sensitive to the classification of interest-bearing and non-interest-bearing assets, which in our calculation is based on a rough classification of the large Norwegian banks' balance sheet items. The result is therefore somewhat uncertain.

In isolation, 0.1 percentage point higher net interest income as a percentage of assets corresponds to about 1 percentage point higher return on equity for the large Norwegian banks. Compared with the historical variation since the financial crisis, the effect of 0.1 percentage point corresponds to just over 1 standard deviation for net interest income as a percentage of assets. The 0.13 percentage point effect for the first two years (Chart 5a) is slightly less than the 0.165 observed during the tightening cycle that started in 2021.[34]

The impact is close to what Windsor et al. (2023) find based on a large sample of banks in 10 different countries, including Norway. They find that the long-term effect of a persistent 1 percentage point policy rate reduction results in a 0.15 percentage point decline in net interest income as a share of interest-bearing assets.[35] Specifically for Norway, they find that the effect is 0.1 percentage point in the short term. This is the same as our result for the first year (Chart 5a).

The impact is considerably less pronounced than Borio et al. (2017) find for large banks in advanced economies. They find that net interest income as a percentage of total assets increases by 0.5 percentage point during the first year when the policy rate is increased from zero to 1 percent but the effect weakens with the rate level and net interest income as a percentage of total assets only increases by 0.2 percentage point with a policy rate hike from 6 to 7 percent.

Historically, banks have adjusted their net interest income in pace with developments in operating expenses. In the VAR model, the estimated effect of operating expenses on net interest income occurs with a slight lag. If we look at the effect of a sustained increase in operating expenses throughout the projection period, net interest income will increase somewhat and dampen the negative impact on banks' earnings (Chart 5b).

The VAR model indicates that increased market stress results in weaker net interest income as a percentage of assets. Chart 5c shows the effect on net interest income as a percentage of assets of an increase in market stress similar to that observed during the financial crisis. A first-round effect of increased market stress may be higher bank funding costs. Market stress and tighter financial conditions also affect macroeconomic developments and thus have more indirect effects. In the simulation, a higher level of the VIX results in lower GDP growth and a somewhat lower interest rate (not shown in the chart). The lower policy rate may also be a factor that pulls down net interest income as a percentage of assets.[36] In Appendix E, we look at alternative indicators of market stress that are more directly related to developments in Norway and are thus endogenously included in the model.

[34]The average quarterly policy rate increased from zero percent in 2021 Q2 to 2.44 percent in 2022 Q4, while net interest income as a percentage of assets increased by 0.4 percentage point.

[35]Windsor et al. (2023) examine net interest income as a percentage of interest-bearing assets (NIM). For Norwegian banks, total assets are somewhat larger than interest-bearing assets (Chart 1), but the percentage point change has been relatively similar over the past five years. Non-interest-bearing assets also make up a relatively small portion of the balance sheet, (Chart 1). We therefore consider the response of net interest income as a percentage of assets to be comparable with the response of net interest income as a percentage of NIM

[36]If we assume that the policy rate path does not change, the VIX will still have a negative effect on net interest income as a percentage of assets, although the effect will be somewhat less pronounced than in Chart 5c.

5.2 Does net interest income always rise in response to a policy rate hike?

There may be a number of reasons for a policy rate hike. A structural interpretation of the VAR model through a Cholesky decomposition makes it possible to examine how the response of net interest income as a percentage of assets depends on the underlying reason for the policy rate hike.[37] Developments in net interest income as a percentage of assets may conceivably differ, for example, in the event of a policy rate hike in response to unexpectedly high inflation while GDP growth is weak (supply shock), a policy rate increase resulting from an unexpected increase in demand (demand shock) and a policy rate hike that is in itself unexpected in the model (monetary policy shock).

Based on the Cholesky decomposition, we have examined the response of net interest income as a percentage of assets to a policy rate hike triggered by three different identified macroeconomic shocks. Chart 6 compares the response of an unexpected policy rate hike (green lines), an unexpected increase in demand (blue lines) and an unexpected increase in inflation (red lines) for a set of the endogenous variables in the model. The size of the shocks is dimensioned so that they all trigger a 1 percentage point increase in the policy rate (Chart 6c).

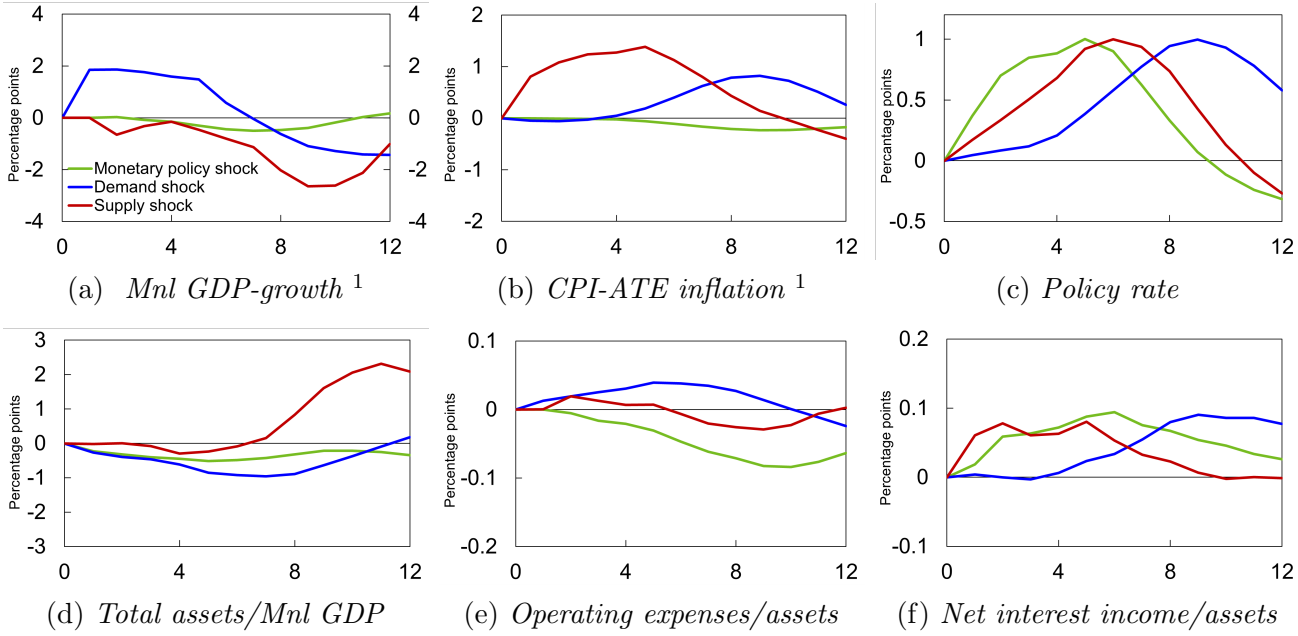
All three macro shocks result in an increase in net interest income as a percentage of assets of close to 0.1 percentage point (Chart 6f) and thus indicate that the movement in the nominal policy rate is important for net interest income. Despite divergent developments in macroeconomic variables (Charts 6a and 6b) in the event of an unexpected increase in the policy rate, an unexpected increase in demand and an unexpected increase in inflation, there is a positive response in net interest income as a percentage of assets in all cases (Chart 6f). In the event of a negative supply shock, the response of net interest income as a percentage of assets slightly leads the response in the policy rate, while the peak in net interest income lags somewhat behind (is contemporaneous with) the policy rate peak in response to a monetary policy shock (demand shock).[38]

The results also indicate that developments in the other bank variables may have an impact on the duration of the response in net interest income as a percentage of assets. In the event of a monetary policy shock, operating expenses as a percentage of assets increase relatively more than for the other two shocks. These developments coincide with a somewhat prolonged response in net interest income as a percentage of assets (see green lines in Charts 6e and 6f), despite the fact that the policy rate eventually turns negative.

[37] The estimated VAR model captures a modelled historical response pattern and the responses are sensitive to the variables included in the ordering in the Cholesky decomposition and estimation period. For information regarding Norges Bank's monetary policy and the analysis system for policy rate decisions, see Norges Bank's Monetary Policy Handbook.

[38] The response of net interest income as a percentage of assets to a monetary policy shock is highly significant (see Appendix D), which also applies to alternative orderings of bank variables in the Cholesky decomposition. The responses of net interest income to demand and supply shocks are marginally significant.

Chart 6: *Impulse-response functions for shocks (surprising changes in the VAR model) to the policy rate, demand and inflation. The shocks have been scaled up for a 1 percentage point increase in the policy rate. Measured as percentage point deviation from long-term equilibrium. All responses are smoothed by taking a four-quarter moving average*



1 Log differences over the past four quarters.
Expenses are reported with a negative sign.
Income statement items are annualised.
The estimation period is between 1994 Q1 and 2022 Q4.
Source: Norges Bank

There is considerable uncertainty as to which variables and transformations should be included in order to best capture the historical relationships. The uncertainty suggests looking at alternative specifications of the model. Appendix F shows consistently positive effects of a policy rate increase on net interest income as a percentage of assets in 25 alternative models.

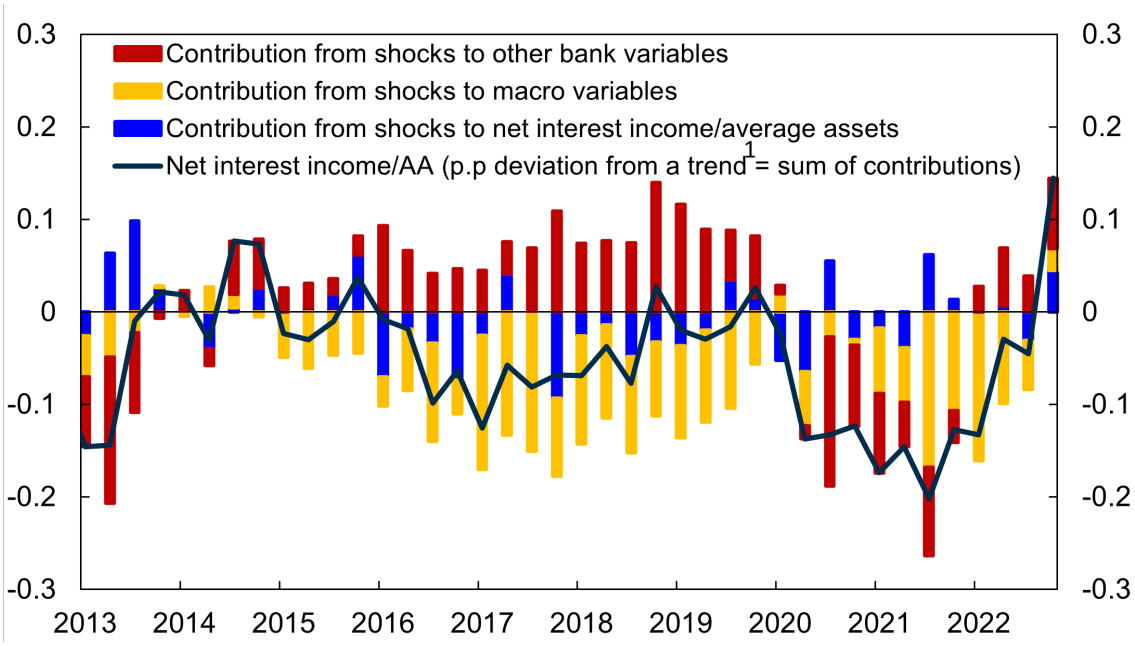
5.3 What has driven net interest income over the past 10 years?

We use our core model and the Cholesky decomposition to determine the drivers of developments in net interest income in recent years. Chart 7 shows the historical contributions from shocks (unexpected changes in the VAR model) to net interest income as a percentage of assets (blue bars), macroeconomic variables (yellow bars) and other bank variables (red bars). The model indicates that developments in net interest income as a percentage of assets can largely be explained by unexpected changes in the other variables (yellow and red bars).[39]

[39]The variance decomposition describes how much of the modelled historical variation in net interest income as a percentage of assets can be explained by the (surprise in) other variables in the VAR model. The decomposition into net interest income as a percentage of assets indicates that close to 85 percent can be explained by the

According to the model, it is largely macroeconomic developments that have pulled down net interest income as a percentage of assets since 2015 (see yellow bars in Chart 7). At the same time, unexpectedly high operating expenses and other bank variables have pushed up net interest income (red bars). Net interest income is largely driven by the same macro shocks that affect the policy rate in the estimated VAR model. In particular, demand shocks (largely through changes in the policy rate) pulled down net interest income as a percentage of assets following the onset of the pandemic in 2020.

Chart 7: *Historical decomposition of developments in net interest income as a percentage point deviation from a trend* [1]*. The bars show contributions from the shocks (surprises) in the VAR model. Percentage points annualised deviation*



1 The trend is the estimate from the VAR model conditioned on information available in 1994 (initial conditions) and developments in the exogenous variable VIX during the estimation period, i.e. the non-stochastic contributions.
Contribution from shocks to macro variables are the sum of the contribution from shocks to growth in mainland GDP, inflation, the policy rate and the real exchange rate.
Contribution from shocks to other bank variables are the sum of contributions from shocks to banks' operating expenses/assets, credit losses/assets and total assets/mainland GDP.
Source: Norges Bank

Since mid-2021, a reversal of the demand shock combined with positive inflation shocks and unexpectedly weak developments in banks' assets relative to nominal mainland GDP[40] have contributed to pulling up net interest income as a percentage of assets. The VAR model also signals that the rise in net interest income at the end of 2022 was somewhat larger than expected (see blue bar for 2022 Q4 in Chart 7). Any non-linear factors associated with the particularly low level of

other variables. About 40 percent of this share can be explained by operating expenses as a percentage of assets. The remaining 60 percent can be explained by a varied combination of the remaining variables. This remaining distribution is fairly similar to the variance decomposition of the policy rate.

[40] Net interest income as a percentage of assets reacts negatively to an unexpected increase in TA/Mnl GDP.

the policy rate in the past may also have contributed to an extraordinary increase in net interest income that is not captured in the linear VAR model. Banks' temporary high deposit-to-loan ratios following the pandemic may have further amplified the non-linear effect. In addition, Norwegian banks' equity ratios have increased since 2013 and the equity effect is probably somewhat greater than the average for the estimation period (see Section 2.2). Nevertheless, the estimated unexplained increase is not substantially larger than what we have observed historically and amounts to slightly less than a standard deviation based on the entire historical variation of the shock.

5.4 Policy exercise - procyclical net interest income supports the use of time-varying capital requirements

We use the reduced-form VAR model to examine the interaction between banks' first line of defence against losses (i.e. current earnings before losses, which largely consist of net interest income (Chart 2)) and macro developments. We find that procyclical developments in banks' net interest income as a percentage of assets indicate that banks should build up capital in good times, which they can draw on in the event of high losses and weaker first-line defence.

High current earnings enable banks to cover larger losses before they operate at a loss and have to draw on equity capital. Chart 8a shows combinations of net interest income and losses resulting in zero profit (blue line) or a capital adequacy ratio equal to the capital requirement (orange line) for the seven large banks combined. The requirement is banks' CET1 capital requirement, including a countercyclical capital buffer of 2.5 percent.[41] Since banks have certain voluntary headroom above the requirement[42], their earnings may be slightly negative before they come down to a capital ratio that is equal to the requirement (represented by the distance between orange and blue lines).

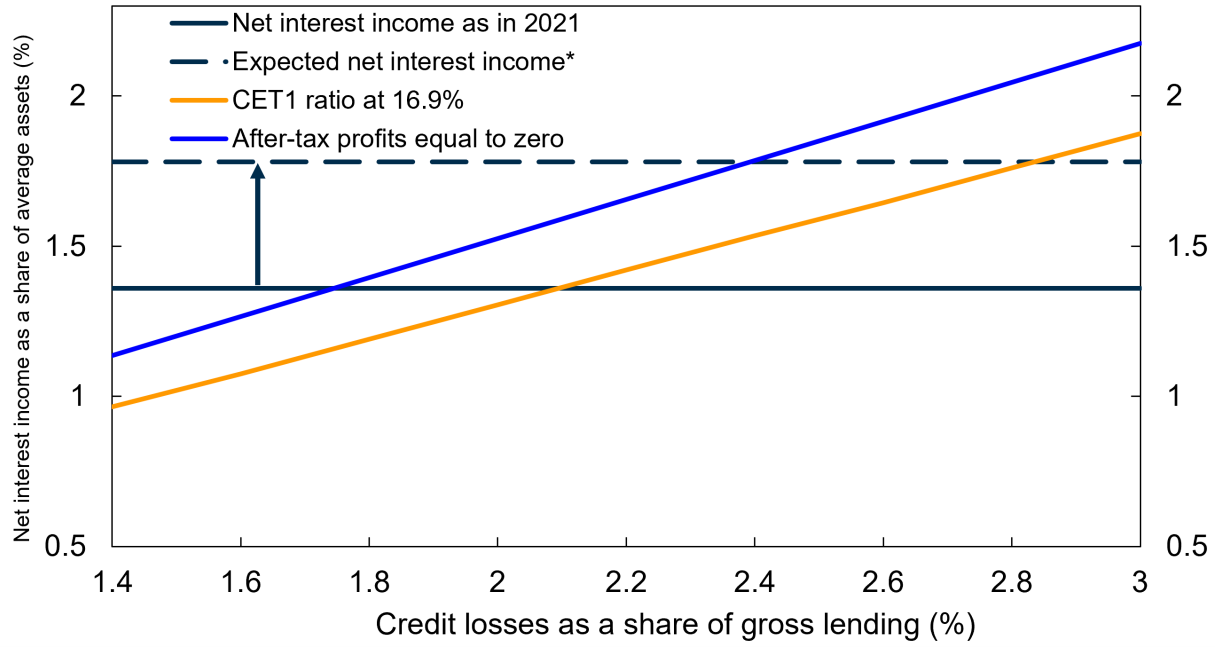
Increased net interest income in isolation strengthens banks' first line of defence against losses (Chart 8a). The broken line shows the VAR model's projection ahead if we base our estimates on the macro variables in *Monetary Policy Report* 1/2023. The projection is primarily driven by a higher policy rate, but also somewhat by higher operating expenses and weaker growth in banks' assets relative to mainland GDP. Compared with the level in 2021, banks' first line of defence strengthens considerably. Banks can now absorb credit losses of 2.4 percent of gross lending before operating at a loss, and credit losses of just over 2.8 percent before breaching the capital requirement.

[41] The capital requirement here is regulatory requirements plus the capital margin requirement. Regulatory requirements are the minimum requirement, a weighted Pillar 2 requirement and the overall buffer requirement.

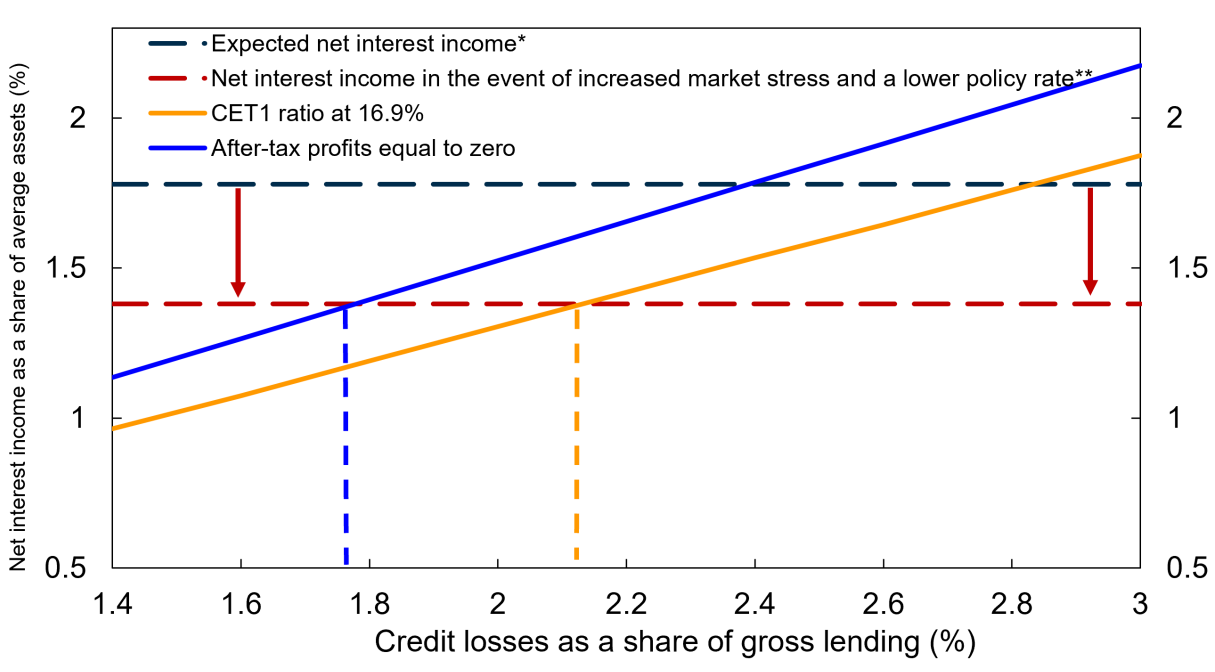
[42] The voluntary headroom usually reflects banks' internal capital targets.

Chart 8: *Net interest income and banks' first line of defence against losses*

(a) *Higher net interest income may strengthen banks' loss-absorbing capacity*

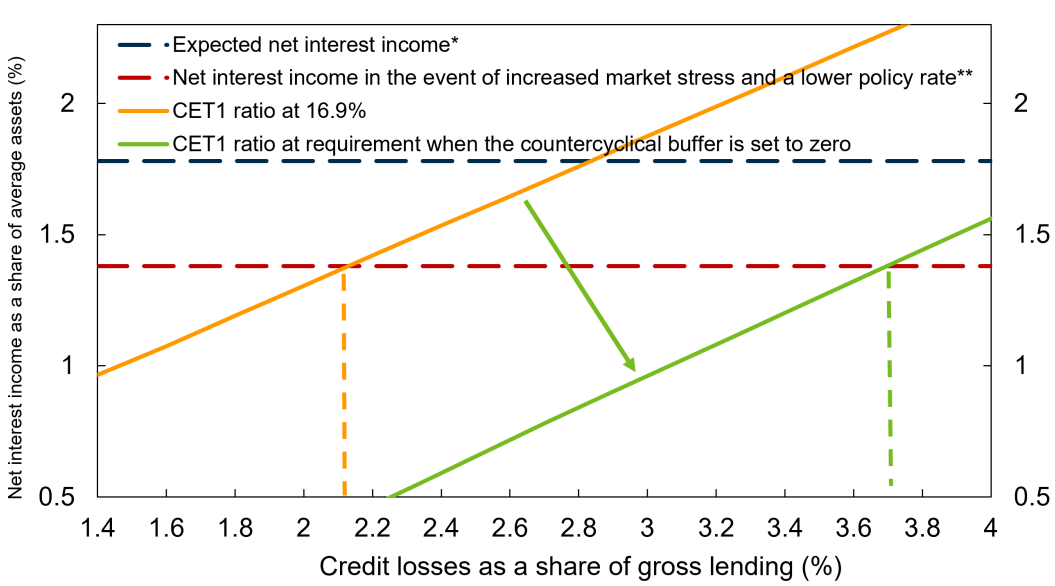


(b) *Loss-absorbing capacity in the event of increased market stress and a lower policy rate*



The orange and blue lines are based on banks' financial statements and CET1 ratio targets for 2022.
**Model estimates conditional on expected macro developments from Monetary Policy Report 1/2023.*
***Shift based on the reduced-form VAR model. The exercise takes into account that the other variables in the model react to a shift in the policy rate and the VIX index. The VIX index follows the same path as during the financial crisis (Chart 4b).*
Source: Norges Bank

(c) *Loss-absorbing capacity when the countercyclical capital buffer is set to zero*



A weakness of this exercise is that it does not take into account possible reactions from the authorities and markets to very high losses in the economy. Periods of high losses are often marked by increased market stress (Chart 4b). In addition, high losses may occur in a period when the policy rate is reduced.[43] Since 1994, the policy rate has been reduced in most periods of higher losses in order to stabilise the economy. Chart 8b shows possible developments in net interest income in the event of increased market stress corresponding to the financial crisis and a policy rate that is technically set at zero. The VAR model signals that banks' first line of defence will be significantly weakened. Banks can now only absorb a 2.1 percent credit losse before they breach the capital requirement.

Time-varying capital requirements, such as the countercyclical capital buffer, are instruments introduced precisely to enable the authorities to influence banks to build capital in good times. By retaining some of their income, banks can ensure that they have buffers for more turbulent times when they may be affected by both higher losses and other lower income. Norwegian banks have built up substantial capital buffers since 2013. Chart 8c shows the combined losses that the seven banks are able to absorb before breaching the capital requirement when the countercyclical capital buffer is set at zero (see green line). If the first line of defence is weakened, banks as a whole can absorb losses of 3.7 percent of gross lending. Allowing banks to draw on the buffer in the event of high losses and weaker first-line defence may reduce the need for tighter credit standards, which could amplify a possible downturn (see Andersen et al. (2019)).[44]

[43] High losses may also occur in a period of high interest rates (see the stress test in *Financial Stability Report* 2022 and EBA (2023)).

[44] In this exercise, we do not allow banks to adjust their balance sheets to comply with capital requirements, but in practice, banks can tighten lending in order to limit the fall in capital adequacy in the event of high losses and a weaker first line of defence.

6 Concluding comments

Based on 30 years of data on banks' balance sheets, we examine what has historically affected developments in net interest income relative to assets. By using a VAR model that includes the most relevant macro and bank variables, we confirm that net interest income as a percentage of total assets is sensitive to developments in the policy rate, operating expenses and heightened market uncertainty, with a higher policy rate and higher operating expenses pushing up net interest income while heightened market uncertainty has the opposite effect. The results are qualitatively and quantitatively well in line with what can be expected based on theory and empirical data from other countries.

Other shocks and indicators not included in our analysis may also be important for net interest income relative to assets. For example, developments in the competitive landscape and regulation are likely of substantial importance. In addition, new assessments of how data breaches should be handled can provide a basis for an improved analysis. Efforts to understand drivers will continue and are likely to be updated as a result of new data and assessments of economic relationships. An overall assessment of developments in banks' profitability should also include an analysis of what drives banks' other income and costs (see e.g. Altavilla et al. (2018), Borio et al. (2017), Goodhart and Kabiri (2019), Windsor et al. (2023) and Zimmermann (2019)).

Our analysis is based on a linear method, where, for example, the effect of a higher policy rate on bank income and losses is assumed to be the same whether the rate increase starts at a high or low level. The linear model also implies that the effect of positive and negative changes in variables (e.g. operating expenses) on net interest income is assumed to be symmetrical. We believe that a linear model is a simplification that provides transparent and qualitatively robust results in the analysis of net interest income. In further work, the significance of non-linearity for net interest income can be further elucidated. However, for a more in-depth analysis of the cost of losses in particular, using non-linear methods will be essential because borrowers' ability and willingness to service debt and the dynamics of losses can change abruptly in deep downturns or crises.

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Appendix

A Break-adjusted time series for large Norwegian banks

We use a number of data sources when analysing how banks' income statement items change with macroeconomic conditions. ORBOF bank statistics provide a rough distribution of various income statement items at parent bank level dating back to 1987, while S&P Capital IQ provides a rough distribution of income statement items at group level for a sample of large Norwegian banks dating back to about 2008.

An advantage of the consolidated accounts from S&P Capital IQ is that they include banks' wholly-owned mortgage companies. Covered bonds were first issued in June 2007 (Bakke et al. (2010)), which became an important source of funding for Norwegian banks, and large volumes of loans were transferred to covered bond mortgage companies in the years that followed. As a result, mortgage companies generate substantial interest income for banks. To include as far as possible the income and total assets of covered bond mortgage companies, consolidated data from S&P Capital IQ has been used as a basis. The data set is chained using time series from ORBOF bank statistics prior to 2008. Note that in 2008 the discrepancy between ORBOF bank statistics and S&P Capital IQ was considerably smaller. For more details on adjustments in the years immediately following 2008, see Appendix A in Galaasen and Johansen (2016).

In addition, the time series for the macro bank have been adjusted for mergers. In the macro bank, we have included the profits and assets of most of the larger banks that have historically merged with one of the seven large banks in the macro bank. S&P Capital IQ covers the consolidated financial statements of the seven large banks, but if there are no available financial statements from S&P Capital IQ for banks that have merged into the group after 2008, figures from ORBOF bank statistics are used.

One advantage of the break-adjusted time series is that they allow us to focus on the interaction between the macroeconomy and large Norwegian banks over time. Nevertheless, there are a number of weaknesses in the adjustments. The definition and classification of financial statement items may vary somewhat across data sets - particularly for banks' operating expenses. In addition, the consolidated financial statements of S&P Capital IQ include banks' foreign branches and foreign subsidiaries.

B Specification of the number of lagged variables in the core model

We choose to include five lags in the core model. With five lags, the residual terms of the VAR model show no sign of autocorrelation (see Table B.1). With fewer lags, the null hypothesis of zero autocorrelation in the residual terms must be rejected.

Table B.1: *Test for autocorrelation in VAR residual terms, core model. Null hypothesis: Zero autocorrelation for lagged variables 1-h*

Lag	Rao F-stat	Probability
1	1.025	0.432
2	1.052	0.355
3	1.037	0.386
4	1.161	0.116
5	1.153	0.137
6	1.167	0.144

The estimation period is 1994 Q1 – 2022 Q4. 116 observations included.
Source: Norges Bank

If we look at different selection criteria for the number lags in the model, some of them indicate that fewer than five lags are appropriate, while others indicate that more are required (see Table B.2). The two criteria not listed here (sequential modified LR test statistic and final prediction error) both indicate selection of five lags. If we estimate the model with six lags instead of five, the Wald test indicates that the sixth lag can be excluded.

Table B.2: *Selection criteria for the number of quarters with lagged variables*

Lag	LogL.	AIC[1]	SC[2]	HQ[3]
0	-845.864	15.411	16.551	15.874
1	148.871	-0.636	2.023*	0.444
2	257.905	-1.412	2.766	0.284*
3	328.171	-1.520	4.177	0.792
4	405.558	-1.751	5.465	1.178
5	506.723	-2.392	6.344	1.154
6	560.936	-2.223	8.032	1.940
7	642.854	-2.532	9.242	2.248
8	731.569	-2.958*	10.335	2.438

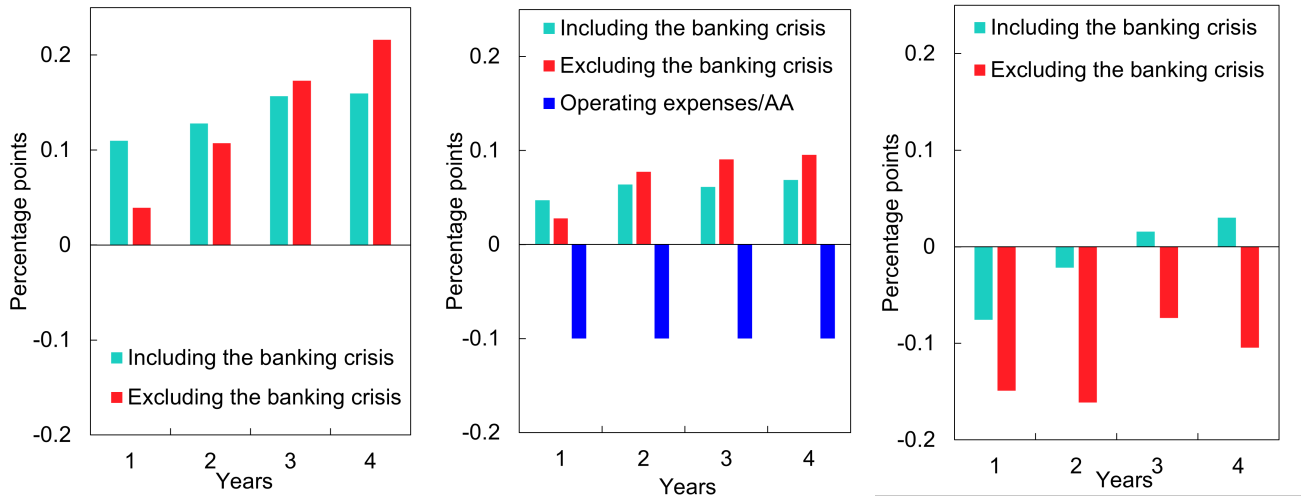
** Indicates the choice of the number of lags according to criterion. The estimation period is 1994 Q1 – 2022 Q4. 116 included observations.*
1) Akaike information criterion.
2) Schwarz information criterion.
3) Hannan-Quinn information criterion.
Source: Norges Bank

C Robustness - including the banking crisis in the estimation period

In the analysis, we have chosen to focus on the historical relationships in the period between 1994 and 2022. The break-adjusted time series for banks' income statements cover the period from 1987 and allow for extending the estimation period to cover the Norwegian banking crisis in the period between 1988 Q2 and 1993 Q3.

Chart C.1 compares the effects described by the model estimated excluding (1994 Q1 – 2022 Q4) and including (1987 Q4 – 2022 Q4) the banking crisis. The estimated effect of the shift has the same sign both when including and excluding the banking crisis, although, as expected, the size and duration vary somewhat. Chart C.1a shows the response of net interest income as a percentage of assets when a persistent 1 percentage point increase in the policy rate is assumed. Net interest income increases more in the long term when the banking crisis is included in the sample, and the effect is slowed somewhat owing to the rate hike. Like the policy rate shift, the effect of higher operating expenses and increased market stress is somewhat more pronounced when the banking crisis is included (Charts C.1b and C.1c).

Chart C.1: *Effect on banks' net interest income of a persistent* [1] *shift in the policy rate, operating expenses and the VIX index based on reduced-form VAR model. Measured as a percentage point shift in net interest income as a percentage of average assets (AA)*



(a) *1 p.p. higher policy rate* (b) *0.1 p.p. higher expenses* (c) *Increased market stress*[2]

1 A persistent shift in the policy rate and operating expenses is based on a simulation covering 10 years.
2 Based on shifts in the VIX index from the average for the period 1994 Q1 – 2022 Q4 to developments during the financial crisis.
Expenses are reported with a negative sign.
Excluding the banking crisis, the estimation period is 1994 Q1 – 2022 Q4.
Including the banking crisis, the estimation period is 1987 Q4 – 2022 Q4.
Annual figures are calculated as the sum of the quarterly shares.
Source: Norges Bank

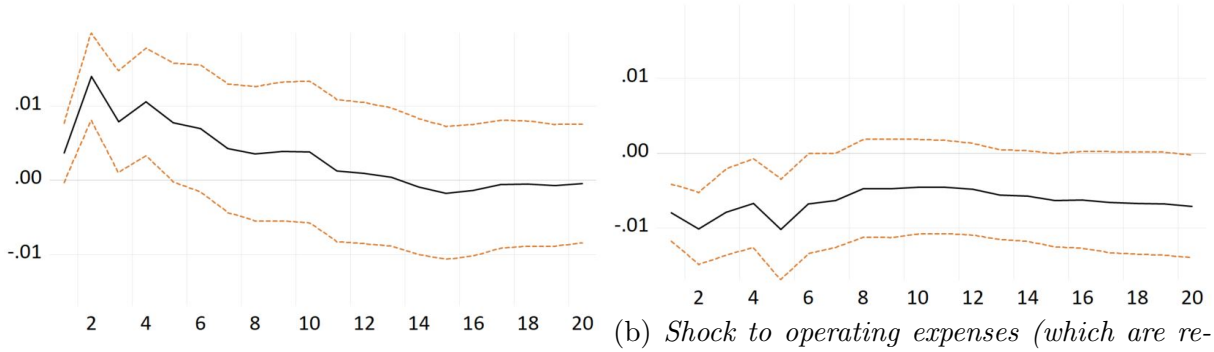
D Effect of identified shocks on net interest income

We use Cholesky decomposition to identify shocks in the VAR model. The sequence of variables in the decomposition is: mainland GDP growth, CPI-ATE inflation, the policy rate, the real exchange rate, banks' total assets as a percentage of nominal mainland GDP, credit losses as a percentage of assets, operating expenses as a percentage of assets and net interest income as a percentage of assets.

The effect of a surprise rate hike on net interest income as a percentage of assets is significantly positive (Chart D.1a). The effect of a surprise reduction in operating expenses is significantly negative (Chart D.1b).

The relatively large number of variables that are included in the model reduces the precision of the estimation, and many of the other responses are therefore not significant. Identified structural shocks have a standard effect on macroeconomic variables in the model, but some of the responses cannot be identified as significant.

Chart D.1: *Impulse responses in banks' net interest income as a percentage of assets. VAR model estimated on level data for the period 1994 Q1 – 2022 Q4. Shocks are identified by the Cholesky decomposition and measured in percentage points*



(a) *Policy rate shock*

(b) *Shock to operating expenses (which are reduced)*

The black line shows the non-annualised percentage point response in net interest income as a percentage of assets to a standard deviation increase in the shock. The broken red lines show +/- 2 asymptotic standard deviation.
Source: Norges Bank

E Robustness – different indicators for market stress and uncertainty

An increase in the uncertainty indicator VIX, which is included in the core model, pulls down net interest income as a percentage of assets (Chart 5c and the first line in Table E.1).

Alternative indicators of uncertainty and/or market stress provide the same qualitative response. Table E.1 includes several indicators that reflect developments in Norway, and the variables are thus endogenously included in the model. Based on the Cholesky decomposition, we assume an unexpected increase in the indicator.

Quantitatively, an unexpected increase in the money market premium (model 2) produces the same effect as the VIX, but in this exercise the policy rate is close to the long-term equilibrium and the movement in the policy rate therefore does not pull down net interest income as a percentage of assets. An unexpected increase in the financial conditions index in Norway (model 3) pulls down net interest income as a percentage of assets and, like in Bowe et al. (2023), mainland GDP, CPI-ATE (after about a year) and the policy rate are also reduced compared with the long-term equilibrium (not shown in the table). In our VAR model, the lower policy rate also pushes down net interest income as a percentage of assets. The response to an unexpected increase in text-based measures of uncertainty (models 4 and 5) is negative and slightly smaller than in models where market indicators are included directly.

Table E.1: *Response in net interest income as a percentage of assets in the event of shocks to various uncertainty indicators. Measured as annualised percentage point deviation from long-term equilibrium*

		Maximum impact on net interest income as a percentage of assets	
	Model version	One standard deviation[1]	Impact as during the financial crisis[2]
1	VIX (as in core model)[3]	-0.04	-0.14
2	Money market premium[4]	-0.04	-0.14
3	FCIN[5]	-0.05	-0.21
4	Macro-uncertainty[6]	-0.03	-0.05
5	Monetary policy uncertainty[6]	-0.04	-0.06

The estimation period is 1994 Q1 – 2022 Q4.
1 Assumes an unexpected increase corresponding to a standard deviation based on the historically observed series. The increase in VIX is exogenous and further development follows from an estimated AR-1 process. 2 Assumes an unexpected increase corresponding to the maximum value observed during the financial crisis. The increase in VIX is exogenous and further development follows from an estimated AR-1 process.
3 VIX is used to designate the Chicago Board Options Exchange's (CBOE) Volitility Index, which is calculated by the CBOE. The index describes expected volatility in the S&P 500 equity index 30 days ahead based on option prices. Exogenously included in the model in log form.
4 Money market premiums are endogenous additions to the variables in the core model, while the VIX is excluded as an exogenous variable. The premium is calculated as the three-month Norwegian money market rate less the expected policy rate in the period.
5 The index of financial conditions in Norway (Bowe et al. (2023)) is included endogenously as an addition to the variables in the core model, while the VIX is excluded as an exogenous variable.
6 Text-based indicators (Juelsrud and Larsen (2023)) are included endogenously as an addition to the variables in the core model, while the VIX is excluded as an exogenous variable.
Source: Norges Bank

F Robustness – Alternative models and the effect of policy rate increases

For a number of alternative models, we find that a policy rate increase, irrespective of cause, results in higher net interest income as a percentage of assets (Table F.1). For each model, it is assumed that a policy rate hike of 1 percentage point will be triggered by three different shocks to the macro economy. For each model and shock, the maximum level of net interest income as a percentage of assets is reported in the period around the peak interest rate of 1 percentage point. The period is from 2 quarters before the policy rate has reached one percentage point and in the 6 quarters from and after the peak. Similarly, the average level over the two years is reported around the interest rate peak of 1 percentage point.

We first focus on various specifications of the core model (estimated in levels) regarding the bank indicators (see models 1-7). In the event of an unexpected increase in the policy rate, and in demand, the response is very stable across the models. For the models estimated on level data, a shock to demand generally results in a somewhat longer-lasting response to net interest income as a percentage of assets (see average over 2 years). For shocks to inflation that trigger a 1 percentage point interest rate increase, the effect is generally positive, but the magnitude of responses varies more across the different model specifications. Excluding the VIX in model 6 generates a slightly larger response in net interest income to a supply shock compared with the core model, while in model 7, without credit losses, the response to a supply shock is slightly smaller.

Andersen (2020) finds that developments in automation and digitalisation have reduced costs for Norwegian banks, while increased regulation has worked in the other direction. In models 8-10, we have included indicators of electronic payment transactions, internet use and regulation as exogenous variables. As expected, the response to operating expenses changes somewhat (not shown in the table), impacting responses to net interest income as a percentage of assets, although the results do not deviate significantly from the core model.

To take into account that developments in banks' earnings can affect, and are affected by, developments in banks' equity ratios (which is the reported measure closest to banks' capital adequacy and requirements throughout the period 1994-2022), we have included banks' equity ratios endogenously in model 11. In the model, an unexpectedly higher equity ratio results in slightly higher net interest income as a percentage of assets compared with long-term equilibrium. The effect may reflect that banks have historically increased earnings to maintain return on equity and/or to meet higher capital requirements (see Section 2.5). Compared with the core model, including banks' equity ratios entails a somewhat weaker response to a supply shock (Model 11).

Table F.1: *Response in net interest income/ATA at 1 percentage point increase in the policy rate. Measured as annualised percentage point deviation from long-term equilibrium*

		MP shock		Demand shock		Supply shock	
	Alternative models	Max[1]	Mean 2Y[1]	Max[1]	Mean 2Y[1]	Max[1]	Mean 2Y[1]
1	Level – Core model	0.10	0.05	0.10	0.07	0.08	0.02
2	Level – Costs[2] last in Cholesky	0.10	0.05	0.10	0.07	0.08	0.02
3	Level – Excluding costs [2]	0.11	0.06	0.10	0.08	0.08	0.04
4	Level – Excluding total assets	0.09	0.04	0.09	0.06	[0.32]	[0.12]
5	Level – Excluding costs[2] and total assets	0.11	0.05	0.09	0.07	[0.25]	[0.12]
6	Level – Excluding VIX index	0.11	0.05	0.10	0.07	0.09	0.03
7	Level – Excluding credit losses	0.11	0.06	0.09	0.08	0.06	0.02
8	Level - Electronic[3] included exogenously	0.12	0.05	0.13	0.09	0.12	0.03
9	Level - Internet[4] included exogenously	0.07	0.02	0.09	0.05	0.15	0.01
10	Level - Regulation[5] included exogenously	0.10	0.06	0.09	0.06	0.08	0.01
11	Level - Equity ratio[6] included exogenously	0.09	0.04	0.11	0.08	0.03	-0.01
12	Level – Deposit share[7] included exogenously	0.12	0.06	0.10	0.05	0.07	0.02
13	Level - Corporate share[8] included exogenously	0.09	0.03	0.12	0.07	0.14	-0.03
14	Level - FCIN[9] included exogenously	0.12	0.05	0.10	0.07	0.09	0.04
15	Level - Premium[10] included exogenously	0.09	0.04	0.09	0.06	0.08	0.04
16	Level - Uncertainty[11] included exogenously	0.10	0.05	0.08	0.06	0.05	0.01
17	Level - 1987-2022	[0.07]	[0.04]	[0.14]	[0.11]	[0.09]	[0.05]
18	Level - 2000-2022	[0.07]	[0.01]	[0.24]	[0.11]	[0.11]	[0.04]
19	Level - 1987-2007 - excluding VIX	[0.10]	[0.00]	[0.06]	[0.05]	[0.15]	[0.05]
20	Level - 6 lags	0.09	0.05	0.10	0.07	0.11	0.07
21	Level - 4 lags	[0.10]	[0.02]	[0.14]	[0.08]	[0.19]	[0.05]
22	Cyclical components[12]	0.10	0.04	0.04	0.01	[0.11]	[0.04]
23	Cyclical comp.[12] - Excluding costs	0.10	0.04	0.04	0.02	[0.09]	[0.04]
24	Cyclical comp.[12] - Excluding total assets	0.10	0.04	0.04	0.01	0.14	0.05
25	Cyclical comp.[12] - Excluding costs and assets	0.10	0.05	0.05	0.03	0.14	0.06
26	Cyclical comp.[12] - with output gap[13]	0.11	0.04	0.05	0.02	0.10	0.03

Unless otherwise stated, the estimation period is 1994 Q1 - 2022 Q4.
Macro variable developments that deviate from the core model are in brackets. The deviation impacts developments in net interest income as a percentage of assets.
1 Based on the period two quarters before the change in the policy rate reaches 1 percentage point and the six quarters during and after the peak.
2 Credit losses and operating expenses as a percentage of assets.
3 Number of electronic payment transactions as a share of total transactions by debit and credit transfers, payment cards and cheques in Norway.
4 Average share of the Norwegian population using the internet daily. Estimates for 1994-1996.
5 Number of employees in Finanstilsynet as a share of the number of banks.
6 Break-adjusted time series for the seven large banks' equity ratios.
7 Break-adjusted time series for the seven large banks' deposits as a share of total assets.
8 Time series for banks and mortgage companies' corporate lending as a share of total retail and corporate lending.
9 The text-based indicator of monetary policy uncertainty (see Bowe et al. (2023)), is included endogenously, as an addition to the variables in the core model, while VIX is excluded as an exogenous variable.
10 Money market premiums are included endogenously in addition to the variables in the core model, while the VIX is excluded as an exogenous variable. The premium is calculated as the Norwegian three-month money market rate less the expected policy rate in the period.
11 Text-based indicators of monetary policy uncertainty (see Juelsrud and Larsen (2023)), endogenously added to the variables in the core model, while the VIX is excluded as an exogenous variable.
12 Deviation between level and trend. Trend calculated using double-sided HP filter with $\lambda = 30\,000$.
13 Norges Banks output gap replaces the discrepancy between level and trend for mainland GDP.
Source: Norges Bank

In model 12, we have included banks' deposits as a percentage of total assets as an endogenous variable. An unexpectedly higher deposit-to-loan ratio (or a reduced wholesale funding ratio) pulls up net interest income as a percentage of assets slightly, but the shock also contributes to a slightly higher policy rate compared with long-term equilibrium. The effect may reflect the fact that wholesale funding has normally been more costly than deposits. The VAR model indicates that the deposit-to-loan ratio tends to decrease with a higher ratio of total assets to mainland GDP. This relationship can be interpreted as banks using other sources of funding than deposits when lending growth is high. In line with the response to the ratio of total assets to mainland GDP in Chart 6d, the response to net interest income as a percentage of assets is slightly less pronounced than the core model when a supply shock occurs (when the ratio of total assets to mainland GDP increases and the deposit-to-loan ratio is reduced) and somewhat more pronounced or the same in response to monetary policy or demand shocks, respectively.

To take account of the tendency of banks to charge higher interest rates when the cost of losses is expected to be higher (see section 2.3), we have included corporate lending as a percentage of total retail and corporate lending (see model 13), where the variable is included endogenously. The time series is based on bank and mortgage company lending from ORBOF bank statistics. In the VAR model, the share of corporate lending increases slightly in response to supply and demand shocks. For similar shocks, the response to net interest income as a percentage of assets is somewhat more pronounced in the short term when compared with the core model, but the results do not deviate materially.

To take account of the fact that changes in financial conditions may occur in Norway and that financial conditions may affect, and are affected by, developments in the macroeconomy and the banking sector, we have included an index for financial conditions in Norway (FCIN) (see model 14 where FCIN is included endogenously and the VIX is excluded). Like Bowe et al. (2023), we find that shocks to the FCIN index pull down activity, prices and the policy rate compared to long-term equilibrium, but including the index does not significantly change the responses to shocks to macroeconomic variables of net interest income compared to the core model. Including instead either the premium on money market rates endogenously (model 15) or a text-based measure of monetary policy uncertainty (model 16) also results in only minor changes compared with the core model.

Despite the fact that macroeconomic dynamics change somewhat across the estimation periods (see models 17-19), particularly for somewhat shorter periods (models 18 and 19), the responses are qualitatively the same as in the core model.

Including an additional lag in the model (six instead of five) yields very similar results to the core model (model 20). A somewhat more persistent trend in operating expenses coincides with a somewhat more prolonged response in net interest income as a percentage of assets when a supply shock occurs. Reducing lags to four changes the macroeconomic and banking sector dynamics somewhat and may reflect that economic activity impacts banks' financial statements

with a considerable lag. Nevertheless, the response in net interest income as a percentage of assets does not deviate significantly from the core model (model 21).

Models 22-26 are based on cyclical components (HP-filtered data). In the event of a monetary policy shock, the responses of net interest income as a percentage of assets are very similar to the response in the level models. For a demand shock, the response is somewhat weaker compared with the level models, and somewhat greater for a supply shock. In models 22 and 24, the demand shock leads to a larger reduction in banks' operating expenses, which may explain the somewhat weaker response of net interest income as a percentage of assets. The responses are robust if we include the output gap rather than the cyclical component of mainland GDP in the model (model 26).