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The cost efficiency improvement of Norwegian banks can be explained by automation and digitalisation

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STAFF MEMO

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NO. 9 | 2020

HENRIK ANDERSEN

NORGES BANK

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The cost efficiency improvement of Norwegian banks can be explained by automation and digitalisation

Henrik Andersen[1]

Operating costs in the Norwegian banking sector have been reduced considerably in recent decades, both as a share of income and assets. This has increased banks' resilience to increased losses and reduced the risk of crises. In this article, I analyse how costs have been reduced and the main drivers of the cost efficiency improvement. The results suggest that automation and the digitalisation of banks' operations have played a key role in improving cost efficiency.

Key words: banks, costs, digitalisation, regulation, business cycle

1. Introduction

Banks provide a number of services that are crucial to economic activity.[2] As access to these services is often disrupted during banking crises, the cost to society of such crises is high.

Cutting costs boosts banks' resilience to increased losses and reduces the risk of crises. Historically, most banking crises have been caused by losses on lending and financial instruments. The first line of defence against such losses is banks' profits. In isolation, cost cuts increase profits krone for krone. Banks therefore reduce costs to improve profitability and thus their first line of defence. For example, Andersson et al (2018) show that the euro area banks demonstrating the highest improvement in profitability after the financial crisis have reduced their cost-to-income ratios.

Banks' cost cuts can also improve monetary policy transmission and contribute to higher growth. According to Jonas and King (2008), cost-efficient banks adjust their loan volumes to the policy rate more than less cost-efficient banks. Cost cuts can also enable banks to offer cheaper services. Lower bank lending rates can for example push up both business investment and consumption (see Andersen and Walle (2015) and Andersen et al. (2016)).

Norwegian banks[3] are cost-efficient compared with banks in other countries. Operating costs have been reduced considerably over the past three decades, both as a share of income (cost-to-income ratio) and assets (cost-to-assets

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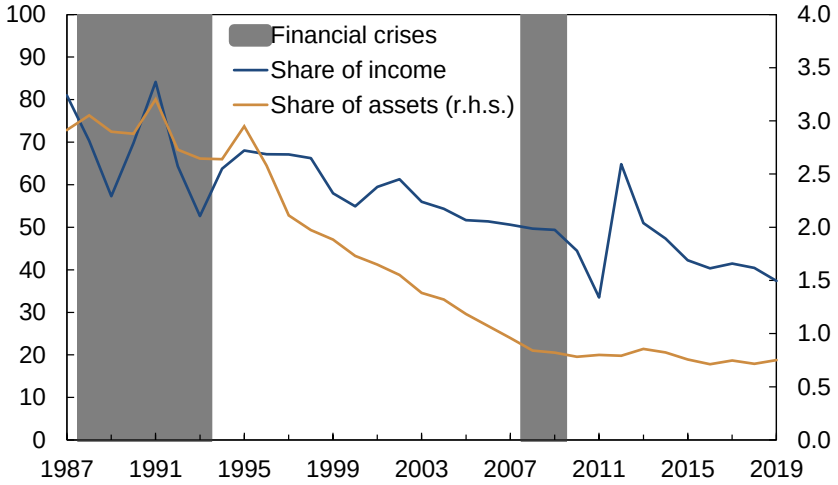
[1] The views and conclusions in this publication are the author's own and do not necessarily reflect, and must not be reported as those of Norges Banks. I thank Håkon Astrup (DNB Markets), Eleonora Granziera, Torbjørn Hægeland, Tom Høiberg (Finance Norway), Einar Nordbø, Knut Sandal, Norman Spencer, Ylva Søvik, Bent Vale, Sindre Weme and Terje Åmås for useful comments and input, as well as Kaja Dørum Haug and John Henrik Mulelid for their kind assistance with background information and charts.
[2] Banks provide loans, accept deposits, execute payments and help customers with managing risk.
[3] All banks and mortgage companies in Norway unless otherwise.

ratio) (Chart 1). As a result, Norwegian banks have the lowest average cost-to-income ratio of all the EEA countries (Chart 2). After the 2008 financial crisis, the same key ratio has increased for euro area banks. According to Andersson et al, euro area banks' cost-to-income ratios have risen because of substantial growth in wage and personnel expenses. Andersson et al. also refer to euro area banks' weak income developments and large stocks of non-performing loans.[4] In addition, Huljak et al (2020) show that productivity growth in the euro area banking sector has fallen.

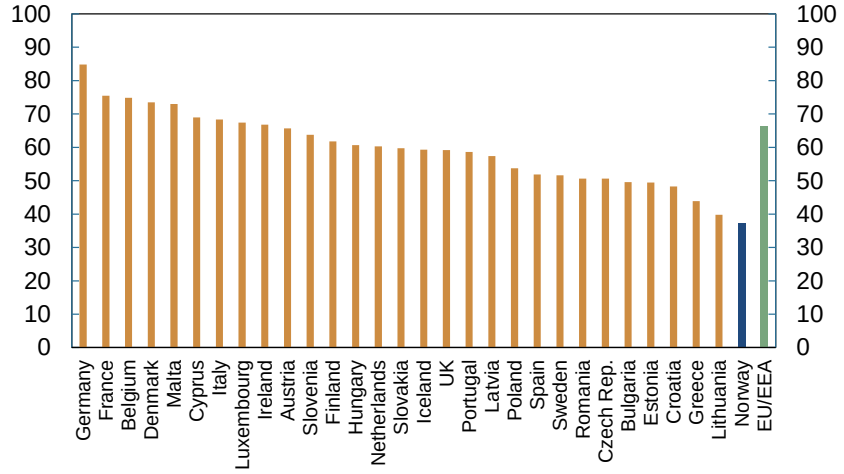
Chart 1 Operating costs in the Norwegian banking sector as a share of operating income and assets.[1] 1987 – 2019



1) See Appendix 1 for more information on the data series.

Source: Norges Bank

Chart 2 Average cost-to-income ratio for Norwegian[1] and European[2] banks for the period 2019 Q3 – 2020 Q2. Percent



1) All banks except branches of foreign banks in Norway.
2) 147 European banks.

Sources: European Banking Authority (EBA) and Norges Bank

[4] Banks may need to devote substantial resources to non-performing loans (see eg Fell et al (2017).

Developments during the Covid-19 pandemic indicate that cost efficiency improvements have increased Norwegian banks' resilience to higher losses. Despite increased credit losses, Norwegian banks have posted profits and largely maintained credit supply. By comparison, the largest German, Belgian and Italian banks as a whole posted losses in 2020 Q1, even though their credit losses were lower than those of Norwegian banks.

In this *Staff Memo*, I analyse how Norwegian banks have reduced their cost-to-assets ratios and the main drivers of cost efficiency improvements. Section 2 describes the dataset. Section 3 decomposes banks' costs and assess how Norwegian banks have reduced their cost-to-assets ratios. Section 4 discusses possible drivers of cost developments. Section 5 models developments in the cost-to-assets ratio, and Section 6 concludes.

2. Data

I use several data sources to analyse how Norwegian banks have reduced their cost-to-assets ratios. Data from the ORBOF[5] bank statistics show developments in banks' costs and assets. The ORBOF bank statistics provide a rough allocation of costs back to 1987 and a more detailed allocation back to 1998. Developments in banks' labour costs are analysed using the ORBOF bank statistics on banks' labour costs and number of employees as well as data from Statistics Norway on hours worked per employee and wage per hour worked. In addition, I complement the ORBOF bank statistics with statistics from Finance Norway on the number of bank offices in Norway to assess developments in other costs.

I analyse the drivers of the improvements in Norwegian banks' cost efficiency with data from a number of different sources. The effects of automation and digitalisation are analysed using Norges Bank data on the number of ATMs, payment terminals and various kinds of payment transaction in Norway. In addition, I use data from Statistics Norway and Finance Norway on Norwegians' use of the internet, smart phones and online banking services. Other potential drivers of the cost developments are analysed using data from the ORBOF bank statistics, Finanstilsynet (Financial Supervisory Authority of Norway) and the Norwegian State Administration Database.

3. Decomposition of costs

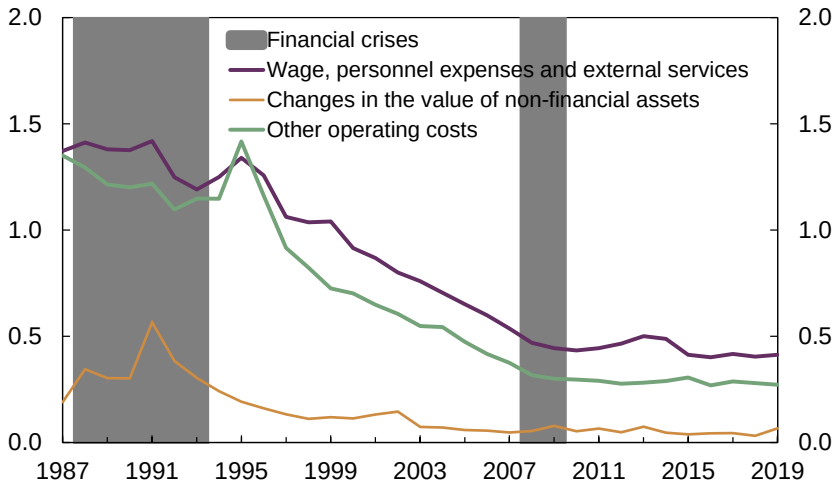
In this section, I decompose developments in banks' costs to provide a better basis for assessing how Norwegian banks have reduced their cost-to-asset ratios. The decomposition shows that nearly half of the decline in the cost-to-assets ratio is due to reductions in wage and personnel expenses by banks relative to assets, which inter alia reflect a fall in the number of employees. The decline in this ratio has been restrained by the average wage of bank employees, which has risen faster that the average wage in Norway. Other

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

operating expenses have also fallen relative to assets, among other reasons, as a result of the reduction in the number of bank offices. Higher costs for IT and external services have dampened the decline in the cost-to-assets ratio.

A large part of the improvements in cost efficiency can be explained by developments in wage and personnel expenses. Wage and personnel expenses and costs for external services fell from 1.4 percent of assets in 1987 to 0.4 percent in 2019 (Chart 3). Developments in these costs explain nearly half of the decline in the total cost-to-assets ratio since 1987.[6] The share attributed to other operating costs also fell.

Chart 3 Norwegian banks' operating costs as share of assets. 1987 – 2019

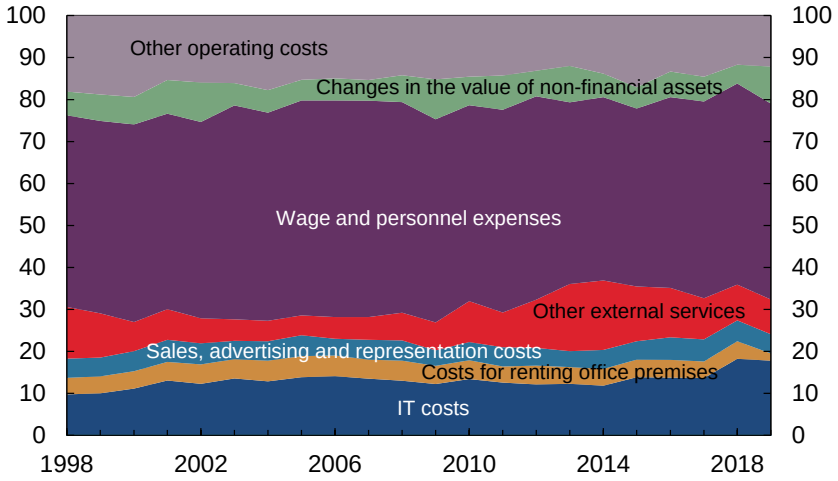


Source: Norges Bank

A more detailed allocation of banks' operating costs shows that the cost composition has been fairly stable over the past two decades (Chart 4). Wages and personnel expenses have generally accounted for around half of total operating costs. On the other hand, IT costs have accounted for an ever greater share. Since 2014, IT costs, which include costs for licences, software and other ICT equipment and costs for external IT services, have contributed to increasing the total cost-to-assets ratio. In this period, IT costs have risen by two-thirds, while other costs have only risen by 3 percent. Costs for external services have also accounted for an ever greater share of operating costs, and in many of the years after the financial crisis, these costs have contributed to an increase in the cost-to-assets ratio.[7] This may be because banks have outsourced larger parts of their operations, for example payroll administration, accounting, canteen operation and janitorial and cleaning services.

[6] Measured as a share of assets, wages, personnel expenses and costs for external services overall fell by 1 percentage point between 1987 to 2019, that is, developments in these costs explain nearly half of the 2.2 percentage point decline in the total cost-to-assets ratio.
[7] During these years, costs for external services increased more relative to assets than other costs.

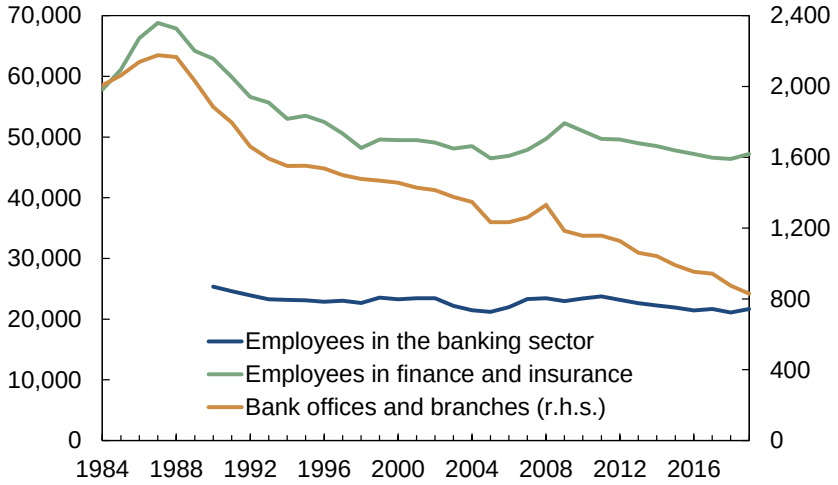
Chart 4 Norwegian banks' operating costs decomposed into subgroups. Percent of total operating costs. 1998 – 2019[1]



1) In 2018, the statistics were restructured and a number of the financial statement items were changed. Changes between 2017 and 2018 must therefore be interpreted with caution.

Source: Norges Bank

Chart 5 Number of employees and number of bank offices and branches.[1]1984 – 2019[2]



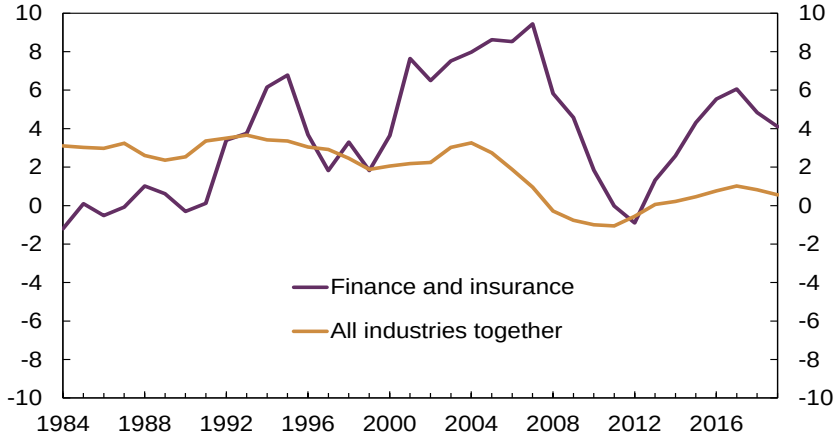
1) All banks in Norway.
2) Statistics for the number of bank offices and branches in 2019 are not available. The number is therefore approximated using information from bank websites.

Sources: Bankplassregisteret, Finance Norge, Statistics Norway and Norges Bank

Norwegian banks have reduced their cost-to-assets ratios by downsizing (Chart 5). The number of employees has fallen by over 14 percent since 1990, even though banks' assets have increased more than twelve-fold. Finance and insurance are among the industries in Norway that have replaced labour with capital in production the most (see Hagelund et al (2017)), and productivity growth in the industry has been high since the start of the 1990s (Chart 6). This downsizing has, in isolation, reduced banks' wage and personnel expenses. The downsizing may have also contributed to reducing

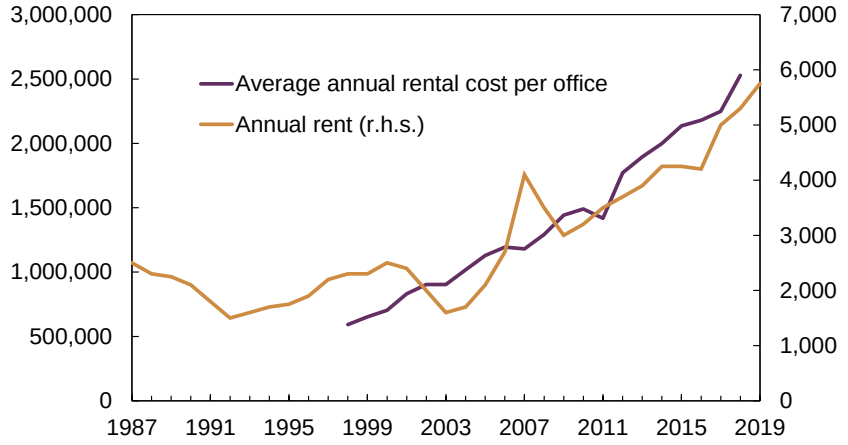
other personnel expenses and other costs, eg costs associated with office premises and office equipment. On the other hand, some of the downsizing may be due to outsourcing, which has increased the costs for external services. In addition, the average wage of bank employees has risen faster than the average wage in Norway, which has contributed to keeping labour costs elevated. In 1987, the average hourly wage for employees in finance and insurance was 16 percent higher than the average wage in Norway. In 2019, this gap was 40 percent. This may be because low-wage employees were replaced by more highly paid new hires, for example, because digitalisation and more burdensome regulation have changed banks' skill needs (see Sections 4.1 and 4.2).[8] In addition, the wages of other bank employees may also have risen more than the average wage in Norway.

Chart 6 Gross product per hour worked. Change from previous year. Constant prices. Five-year moving average. Percent. 1984 – 2019



Source: Statistics Norway

Chart 7 Rent per square metre for prime office space in Oslo. Banks'[1] average rental cost per office. In NOK. 1987 – 2019[2]



1) All banks and mortgage companies in Norway.
2) 1998-2018 for average annual rent per office.

Sources: CBRE and Norges Bank

[8] The number of hours worked per employee in finance and insurance have risen only marginally in the analysis period.

Norwegian banks have also lowered their cost-to-asset ratios by closing bank offices. The number of bank offices in Norway has fallen by over 60 percent since 1987 (Chart 5). This reflects the reduction in the number of employees. Despite the sharp reduction in the number of bank offices, costs for renting office premises have accounted for a fairly stable share of banks' total costs in recent decades (Chart 4). This can be explained by the rise in rents for commercial property (Chart 7). Moreover, book values of bank offices indicate that banks lease an ever increasing share of their offices.[9] A third explanation may be that the average size or quality of banks' premises has risen, among other reasons because banks have kept large properties in urbanised areas with high rents.

4. Underlying drivers of cost developments

This section examines more closely six factors that may explain cost developments at Norwegian banks:

1. Automation and digitalisation of banking services
2. Burdensome regulation
3. Economies of scale
4. Competition
5. Changes in the importance of business areas
6. Cyclical effects

There may also be a number of other factors affecting cost developments, but which are difficult to analyse owing to limited data availability. These may include a change in the focus of core activities, outsourcing services and optimisation of processes.

4.1. Automation and digitalisation of banking services

In Norway, automation and digitalisation have over several decades contributed to improving banks' cost efficiency. Automation and digitalisation have reduced the need for bank personnel who perform routine tasks, such as manually processing cheques and bank transfers, cash handling services and other counter services. In addition, digitalisation has simplified the distribution of banking services, made bank customers more self-sufficient and reduced the need for customers to visit bank offices. In this way, automation and digitalisation have reduced banks' need for both employees and office space.

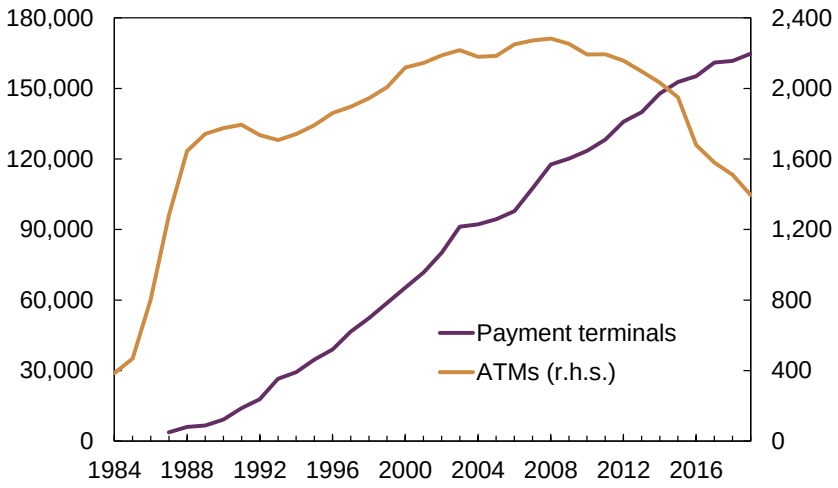
4.1.1. Automation of payment services

Norwegian banks have automated payment services since the 1970s. In 1977, banks introduced self-service when they rolled out the first ATMs, and the number of ATMs rose sharply in the 1980s (Chart 8). As more and more

[9] Book value of bank offices as a share of banks' total assets fell from 1.17 percent in 1987 to 0.04 percent in 2019.

customers made cash withdrawals from ATMs, this reduced the need for counter services. From the end of the 1980s, payment terminals became more common in shops and petrol stations (Chart 8), and cash was increasingly replaced by bank cards. In addition, electronic payment cards and bank transfers increasingly replaced manual giro services, such as cheques, postal giros and paying bills at the counter. The share of electronic payment transactions therefore increased markedly, and today close to 100 percent of all card and giro payments are made electronically (Chart 9). This has reduced the need for bank personnel who perform routine tasks such as manually processing cheques and giros.

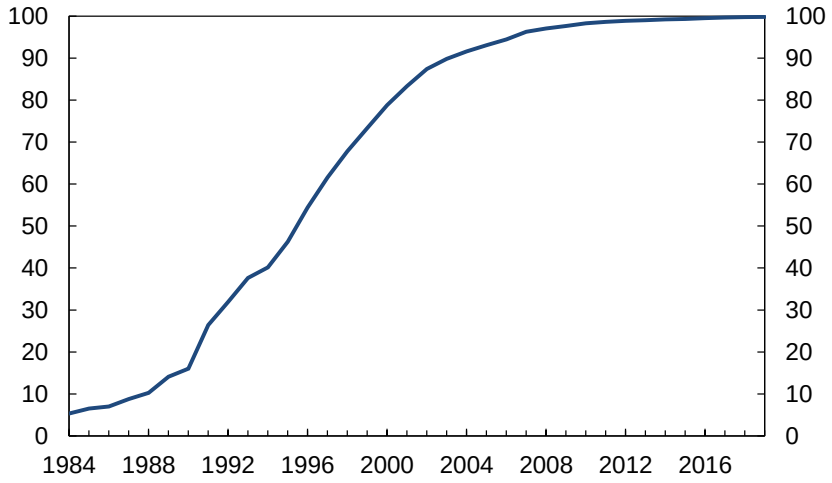
Chart 8 Number of ATMs and payment terminals[1] in Norway. 1984 – 2019



1) For more information on the data series, see Appendix 1.

Source: Norges Bank

Chart 9 Share of giro, payment card and cheque transactions that are electronic in Norway.[1] 1984 – 2019



1) For more information on the data series, see Appendix 1.

Source: Norges Bank

Norwegian banks have collaborated on developing infrastructure to improve the efficiency of payment services. In 1972, the infrastructure company Bankenes Betalingssentral (BBS) was formed to enable banks to coordinate and streamline their work in payment services (see Skule and Gryti (1997)). BBS offered shared services in the areas of IT, bill payments, clearing and information services. BBS also stood behind the establishment of the national payment system BankAxept at the beginning of the 1990s, and in 2019, around two-thirds of Norwegian card transactions were executed through the BankAxept system (see Norges Bank (2020). Earlier surveys show that the unit cost for card payments of this type are clearly the lowest for payment services (see Norges Bank (2014)). Norwegian banks have also collaborated on a common payment infrastructure, and in 2016, Bits AS was established to strengthen and revitalise this effort.

Results from the literature and surveys indicate that automation of payment services has reduced banks' costs (see eg Berger (2003), Lindquist (2002), Humphrey and Vale (2004) and Norges Bank (2014)). According to Humphrey and Vale's analyses, the transition to electronic payments contributed to reducing Norwegian banks' total costs per krone under management by 13 percent in the period 1987-1998. According to Norges Bank's surveys of banks and other payment system participants, banks' costs for payment purposes were reduced by more than half as a share of GDP between 1988 and 2013. Moreover, comparisons with other countries show that the costs in the Norwegian payment system are low.

4.1.1. Internet and digitalisation of banking services

The emergence of the internet has played a key role in the digitalisation and efficiency improvements in banking. The internet has enabled banks to automate processes and simplify communication with customers and the distribution of banking services. In addition, online services make customers more self-sufficient and less dependent on physical presence, reducing banks' needs for both employees and office space.[10] In Norway, two-thirds of respondents to a recent survey report that they visit bank offices less frequently than once a year (see Finance (2020)). According to SpareBank 1 Nord-Norge, "very few" customers visit a traditional bank office in 2020, because the customers perform banking tasks on their own (see SpareBank 1 Nord-Norge (2020)). SpareBank 1 Nord-Norge therefore intends to downsize and close more than half of its bank offices. Similar trends are seen in a survey DNB Markets has conducted among the 50 largest banks in Norway (see DNB Markets (2020)). Over two-thirds of the banks in the survey will downsize in the coming year, while one in seven banks will reduce the number of bank offices.

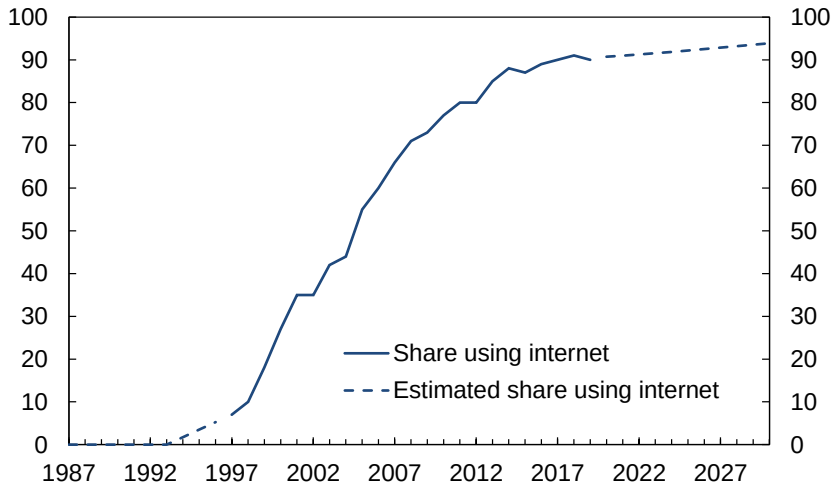
Results from the literature indicate that IT investment and digitalisation increases the profitability of both banks and other firms (see Andersson et al,

[10] According to Huljak et al (2018), a low degree of bank digitalisation often correlates with a large need for offices and staff.

Bessen and Righi (2019) and Huljak et al (2018)). Andersson et al found that banks with best profit performance after the financial crisis had increased IT expenditure by nearly 60 percent between 2009 and 2017. This is in line with the results in Huljak et al (2018).[11]

In Norway, the internet has improved the efficiency of banking since the 1990s. The internet became commercially available in Norway in 1993 (see Kjærnsrød (2001) and Arts Council Norway (2014)). In 1997, 7 percent of the Norwegian population used the internet on a daily basis, and in the following decades this share rose sharply (Chart 10). Use will likely continue to rise (Chart 10).

Chart 10 Share of the population using the internet daily. 1987 – 2030[1]



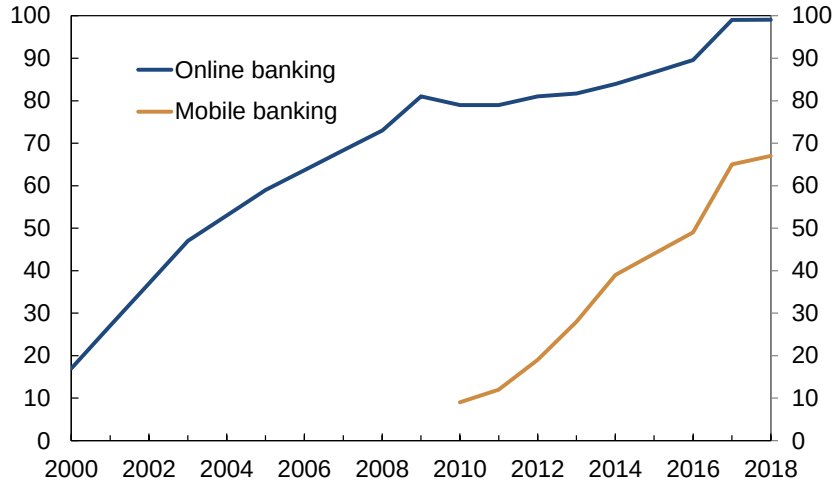
1) For more information on the data series, see Appendix 1.

Sources: Statistics Norway and Norges Bank

The internet laid the foundation for technological advances in the Norwegian banking sector. In 1996, Sparebanken Hedmark was the first in Europe to launch online banking (see SpareBank 1 Østlandet (2016)). Today, Norway has Europe's highest share of users of online banking, and users encompass nearly the entire population (Charts 11 and 12). Online banking gives bank customers access to banking services around the clock. Online banking enables customers to make payments and perform other transactions themselves as well as apply for loans, deposits and a broad spectrum of other financial services. The result is that around a third of all insurance products and four-fifths of savings products are purchased without contact with a financial adviser (see Finance Industry Authorisation schemes (2020)). In addition, a considerable portion of residential mortgages and consumer loans are granted without contact with an adviser.

[11] However, Becalli (2007) found no significant effects of IT investment on European banks' profitability or efficiency in the period 1995-2000.

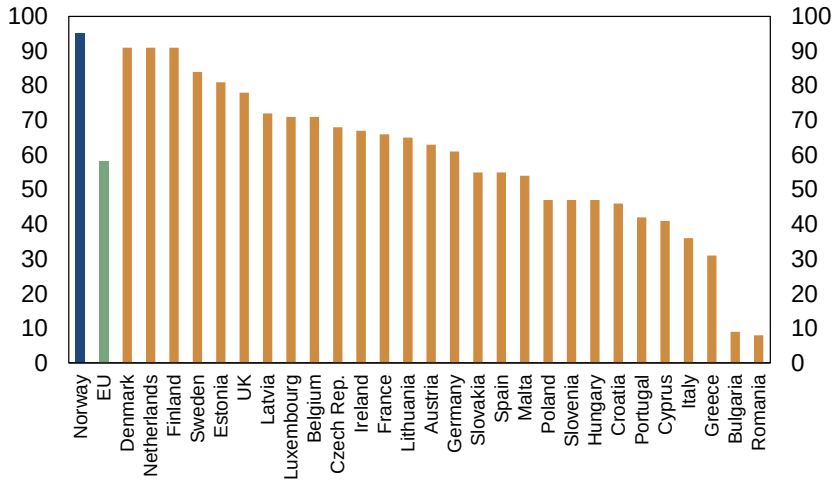
Chart 11 Share of the population using online and mobile banking. 2000 – 2018[1]



1) For more information on the data series, see Appendix 1.

Sources: Finance Norway and Kantar TNS

Chart 12 Share of the population of EU countries and Norway who use online banking. Percent. 2019



Source: Eurostat

In the 2000s, banks in Norway introduced a number of new online services. In 2004, banks launched BankID, a secure and efficient means of electronic identification. This has likely helped to increase the use of online services by making them efficient and secure. In 2010, banks introduced the first smart phone mobile banking apps (Finance Norway (2013), and in 2018, two-thirds of the Norwegian population used mobile banking services (Chart 11). Mobile banking gives bank customers access to banking services anytime and anywhere as long as that there is mobile data coverage. This has further reduced the need to visit bank offices. Since 2014, banks have also launched payment apps that have reduced the need for cash, ATMs and other services

associated with cash handling.[12] In 2017, banks entered into a collaboration to enhance DNB's Vipps payment app, and today, 89 percent of the Norwegian population uses Vipps (see Finance Norway (2020)).

Services based on robotic process automation (called "bots") are one of the latest of banks' technological advances. Banking bots have already taken over a number of tasks, including customer contact and processing loan applications. For example, DNB's chatbot replies to the majority of customer queries by chat or e-mail (see DNB (2019b)). DNB receives 70 percent of its residential mortgage loan applications digitally (see DNB (2020)), and bots fully or partially process many of these applications. This cut the time in half that the bank spent on processing an average residential mortgage application between 2016 and 2018 (see DNB (2019a)). In time, bots may perform advanced work tasks faster and more efficiently than humans, and KPMG (2016) estimates that bots can reduced financial institutions' costs by up to 75 percent.

Several studies indicate that the banking sector will continue to invest heavily in IT. Large European banks view automation and digitalisation as the most important tools for reducing costs ahead (see EBA 2019). The consultancy firm Celent estimates that global banks' IT expenditure will increase by 4 percent annually in the period 2020-2022 (see Greer et al (2019)). In the survey by DNB Markets, 70 percent of banks responded that they will maintain their investment in digitalisation in the coming year (see DNB Markets (2020)). In addition, the Covid-19 pandemic may further speed up digitalisation, because increased digital customer contact is an effective containment measure.

The impact of digitalisation on banks' costs is limited by some factors. Many customers still prefer to visit a bank office in person when making major financial decisions (see Finance Norway (2015)). There is therefore still a need for offices and employees to advise customers. Even though digitalisation has reduced banks' needs for office space and staff, digitalisation has increase the need for IT expertise, licences, software and other ICT equipment. IT costs have therefore accounted for an increasingly larger share of bank's operating costs (Chart 4). In addition, digitalisation has increased the risk of operational disruptions and cyber crime, which in turn has increased the need for security and control staff.

4.2. Burdensome regulation

Regulation provides economic gains, but raises banks' operating costs because compliance requires qualified staff, data, systems and office premises. Banking regulation is normally justified by the fact that a laissez-faire approach is not socially optimal. In such a situation, regulation will

[12] DNB, Danske Bank, the SpareBank 1 Alliance and the Eika Group launched proprietary payment apps in the period 2014-2015.

provide an economic net gain, if the direct cost to banks is less than the gain from curbing market failures (see Borchgrevink et al (2013)).

A number of studies indicate that it is costly for banks to comply with regulation (compliance costs). Older studies and investigations find that compliance costs account for between 6 and 14 percent of banks' total costs (see Thornton (1993) and Elliehausen (1998)). Results from more recent studies and surveys suggest that compliance costs represent an ever larger share (see Cyree (2016), Deloitte (2017), Depman (2016), Hogan and Burns (2019) and Hui et al (2016)). Hogan and Burns point out that regulatory changes have increased costs in the form of data processing, consultants, lawyers and auditors.

Several factors suggest that the regulatory burden has risen for Norwegian banks. The capital adequacy rules have increased in scope and complexity. These rules were modified already in the 1990s[13], but the biggest change came in 2007, when the 30-page Basel I framework was replaced by the 347-page Basel II framework (see Basel Committee (1988) and Basel Committee (2006)). The increase in the number of pages alone implies that banks needed to devote considerably more resources to complying with Basel II than with Basel I. In addition, Basel II permitted banks to calculate their own capital requirements for credit risk using internal models (IRB approach).[14] This has led the largest Norwegian banks to spend more on development, validation and follow-up of risk models. The financial crisis uncovered a number of weaknesses of Basel II, and in December 2010, the Basel Committee proposed an even more extensive set of rules totalling 616 pages (Basel III) (see Basel Committee (2010), Haldane (2012) and Lund and Nordal (2017)). Among other measures, Basel III introduced quantitative liquidity requirements and a number of new capital buffer requirements for banks. These rules were phased in from summer 2013 in Norway.[15]

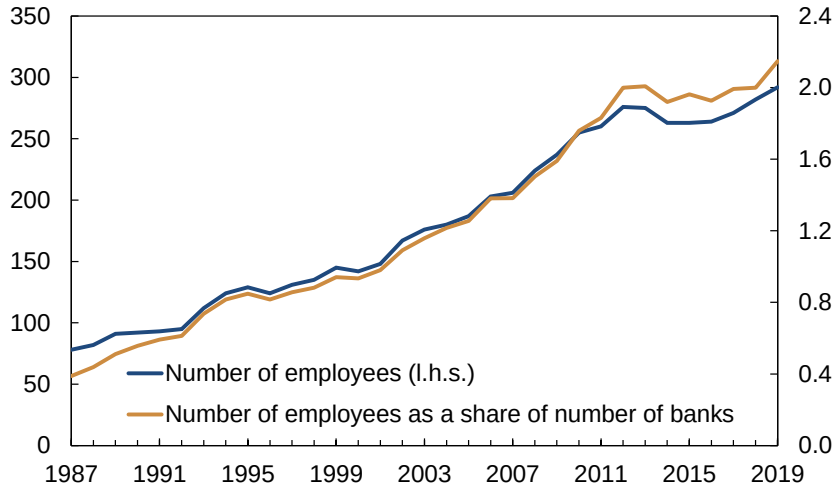
Norwegian banking regulation has probably also become more burdensome in other areas. The Norwegian authorities introduced guidelines and requirements for prudent lending standards for residential mortgages from 2010 and consumer credit from 2017. In autumn 2018, the Ministry of Finance introduced a new Money Laundering Act, which according to Finance Norway, entailed increased efforts by financial institutions (see Finance Norway (2018b)). This is consistent with Depman's findings that anti-money laundering work, consumer protection and credit standards are the primary drivers of costs associated with regulatory compliance. In recent year, banks have also

[13] A simple unweighted capital ratio was replaced by a risk-weighted capital ratio (Basel I) in 1991. The risk-weighted requirement was calculated using standardised, fixed weights, and the asset classes were relatively broad (see Basel Committee (1988) and Haldane (2012)). In 1996, banks were permitted to calculate capital requirements for market risk using internal models (see Basel Committee (1996)). This made the rules considerably more complex.
[14] Basel II also introduced capital requirements for operational risk.
[15] Looking ahead, the capital adequacy rules may become somewhat less complex. The Basel Committee has recommended that the authorities rescind the right to use internal models to calculate capital requirements for operational risk and for calculating capital requirements for credit risk in certain areas (see Basel Committee (2017)).The recommendations are to be phased in between 2023 and 2028.

devoted resources on adapting to the revised Payment Services Directive (PSD2), including by developing systems that give third-party providers access to account information.

Finanstilsynet is responsible for banks' regulatory compliance. The number of employees of this supervisory authority can therefore be a reliable proxy for how burdensome the regulations are. Since 1987, the number of employees of Finanstilsynet has risen sharply (Chart 13). At the same time, the number of banks has fallen. The number of supervisory FTEs per bank has thus risen from 0.4 in 1987 to 2.1 in 2019. This may indicate that regulating Norwegian banks has become significantly more burdensome. On the other hand, banks' average size has increased in the period (see Section 4.3). This may explain some of the increase in the number of supervisory FTEs per bank.

Chart 13 Number of Finanstilsynet employees. In number of persons and as a share of the number of banks. 1987 – 2019



Sources: Finanstilsynet, Norwegian State Administration Database and Norges Bank

4.3. Economies of scale

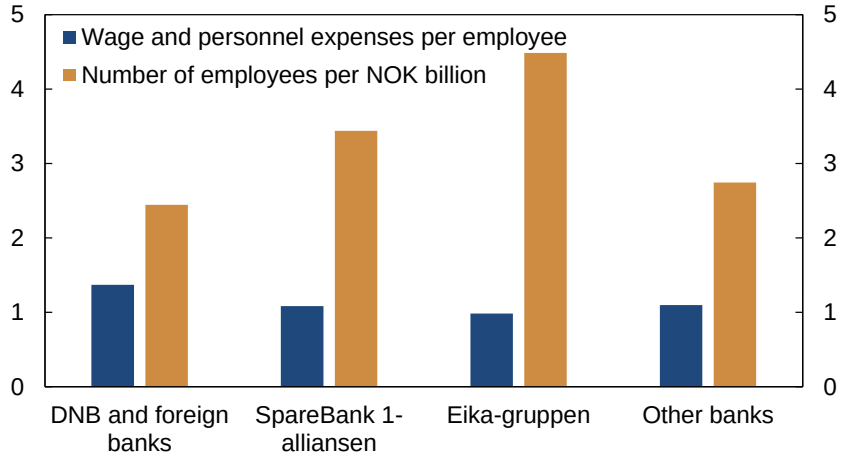
An explanation for Norwegian banks' efficiency gains may be that they have become bigger. When banks get bigger, they can exploit economies of scale, ie the costs per produced service falls when the number of produced services rises. There may be a number of sources of economies of scale in banking. Banks may have expertise, systems and office space that can handle more customers without incurring substantial additional costs.[16] Thus, organic growth, acquisitions and mergers can reduce the cost-to-asset ratio. Bank mergers are therefore often motivated by economies of scale (see Schmitz and Tirpák (2017)). For example, the two Spanish banks CaixaBank and

[16] According to Roades (1998), bank mergers result in cost saving in the form of downsizing and improved IT system and infrastructure utilisation, with downsizing representing in many cases more than half of the saving.

Bankia expect an annual cost reduction of at least EUR 770 million if they merge (see CaixaBank (2020)).

A number of studies document economies of scale in the banking sector (see eg Beccalli et al (2015), Berger and Mester (1997), Demirgüç-Kunt and Huizinga (2011), Humphrey and Vale (2004) and Dijkstra (2013)). However, results from several other studies suggests that economies of scale diminish or disappear when banks reach a certain size (see Andreeva et al (2019)), Berger and Mester, Demirgüç-Kunt and Huizinga, Feng and Serletis (2009) and Huljak et al (2020)). Huljak et al explain the diminishing economies of scale by noting that large banks often employ more sophisticated business models and are more difficult to manage. Demirgüç-Kunt and Huizinga (2011) point out that banks that become large relative to domestic GDP may run out of profitable business opportunities. Moreover, in Norway, DNB, which is Norway's largest bank, with assets of over NOK 3 trillion, and the large foreign banks have higher wage and personnel expenses per employee than the small and medium-sized banks that are members of the SpareBank 1 Alliance and the Eika Group (Chart 14). On the other hand, the SpareBank 1 Alliance and Eika Group banks have more employees per NOK billion under management than the large banks (Chart 14).

Chart 14 Wage and personnel expenses in millions of NOK as a share of the number of employees. Number of employees as a share of total assets in billions of NOK. 2019

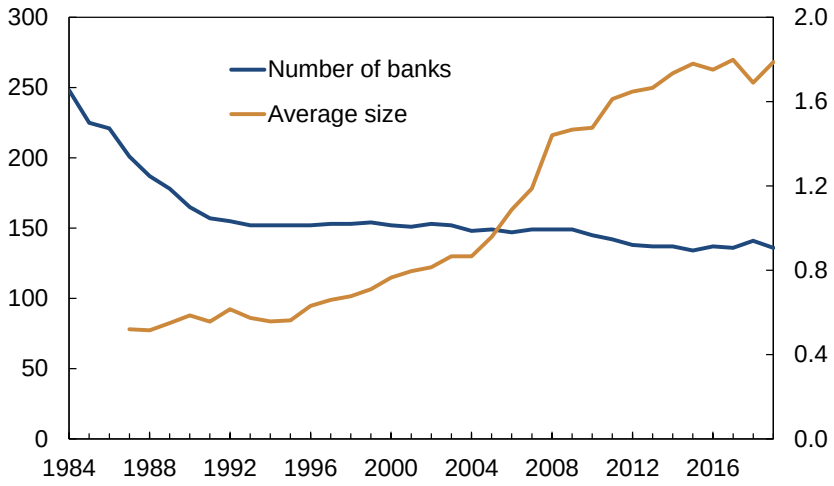


Source: Norges Bank

Banks in Norway have likely been exploiting economies of scale since the 1980s. Humphrey and Vale's analyses indicate that Norwegian banks exploited economies of scale in the period 1987-1998. Mergers and acquisitions reduced the number of banks, especially in the 1980s and beginning of the 1990s (Chart 15). This has led to higher concentration in the

Norwegian banking sector.[17] In addition, organic growth has boosted banks' average size especially in the 2000s (Chart 15).

Chart 15 Number of banks in Norway. Banks' average total assets as a share of mainland GDP.[1] 1984 – 2019



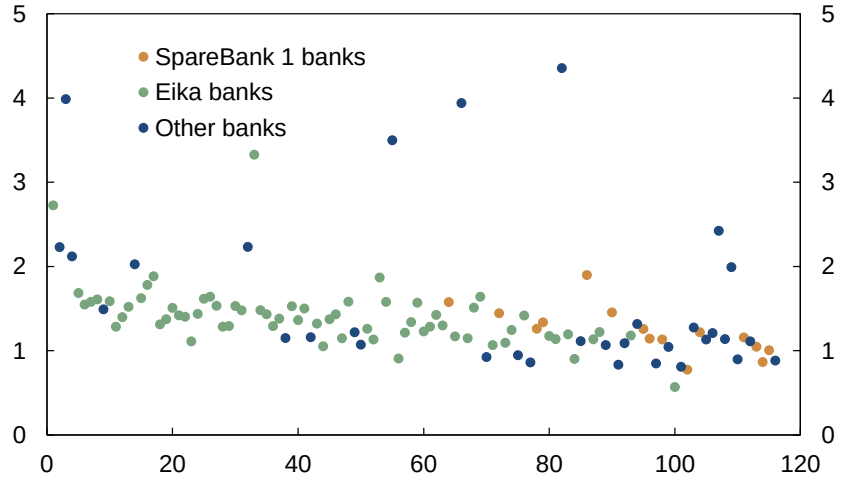
1) Market value at current prices.

Sources: Norges Bank and Statistics Norway

Both organic growth and cooperation have likely resulted in economies of scale for the small and medium-sized banks in Norway. Small and medium-sized banks have grown more overall than the largest banks.[18] In addition, many of the small and medium-sized banks have become members of the SpareBank Alliance and the Eika Group. The aim of these alliances is to exploit economies of scale by sharing expertise and collaborating on banking services, branding, payments and IT infrastructure. Nevertheless, the cost-to-asset ratios of small banks is high compared with large banks (Chart 16).

[17] According to Ulltveit-Moe et al (2013), the Norwegian banking sector was already highly concentrated in 2013, in comparison to both other countries and other sectors. Ulltveit-Moe et al explain the high concentration by citing economies of scale, among other factors.
[18] At the end of 2019, seven Norwegian banks had assets of more than NOK 100 billion. Since 2000, these seven banks have grown less than the Norwegian banking sector as a whole.

Chart 16 Banks'[1] cost-to-assets ratios (vertical scale). Banks ranked from smallest (1) to largest (116) by assets. Percent. 2019

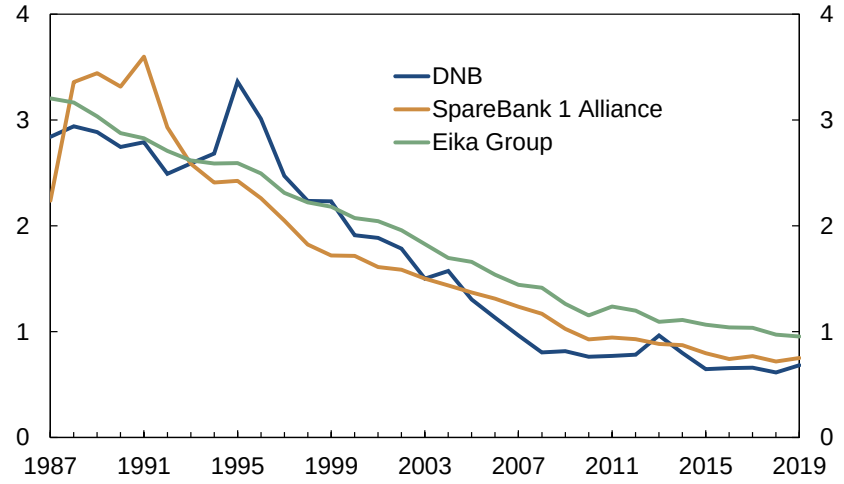


1) Parent bank data for all banks in Norway, excluding branches of foreign banks and four banks with a cost-to-assets ratio above 5 percent.

Source: Norges Bank

Cost developments at Norwegian banks show no indication that economies of scale have diminished or disappeared as banks have become larger. Since the end of the 1980s, the largest banks have reduced their cost-to-assets ratios more than small banks. DNB has reduced its cost-to-assets ratio more than the SpareBank 1 Alliance and Eika Group banks (Chart 17). At the same time, the SpareBank 1 Alliance, which is dominated by four savings banks with assets over NOK 100 billion, has reduced its cost-to-assets ratio more than the Eika Group.

Chart 17 Banks' cost-to-assets ratios. Percent. 1987 – 2019



Source: Norges Bank

Both digitalisation and more burdensome regulation may have increased the advantages of being large (see Sections 4.1 and 4.2). Digitalisation requires substantial investment, and in many cases, IT systems may only be profitable if used on a large scale (see Amel et al (2004)). In the DNB Markets survey,

37 percent of the banks responded that economies of scale associated with digitalisation are the primary driver of consolidation, while 61 percent of the banks responded that the primary driver of consolidation are economies of scale associated with regulation and reporting.[19] In addition, use of the IRB approach, which lowers banks' capital requirements, is limited to large and medium-sized banks.[20]

Looking ahead, mergers and acquisitions may further increase the average size of Norwegian banks. On average, the banks in the DNB Markets survey expect that the number of banks will be reduced by nearly a third in the coming decade. However, the ownership structure of Norwegian savings banks may limit consolidation, because mergers require the approval of shareholders, employees, customers and politically appointed representatives (see Bøhren (2014)).[21]

4.4. Competition

Some of the fall in banks' cost-to-assets ratios may reflect increased competition. Increased competition can force banks to cut costs, because margins and profitability come under pressure.

A number of studies find correlations between competition and banks' margins and costs. Lian (2017) and Joaquim et al (2019) both show that increased competition lowers banks' lending margins, while Carbó et al (2009) and Nguyen and Nghiem (2017) document that lower interest margins and increased competition, respectively, often coincide with greater cost efficiency.

The literature measures competition using several indicators. There is often low competition in sectors dominated by firms with substantial market power. The literature therefore often uses measures of market share and concentration as indicators of competition, for example the Herfindahl Index or the largest firms' market share (see Carbó et al). The Herfindahl Index is calculated as the sum of the squares of the market shares of all firms in a sector. High values indicate high market concentration and thus low competition, whereas low values indicate high competition. The literature also uses interest rate margin and return on total capital as indicators of competition, because increased competition can weaken margins and profitability.

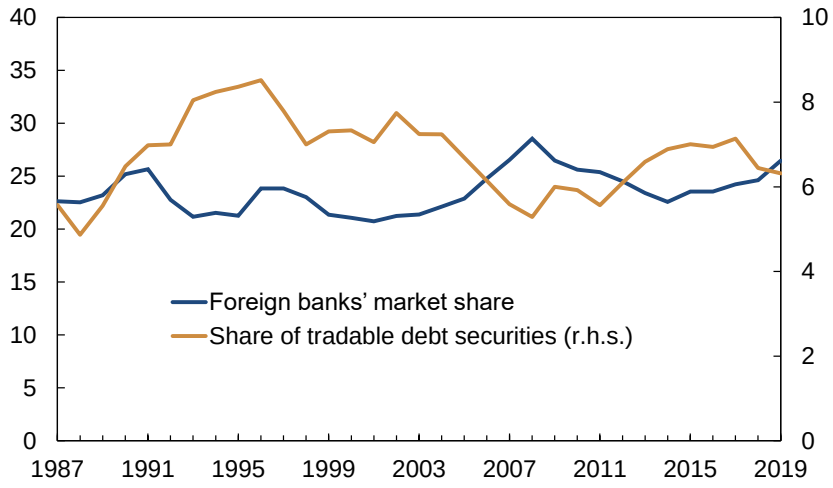
In Norway, Ulltveit-Moe et al (2013) pointed out three factors that contribute to competition in the Norwegian banking sector. First, Norwegian banks compete with foreign banks with branches and subsidiaries in Norway. Second,

[19] The results from the survey suggest that the small banks have the greatest need to invest in digitalisation. 64 percent of the small banks in the survey expect that they will invest more in digitalisation, while only 13 percent of the large banks expect an increase.
[20] According to Finanstilsynet, banks with less than NOK 30 billion in corporate exposures cannot expect permission to use the IRB approach (see Finanstilsynet (2018)).
[21] The board of trustees/supervisory board, which is a savings bank's highest decision-making body, shall comprise customers, employees, public sector representatives and owners, if any.

digitalisation has increased competition from institutions that offer banking services without physical presence. Third, Norwegian banks compete with the bond market to finance firms. Ulltveit-Moe et al concluded that competition from foreign banks has increased, while non-financial enterprises' bond debt had risen less than their bank debt.

The competition indicators from the literature do not provide an unambiguous conclusion on how competition has evolved in the Norwegian banking sector. Foreign banks' market shares and interest margins indicate increased competition (Charts 18 and 19). However, the fall in the interest margin may just as likely be a result of cost cutting as of changes in the competitive environment. For example, the return on total capital has remained at broadly the same level after the banking crisis, which indicates stable competition. Moreover, the Herfindahl Index signals that competition has declined (Chart 20). Tradable debt securities as a share of total debt (Chart 18) and the market shares of the largest banks (Chart 20) suggest that competition has remained relatively stable.

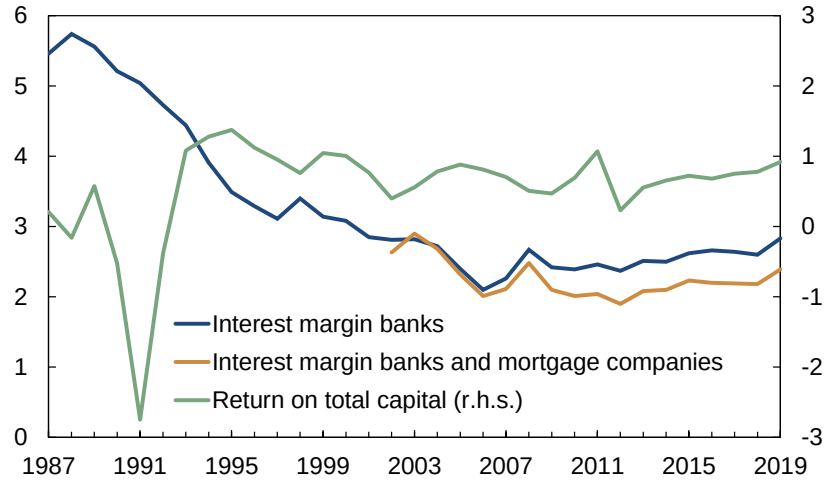
Chart 18 Foreign banks' market share.[1] Tradable debt securities as a share of total domestic debt (C2) owed by the general public. Percent. 1987 – 2019



1) Market share is calculated by each bank's total exposure in Norway.

Sources: Statistics Norway and Norges Bank

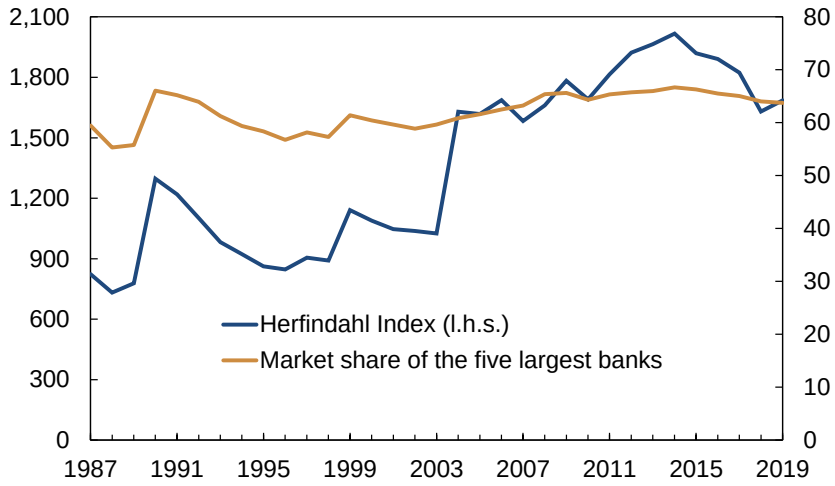
Chart 19 Interest margin and after-tax return on total capital for the Norwegian banking sector.[1] Percent. 1987 – 2019



1) Return on total capital is calculated for all banks and mortgage companies in Norway.

Sources: Statistics Norway and Norges Bank

Chart 20 Herfindahl Index for all banks in Norway and market share of the five largest banks in Norway.[1] 1987 – 2019



1) For more information on the data series, see Appendix 1.

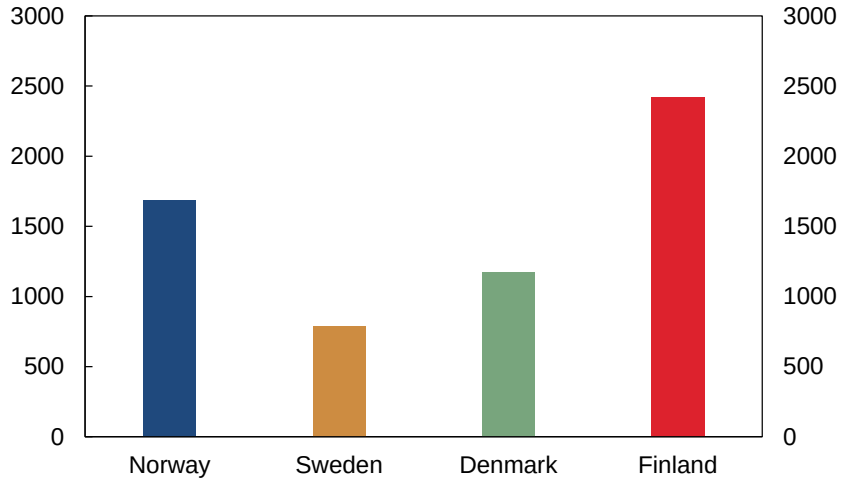
Source: Norges Bank

Competition in the Norwegian banking sector may increase ahead. The Herfindahl Index indicates lower competition in the Norwegian banking sector than in the Swedish and Danish banking sectors (Chart 21), and the majority of the 50 largest banks in Norway fear increased competition in the coming years (see DNB Markets (2020)).[22] Digitalisation may increase competition by making information more easily available, reducing the importance of physical presence and making it easier to switch banks. In addition, PSD2 has

[22] In the DNB Markets' survey, 71 percent of banks responded that their greatest concerns for the next three years were increased competition and pressure on margins.

promoted new services that make it easier to compare the terms of banking services. For example, a number of banks' online banking portals now enable customers to check account information in other banks. This may contribute to increasing competition.

Chart 21 Herfindahl Index for selected Nordic countries.[1] 2019



1) Calculated for credit institutions in Denmark, Sweden and Finland.

Sources: ECB and Norges Bank

4.5. Changes in the importance of business areas

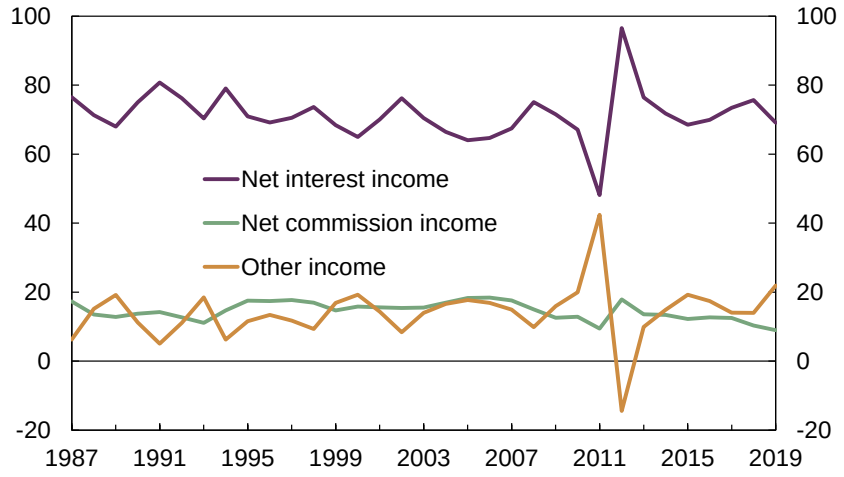
Banks' cost-to-assets ratios may be affected by changes in business areas' relative size. Banks' most important business areas are lending activities, payments and transactions, insurance, estate agency and trading in financial instruments and currencies. Cost-to-assets ratios often vary across business areas. Banks may choose to focus more on a business area with a high cost-to-assets ratio, among other reasons, because the business area's return on equity is high. An example of such a business area may be non-life insurance. In recent years, the cost-to-asset ratios and return on equity of large Nordic non-life insurance companies[23] were higher than those of Norwegian banks.

Banks' income does not indicate any substantial changes in banks' focus on different business areas. Over the past three decades, net interest income, which is primarily generated by lending activity, has accounted for around three-fourths of banks' total operating income (Chart 22). This suggests that the importance of lending activity is broadly the same today as at the end of the 1980s. At the same time, commission income has edged somewhat down over the past decade (Chart 22). This may indicate a slight reduction in the importance of business areas such as insurance, estate agency, payments and transactions, but the decline in this share may also be a result of

[23] Gjensidige Forsikring, Top Danmark, Tryg and Sampo Oyj.

increased competition and pressure on margins. Other income, such as gains and losses on financial instruments, has risen a little.

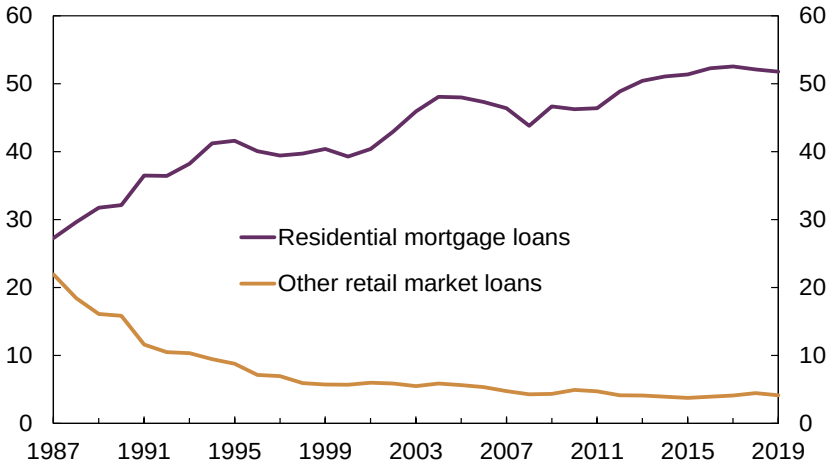
Chart 22 Norwegian banks' income items as a share or total operating income. Percent. 1987 – 2019



Source: Norges Bank

Cost-to-assets ratios may also be affected by changes in the relative size in lending to various sectors and groups of borrowers. Reported data for banks' mortgage companies suggest that the cost-to-assets ratio for residential mortgages loans is lower than for other loans. This may be because residential mortgages are a simpler and more homogeneous product than corporate loans, which makes it easier to automate the credit process for residential mortgages. Chart 23 shows that residential mortgages have accounted for an ever increasing share of banks' total lending. This may explain some of the decline in banks' cost-to-asset ratios. Banks have also automated the credit process for other retail market loans, including consumer credit. However, since 1987, such lending has become less important for banks (Chart 23).

Chart 23 Norwegian banks' residential mortgage and other retail market loans as a share of gross lending. Percent. 1987 – 2019

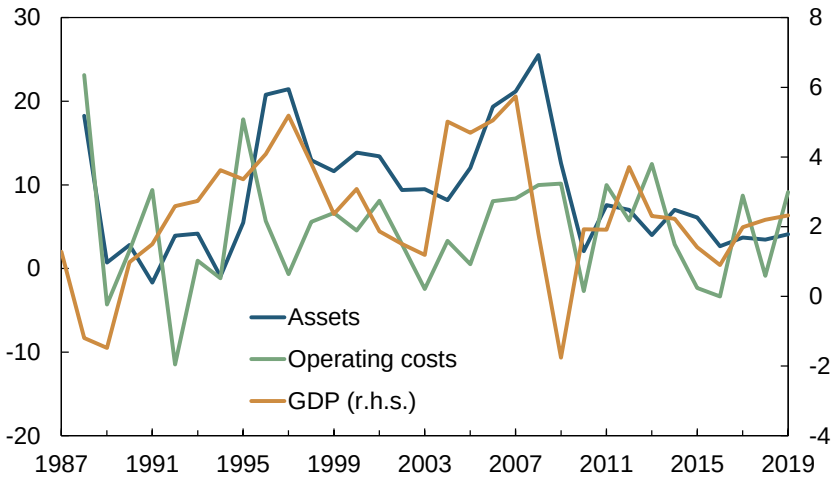


Source: Norges Bank

4.6. Cyclical effects

Cyclical conditions may contribute to short-term fluctuations in banks' cost-to-assets ratios, because both costs and assets are affected by economic activity. In the period 1987-2019, growth in banks' assets was positively correlated with GDP.[24] This suggests in isolation that banks' cost-to-assets ratios should fall in good times and vice versa. The positive correlation may be explained by the fact that demand for banking services tend to be greater in good times. In addition, the range of banking services offered generally increases in good times. In this case, banks' assets grow more, and banks are more able to exploit economies of scale in good times. For example, assets increased by over 10 percent annually both during the upturn at the end of the 1990s and prior to the financial crisis in 2008 (Chart 24). In bad times, the effects may be the opposite. For instance, assets fell by nearly 2 percent during the banking crisis in 1991.

Chart 24 Annual growth in Norwegian banks assets and operating costs. Annual growth in mainland GDP. 1987 – 2019



Sources: Statistics Norway and Norges Bank

Costs may also depend on macroeconomic developments. The correlation between cost and GDP growth is weakly negative in the analysis period.[25] This suggests that banks' cost-to-assets ratios should rise in bad times and vice versa. For example, costs rose by 9 percent in 1991 and by around 10 percent in both 2008 and 2009 (Chart 24), among other reasons on account of higher wage and personnel costs and changes in the value of non-financial assets. High cost growth in bad times may be explained by cost-cutting programmes introduced by banks as a response to weak results, which in the short term results in restructuring costs for banks. For example, a number of banks, such as Credit Suisse, Danske Bank, Deutsche Bank, Handelsbanken, HSBC and Société Générale, have announced cost cuts during the ongoing

[24] The correlation is highest when assets are lagged by two years (0.67).
[25] The correlation between assets and GDP becomes weakly positive when assets are lagged by at least a year.

Covid-19 pandemic. The cost-cutting programmes cover everything from downsizing and office closures to sale or downscaling of operations as well as investment in systems, technology and skills. Such adjustments may reduce costs in the longer term, but in the short term they may result in restructuring costs that keep cost-to-asset ratios elevated. According to Roades (1998), it takes up to three years before banks have realised all of the cost saving from downsizing and other restructuring. An example of this is Handelsbanken's most recent cost-cutting programme. This cost-cutting programme will require IT investment of SEK 1 billion over the next two years (see Handelsbanken (2020)). In addition, the bank is recognising SEK 1.5 billion in charges for anticipated expenses related to downsizing. The bank therefore does not expect the full effect of the cost-cutting programme until 2023. If banks introduce cost-cutting programmes when economic activity is low, restructuring costs may therefore pull up cost-to-assets ratios in bad times. In addition, activity may have picked up before the restructuring results in cost reductions.

Macroeconomic developments can also affect costs if banks' need for labour, office space and other equipment increases with economic activity. For example, both the number of bank offices and employees in finance and insurance increased during the upturns prior to the banking crisis and financial crisis (Chart 5). In addition, resource shortages may result in faster rises in wages, office rents and prices for other factor inputs. In bad times, the opposite may be the case. However, the negative correlation between costs and GDP suggests that such effects are less dominant than effects of restructuring costs.

5. Econometric analysis

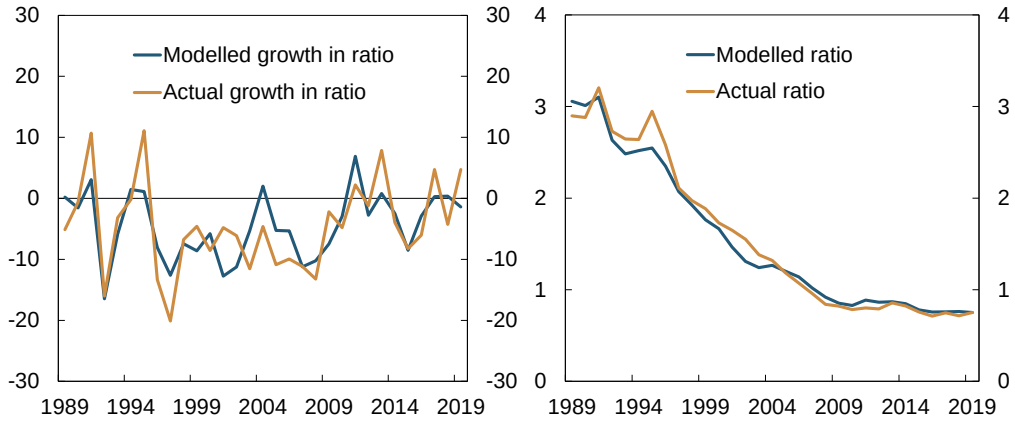
To ascertain the primary drivers of improvements in Norwegian banks' cost efficiency, I model developments in banks cost-to-assets ratios using a number of explanatory variables from the review in Section 4.[26] I follow a procedure where I model the cost-to-assets ratio using a combination of explanatory variables. First, explanatory variables are excluded if the sign of the estimated coefficients does not correspond with theory and evidence in Section 4. Then the least significant variables are excluded sequentially up until the model only contains variables that are significant at a 5 percent significance level.

The preferred model of the cost-to-assets ratio is estimated using annual data from 1987 to 2019 (see Box 1). The model contains effects of automation, digitalisation, regulation and activity level. Several tests indicate that the model is well specified. The error term is stationary[27] and contains neither positive

[26] The explanatory variables are described in Appendix 1.
[27] If the error term is not stationary, the value of the error term will rise or fall over time.

autocorrelation[28] nor heteroscedasticity[29] (see Tables 1-3 in Appendix 2). In addition, the coefficients are stable when estimated recursively (Chart 1 in Appendix 2). With an explanatory power of 55 percent, the model explains a substantial part of developments in the cost-to-assets ratio (Chart 25).

Chart 25 Actual and modelled developments in the cost-to-assets ratio. Percent. 1989 – 2019



Source: Norges Bank

According to the model, automation and digitalisation have played a decisive role in banks' cost-efficiency improvements. Both the share of electronic payment transactions and the share of Norwegians who use the internet daily are included in the estimated model with a significant negative effect. In addition, Engle-Granger cointegration tests show a significant long-term correlation between the cost-to-assets ratio, the share of electronic payment transactions and the share of daily internet users (see Table 4 in Appendix 2). According to the model estimates, increased automation and digitalisation will reduce the cost-to-assets ratio with a one- to two-year lag. There may be a number of reasons why automation and digitalisation reduce the cost-to-assets ratio with a lag. Automation and digitalisation require investment that can keep costs elevated in the short term. In addition, such restructuring may change banks' skill needs. This may help to keep costs high in the short term, eg as a consequence of termination packages and recruitment and training costs.

The model also indicates that more burdensome regulation has contributed to keeping the cost-to-assets ratio elevated. The number of supervisory employees per bank, a proxy for how burdensome the regulations are, are included in the model with a significant positive effect. A number of factors suggest that the costs of regulation have risen (see Section 4.2). In recent decades, the capital adequacy rules have increased in scope and complexity.

[28] If the error term does not contain autocorrelation, the value of the error term in period t will affect the value of the error term in period t+1. The value of the error term will therefore rise over time if the error term contains positive autocorrelation.
[29] If the error term contains heteroscedasticity, the variance in the error term is not constant over time.

In addition, the Norwegian authorities have introduced prudent lending guidelines and requirements and a new Money Laundering Act, among others.

Box 1 Model of banks' cost-to-assets ratio

$$\Delta(costs - total\ assets)_t = 0.02 - \underset{(4.03)}{0.41}\Delta electronic_{t-1}$$

$$-\underset{(3.07)}{0.01}\Delta INTERNET_{t-2} + \underset{(2.53)}{0.51}\Delta regulation_{t-1} - \underset{(2.12)}{1.25}\Delta gdp_{t-2}$$

$R^2 = 0.55.$
$Durbin - Watson\ test = 2.01.$
$Estimation\ period: 1987 - 2019.$
$Estimation\ method: Least\ squares\ method.$

Absolute t-values appear in brackets under the estimates.
R^2 is the share of the variation in the left-side variable that is explained by the model.
Δ is a difference operator: $\Delta X_t = X_t - X_{t-1}$.
The variables are defined as (lower case letters indicate that the variable is measured on a logarithmic scale):

costs	= Total operating costs for all banks and mortgage companies in Norway
total assets	= Total assets of all banks and mortgage companies in Norway. Average total assets for the year in question
electronic	= Number of electronic payment transactions as a share of total debit and credit transfer, payment card and cheque transactions in Norway
INTERNET	= Average share of the Norwegian population using the internet daily. Estimates for 1987-1996
regulation	= Number of Finanstilsynet employees as share of the number of banks
gdp	= GDP for mainland Norway. Volume

According to the model, higher economic activity results in a lower cost-to-assets ratio and vice versa. GDP growth is included in the model with a significant negative effect. A possible explanation is that banks' assets grow more in good times, enabling banks to exploit economies of scale. It may also be because banks adjust to weak results in bad times by downsizing and

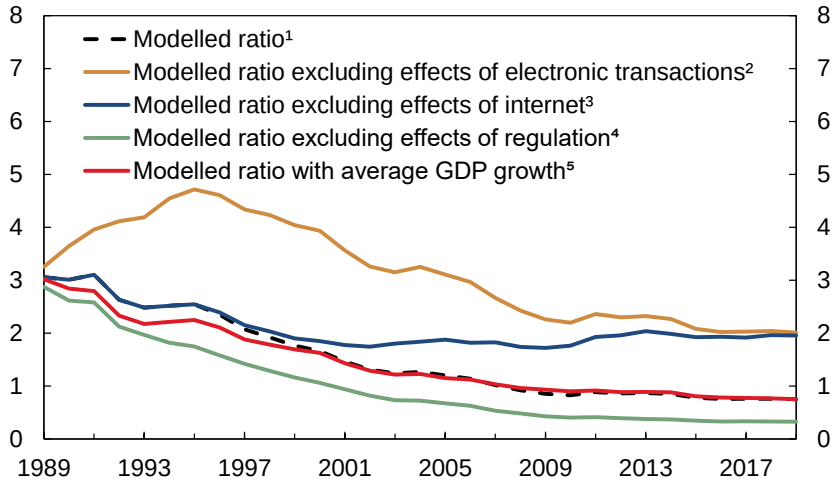
restructuring. Such changes may reduce costs in the longer term, but in the short term they may result in restructuring cost for banks, eg owing to termination packages and investment. In the model, the effect of GDP growth has a two-year lag. This may be because the lagged effect of economic activity on banks' growth and results.

The model does not contain any indicators for competition, economies of scale or the importance of business areas. Nevertheless, the model estimates for digitalisation and economic activity can still capture effects of both economic activity and economies of scale. The explanatory variable for economic activity, ie GDP growth, likely captures economies of scale exploited by banks in good times when they grow considerably. Moreover, digitalisation may have increased the benefits of being large (see Section 4.3). Digitalisation may also increase competition by making information more easily available, reducing the importance of physical presence and making it easier to switch banks (see Section 4.4). Moreover, the estimates suggest that an increase in the share of lending to the retail market, ie changes in the importance of business areas, may have contributed somewhat to the reduction in the cost-to-assets ratio.[30] However, this correlation is not significant at the 5 percent significance level.

According to the model, automation and digitalisation have reduced banks' cost-to-assets ratios considerably, while more burdensome regulation has contributed to keeping costs elevated. Chart 26 shows the modelled cost-to-assets ratio. In addition, the chart shows model estimates excluding the effect of each explanatory variable and actual values for the other explanatory variables. According to the model, automation of payment services was the most important driver of cost-efficiency improvements at the end of the 1980s and much of the 1990s. The model estimates a substantially higher cost-to-assets ratio if we exclude effects of an increasing share of electronic transactions, especially in the second half of the 1990s. The model estimate is also considerably higher in the 2000s, if we exclude effects of increased internet usage. This effect has become increasingly more pronounced over the past two decades. On the other hand, the model estimates a lower cost-to-assets ratio if we exclude effects of more burdensome regulation. The estimates also indicate that the cyclical effects on banks' costs were at their strongest during the banking crisis, when weak economic growth increased banks' cost-to-assets ratios.

[30] The variable is significant at a 10 percent significance level.

Chart 26 Model estimates of banks' operating costs as a share of assets. Percent. 1989 – 2019



1) Calculated with actual values for all explanatory variables.
2) As 1), but with an unchanged share of electronic transactions after 1988.
3) As 1), but with an unchanged share of internet users after 1987.
4) As 1), but with an unchanged number of supervisory employees per bank after 1988.
5) As 1), but with average GDP growth in the period 1987-2017.

Source: Norges Bank

The model shows satisfactory forecasting power compared with a simple AR(1) model[31] and a random walk assumption, ie that growth in the cost-to assets ratio will be the same as in the previous year. In the assessment of forecasting power, I first estimate the models with data up to and including 2009. Then I let the model predict growth in the cost-to-assets ratio for the period 2010-2019 with actual values for the explanatory variables. I use the deviation between actual and predicted growth to assess forecasting power (Table 1). Overall, the preferred model shows considerably lower forecast errors (RMSFE[32]) than the AR(1) model and a "random walk" (Table 1). The preferred model shows the greatest forecast errors for 2013 and 2019. Changes in the value of non-financial assets increased the cost-to-assets ratio in both of these years. Such changes in value can be difficult to foresee, and the model does not contain any variables that measure such effects directly.

[31] $\Delta(costs - total\ assets)_t = constant\ term + \Delta(costs - total\ assets)_{t-1} + \varepsilon_t$

[32] RMSFE (Root Mean Squared Forecast Error) = $\sqrt{\left[\frac{1}{n}\sum_{i=1}^{n}(X_i - Y_i)^2\right]}$, where n er is the number of projected quarters, X_i is actual growth in year i, and Y_i is predicted growth in year i.

Tabell 1 Forecast error (RMSFE) and deviation between actual and predicted growth in the cost-to-assets ratio. Percentage points. 2010 – 2019

	Preferred model	AR(1) model	Random walk
2010	1.8	-1.3	2.6
2011	5.0	-8.4	-7.0
2012	-1.9	-4.8	3.4
2013	-7.3	-14.0	-9.1
2014	-0.1	-1.9	11.8
2015	-1.1	2.1	4.3
2016	2.4	-0.3	-2.2
2017	-5.9	-11.0	-10.7
2018	4.1	-1.7	9.0
2019	-7.2	-10.9	-9.0
RMSFE	**4.4**	**7.4**	**12.1**

Source: Norges Bank

Norges Bank estimates Norwegian banks' costs in an annual stress test of the banks. The preferred model may be useful in this work. With actual values for the explanatory variables, the model estimates that the cost-to-assets ratio will increase from 0.75 percent in 2019 to 0.76 percent in 2020. According to the model, more burdensome regulation will pull up the cost-to-assets ratio, while automation and digitalisation of banking services will pull it down. With GDP growth from the stress test in *Financial Stability Report 2019* and simple assumptions for the other explanatory variables, the cost-to-assets ratio increases to 0.86 percent in 2023.[33] Negative GDP growth in 2020 and 2021 increases the cost-to-assets ratio in the two succeeding years, while automation and digitalisation pull in the opposite direction.

6. Conclusion

Norwegian banks have reduced operating costs substantially in recent decades, both as a share of income and assets. As a result, Norwegian banks' average cost-to-income ratio is the lowest in the entire EEA area.

These cost-efficiency improvements have made Norwegian banks more resilient to higher losses and reduced the risk of costly crises. The developments during the Covid-19 pandemic may be an example of that. Despite higher credit losses, Norwegian banks have turned a profit and have largely maintained credit supply. By comparison, the largest German, Belgian and Italian banks as a whole posted losses in 2020 Q1, even though their credit losses were lower than Norwegian banks'.

Our dataset shows that Norwegian banks have reduced all large cost items relative to assets. Nearly half of the decline in cost-to-assets ratios is due to banks' reduction of wage and personnel expenses relative to assets, which

[33] I project the indicators for burdensome regulation and automation of payment services using average growth for the period 2018-2019. The indicator for internet usage is projected using population projections from Statistics Norway (Chart 10).

primarily reflects a reduction in the number of employees. The decline in the cost-to-assets ratio has been dampened by the average wage of bank employees, which has risen faster than the average wage in Norway. Other operating costs have also fallen relative to assets, among other reasons, as a result of the reduction in the number of bank offices. Increased costs for external services and IT has restrained the decline in cost-to-assets ratios.

To ascertain the primary drivers of improvements in Norwegian banks' cost efficiency, I have estimated a model for developments in the cost-to-assets ratio using a number of indicators from theory and literature. The model explains cost developments well. According to the model, automation and digitalisation have reduced the cost-to-assets ratio, while more extensive and complex regulation have contributed to keeping the cost-to-income ratio elevated. In addition, the results suggest that lower economic activity lowers the cost-to-income ratio and vice versa.

The model estimates indicate that automation and digitalisation of banking services have been decisive for Norwegian banks' cost-efficiency improvements. According to the model, the automation of payment services was the primary driver of the cost-efficiency improvements at the end of the 1980s and much of the 1990s. The model estimates also suggest that the transition to online banking services has been crucial for the cost-efficiency improvements in the past two decades. Internet usage in Norway has grown considerably since the end of the 1990s, and in 2019, the share of online banking users in Norway was the highest in Europe. Online and mobile banking, payment apps and other web-based services have made bank customers more self-sufficient and reduced the need for bank personnel and bank offices. Moreover, digitalisation has also enabled banks to automate other aspects of banking, including customer contact and processing of loan applications. In addition, digitalisation may have increased competition and economies of scale in the banking sector, which may have further contributed to cost-efficiency improvements.

According to the model, automation and digitalisation may contribute to further reductions in cost-to-asset ratios ahead. A number of studies indicate that the banking sector will continue to invest substantially in digitalisation. In addition, the Covid-19 pandemic may further speed up digitalisation, because increasing digital customer contact is an effective containment measure.

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Appendix 1 – Data series

Banks' operating costs	Total operating costs for all banks and mortgage companies in Norway. 1987 – 2019. Annual data. In NOK
Banks' operating income	Total operating income for all banks and mortgage companies in Norway. 1987 – 2019. Annual data. In NOK
Banks' total assets	Aggregate total assets of all banks and mortgage companies in Norway. Average total assets for the year in question. Average total assets for 1987 is estimated using data for the end of January and November 1987. 1987 – 2019. Annual data. In NOK
Banks' return on total capital	Total after-tax profit as a percentage of average total assets for all banks and mortgage companies in Norway. Percent. 1987 – 2019
Banks' size	Average total assets of all banks and mortgage companies in Norway as a share of GDP mainland Norway measured as market value at current prices. 1987 – 2019
Number of banks	Number of banks in Norway. 1982 – 2019
Herfindahl Index for the Norwegian banking sector	Herfindahl Index for all banks in Norway (parent bank data). The index is calculated by summing the squares of banks' market shares in percent. Market shares are measured by total assets. The index generates values between 0 and 10000. 1987 – 2019
Market share of the five largest banks	Market share of the five largest banks in Norway measured by total assets. Percent. 1987 – 2019
Foreign banks' market share	Foreign banks' market share measured by each bank's total exposures in Norway. Percent. 1987 – 2019
Number of ATMs	Number of ATMs in Norway. 1982 – 2019
Number of payment terminals	Number of payment terminals owned by banks and others in Norway. Observations for the period 1991-1993 are estimated using the number of bank-owned payment terminals owing to insufficient data. 1987 – 2019

Share of electronic payments	Number of electronic payment transactions as a share of total debit and credit transfer (giro), payment card (goods purchases) and cheque transactions in Norway. Calculated share does not include payment card transactions prior to 1991. Data for electronic giros prior to 2002 do not include miscellaneous credit transfers, including standing payment orders. 1984 – 2019
Share of persons who have used the internet	Share of a representative sample of the Norwegian population that has used the internet on an average day. 1997 – 2019. Estimates for 1987-1996. The internet was not commercially available in Norway prior to 1993. I therefore assume that the share was 0 up to and including 1993 and that it increased linearly until 1997. Projections for the period 2020-2030 are based on Statistics Norway's population projections (main alternative) and assumptions that the current population will maintain its internet usage and internet usage of new residents will be at the same level as today's younger population cohorts
Share of persons who use online banking	Reported share of respondents to grocery market survey who use online banking services. The survey is conducted by Kantar TNS in collaboration with Finance Norway. 2000 – 2018. The share is approximated by interpolating for the years 2001, 2002, 2004, 2006 and 2007 owing to insufficient observations. From 2019, the share of online banking and mobile banking is reported together
Share of persons using mobile banking	Reported share of respondents to grocery market survey who use online banking services. 2010 – 2018
Number of Finanstilsynet employees	Number of Finanstilsynet employees. 1987 – 2019
GDP	GDP for mainland Norway. Rebased volume. 1971 – 2019
Financial crises	Financial crises in Norway. 1987 – 2019
Share of residential mortgages	Total residential mortgage lending of all banks and mortgage companies in Norway as a share of gross lending. 1987 – 2019

Share of retail market loans	Total retail market lending of all banks and mortgage companies in Norway as a share of gross lending. 1987 – 2019
Share of net interest income	Net interest income of all banks and mortgage companies in Norway as a share of total operating income. 1987 – 2019
Share of net commission incomer	Net commission income of all banks and mortgage companies in Norway as a share of total operating income. 1987 – 2019

Appendix 2 – Documentation of estimations

Table 1 Preferred model

Dependent Variable: D(LOG(COSTS)-LOG(ASSETS))
Method: Least Squares
Date: 09/01/20 Time: 09:33
Sample (adjusted): 1989 2019
Included observations: 31 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.019711	0.023589	0.835583	0.4110
D(LOG(ELECTRONIC_PAYMENT(-1)))	-0.405302	0.100481	-4.033620	0.0004
D((INTERNET(-2)))	-0.010640	0.003462	-3.073715	0.0049
D(LOG(FSA_EMPLOY2(-1)))	0.507363	0.200310	2.532895	0.0177
D(LOG(GDP(-2)))	-1.251506	0.589337	-2.123584	0.0434

R-squared	0.548377	Mean dependent var	-0.045209
Adjusted R-squared	0.478897	S.D. dependent var	0.073678
S.E. of regression	0.053186	Akaike info criterion	-2.883337
Sum squared resid	0.073549	Schwarz criterion	-2.652049
Log likelihood	49.69173	Hannan-Quinn criter.	-2.807943
F-statistic	7.892539	Durbin-Watson stat	2.013578
Prob(F-statistic)	0.000264		

Table 2 Stationarity test

Null Hypothesis: RESIDUAL has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.542469	0.0001
Test critical values:	1% level	-3.670170	
	5% level	-2.963972	
	10% level	-2.621007	

*MacKinnon (1996) one-sided p-values.

Table 3 Heteroscedasticity

Heteroscedasticity Test: Breusch-Pagan-Godfrey
Null hypothesis: Homoscedasticity

F-statistic	0.350527	Prob. F(4,26)	0.8412
Obs*R-squared	1.586203	Prob. Chi-Square(4)	0.8113
Scaled explained SS	0.533479	Prob. Chi-Square(4)	0.9702

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 09/01/20 Time: 09:37
Sample: 1989 2019
Included observations: 31

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.003279	0.001094	2.995875	0.0059
D(LOG(ELECTRONIC_PAYMENT(-1)))	-0.004621	0.004662	-0.991224	0.3307
D((INTERNET(-2)))	-5.51E-05	0.000161	-0.343064	0.7343
D(LOG(FSA_EMPLOY2(-1)))	0.000954	0.009294	0.102690	0.9190
D(LOG(GDP(-2)))	-0.018695	0.027343	-0.683731	0.5002

R-squared	0.051168	Mean dependent var	0.002373
Adjusted R-squared	-0.094806	S.D. dependent var	0.002358
S.E. of regression	0.002468	Akaike info criterion	-9.024405
Sum squared resid	0.000158	Schwarz criterion	-8.793117
Log likelihood	144.8783	Hannan-Quinn criter.	-8.949011
F-statistic	0.350527	Durbin-Watson stat	2.086990
Prob(F-statistic)	0.841248		

Table 4 Cointegration test

Cointegration Test - Engle-Granger
Date: 09/11/20 Time: 11:04
Equation: ENDELIG
Specification: LOG(COSTS)-LOG(ASSETS) ELECTRONIC_PAYMENT INTERNET(-1) C
Cointegrating equation deterministics: C
Null hypothesis: Series are not cointegrated
Automatic lag specification (lag=0 based on Schwarz Info Criterion, maxlag=7)

	Value	Prob.*
Engle-Granger tau-statistic	-3.683002	0.0942
Engle-Granger z-statistic	-19.53273	0.0763

*MacKinnon (1996) p-values.

Intermediate Results:	
Rho - 1	-0.610398
Rho S.E.	0.165734
Residual variance	0.003684
Long-run residual variance	0.003684
Number of lags	0
Number of observations	32
Number of stochastic trends**	3

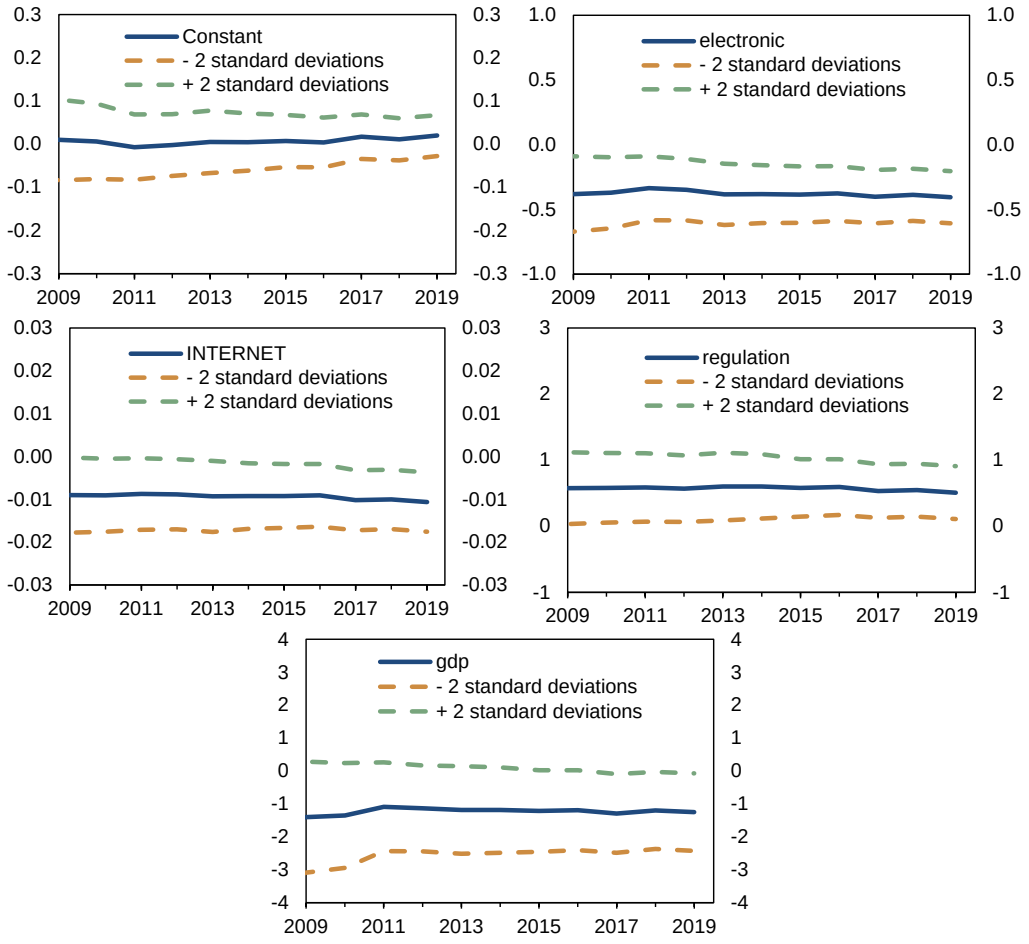
**Number of stochastic trends in asymptotic distribution.

Engle-Granger Test Equation:
Dependent Variable: D(RESID)
Method: Least Squares
Date: 09/11/20 Time: 11:04
Sample (adjusted): 1988 2019
Included observations: 32 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESID(-1)	-0.610398	0.165734	-3.683002	0.0009

R-squared	0.302192	Mean dependent var	0.004010
Adjusted R-squared	0.302192	S.D. dependent var	0.072657
S.E. of regression	0.060694	Akaike info criterion	-2.735196
Sum squared resid	0.114196	Schwarz criterion	-2.689392
Log likelihood	44.76313	Hannan-Quinn criter.	-2.720013
Durbin-Watson stat	1.852265		

Chart 1 Recursive coefficient estimates. 2009 – 2019



Source: Norges Bank