STAFF MEMO

A Heatmap for Monitoring Systemic Risk in Norway

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A Heatmap for Monitoring Systemic Risk in Norway*

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Abstract

We develop a tool to monitor systemic risk in Norway's financial system. In particular, we construct 39 indicators capturing a wide range of financial vulnerabilities and organise them under three broad classes of vulnerabilities: risk appetite and asset valuations, non-financial sector imbalances and financial sector vulnerabilities. We track their evolution over time using ribbon heatmaps and construct summary indicators. By including a broad set of indicators, the heatmap is better able to capture the complex set of factors that are associated with the financial cycle and a wide range of risks and vulnerabilities. The heatmap signals the build-up of risks in the Norwegian financial system leading up to the banking crisis in Norway (1988-93) and the financial crisis (2008-09). Furthermore, an analysis of the relationship between different components of the heatmap suggests that increases in risk appetite and asset valuations tend to foreshadow increases in imbalances in the non-financial sector, as well as higher leverage and exposure to funding risks in the banking system. Several heatmap indicators also tend to lead standard measures of imbalances used by policymakers such as the credit-to-GDP gap. Providing early and broad-based signals of risks, the heatmap can therefore serve as a useful input for macroprudential policy.

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1 Introduction

Monitoring of risks to financial stability has taken centre stage since the onset of the financial crisis of 2008-09. A host of models and tools have been developed to monitor financial stability risks and inform the calibration of different macroprudential tools. The crisis has also led to important changes in the global regulatory landscape with the adoption of stronger capital and liquidity requirements for banks and greater emphasis on macroprudential policies (Basel Committee on Banking Supervision (2010b)). Although Norwegian banks fared better during the financial crisis compared with their counterparts in the US and Europe, they nevertheless faced significant challenges in terms of liquidity management and increased funding costs. Financial conditions tightened considerably, as also reflected in composite indicators of systemic stress.[1] After the crisis, capital and liquidity requirements were gradually tightened in Norway and a countercyclical capital buffer was introduced in 2013.[2]

Against this backdrop, we develop a monitoring tool to capture the build-up of vulnerabilities and systemic risk in the Norwegian financial system. The objective of our monitoring tool is not to predict the timing of a crisis per se, but to identify underlying vulnerabilities that may predispose the system to a crisis. We concentrate our efforts on measuring cyclical/time-varying movements in risk factors and to a lesser extent on structural features of the financial system and the associated risks.

We construct 39 indicators and group them under three broad classes of vulnerabilities following the framework of Aikman et al. (2017): risk appetite and asset valuations, non-financial sector imbalances and financial sector vulnerabilities. We track the evolution of these indicators over time using ribbon heatmaps and construct summary indicators. Our choice of indicators is guided by an extensive theoretical and empirical literature on systemic risk and early-warning models. We use a broad set of indicators to provide more information on emerging risks, which can be highly complex and therefore often cannot be reduced to a single indicator. This also ensures that the monitoring tool is robust to risks that could emerge in different risk segments and sectors of the economy or the financial system.[3]

[1] A composite indicator of systemic stress (CISS) for Norway increased significantly during this period. See Wen (2015) for more details.

[2] The countercyclical capital buffer was introduced to strengthen banks' resilience to an economic downturn by building up higher capital buffers when financial imbalances are building up and reducing the capital buffer to counter excessive fluctuations in the credit supply that could amplify the economic cycle in a downturn. See Norges Bank (2013).

[3] Norges Bank has previously developed a monitoring tool (the cobweb model) that also uses a broad

The broad coverage of the indicators requires care in interpreting the heatmap and in constructing summary indices given that different indicators tend to behave differently over the financial cycle. For example, while some indicators function as leading and coincident indicators of stress (e.g. bond spreads), others only function as leading indicators (e.g. credit gap indicators). The heatmap aims to capture the build-up phase of financial vulnerabilities, and hence we concentrate on the early-warning properties of our indicators.

The monitoring tool provides useful insights into the evolution of financial stability risks in Norway over time. Many risk components in the heatmap were elevated prior to the Norwegian banking crisis of 1988-1993 as well as the financial crisis of 2008-09. Elevated real estate prices, higher risk appetite and a build-up of risks in the non-financial private sector were observed leading up to both crises. Banks had also become more reliant on wholesale funding and on funding from foreign sources.

During the period following the global financial crisis, there has been an improvement in several risk factors. However, vulnerabilities in the housing segment have re-emerged in recent years, and household leverage and banks' exposure to the housing sector increased. Other risk factors that have increased during this period include vulnerabilities related to banks' connectedness with other domestic financial institutions and foreigners[4] and potential risks from strong growth in non-bank credit to the private sector.

An analysis of the relationship between different components of the heatmap yields interesting insights related to the financial cycle in Norway. We find that increased risk appetite and elevated asset prices (especially in real estate) tend to precede higher credit growth and indebtedness in the non-financial private sector and increased vulnerabilities in the banking system related to leverage and exposure to funding risks. We also find two-way linkages between non-financial sector imbalances, especially those related to the household sector, and banking system leverage and funding vulnerabilities.

The heatmap developed in this paper may be a useful input for macroprudential policy in Norway, supporting the assessment of risks and vulnerabilities. For example, the heatmap can be a useful complement to the four key indicators used in the decision basis for the countercyclical capital buffer (CCB).[5] First, by utilising a broader set of

set of indicators. This model was used for a period of time to illustrate risks in Norges Bank's *Financial Stability Report*. See Dahl et al. (2011) for a discussion.

[4]Foreigners include foreign financial institutions and customers.

[5]The four key indicators are aggregate credit-to-GDP gap, house price-to-household disposable income gap, commercial property price gap and wholesale funding ratio gap. See Norges Bank (2013) for more details.

indicators, it can provide insight into the sources of risks emerging in different sectors. Second, we find that many indicators in the heatmap help predict some of these key indicators (such as the credit-to-GDP gap) and hence can provide even earlier warning signals.

The paper proceeds as follows. In the next section, we summarise the related literature on measuring systemic risk, financial cycles and early-warning models. In Section 3, we present the overall structure of the monitoring tool, provide a detailed description of the indicators and describe the construction of the ribbon heatmap. We present our results in Section 4 and outline our main conclusions in the last section.

2 Related Literature

The financial crisis of 2008-09 highlighted the importance of understanding the role the financial system plays in amplifying shocks to the real economy[6] and the mechanisms behind boom-bust cycles in credit.

An extensive literature on early-warning models prior to the financial crisis has identified a range of leading indicators that are good predictors of banking and currency crises (Frenkel and Rose (1996), Kaminsky et al. (1998), Kaminsky and Reinhart (1999), Demirguc-Kunt and Detragiache (1998), Demirguc-Kunt and Detragiache (2000), Detragiache and Spilimbergo (2001)). This early literature was motivated by the emerging market crises in the 1990s and emphasised the role of macroeconomic indicators, and the nexus between external sector imbalances, financial liberalisation and credit.[7] The global financial crisis fuelled new analysis on the leading sources of vulnerabilities in the financial system. For example, Reinhart and Rogoff (2008) and Reinhart and Rogoff (2009) have argued that the 2008-09 financial crisis in the US had similarities to previous banking crises. An asset price boom, increased debt accumulation and high current account deficits were preceded by financial innovation and liberalisation.[8] A series of papers emphasised the rapid increase in household debt in setting the stage for the crisis

[6] For example, the financial accelerator mechanism discussed in Bernanke et al. (1996) implies that standard credit market frictions, such as asymmetric information, cause the financial system to propagate real shocks through its procyclical effects on investors' net worth and the countercyclical movements in the external finance premium. See Borio et al. (2001), Kashyap and Stein (2004), Adrian and Shin (2010a), Adrian and Shin (2010b) and Hanson et al. (2011) for more on the pro-cyclicality of the financial system.

[7] It is some time since the central role of credit booms in financial crises was first identified in the literature. See Minsky (1972) and Kindelberger (1978).

[8] Reinhart and Rogoff (2008) argues that while in the US there has been no major de jure liberalisation, the de facto liberalisation related to the increased importance of lightly regulated financial entities in the financial system has played an important role in the crisis.

in the US and the resulting debt overhang as a key mechanism in understanding the weak macroeconomic recovery since then. (Eggertsson and Krugman (2012) and Mian et al. (2013)).

Systemic studies of financial crises that have emerged since the global financial crisis have indeed identified credit booms as the leading predictor of crises (Schularick and Taylor (2012), Dell Ariccia et al. (2012)). Jordà et al. (2013) show that financial crises preceded by credit booms are also more costly than other crises, suggesting an important link not only between credit booms and the probability of a crisis but also between credit booms and the costs associated with a crisis. Several papers by the Bank for International Settlements have also proposed an important role for credit indicators in anchoring countercyclical capital buffers (Drehmann et al. (2011), Drehmann et al. (2014)), building upon earlier studies on banking crises (Borio and Lowe (2002), Borio and Lowe (2004)).

Other papers have highlighted the importance of going beyond aggregate credit indicators in early-warning models. For example Giese et al. (2014) discuss the conceptual importance of including the level of leverage, its sectoral composition, the sources of funding and credit quality. Behn et al. (2013) conclude that using a broader set of early-warning indicators improves the ability of policymakers to predict financial crises. Drehmann et al. (2012a) find an important role for debt service costs as an early-warning indicator (especially in the short-run), emphasising the fact that when debt service costs are high, even small shocks to income or interest rates can lead to higher macroeconomic volatility. Anundsen et al. (2016) find significant effects of bubble-like behaviour in housing and credit markets, especially when they coincide with high household leverage.

Several papers have emphasised the funding of credit booms as an important determinant of financial vulnerabilities. For example, Hahm et al. (2013) find empirical evidence suggesting that measures of non-core liabilities contain valuable information about financial vulnerabilities in both advanced and emerging market economies. Shin and Shin (2011) present similar evidence, suggesting that non-core liabilities (funding sources other than retail deposits) can serve as a measure of the stage in the financial cycle and vulnerability to contagion. A related literature has explored the relationship between capital flows, external imbalances, and financial stability. An important conclusion from this literature is that while persistently large net capital flows and current account positions could provide useful signals, gross flows and positions are likely to be more relevant from a financial stability perspective.[9] Finally, there has also been empha-

[9]See Acharya and Schnabl (2010), Borio and Disyatat (2011), Jordà et al. (2011), Obstfeld (2012)

sis on financial institutions' leverage as a key indicator. Barrell et al. (2010) find that higher capital adequacy and liquidity ratios have significant effects on crisis probabilities in a sample of OECD countries. Jordà et al. (2017) find that the equity ratio does not have strong predictive power in signalling financial crises, but that it has a significant effect on the severity of the crisis.

A related strand of the literature has focused on characterising financial cycles. The financial cycle is often characterised by swings in credit growth, asset prices, terms of access to external funding, and other financial developments.[10] Early work in this area has highlighted the co-movement of medium-term cycles in credit and property prices as the defining characteristic of the financial cycle (Claessens et al. (2011), Drehmann et al. (2012b), Aikman et al. (2015)). These papers find that cycles in financial variables tend to be distinct from business cycles and have a lower frequency. They also find that financial cycles' duration and amplitude have increased since the mid-1980s and become more synchronous across countries. Finally, Rey (2013), Miranda-Agrippino and Rey (2015) and International Monetary Fund (2017) highlight the importance of global financial cycles in driving domestic financial cycles.

Finally, several studies have explored the signalling properties of different indicators using Norwegian data. Using data going back to 1819, Riiser (2005) finds that house prices, equity prices, as well as investment and credit developments are useful in predicting past banking crises in Norway. The same indicators are found to be useful in signalling vulnerabilities using quarterly data since 1970 (Riiser (2012)). Finally, Gerdrup (2003) finds that the boom periods that preceded the three banking crises in Norway (1899-1905, 1920-28 and 1988-92) were characterised by significant bank expansion, high asset price inflation and increased indebtedness.

3 The Methodology

This section provides a detailed description of the overall structure of the heatmap, the indicators used and the construction of the heatmap.

3.1 Structure

Across policy institutions, it is possible to find a range of different approaches to constructing monitoring tools for the financial system (Appendix A). While the heatmap

and references therein for a useful discussion on global imbalances, financial flows and financial stability.

[10] See Borio (2012) for a discussion of the financial cycle and its role in macroeconomic dynamics.

we present in this paper shares important similarities with the tools used in other policy institutions in terms of its overall structure, it follows more closely the heatmap constructed in Aikman et al. (2017) for the US. In their framework, vulnerabilities are organised around three broad categories:

1. **Risk appetite and asset valuations:** As in the stylised systemic risk framework of Adrian et al. (2015), the price of risk falls and risk-taking increases as economic and financial activity expands, resulting in elevated asset prices and more credit intermediation. A lower price of risk can increase vulnerabilities in the financial system, generating higher leverage, maturity transformation and connectedness. Elevated asset prices can also increase vulnerabilities in the financial system, especially if these assets also serve as collateral.

2. **Non-financial sector imbalances:** Imbalances in the non-financial sector (such as excessive leverage and high debt service burdens) can be an important source of vulnerability for the financial system. Vulnerabilities can amplify the effects of an adverse shock to income or to the interest rate, leading to a severe recession.

3. **Financial sector vulnerabilities:** Vulnerabilities in the financial sector can be related to: a) increased leverage, which implies lower buffers to absorb losses in a downturn; b) maturity transformation and exposure to funding shocks that could generate fire sales and losses as well as a sharp contraction in financial institutions' balance sheets; and c) higher connectedness and concentration, which implies stronger amplification of shocks through spillovers and potential contagion effects.

Figure 1: Structure of Heatmap

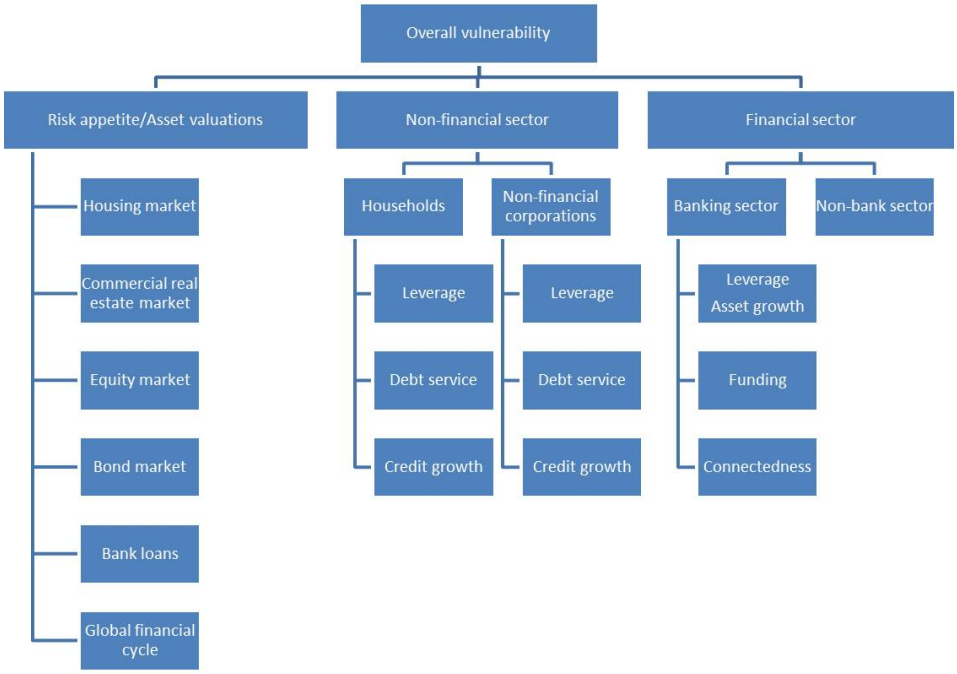


Figure 1 provides a broad summary of the overall structure of the monitoring tool. Under the first category (risk appetite and asset valuations), the heatmap features six components, concentrating on important asset markets such as housing, commercial real estate, equity and bond markets. The bank loans component aims to capture risk appetite as reflected in the pricing of bank loans and credit standards. We also include measures of the global financial cycle as a component, given potentially important links between the domestic financial system and global financial conditions.[11] Under the second category, we have six components, reflecting risks from leverage, debt service as well as high credit growth for households and non-financial corporations (NFCs) separately. Components under the third category capture different types of risks and vulnerabilities in the financial system, mainly related to the banking system. In addition, a seperate component on the non-bank financial system is included to capture developments in this growing segment of the financial system.[12] There is therefore a clear mapping of the different types of risks and the components in the heatmap.

[11] See Rey (2013), Miranda-Agrippino and Rey (2015) and International Monetary Fund (2017) for more cross-country evidence on the importance of the global financial cycle for domestic financial conditions.

[12] The banking system refers to banks and mortgage companies, while non-banks include money market funds, other mutual funds, insurance companies, pension funds, state lending institutions and finance companies.

3.2 Indicators

Our choice of indicators in the heatmap is guided to a large extent by the previous empirical and theoretical literature on measuring risks in the financial system as well as previous studies on Norway's financial system and previous crises. In this subsection, we describe in more detail the indicators used in the heatmap and the rationale for their inclusion. In Appendix B, we present figures that summarise the composition of the heatmap in terms of the type of indicators (e.g. price indicators, quantity indicators) and the type of risks captured (e.g. credit risk, funding risk). In Appendix C, we provide further details for all the indicators including data sources and sample period.

De-trending: Several heatmap indicators are de-trended, reflecting the fact that they are expected to have time-trends that could be considered sustainable from a financial stability perspective.[13] For example, the credit-to-GDP ratio is typically used in terms of its deviation relative to a long-run trend. The rationale for this is the idea that some degree of financial deepening is normal and expected to happen alongside increasing access to finance by a broader group of borrowers. An important challenge is estimating this sustainable trend for different indicators, and as of now there are no widely-accepted structural models or tools.[14]

We use the one-sided HP filter augmented by a simple forecast of the indicator as in Gerdrup et al. (2013) and a smoothing parameter (λ) of 400,000 in all of our baseline results.[15] Using the HP filter to detrend the credit-to-GDP ratio has performed well in signalling crises (Drehmann et al. (2010)), and the smoothing parameter can be selected appropriately to reflect the long nature of financial cycles. However, as a purely statistical technique, the HP filter cannot capture the sustainable level of a given indicator. Statistical methods are also constrained by the short time-series available for many indicators, making it difficult to have reliable estimates of the trend and cycle given that financial cycles tend to be longer than business cycles. Another common trend estimate is a simple backward-looking moving average of the indicators, spanning a long time period. We therefore also repeat our estimates using the 10-year moving average as an alternative de-trending method.[16]

[13] We use judgment based on economic reasoning in determining whether to use different indicators in levels or gaps relative to a trend.

[14] A notable exception is the recent work on structural models for the credit gap as in Lang and Welz (2017)

[15] See Hodrick and Prescott (1997). The method separates a time series into a cyclical and a trend component, and the smoothness of the trend is determined by the parameter λ. The higher the value of λ, the higher is the degree of smoothing of the trend.

[16] Some papers have explored using simple transformations of credit indicators (such as the change in

Risk appetite and asset valuations: As mentioned earlier, under the first category we aim to capture risk appetite and valuation pressures in different asset and credit markets. Housing constitutes an important share of household wealth and its major role as collateral makes it important in assessing vulnerabilities in the financial system. Under this category, we track the ratio of the house price index to disposable income per capita and the ratio of housing investment to mainland GDP. Both indicators are de-trended to account for structural changes in the economy and the housing market.[17] Figure 2(a) shows that both indicators have been at elevated levels prior to previous crises in Norway. Commercial real estate constitutes a considerable share of bank loans in Norway. Valuation pressures and excessive risk-taking in this market could therefore have important financial stability implications.[18] We use developments in real commercial property prices (Figure 2(b)) relative to a long-run trend and changes in banks' credit standards as our indicators for this component.

Equity and bond markets are important markets for corporations to raise funding. Signs of increasing risk appetite in these markets can be captured through elevated asset valuations and low interest rate spreads. Elevated valuations in equity and bond markets can also lead to a sharp correction later on and hence be a source of market risk for financial institutions. We use the real equity price index relative to a trend to capture valuation pressures and the price-to-earnings ratio to capture risk appetite in the equity market. Figure 2(c) shows that both indicators increased sharply prior to the financial crisis of 2008-09. For the bond market we use spreads for investment grade corporations and banks (senior bonds). As shown in Figure 2(d), bond spreads were compressed prior to the financial crisis, potentially signalling higher risk appetite. We also track interest rate spreads for bank loans[19] (Figure 2(e)) and a survey-based measure of changes in credit standards to capture risk appetite in bank lending. Banks' lending margins were relatively low prior to the Norwegian banking crisis (1988-93) and the financial crisis (2008-09), suggesting an increase in risk appetite and a potential easing of lending standards.

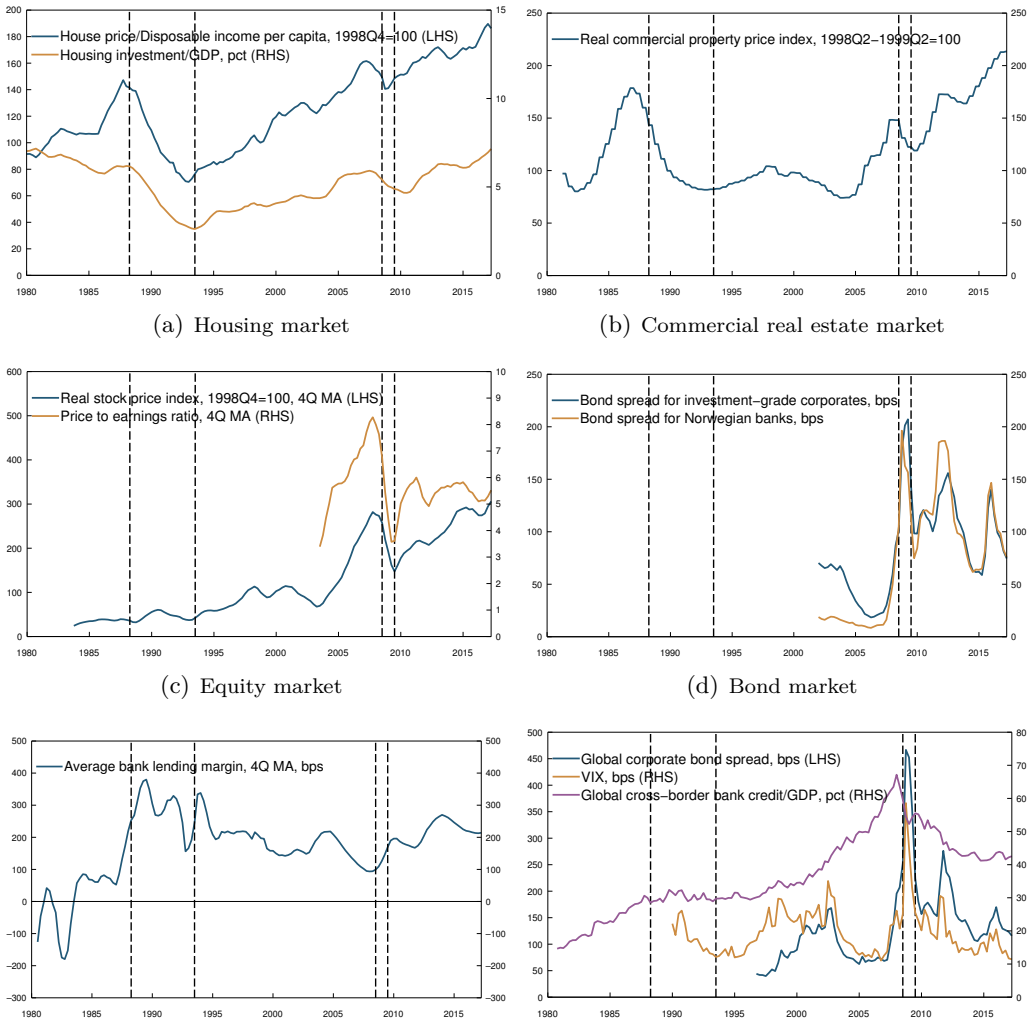
credit-to-GDP ratio over a certain period) as opposed to the HP filter in early-warning models and have found more significant prediction power (e.g. Klaus et al. (2017)).

[17] For example, a decline in the neutral interest rate can push up the price of housing relative to income.

[18] In their analysis of bank losses during financial crises in Norway and in other countries, Kragh-Sørensen and Solheim (2014) find that the main cause of bank losses has been property-related corporate lending and in particular commercial property loans.

[19] We use the average for loans to households and non-financial corporations.

Figure 2: Selected raw indicators: Risk appetite and asset valuations



(a) Housing market (b) Commercial real estate market

(c) Equity market (d) Bond market

(e) Bank loans (f) Global financial cycle

Sources: Eiendomsverdi, Finn.no, Norwegian Association of Real Estate Agents (NEF), Real Estate Norway, OPAK, Dagens Næringsliv, Thomson Reuters, Bloomberg, DNB Markets, BIS, OECD, Statistics Norway and Norges Bank.
Dashed lines indicate the Norwegian banking crisis of 1988Q2-1993Q3 and the financial crisis of 2008Q3-2009Q3.
See Appendix C for a detailed description of all raw indicators.

Finally, we use the VIX index and an average of the investment-grade corporate bond spreads in the US and in Europe as measures of global risk appetite under the global financial cycle component.[20] These measures are highly correlated and both declined

[20] Danielsson et al. (2016) find that episodes of unusually low volatility tend to be followed by credit build-ups, suggesting more risk taking.

considerably prior to the financial crisis of 2008-09. We also complement these price-based indicators with a measure of the global cross-border bank credit-to-GDP ratio relative to a long-run trend from the BIS. Figure 2(f) shows that global cross-border bank credit increased significantly prior to both crises, which suggests that the domestic financial cycle could in part be driven by common or global factors.

Non-financial sector imbalances: In this category we capture vulnerabilities in the household and non-financial corporate sectors related to leverage, debt service and high credit growth.[21] For households we capture risks related to leverage through the ratio of household credit to GDP (Figure 3(a)) relative to a long-run trend (household credit gap). The household credit gap signals periods of sustained and large increases in leverage, which is typically associated with higher credit risk and has been a good predictor of financial crises.[22] Under debt service risks, we aim to capture risks from high debt burdens that can lead households to cut consumption or default on their loans when faced with adverse shocks (for example to income or lending rates).[23] For households we use the debt service ratio (i.e. interest and amortisation payments relative to after-tax disposable income) to capture these risks. High credit growth signals rising imbalances in the household sector, which are captured in our heatmap through three indicators: growth in real credit to households relative to a long-run trend, households' net lending relative to disposable income (with a negative sign) and a survey-based measure of the change in households' credit demand. Episodes of higher growth in real credit could signal lower lending standards and tends to result in higher leverage in the future. A low level of net lending could also be associated with potentially unsustainable trends in consumption. Figure 3(b) shows that both prior to the Norwegian banking crisis and the financial crisis, net lending declined, coinciding with higher growth in real credit and reversed sharply with the onset of the crisis.[24] Finally, we include the survey-based indicator on household credit demand under this category. Even though the time series

[21] See Dahl and Vatne (2012) for a detailed summary of the evolution of aggregate debt in Norway, its composition and how it has been funded over time.

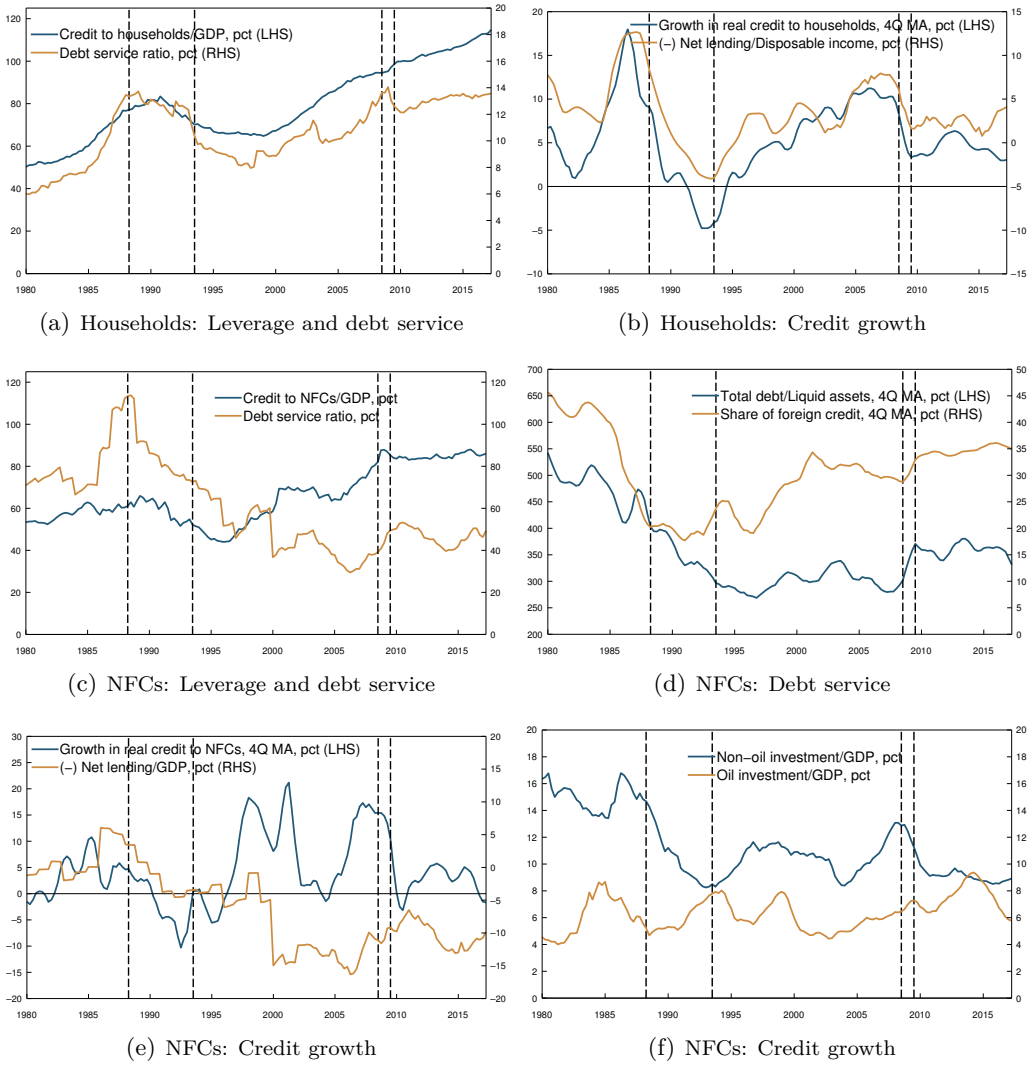
[22] It is important to note that while it would have been preferable to also include indicators that capture the distribution of debt using micro data (for example median debt burden) and the quality of credit (for example loan-to-value measures), such indicators are released with a long time lag and are usually available at an annual frequency. See Lindquist et al. (2014) for different indicators of vulnerabilities for the household sector using household-level data.

[23] Using household-level data, Lindquist et al. (2016) find that a considerable portion of household consumption expenditure (about 15-20 percent) depends on access to new borrowing. Therefore if households were constrained from taking on new debt, this could significantly affect households' ability to maintain their level of consumption.

[24] Riiser (2009) points to important differences in the behaviour of different groups of households in terms of net lending.

for the indicators from the Norges Bank's bank lending survey are relatively short, they are the only indicators that can give some indication as to whether credit growth is driven by demand versus supply factors.

Figure 3: Selected raw indicators: Non-financial sector imbalances



(a) Households: Leverage and debt service

(b) Households: Credit growth

(c) NFCs: Leverage and debt service

(d) NFCs: Debt service

(e) NFCs: Credit growth

(f) NFCs: Credit growth

Sources: IMF, Statistics Norway and Norges Bank.
Dashed lines indicate the Norwegian banking crisis of 1988Q2-1993Q3 and the financial crisis of 2008Q3-2009Q3.
See Appendix C for a detailed description of all raw indicators.

For non-financial corporations (NFCs), we use similar indicators as for the household sector to capture risks related to leverage and debt service. Figure 3(c) shows a steady increase in the aggregate NFC credit-to-GDP ratio from the mid-1990s, but the debt

service ratio has trended downward since the highs reached during the banking crisis.[25] Figure 3(d) shows two additional indicators we use to capture debt service risks: the ratio of corporate sector debt to liquid assets and the share of foreign credit. Both indicators declined during the early part of our sample from historically high levels. While non-financial corporations currently have larger financial buffers based on the ratio of corporate sector debt to liquid assets, there has been a deterioration since the global financial crisis of 2008-09. In the case of foreign credit share, it is important to note that this indicator also reflects inter-company loans, which can shift over time with changes in the corporate structure, tax treatment of inter-company debt and the composition of the corporate sector.[26] We therefore detrend this indicator to capture potential changes over time in the foreign credit share. Finally, we capture risks associated with high credit growth through growth in real credit relative to a long-run trend, net lending relative to disposable income and deviations in the private sector investment to GDP ratio relative to its trend (for non-oil and oil sectors separately) (Figures 3(e-f)). We include the latter two indicators to capture potential credit risks associated with investment booms. Finally, a survey-based measure of the change in credit demand is included in this component of the heatmap, following a similar rationale as for the household sector.

Financial sector vulnerabilities: Under banking system vulnerabilities, we capture risks related to leverage through the equity ratio (equity divided by assets) with a negative sign, and the growth in assets using the ratio of banking system assets to GDP and total loans to domestic customers to GDP (Figures 4(a-b)). The latter two indicators are measured in gaps relative to a long-run trend. The equity ratio of Norwegian banks was relatively low and declining leading up to the Norwegian banking crisis and the financial crisis. We also observe a sharp increase in total assets and loans leading up to the financial crisis. For potential vulnerabilities related to funding risks we use the wholesale funding ratio and loan-to-deposit ratio relative to a long-run trend (Figure 4(c)). These two indicators move together over time and have tended to increase prior to previous crises in Norway. Foreign liabilities of the banking system are included to capture vulnerabilities related to both funding risks and connectedness. This indicator tends to move in tandem with the wholesale funding ratio, reflecting the important role of foreign funding in the total market funding of Norwegian banks.[27] Other indicators to

[25] See Hjelseth and Raknerud (2016) for a model of corporate debt at risk using micro data.

[26] For example, inter-company lending could be more prevalent in certain sectors.

[27] For a small open economy like Norway, it is important to include indicators that capture potential vulnerabilities related to external imbalances and capital inflows. We use foreign liabilities of the banking and corporate sectors to capture potential vulnerabilities related to gross external positions.

capture the connectedness of the banking system include the share of claims on foreigners (relative to a trend), the claims of banks on other financial institutions as a share of their total assets and the share of bank bonds held by the non-bank financial system (Figures 4(d-e)).[28] Risks related to connectedness were elevated leading up to the Norwegian banking crisis and some of the indicators we track have trended down during the 2000s. However, it is important to note that the heatmap indicators capture connectedness only through direct balance sheet exposures between banks and other financial institutions. A recent literature on fire sale spillovers emphasises indirect spillovers through common asset holdings during financial distress episodes (Cont and Schaanning (2017)).[29]

We also try to capture risks related to concentration through total exposures of the banking system to real estate, where we include banks' mortgage loans to the retail market, loans to real estate companies and construction, as well as banks' holdings of covered bonds issued by other banks (Figure 4(e)). This indicator is also expressed relative to a trend to capture cyclical developments in concentration. We concentrate on real estate given its prominent role in bank and household balance sheets. We see that exposures to the real estate market increased steadily before declining somewhat during the financial crisis. Since then, the real estate exposures of banks have started to increase again, driven by increased mortgage lending to the retail market as well as a sharp increase in holdings of covered bonds.

Finally, to capture risks related to the non-bank financial sector we use the ratio of total non-bank financial system assets to GDP and credit provided to the private sector by non-banks, both expressed relative to a long-run trend (Figure 4(f)). Our motivation for including indicators for non-banks is to capture the role of this growing segment of the financial system in credit creation and to provide a more comprehensive measure of the financial cycle.[30] The size of the non-bank financial system in Norway has increased over time, and at a faster pace since 2003. Private sector credit provided by the non-bank financial sector as a share of GDP has also increased in recent years, but remains much lower than its level prior to the Norwegian banking crisis. This reflects in part the changing composition of non-bank financial institutions in credit intermediation. A

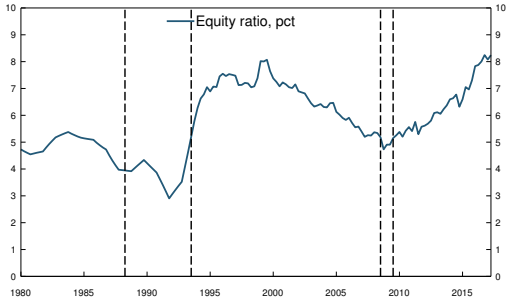
[28] See Lind (2016) for a detailed discussion of banks' exposures to other financial institutions and the importance of the covered bond market.

[29] Norwegian banks' holdings of covered bonds have been identified as a source of vulnerability in this context. See Bakke et al. (2010) for more on the covered bond market in Norway and potential financial stability risks.

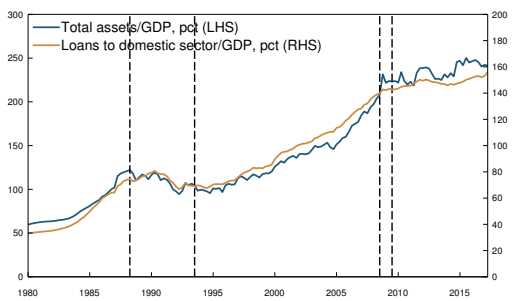
[30] While it would be important to also capture different risks faced by non-banks, given the diverse nature of non-bank financial institutions (in terms of business model and composition of balance sheets) it would be difficult to realistically capture such risks using only a few indicators.

significant share of the private sector credit provided by non-banks in the 1980s reflects the lending activities of state lending institutions. In the latter part of the sample, pension and insurance funds have become more important.

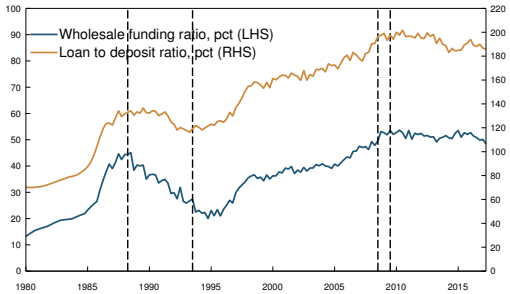
Figure 4: Selected raw indicators: Financial sector vulnerabilities



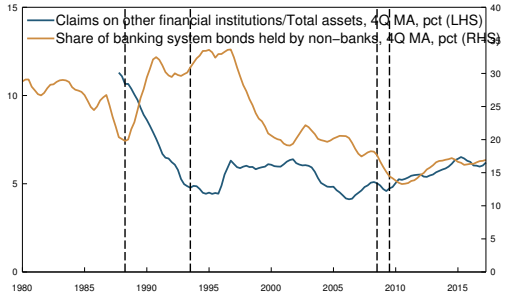
(a) Banking sector: Equity ratio[1)]



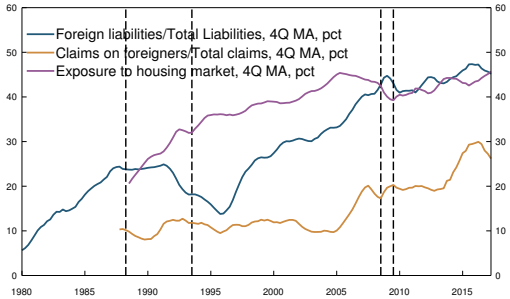
(b) Banking sector: Growth in assets



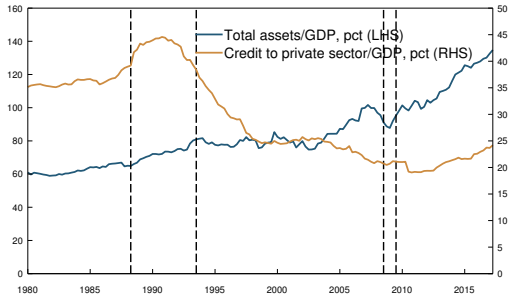
(c) Banking sector: Funding[1)]



(d) Banking sector: Connectedness



(e) Banking sector: Connectedness and concentration[2)]



(f) Non-bank sector

1) Equity ratio and wholesale funding ratio exclude foreign branches and subsidiaries.
2) Claims on foreigners excludes claims of foreign branches operating in Norway and Nordea, but includes claims of branches of Norwegian banks outside of Norway.
Sources: Statistics Norway, OECD and Norges Bank
Dashed lines indicate the Norwegian banking crisis of 1988Q2-1993Q3 and the financial crisis of 2008Q3-2009Q3.
See Appendix C for a detailed description of all raw indicators.

3.3 Constructing the Heatmap

The first step in constructing the heatmap involves transforming each raw indicator such that a high value indicates a higher risk of imbalances unravelling. We then standardise these transformed raw indicators to be able to map them into a common colour-coding scheme. There are several options for standardising indicators with different scales. We follow the same method as in Hollo et al. (2012) and normalize each indicator into the range (0,1] on the basis of its empirical cumulative distribution function (empirical CDF).[31] We apply the following two steps:

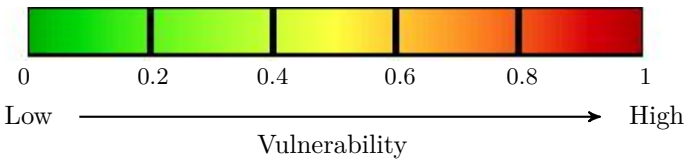
1. First, each indicator is normalised based on its empirical CDF. For each time series (x_1,x_2,...,x_t,...,x_N) the quarterly observations of the indicator are ranked in ascending order from the lowest to the highest ($x^1 \leq x^2 \leq ... \leq x^r \leq ... \leq x^N$), where N is the total number of observations, the subscript t denotes time and the superscript r refers to the ranking number assigned to a particular realisation of x_t. The normalised indicator z_t is then constructed on the basis of the empirical CDF:

$$z_t = F_N(x_t) = \begin{cases} \frac{r}{N} & for \quad x^r \leq x_t < x^{r+1}, \quad r = 1, 2, ..., N-1 \\ 1 & for \quad x_t \geq x^N \end{cases}$$

   The normalised indicator z_t measures the share of observations that are less than or equal to x_t. If a normalised indicator equals 0.3, this means that 30% of the historical values are less than or equal to x_t. Similarly, the highest values of the indicator will take on the normalised value of 1.

2. Next, the normalised indicators are mapped to the colour bar in Figure 5.

Figure 5: Colour bar indicating vulnerability

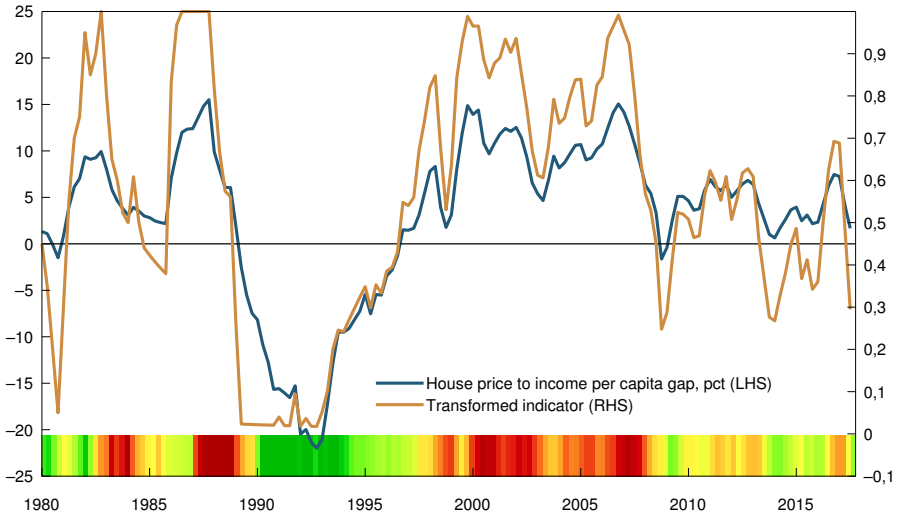


[31] While there are other alternatives to standardise indicators (for example using the mean and the standard deviation of the series), we opt for using empirical CDFs given that they are more robust to outliers than some of the other standardisation methods.

The normalised indicators are calculated both recursively (i.e. using an expanding sample) and using the full sample.[32] The recursive calculation allows us to evaluate the performance of each indicator in quasi real-time.[33] It also means that at each point in time the empirical CDF is not affected by later observations. Using the full sample in normalising the indicators has the advantage that it allows us to interpret the level of different indicators relative to the whole sample. For example, it would be possible to compare the current level of a given normalised indicator with its previous peaks. The recursive and full sample approaches yield the same results for the last observation.

Figure 6 demonstrates steps 1-2 using the house price to disposable income per capita gap as an example. The colour shading on the bottom moves from green (low risk) to dark red (high risk) as the normalised indicator moves from 0 to 1. As the first five years of data are used to initialise the indicator, the normalised indicator is not constructed recursively for that time period.

Figure 6: Data transformation: An example using house price to disposable income per capita gap (recursive)



Sources: Eiendomsverdi, Finn.no, Norwegian Association of Real Estate Agents (NEF), Real Estate Norway, Statistics Norway and Norges Bank.

[32] For further details on how we normalise the indicators recursively based on an expanding sample see Hollo et al. (2012).

[33] The recursive calculation does not reflect a real-time assessment as it does not account for potential data revisions.

4 Results

4.1 Heatmap Indicators

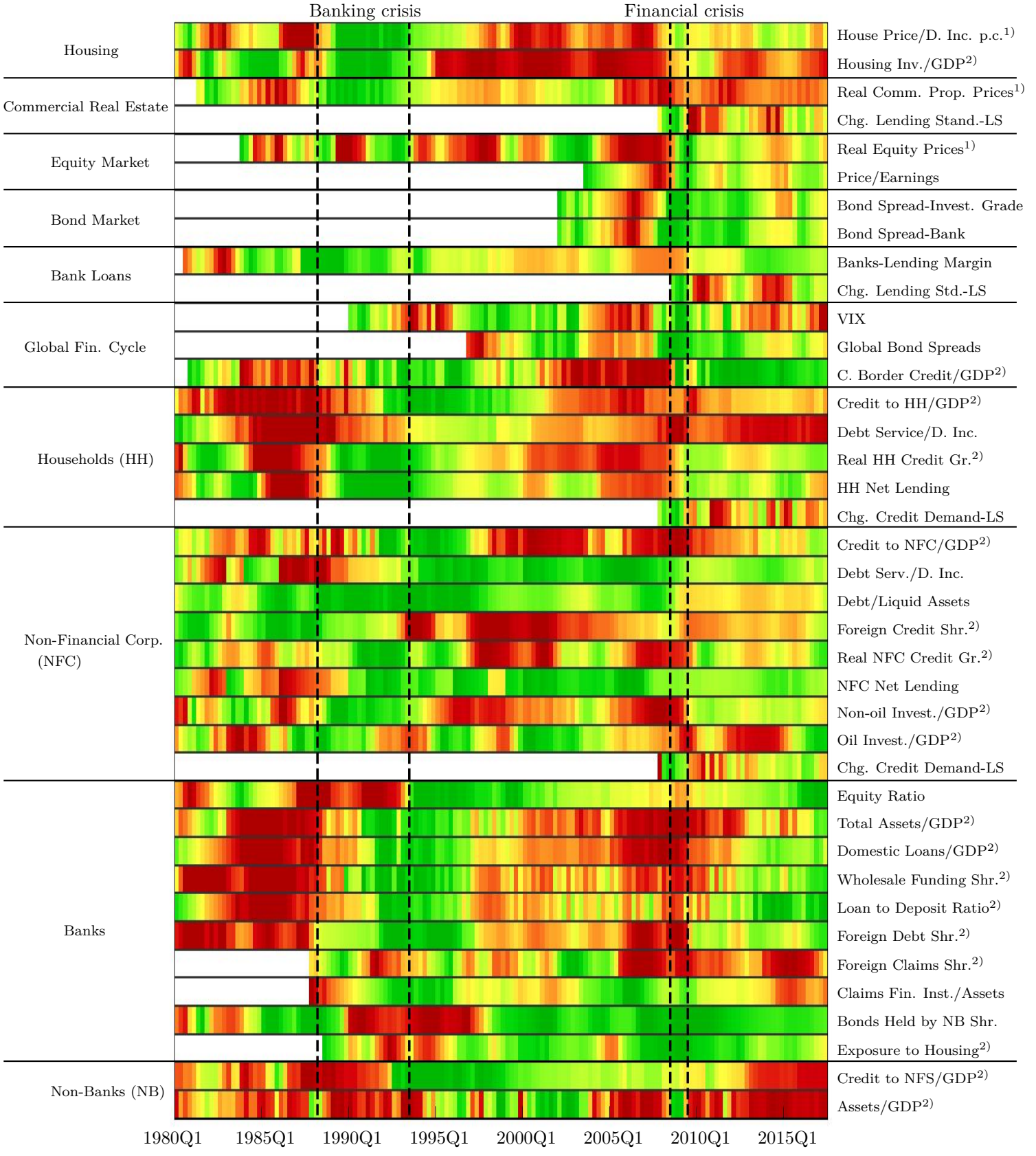
Figures 7 and 8 present the heatmap indicators using recursive and non-recursive approaches respectively. The indicators are organised around different components of vulnerabilities discussed in Section 3. This subsection discusses developments in heatmap indicators leading up to the Norwegian banking crisis of 1988-93 and the financial crisis of 2008-09 as well as more recent developments.

Norwegian banking crisis (1988-1993)

Assessing the quasi real-time performance of the heatmap indicators for the period leading up to the banking crisis is made difficult by the short time series. Bearing this caveat in mind, the heatmap shows vulnerabilities in the housing market, preceded by elevated asset valuations in the commercial real estate and equity markets. Higher risk appetite has been identified as an important element in the banking crisis driven by the financial deregulation of the mid-1980s and banks' immediate focus on capturing market shares (Moe et al. (2004)). This can be seen in banks' lending margins, which were fairly low during this period (Figure 8). The household sector also shows significant vulnerabilities related to leverage, debt service capacity and a sharp deterioration in net lending. The non-financial corporations segment shows high risks related mainly to debt service (for example debt service-to-disposable income) and credit growth. The debt-to-liquid assets indicator shows up as green, giving misleading results in the recursive assessment since this indicator was on a downward trend, but from historically high levels. The non-recursive assessment (Figure 8) reflects that in retrospect, this indicator shows a relatively high level of vulnerability during this period. If we look at the banking sector indicators, it is possible to see the deterioration in banks' equity ratio and the increasing reliance on market funding, some of which seems to have been driven by foreign funding.[34] Finally, we observe a rise in private credit provided by non-banks and an overall growth in their assets during this period.

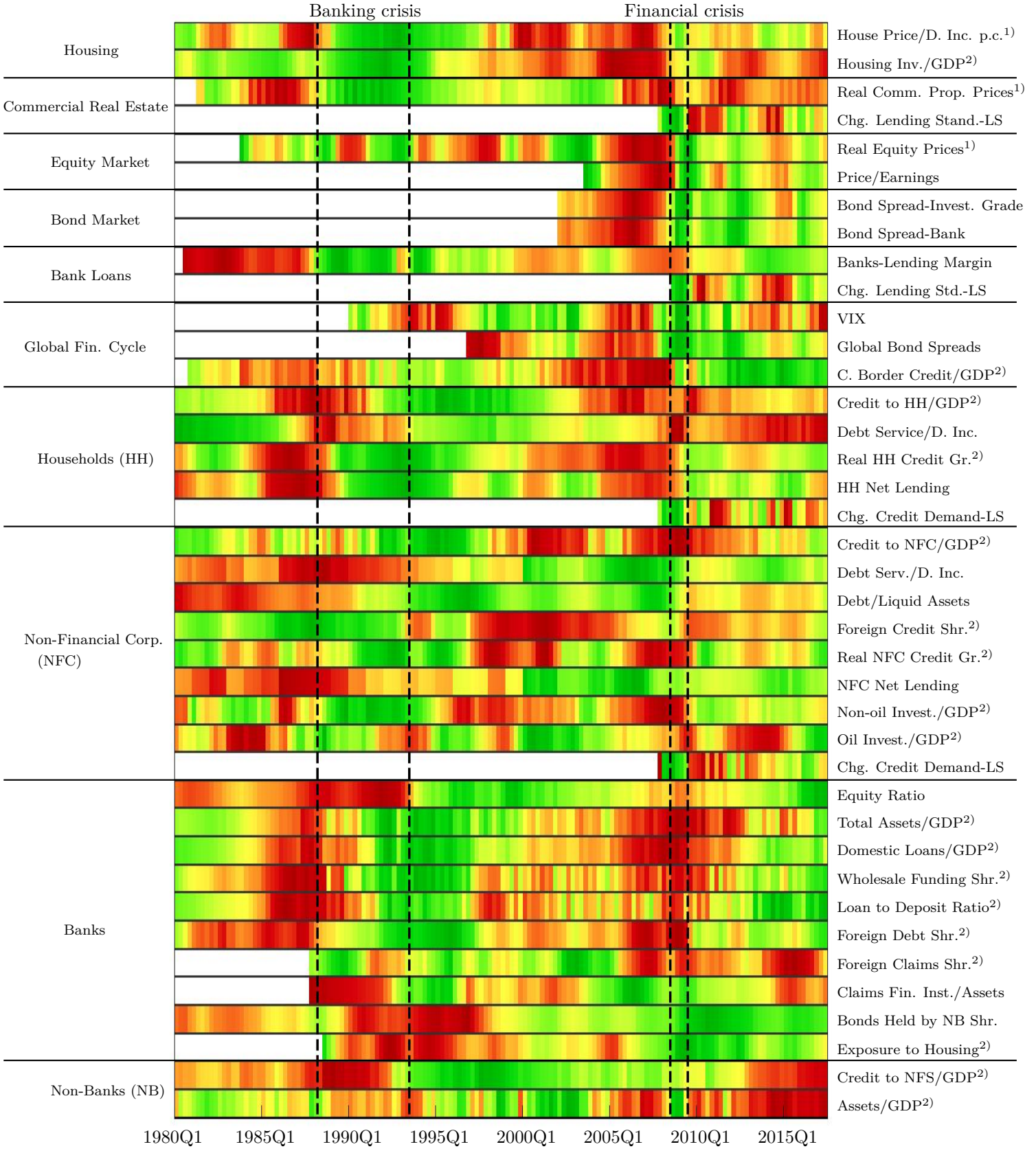
[34] See Figure 4(e).

Figure 7: Heatmap: Recursive 1980Q1-2017Q2



1) Deviation from estimated trend. Percent. The trend is estimated using a one-sided Hodrick-Prescott filter estimated on data augmented with a simple projection. Lambda = 400,000.
2) Deviation from estimated trend. Percentage points. The trend is estimated using a one-sided Hodrick-Prescott filter estimated on data augmented with a simple projection. Lambda = 400,000.
Sources: Eiendom Norge, Norwegian Association of Real Estate Agents (NEF), Finn.no, Eiendomsverdi, OPAK, Dagens Næringsliv, Thomson Reuters, Bloomberg, DNB Markets, OECD, BIS, Statistics Norway and Norges Bank.

Figure 8: Heatmap: Non-recursive 1980Q1-2017Q2



1) Deviation from estimated trend. Percent. The trend is estimated using a one-sided Hodrick-Prescott filter estimated on data augmented with a simple projection. Lambda = 400,000.
2) Deviation from estimated trend. Percentage points. The trend is estimated using a one-sided Hodrick-Prescott filter estimated on data augmented with a simple projection. Lambda = 400,000.
Sources: Eiendom Norge, Norwegian Association of Real Estate Agents (NEF), Finn.no, Eiendomsverdi, OPAK, Dagens Næringsliv, Thomson Reuters, Bloomberg, DNB Markets, OECD, BIS, Statistics Norway and Norges Bank.

Financial crisis (2008-09)

Leading up to the financial crisis of 2008-09, we are in a better position to assess heatmap indicators as we have observed a full cycle for many of them. Looking at the recursive assessment, we can see many indicators signalling higher risks. The housing sector showed signs of strong growth in asset valuations and investment. We also observe rising vulnerabilities related to elevated asset valuations and risk appetite in other segments including commercial real estate, equity and bond markets, bank loans and the global financial cycle. Higher vulnerabilities due to elevated asset valuations and risk appetite were accompanied by rising vulnerabilities with respect to households' leverage, deterioration in debt service capacity and high credit growth. For the non-financial corporations, we observe strong credit growth relative to GDP; however, debt-to-equity ratio and debt service risks have remained low. Looking at banking system indicators we observe some deterioration in banks' equity ratios, a strong growth in balance sheets and lending to the domestic sector (consistent with increasing credit to the non-financial sector). Liquidity indicators have also deteriorated during this period, as a higher share of market and external funding was used to finance the increased credit growth to the domestic economy. In terms of connectedness and concentration risks, we observe higher exposures to foreigners and a pick up in the share of real estate-related lending. Finally, the pre-financial crisis period also coincides with strong growth in non-bank balance sheets.

Developments since the financial crisis

In the immediate aftermath of the financial crisis, we observed declining vulnerabilities in some segments (for example, certain risk appetite indicators, asset valuations in the housing and equity markets and global financial cycle indicators). This is expected as price indicators tend to adjust more quickly in the face of financial stress. A similar picture emerges for indicators that capture credit growth, developments in private investment and net lending as these indicators are related to the flow of credit, which also tends to adjust more quickly. We observe a more gradual improvement in certain leverage indicators such as credit to households and non-financial corporations as a share of GDP, which reflects both persistent stock effects and the slowdown in GDP growth. It is important to note that the household credit-to-GDP gap remains relatively high, reflecting continued growth in household debt. When we look at debt service risks (especially for households), we actually see rising risks in the post-financial crisis period. This re-

flects the fact that credit growth has been stronger than household income growth.[35] For non-financial corporations, debt service-to-income and debt-to-liquid asset ratios have also deteriorated somewhat and there has been increasing reliance on foreign funding.

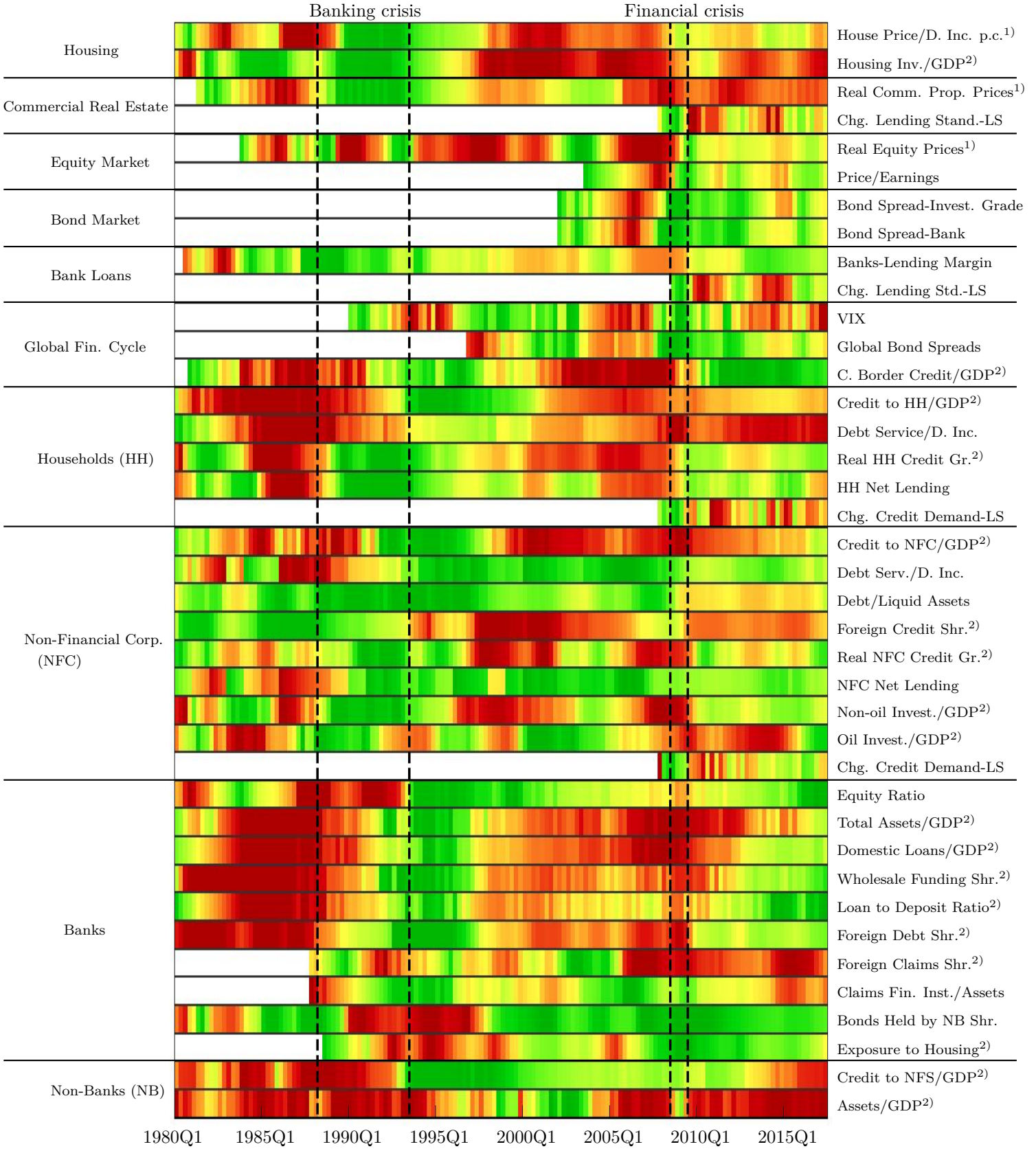
An important development since the financial crisis was the re-emergence of risks in the housing segment. Housing investment and prices have picked up after a brief slowdown and commercial real estate prices have continued to increase sharply. This may have played a role in pushing up credit growth and is also reflected in a further increase in concentration risks. Under the banking sector indicators, we observe a gradual and steady improvement in equity ratios, driven in part by regulatory efforts to step up capital requirements. In terms of bank leverage and market funding risks, we also observe an improvement (in terms of gaps) as these indicators have stabilised, albeit at historically high levels. Banks' connectedness with other domestic financial institutions and with foreigners has increased somewhat during this period as well. Finally, we observe an increase in risks related to the non-bank sector driven by strong growth in credit to the private sector from non-banks and their total assets. This reflects in part the substitution of bank financing by bond financing by non-financial corporations as a consequence of Norwegian banks' adjustment to higher capital requirements.

Sensitivity analysis of de-trending methods

As mentioned earlier, many indicators in the heatmap are expressed relative to a time-varying trend. In our baseline results we presented figures using the one-sided HP filter (with a smoothing parameter of 400,000). In Figure 9, we present a version of the heatmap using the 10-year moving average as the trend for the applicable variables. Comparing the results from the 10-year moving average and the HP filter, we observe that heatmap indicators have broadly similar movements over time, although using the 10-year moving average generates more persistent and somewhat higher vulnerabilities.

[35] It is also important to note that while the credit-to-GDP gap will stabilise around zero when credit grows at the same pace as nominal GDP for a while, the debt service-to-income ratio will stabilise at a high level if credit growth has outstripped nominal GDP growth in the past.

Figure 9: Heatmap: Recursive (10-year moving average) 1980Q1-2017Q2



1) Deviation from estimated trend. Percent. The trend is estimated using a one-sided Hodrick-Prescott filter estimated on data augmented with a simple projection. Lambda = 400.000.
2) Deviation from estimated trend. Percentage points. The trend is estimated using a one-sided Hodrick-Prescott filter estimated on data augmented with a simple projection. Lambda = 400.000.
Sources: Eiendom Norge, Norwegian Association of Real Estate Agents (NEF), Finn.no, Eiendomsverdi, OPAK, Dagens Næringsliv, Thomson Reuters, Bloomberg, DNB Markets, OECD, BIS, Statistics Norway and Norges Bank.

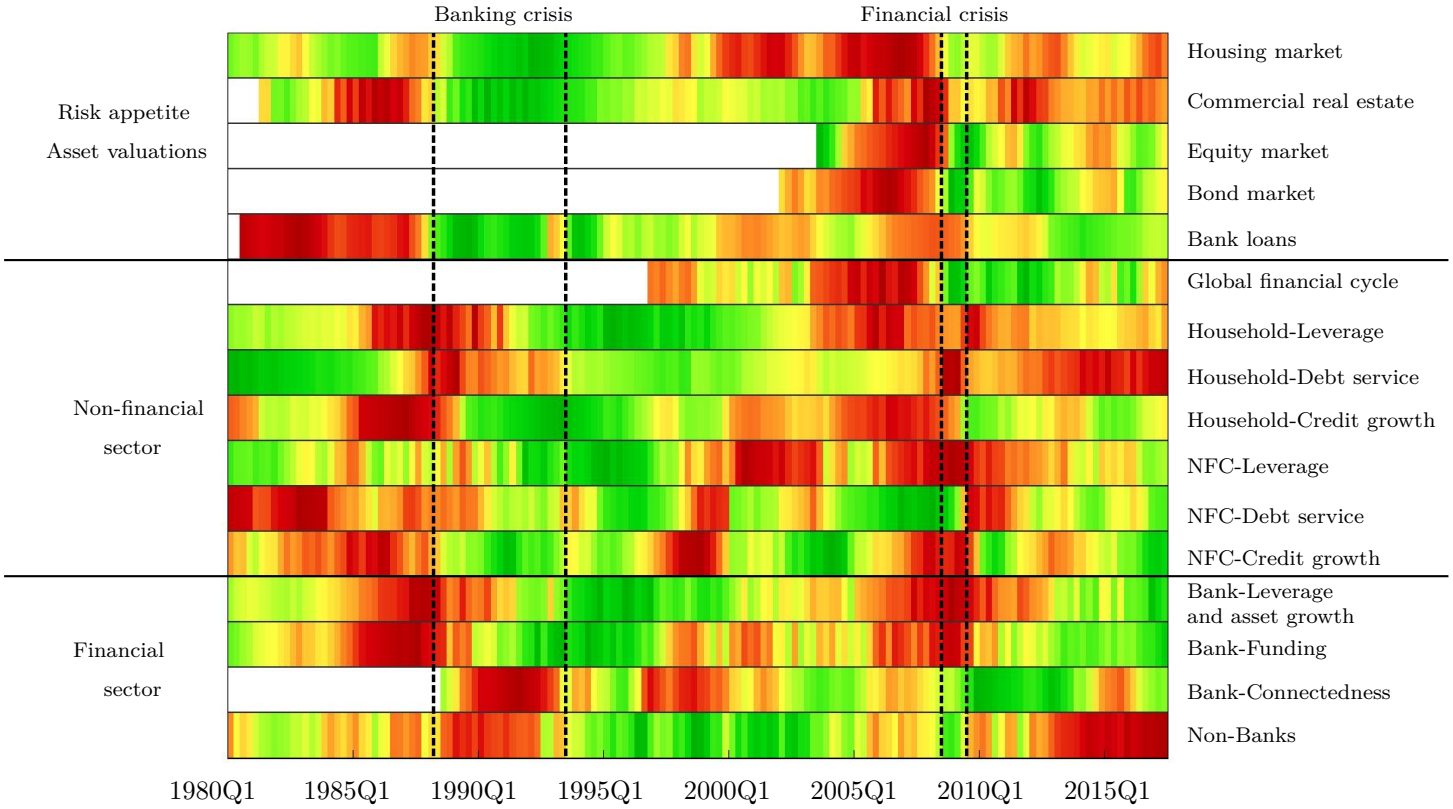
4.2 Summary indicators

Figure 10 shows heatmap indicators organised around different components discussed in Section 3 and using the non-recursive approach. The summary indicators are constructed by averaging normalised individual indicators under each component and normalising these averages again. To ensure that we have a consistent summary indicator for each component, we only use the sample for which we have all the indicators under that component. Given that the Norges Bank's bank lending survey only started in 2007Q4 and hence can significantly limit the availability of our summary indicators, we do not include these survey indicators in constructing the summary indicators.

The summary heatmap offers a coherent visual summary of the information contained in heatmap indicators and can be a useful starting point in the assessment of risks and vulnerabilities. Given the more limited set of summary measures available for the pre-banking crisis period, we concentrate on the period leading up to and following the financial crisis in our discussion of results.

The summary heatmap shows a persistent increase in risks related to the housing market leading up to the financial crisis. Risks in other markets such as commercial real estate, bond markets and equity markets have also increased during this period, coinciding with higher global risk appetite. Non-financial sector imbalances, especially related to households, were also elevated during this period (risks related to leverage, debt service and credit growth). Looking at the risks in the banking system, we observe an increase in leverage and asset growth, and higher exposure to liquidity/funding risks. Other risk components, namely connectedness and risks related to non-bank financial system, also increased. Since the financial crisis, we observe a gradual decline in several risk components related to the financial sector. In other risk components such as asset valuations (housing, commercial real estate), the household sector and non-bank financial system, vulnerabilities remain high.

Figure 10: Summary heatmap: Non-recursive 1980Q1-2017Q2



Sources: Eiendom Norge, Norwegian Association of Real Estate Agents (NEF), Finn.no, Eiendomsverdi, OPAK, Dagens Næringsliv, Thomson Reuters, Bloomberg, DNB Markets, OECD, BIS, Statistics Norway and Norges Bank.

4.3 Relationship between heatmap indicators

As the next step in our analysis, we explore how different components of the heatmap relate to each other, including the lead/lag relationships using cross-correlations and Granger-causality tests. This is useful in interpreting developments in different components of the heatmap and can also offer useful insights for characterising the financial cycle in Norway. Table 1 shows the bilateral contemporaneous correlations between heatmap indicators that are organised around different components.[36] Only the correlations that are higher than or equal to 0.3 are highlighted with colours ranging from yellow to red as the level of correlation increases from 0.3 to 1.[37]

[36] We use the heatmap indicators constructed using the non-recursive approach in these calculations.

[37] The sample period for different pairs of indicators are different, reflecting the fact that some indicators have a shorter sample.

Three main observations stand out. First, indicators under risk appetite and asset valuations tend to display higher correlations with each other. Although this segment of the heatmap features developments in different asset classes, it suggests that changes in risk appetite and asset prices tend to move in tandem over time. Second, indicators under risk appetite and asset valuations tend to be highly correlated with vulnerabilities in the non-financial sector. This is particularly relevant for indicators capturing risks related to high household credit growth. Third, indicators under non-financial sector imbalances and indicators capturing risks related to the banking system tend to be highly correlated. This is intuitive given that strong credit growth and leverage in the non-financial sector can lead to higher growth in bank assets, a more leveraged banking sector and higher reliance on wholesale funding.

We also consider the relationship between heatmap indicators at different leads and lags using cross-correlations and Granger causality tests.[38] Tables 2 and 3 show the cross-correlations between heatmap indicators at four and eight quarters. For example the first row in Table 2 shows the correlation between house price-to-disposable income per capita gap and the four-quarter leads of all the heatmap indicators. We only highlight the pairs of indicators that a) have a relatively high cross-correlation (defined as higher than 0.3) and; b) have an increasing cross-correlation (defined as a cross-correlation higher than the contemporaneous correlation between the same pair of indicators). Therefore, if the house price-to-disposable income per capita gap was leading other indicators in the heatmap, the first row would be highlighted and show the degree of cross-correlation. As mentioned above, we also run bilateral Granger causality tests for a more formal econometric test of the lead/lag relationships between different indicators.[39] Table 4 indicates whether different indicator pairs Granger-cause each other. The red/green colour is used if the indicators on the vertical/horizontal axis Granger-cause the indicators on the horizontal/vertical axis and not vice versa.[40] The yellow colour is used if both indicators Granger-cause each other. Finally, the white colour is used if neither of the two indicators Granger-cause the other one. Two observations stand out when we consider the relationship between different groups of indicators:

[38] It is important to note that correlation does not necessarily imply causation. Nevertheless, looking at correlations between different indicators at different leads and lags offers useful information about the relationships between different components of the heatmap.

[39] Granger causality tests also provide information on the level of significance in assessing lead/lag relationships between different indicators.

[40] We conduct the Granger causality tests based on a bi-variate vector autoregression with four lags of both variables. P-values that suggest significance at the 10 percent level or higher are considered.

1. ***Indicators that capture risk appetite and asset valuations tend to lead indicators in other categories.*** This can be seen by the relatively large number of highlighted cells in the first group of rows in Tables 2 and 3 and the large number of red cells in the first group of rows in Table 4. Looking at different components under risk appetite/asset valuations, the housing market segment tends to lead indicators related to private sector leverage (captured by credit gaps), credit growth and debt service. This could be explained by the fact that housing market indicators reflect higher house prices and investment activity, which can increase credit growth due to both direct and indirect effects (e.g. higher collateral valuations). It is interesting to note that for the house price indicator (i.e. the first indicator), the Granger causality tests suggest a two-way relationship with household credit growth and debt service. This is consistent with the notion that there are feedback effects between credit growth and asset valuations, which has also been documented in Anundsen and Jansen (2013). Commercial real estate prices also feature a strong relationship with imbalances in the non-financial sector and in particular the non-financial corporate segment. Bond market indicators (bond spreads) and banks' lending margins tend to lead imbalances in the non-financial sector, but also vulnerabilities related to bank leverage and exposure to funding risks. This is intuitive as bond spreads and lending margins may contain signals for both the demand and the supply of credit. Finally global financial cycle indicators tend to lead some indicators under non-financial sector imbalances and also as expected tend to Granger-cause indicators related to banks' leverage and exposure to funding risks.

2. ***Non-financial sector imbalances, and in particular those related to the household sector, tend to lead indicators related to banking system leverage and funding vulnerabilities and vice versa.*** This can be seen by the overlap in cells that capture the lead-lag relationship between these two groups of indicators in Tables 2 and 3, as well as the Granger causality tests in Table 4. This two-way relationship is consistent with the fact that imbalances in the non-financial sector can translate into vulnerabilities in the financial system (for example by leading to higher leverage in the banking system as discussed above). At the same time, increases in banking system vulnerabilities (for example higher reliance on foreign or wholesale funding) can also lead to higher imbalances in the non-financial sector. Finally, the two-way relationship could also be driven by

common factors (such as changes in risk appetite) affecting these two components of the heatmap with similar lags.

These main takeaways are summarised in Figure 11, which is consistent with a characterisation of the financial cycle whereby changes in investors' risk appetite lead to higher asset prices, lower cost of credit for the non-financial sector and lower funding costs for banks. This in turn leads to higher credit growth and increased vulnerabilities in both the non-financial sector (leverage and debt service) and the banking system (leverage and exposure to funding risks). These results are broadly consistent with Aikman et al. (2017) where the authors undertake a similar analysis using US data and composite measures of risks for similar categories.

Figure 11: Relationship between heatmap components

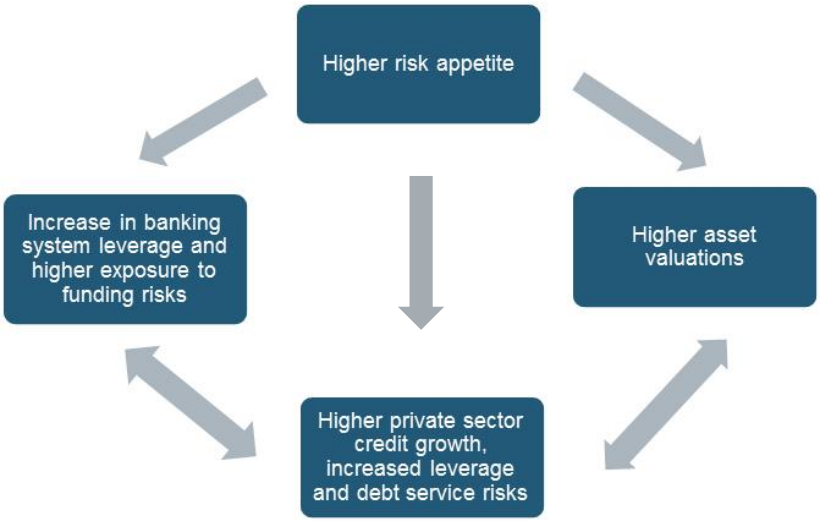
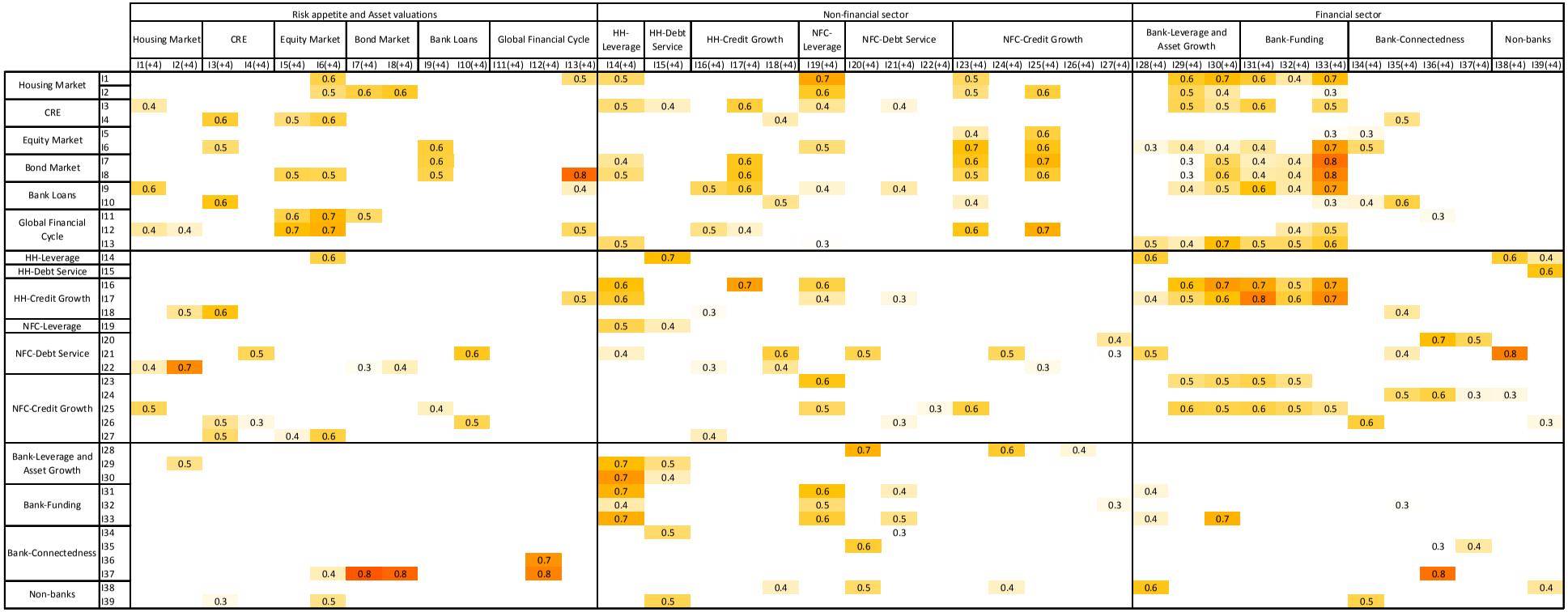


Table 1: Relationship between heatmap indicators: Contemporaneous correlations

			Risk appetite and Asset valuations													Non-financial sector															Financial sector										
			Housing Market		CRE		Equity Market		Bond Market		Bank Loans		Global Financial Cycle			HH-Leverage	HH-Debt Service	HH-Credit Growth		NFC-Leverage	NFC-Debt Service			NFC-Credit Growth					Bank-Leverage and Asset Growth			Bank-Funding			Bank-Connectedness				Non-banks	
			I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15	I16	I17	I18	I19	I20	I21	I22	I23	I24	I25	I26	I27	I28	I29	I30	I31	I32	I33	I34	I35	I36	I37	I38	I39
Risk appetite and Asset valuations	Housing Market	I1	1.0	0.6	0.4			0.4	0.6	0.7	0.5			0.3	0.4	0.4		0.7	0.6		0.5				0.5		0.5		0.3		0.5	0.6	0.6	0.4	0.6						
		I2	0.6	1.0	0.4			0.4	0.5	0.5				0.3				0.5			0.5			0.6	0.4		0.6				0.5	0.4									
	CRE	I3	0.4	0.4	1.0			0.5			0.4					0.4		0.6	0.6		0.4				0.5		0.4				0.5	0.4	0.5		0.5	0.5					
		I4				1.0				0.3		0.8		0.4						0.4		0.5	0.5						0.7												0.5
	Equity Market	I5					1.0	0.9	0.7	0.5		0.5		0.6											0.4		0.4														
		I6	0.4	0.4	0.5		0.9	1.0	0.6	0.5	0.3	0.5		0.4	0.4			0.5	0.6						0.6		0.5							0.3			0.3				
	Bond Market	I7	0.6	0.5			0.7	0.6	1.0	1.0		0.7	0.5	0.9	0.7	0.3		0.7	0.5								0.3							0.3			0.7	0.6		
		I8	0.7	0.5		0.3	0.5	0.5	1.0	1.0		0.7	0.4	0.9	0.8	0.4		0.8	0.5								0.3							0.3			0.8	0.7		
	Bank Loans	I9	0.5		0.4			0.3			1.0				0.4			0.5	0.5						0.4		0.4					0.4	0.5	0.7							
		I10				0.8	0.5	0.5	0.7	0.7		1.0	0.3	0.6									0.4	0.4					0.6												0.5
	Global Financial Cycle	I11							0.5	0.4		0.3	1.0	0.4																										
		I12	0.3	0.3		0.4	0.6	0.4	0.9	0.9		0.6	0.4	1.0	0.4			0.4		0.4							0.3										0.7	0.7		
		I13	0.4					0.4	0.7	0.8	0.4			0.4	1.0	0.5		0.6	0.5													0.6	0.5	0.5	0.6						
Non-financial sector	HH-Leverage	I14	0.4		0.4				0.3	0.4					0.5	1.0	0.5	0.5	0.5		0.4		0.3							0.4	0.6	0.7	0.6	0.3	0.5				0.5	0.3
	HH-Debt Service	I15														0.5	1.0																		0.5				0.5	0.5
	HH-Credit Growth	I16	0.7	0.5	0.6			0.5	0.7	0.8	0.5			0.4	0.6	0.5		1.0	0.6		0.5				0.5		0.5				0.6	0.7	0.6	0.5	0.6						
		I17	0.6		0.6			0.6	0.5	0.5	0.5				0.5	0.5		0.6	1.0						0.4		0.5				0.4	0.6	0.6	0.5	0.7						
		I18				0.4								0.4						1.0		0.4	0.4												0.3					0.4
	NFC-Leverage	I19	0.5	0.5	0.4											0.4		0.5			1.0			0.4	0.6						0.8	0.7	0.6	0.4	0.6						
	NFC-Debt Service	I20																		0.4		1.0	0.5			0.9		0.4	0.6						0.5	0.6	0.4	0.4		
		I21				0.5						0.4				0.3				0.4		0.5	1.0			0.5		0.3	0.5					0.3		0.4			0.7	
		I22		0.6		0.5						0.4									0.4			1.0				0.5												
	NFC-Credit Growth	I23	0.5	0.4	0.5		0.4	0.6			0.4							0.5	0.4		0.6				1.0		0.6				0.5	0.5	0.5	0.5	0.6						
		I24																			0.9	0.5				1.0			0.4	0.6						0.4	0.5	0.3	0.3		
		I25	0.5	0.6	0.4		0.4	0.5	0.3	0.3	0.4			0.3				0.5	0.5						0.6		1.0				0.4	0.4	0.3	0.4	0.4						
		I26																				0.3						1.0						0.5							
		I27	0.3			0.7						0.6									0.4		0.5			0.4			1.0												0.4
Financial sector	Bank-Leverage and Asset Growth	I28														0.4					0.6	0.5			0.6					1.0										0.5	
		I29	0.5	0.5	0.5											0.6		0.6	0.4		0.8				0.5		0.4				1.0	0.9	0.7	0.5	0.6						
		I30	0.6	0.4	0.4						0.4				0.6	0.7		0.7	0.6		0.7				0.5		0.4				0.9	1.0	0.8	0.7	0.7						
	Bank-Funding	I31	0.6		0.5						0.5				0.5	0.6		0.6	0.6		0.6				0.5		0.3				0.7	0.8	1.0	0.8	0.8						
		I32	0.4												0.5	0.3		0.5	0.5		0.4				0.5		0.4				0.5	0.7	0.8	1.0	0.6						
		I33	0.6		0.5			0.3	0.3	0.3	0.7				0.6	0.5		0.6	0.7		0.6		0.3		0.6		0.4				0.6	0.7	0.8	0.6	1.0						
	Bank-Connectedness	I34			0.5												0.5			0.3		0.5	0.4			0.4	0.5								1.0					0.5	
		I35																				0.5	0.4			0.4										1.0				0.5	
		I36						0.3	0.7	0.8				0.7								0.6				0.5											1.0	0.7		
		I37							0.6	0.7			0.5	0.7								0.4				0.3											0.7	1.0		
	Non-banks	I38														0.5	0.5					0.4	0.7			0.3				0.5						0.5			1.0	0.4
		I39				0.5						0.5	0.6			0.3	0.5			0.4									0.4						0.5				0.4	1.0

Note: This table shows the correlation between heatmap indicators on the vertical axis and the heatmap indicators on the horizontal axis. Only the pairs of indicators with a correlation that is higher than or equal to 0.3 are highlighted. The sample period for the calculations differs across pairs of indicators depending on the overlap between the indicators.

Table 2: Relationship between heatmap indicators: Cross-correlations (4-quarter)



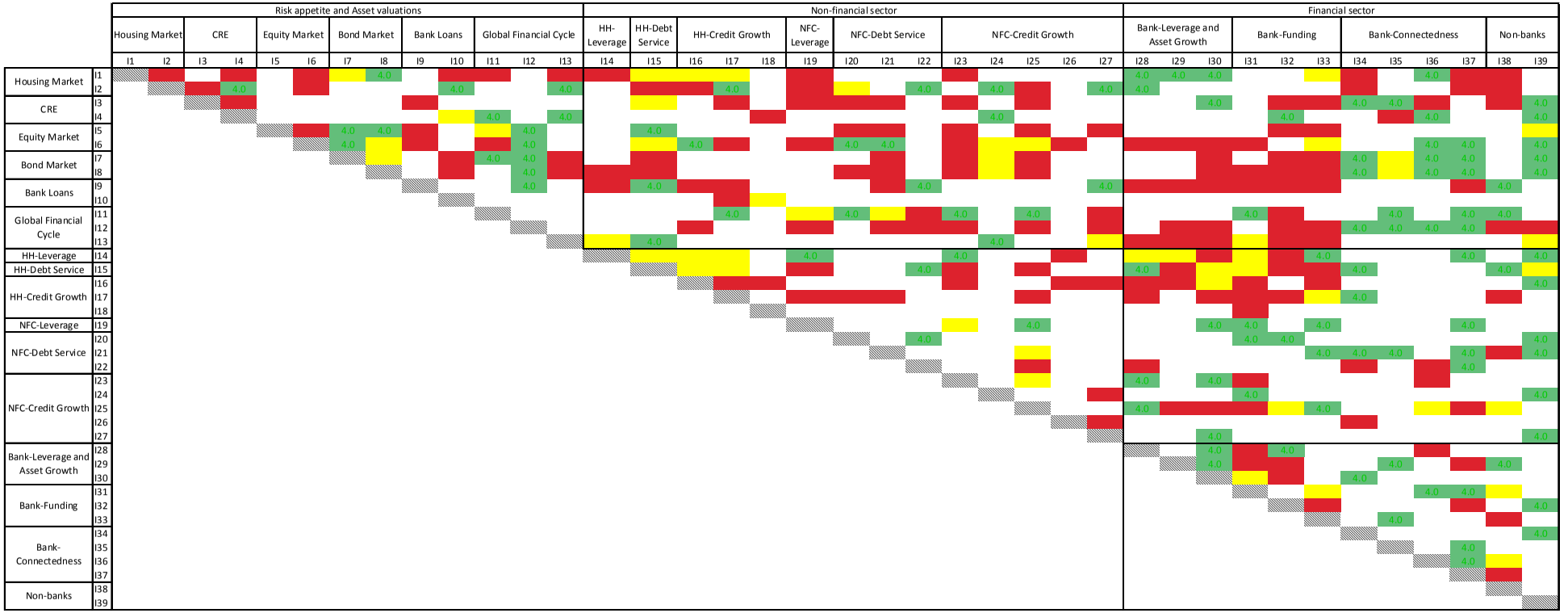
Note: This table shows the correlation between heatmap indicators on the vertical axis and the 4 quarter leads of the heatmap indicators on the horizontal axis. Only the pairs of indicators with a cross-correlation that is higher than their contemporanous correlation and those with a cross-correlation that are equal to or higher than 0.3 are highlighted. The sample period for the calculations differs across pairs of indicators depending on the overlap between the indicators.

Table 3: Relationship between heatmap indicators: Cross-correlations (8-quarter)

		Risk appetite and Asset valuations												Non-financial sector														Financial sector																							
		Housing Market		CRE		Equity Market		Bond Market		Bank Loans		Global Financial Cycle		HH-Leverage	HH-Debt Service	HH-Credit Growth			NFC-Leverage	NFC-Debt Service			NFC-Credit Growth						Bank-Leverage and Asset Growth			Bank-Funding			Bank-Connectedness						Non-banks											
		I1(+8)	I2(+8)	I3(+8)	I4(+8)	I5(+8)	I6(+8)	I7(+8)	I8(+8)	I9(+8)	I10(+8)	I11(+8)	I12(+8)	I13(+8)	I14(+8)	I15(+8)	I16(+8)	I17(+8)	I18(+8)	I19(+8)	I20(+8)	I21(+8)	I22(+8)	I23(+8)	I24(+8)	I25(+8)	I26(+8)	I27(+8)	I28(+8)	I29(+8)	I30(+8)	I31(+8)	I32(+8)	I33(+8)	I34(+8)	I35(+8)	I36(+8)	I37(+8)	I38(+8)	I39(+8)
Housing Market	I1												0.5	0.7	0.3				0.7										0.6	0.6																			
	I2													0.4					0.7										0.6	0.5	0.4		0.4	0.3															
CRE	I3				0.3						0.4			0.6	0.6				0.4		0.5								0.4	0.5	0.3																		
	I4	0.3	0.7	0.5													0.4						0.3		0.5																							
Equity Market	I5									0.3									0.3															0.4															
	I6																		0.4												0.3		0.4															
Bond Market	I7									0.7				0.6			0.6		0.4				0.4		0.8				0.3	0.6	0.5	0.6	0.6															
	I8									0.7			0.8	0.7			0.7		0.4				0.4		0.8				0.3	0.4	0.7	0.6	0.7	0.8														
Bank Loans	I9												0.4	0.5		0.5			0.4		0.6							0.3	0.4	0.5	0.7	0.5																
	I10		0.7												0.3										0.6									0.3														
Global Financial Cycle	I11					0.4																			0.4										0.3											
	I12	0.5								0.7			0.5				0.5		0.4				0.6		0.8					0.4	0.3	0.5	0.6															
	I13													0.6															0.6	0.5	0.7																	
HH-Leverage	I14						0.5								0.7														0.7						0.4							0.6	0.5				
HH-Debt Service	I15				0.5						0.4							0.5																										0.6			
HH-Credit Growth	I16													0.8	0.4				0.6											0.7	0.7	0.6														
	I17													0.6					0.5		0.5								0.5	0.4		0.6														
	I18		0.8									0.5			0.5		0.4								0.7											0.5	0.6	0.5							
NFC-Leverage	I19													0.6	0.5												0.4																			
NFC-Debt Service	I20												0.3																							0.7	0.6								
	I21											0.4		0.4				0.5		0.6			0.5						0.6					0.5							0.8					
	I22	0.5	0.8					0.5	0.6							0.5			0.5						0.5					0.4																
NFC-Credit Growth	I23																		0.7																											
	I24				0.5						0.6							0.3									0.5									0.6	0.6	0.4	0.4						
	I25	0.5																	0.7			0.4							0.6	0.5	0.6	0.5	0.4													
	I26			0.5	0.3						0.4						0.6																												
	I27		0.5													0.3	0.6							0.5		0.5	0.4					0.4														
Bank-Leverage and Asset Growth	I28				0.3							0.3								0.7				0.6		0.4	0.4									0.4	0.4								
	I29													0.6	0.6												0.4																			
	I30													0.7	0.5														0.4																	
Bank-Funding	I31													0.7	0.4						0.5								0.5													0.4				
	I32													0.4					0.5									0.3	0.4					0.4												
	I33													0.7							0.5								0.5													0.4				
Bank-Connectedness	I34																				0.5																									
	I35								0.3				0.3																								0.4	0.7								
	I36																																														
	I37					0.3	0.4	0.6																													0.7									
Non-banks	I38											0.4				0.4					0.6								0.6								0.4		0.4							
	I39														0.5																			0.6												

Note: This table shows the correlation between heatmap indicators on the vertical axis and the 8 quarter leads of the heatmap indicators on the horizontal axis. Only the pairs of indicators with a cross-correlation that is higher than their contemporanous correlation and those with a cross-correlation that are equal to or higher than 0.3 are highlighted. The sample period for the calculations differs across pairs of indicators depending on the overlap between the indicators.

Table 4: Relationship between heatmap indicators: Granger causality tests



Note: This table shows the results from Granger causality tests between different heatmap indicators. The sample period for the calculations differs across pairs of indicators depending on the overlap between the indicators.

Red color indicates that the heatmap indicator on the vertical axis Granger causes the heatmap indicator on the horizontal axis and not vice versa.

Yellow color indicates that the the heatmap indicator on the vertical and horizontal axes both Granger cause each other.

Green color indicates that the the heatmap indicator on the horizontal axis Granger causes the heatmap indicator on the vertical axis and not vice versa.

White color indicates that none of the two indicators Granger cause the other one.

4.4 Relationship between heatmap indicators and other leading indicators

We also consider how leading indicators of financial vulnerabilities that are used by the Norges Bank (i.e. the four core indicators outlined in Norges Bank (2013)) relate to the different heatmap indicators. Gerdrup et al. (2013) highlight that the four indicators used for the Norges Bank's advice on the countercyclical capital buffer have historically provided early warning signals of episodes of financial instability. These include the credit-to-GDP gap, house price-to-household disposable income gap, real commercial property price gap and wholesale funding ratio gap. The credit-to-GDP gap is also relevant given its wide use in other policy institutions based on the Basel Committee recommendations (Basel Committee on Banking Supervision (2010a)). We must note that there is some overlap between the heatmap indicators and the four core indicators. Three of the core indicators (the house price-to-household disposable income gap,[41] commercial property price gap and wholesale funding ratio gap) are used directly in the heatmap.[42] The heatmap does not include the credit-to-GDP gap, but instead includes a credit-to-GDP gap for the household and corporate sectors separately.

We proceed as in the previous sub-section and consider estimates of cross-correlations as well as Granger causality tests to assess the relationship between heatmap indicators and the four key indicators (Table 5). Overall, the core indicators are highly correlated with many of the heatmap indicators, especially with the housing market segment, the non-financial sector imbalances and the banks' vulnerabilities related to leverage and funding risks. This is not surprising given that the core indicators cover these areas. Cross-correlations between heatmap indicators and the four- and eight-quarter leads of the core indicators suggest that many heatmap indicators tend to lead the credit-to-GDP gap and to some extent the wholesale funding ratio gap. A similar conclusion can be drawn from the Granger causality tests. This suggests that the credit-to-GDP gap is closely related to a broad range of indicators and hence can be considered a good summary indicator for the build-up of systemic risk. However, it appears to be a lagging indicator and the heatmap indicators could give earlier signals of the build-up of risks. Finally, one can also observe that the ratio of house prices-to-disposable income and the

[41] There is a small difference between the core indicator and the heatmap indicator related to the definition of disposable income. In the core indicator, total disposable income is used, whereas in the heatmap indicator disposable income per capita is used.

[42] One difference is the fact that in the heatmap these indicators are expressed in terms of their cumulative distribution instead of their actual level. Therefore the correlation between the indicators is not exactly 1.

real commercial real estate price gap tend to Granger-cause some of the indicators in the heatmap (mainly in the non-financial sector imbalances). This is consistent with the previous results where indicators reflecting risk appetite and asset valuations were found to lead indicators in other components of the heatmap.

Table 5: Relationship between heatmap indicators and Norges Bank's core indicators

		Correlation				Cross-correlation (4-leads)				Cross-correlation (8-leads)				Granger Causality Tests			
		House price/Disp. income, gap	Total credit/GDP, gap	Wholesale funding, gap	Real CRE price, gap	House price/Disp. income, gap	Total credit/GDP, gap	Wholesale funding, gap	Real CRE price, gap	House price/Disp. income, gap	Total credit/GDP, gap	Wholesale funding, gap	Real CRE price, gap	House price/Disp. income, gap	Total credit/GDP, gap	Wholesale funding, gap	Real CRE price, gap
Housing Market	I1	0.9	0.5	0.6	0.4		0.7				0.8						
	I2	0.6	0.4		0.4		0.5				0.6	0.3		4.0			
CRE	I3	0.5	0.4	0.5	1.0	0.5	0.6	0.6			0.6	0.6					
	I4								0.6				0.5				4.0
Equity Market	I5																
	I6	0.4			0.5		0.5	0.5			0.4			4.0			
Bond Market	I7	0.7					0.4	0.4			0.6	0.5					
	I8	0.8					0.4	0.4			0.7	0.5					
Bank Loans	I9	0.5		0.5	0.5	0.6	0.4	0.6			0.5	0.7					4.0
	I10								0.6								
Global Financial Cycle	I11																
	I12	0.5				0.5				0.6		0.3					
	I13	0.4	0.4	0.4			0.5	0.5			0.4						
HH-Leverage	I14	0.3	0.8	0.6	0.4												
HH-Debt Service	I15		0.5											4.0			4.0
HH-Credit Growth	I16	0.7	0.5	0.6	0.6		0.7	0.7			0.8	0.7		4.0			
	I17	0.7	0.4	0.7	0.6		0.6	0.8			0.7			4.0			4.0
	I18								0.6								4.0
NFC-Leverage	I19	0.5	0.8	0.5	0.4									4.0		4.0	4.0
NFC-Debt Service	I20															4.0	
	I21			0.4													4.0
	I22	0.3				0.4				0.5							
NFC-Credit Growth	I23	0.5	0.4	0.5	0.5		0.5	0.5			0.6						4.0
	I24																
	I25	0.6		0.4	0.5	0.6	0.4	0.5			0.5	0.5					4.0
	I26								0.4				0.5				
	I27	0.3							0.5								
Bank-Leverage and Asset Growth	I28													4.0			
	I29	0.6	0.8	0.7	0.5		0.8							4.0			
	I30	0.6	0.8	0.7	0.4		0.8							4.0			
Bank-Funding	I31	0.6	0.7	0.9	0.5		0.8				0.8						
	I32	0.5	0.4	0.8			0.5				0.5						4.0
	I33	0.7	0.7	0.8	0.5		0.8				0.8			4.0			4.0
Bank-Connectedness	I34				0.5												
	I35																
	I36																4.0
	I37																
Non-banks	I38		0.3											4.0			4.0
	I39								0.3								

Note: This table shows 1) the correlation between heatmap indicators and the four core indicators (only the pairs of indicators with a correlation equal to or higher than 0.3 are highlighted); 2) the correlation between heatmap indicators and the 4 and 8 quarter leads of the four core indicators (only the pairs of indicators with a cross-correlation that is higher than their contemporanous correlation and those with a cross-correlation that are equal to or higher than 0.3 are highlighted); and 3) the results from Granger causality tests between each heatmap indicator and the four core indicators. The sample period for the calculations differs across pairs of indicators depending on the overlap between the indicators.

Red color indicates that the heatmap indicator Granger causes the core indicator and not vice versa.
Yellow color indicates that the heatmap indicator and the core indicator both Granger cause each other.
Green color indicates that the core indicator Granger causes the heatmap indicator and not vice versa.
White color indicates that none of the two indicators Granger cause the other one.

5 Conclusion

We developed a monitoring tool to capture the build-up of vulnerabilities and systemic risk in the Norwegian financial system. In particular, we constructed 39 indicators capturing a wide range of financial vulnerabilities. We grouped these indicators under three broad classes of vulnerabilities: risk appetite and asset valuations, non-financial sector imbalances and financial sector vulnerabilities. We then used ribbon heatmaps to highlight the sources of risks emerging in different sectors.

The heatmap provides useful insights on the evolution of financial stability risks in Norway over time, and many of the indicators signalled elevated risks prior to the Norwegian banking crisis of 1988-93 and the financial crisis of 2008-09. Several common risk factors were present leading up to these crises. First, elevated real estate prices and high risk appetite seem to have contributed to a significant build-up of imbalances, mainly in the household sector. Second, reliance on wholesale and foreign funding were elevated prior to both crises, driven in part by declining savings and high credit growth in the non-financial private sector.

An analysis of the relationship between different components of the heatmap yields interesting insights related to the financial cycle in Norway. We find that increased risk appetite and elevated asset prices (especially in real estate) tend to precede higher credit growth and indebtedness in the non-financial private sector and increased vulnerabilities in the banking system related to leverage and exposure to funding risks. We also find two-way relationships between non-financial sector imbalances, especially those related to the household sector, and banking system leverage and funding vulnerabilities.

The heatmap developed in this paper can provide useful input for macroprudential policy in Norway. It can for example, supplement the four key indicators used as part of the decision basis for the countercyclical capital buffer. Utilising a broader set of indicators, the heatmap provides a more comprehensive assessment of the sources of risks. In addition, several components of the heatmap help predict some of these key indicators and hence can provide even earlier signals when financial stability risks are building up. Going forward, it will be important to update and adjust indicators used in the heatmap as new indicators become available and different financial system vulnerabilities may emerge.

A Appendix: Practices in other policy institutions

Many policy institutions (central banks, other financial regulators, and international organisations) have operationalised tools to monitor risks and to guide their macroprudential policies. Table 6 outlines the key characteristics of some of the tools used in other policy institutions. Several differences can be observed. First, monitoring tools vary with respect to how they are organised. While some of them are organised around different types of risks (Denmark's Systemic Risk Council, European Systemic Risk Board (ESRB), International Monetary Fund (IMF), Office of Financial Research (OFR), Reserve Bank of New Zealand), others are organised around different economic segments (Bank of England, OECD). The number of indicators/charts used in different monitoring tools vary as well, with some comprising about 20 indicators (Bank of England, Denmark's Systemic Risk Council), while others include a more extensive set of indicators (Reserve Bank of New Zealand with 42, ESRB and OFR with about 60, and OECD with 73). There are also differences between monitoring tools in terms of their use of visualisation techniques. While some use tables or chart packs (Bank of England, Denmark's Systemic Risk Council, ESRB, OECD, Reserve Bank of New Zealand), others use heatmaps or spider charts (IMF, OFR).

The monitoring tool presented in this paper is closer to the tools used by the Bank of England and the OECD in terms of its overall organisation as it concentrates on risks related to key economic segments. However, it also has similarities with the tools used in other institutions such as Denmark's Systemic Risk Council given its coverage of different types of risks under different sub-components. With its coverage of 39 indicators, the monitoring tool presented in this paper falls somewhere in between the two groups mentioned above in terms of size.

Table 6: Use of monitoring tools for financial stability in other policy institutions

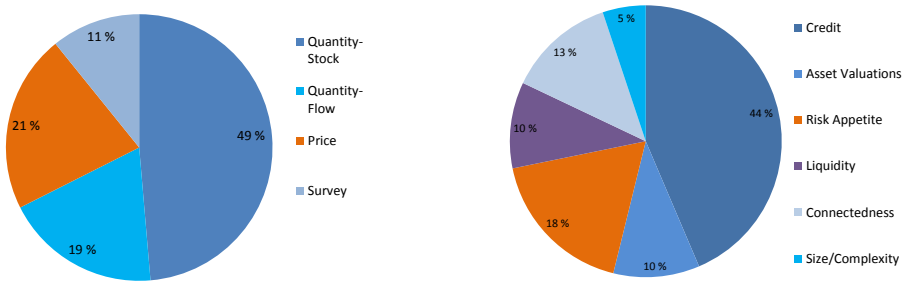
Name of Institution	Broad Categories	Indicators/ Charts	Visualisation Techniques	Aggregation
Bank of England[1)]	3 main categories: Non-bank balance sheet stretch, Bank balance sheet stretch, Terms and conditions in markets	22-25	Table	No aggregation
Denmark's Systemic Risk Council[2)]	6 main categories: Excessive credit growth and leverage, Maturity mismatches and market liquidity, Exposure concentration, Interconnectedness, SIFIs and misaligned incentives, Financial structures	18	Chart pack	No aggregation
ESRB's Risk Dashboard[3)]	7 main categories: Interlinkages and composite measures of systemic risk, Macroeconomic risk, Credit risk, Liquidity and funding risk, Market risk, Solvency and profitability risk, Structural risk	59	Chart pack	No aggregation
IMF's Global Financial Stability Map[4)]	4 main risk categories: Macroeconomic risks, Emerging market risks, Credit risks, Market and liquidity risks. 2 conditions: Monetary and Financial, Risk appetite	31	Spider chart	Equally weighted average of sub-components for 4 risk categories and conditions
OECD[5)]	6 main risk categories: Financial sector, Non-financial sector, Asset market, Public sector, External sector Int. spillovers and contagion	73	Table/Data	No aggregation
Office of Financial Research Financial System Vulnerabilities Monitor[6)]	6 main risk categories: Macroeconomic risks, Market risk, Credit risk, Solvency and leverage risk, Funding and liquidity risk, Contagion risk	58	Heatmap	Aggregation based on sub-components
Reserve Bank of New Zealand Macroprudential Chart Pack[7)]	3 main risk categories: Aggregate risks, Housing risks, Other sectoral risks	42	Chart pack	No aggregation

1) http://www.bankofengland.co.uk/financialstability/Pages/fpc/coreindicators.aspx.
2) http://risikoraad.dk/.
3) https://www.esrb.europa.eu/pub/rd/html/index.en.html.
4) Dattels et al. (2010).
5) OECD (2015).
6) https://www.financialresearch.gov/financial-vulnerabilities//.
7) http://www.rbnz.govt.nz/financial-stability/macro-prudential-indicators.

B Appendix: Composition of heatmap

The heatmap aims to capture different types of risks and vulnerabilities (e.g. credit risk, exposure to liquidity risks). Figure 12 shows the composition of the heatmap in terms of both the type of indicators used and the different risks captured.

Figure 12: Composition of heatmap indicators by type and captured risks



(a) Indicators by type

(b) Indicators by type of risk captured[1)]

1) Some indicators capture multiple types of risks and are counted under multiple types of risks in calculating the percentages.

C Appendix: Indicators

Table 7: Risk appetite and asset valuations (1/3)

Components	Indicators	Rationale	Description	Dir. of incr. risk	Data trans.	Start Date	Sources
Housing Market	House price/ Disposable income per capita	Elevated house price valuations can lead to higher losses for lenders and can reinforce unsustainable lending growth by increasing collateral valuations. An abrupt fall in house prices can lead to an increase in bank losses, either directly through losses on housing loans or indirectly through its effect on aggregate demand.	House prices divided by total household disposable income per 15-74 year old population. 1998Q4=100. House prices for the period after 2003Q1 is based on house price statistics from the real estate industry (House price index). For the period 1990Q4-2002Q4 house prices were chained back in time using price per m2 from the real estate industry (Price per m2 of an average dwelling of approximately 100 m2. NOK 1000). For the period 1975Q1-1990Q3 house prices were chained back in time using Historical Monetary Statistics for house price inflation (total) and converted to quarterly data using linear interpolation. Households' disposable income for the period after 2002Q1 is the quarterly disposable income adjusted for reinvested dividend income in 2000-2005 and redemption/reduction of equity capital from 2006. For the period 1978Q1-2001Q4 it is annual disposable income adjusted for reinvested dividend income in 2000 and 2001 which is converted to quarterly data using quarterly wage income as weights.	+	Gap (pct.)	1978Q4	Eiendoms Norge, Finn.no, Eiendomsverdi AS, Norwegian Association of Real Estate Agents (NEF), Association of Real Estate Agency Firms (EEF), ECON, Statistics Norway and Norges Bank
	Housing investment /GDP	Excessive housing investment can be a sign of a housing market boom.	Gross fixed capital formation in dwelling services (4-quarter moving sum) divided by gross domestic product for mainland Norway (4-quarter moving sum).	+	Gap (pct. point)	1978Q1	Statistics Norway
Commercial Real Estate Market	Real commercial property price index	Elevated valuations can lead to higher losses for lenders and can reinforce unsustainable lending growth by increasing collateral valuations. Commercial real estate is the largest industry in terms of bank lending and is among the industries that have historically exposed banks to the largest loan losses.	Estimated market value of centrally located high-standard office premises in central Oslo deflated by the GDP deflator for mainland Norway. NOK/m2. Semi-annual data converted to quarterly data by setting Q2=Q3 and Q4=Q1 the following year. 1998Q2-1999Q2=100.	+	Gap (pct.)	1981Q2	OPAK, Dagens Næringsliv, Statistics Norway and Norges Bank
	Change in credit standards	Easing of lending standards could lead to elevated credit growth and asset valuations.	Based on Norges Bank's Quarterly Bank Lending Survey. 10 largest financial institutions are asked whether credit standards have changed "a lot", "a little" or are "unchanged" relative to the previous quarter. 9 largest financial institutions were asked before 2017Q2 and 8 largest financial institutions ranked according to the annual change in lending to households and to non-financial corporations were asked before 2015Q2. A higher value in this variable indicates easing of credit standards.	+	Level	2007Q4	Norges Bank

Table 7: Risk appetite and asset valuations (2/3)

Components	Indicators	Rationale	Description	Dir. of incr. risk	Data trans.	Start Date	Sources
Equity Market	Real stock price index	Elevated stock market valuations can lead to higher losses through market risk and also signal increasing risk appetite and asset valuations.	OSEAX Index deflated by CPI (4-quarter moving average).	+	Gap (pct.)	1983Q1	Thomson Reuters and Statistics Norway
	Price to earnings ratio	High stock market valuations relative to earnings can signal higher market risk, increasing risk appetite and excessive asset valuations.	Stock price relative to realized earnings before interest, tax, depreciation and amortization (EBITDA) for companies traded in OSEAX (4-quarter moving average).	+	Level	2002Q4	Bloomberg
Bond Market	Bond spread for investment-grade corporations	Low bond spreads could signal higher risk appetite, leading to mispricing of risk and higher credit growth.	Average of the risk premium for new 5-year bonds by Norwegian industrial and hydro-power utility issuers. Percentage points over 3 month Nibor.	-	Level	2002Q1	DNB Markets
	Bond spread for Norwegian banks	Low bond spreads could signal higher risk appetite, leading to mispricing of risk and higher credit growth.	Bond spreads for new 5-year senior bank bonds. Percentage points over 3 month Nibor.	-	Level	2002Q1	DNB Markets
Bank Loans	Average bank lending margin (households and corporations)	Lower lending margins could signal relaxed lending standards and low profits in the banking system.	Calculated as the average interest rates on outstanding loans to households and non-financial corporations from banks and mortgage companies. Before 2002Q1, the series is based on average weighted interest rate on total bank loans. Percentage points over 3 month Nibor (4-quarter moving average).	-	Level	1980Q1	Statistics Norway and Norges Bank
	Change in credit standards (households and corporations)	Easing of lending standards could lead to elevated credit growth and asset valuations.	Based on Norges Bank's Quarterly Bank Lending Survey. 10 largest financial institutions are asked whether credit standards have changed "a lot", "a little" or are "unchanged" relative to the previous quarter. 9 largest financial institutions were asked before 2017Q2 and 8 largest financial institutions ranked according to the annual change in lending to households and to non-financial corporations were asked before 2015Q2. The average for the change in credit standards for households and non-financial corporations is used. A higher value in this variable indicates looser credit standards.	+	Level	2007Q4	Norges Bank

Table 7: Risk appetite and asset valuations (3/3)

Components	Indicators	Rationale	Description	Dir. of incr. risk	Data trans.	Start Date	Sources
Global Financial Cycle	VIX	Periods of low expected volatility can be associated with higher risk appetite and mispricing of risk.	The Chicago Board Options Exchange Volatility Index, VIX.	-	Level	1990Q1	Bloomberg
	Global corporate bond spread	Low global corporate bond spreads could signal higher risk appetite, mispricing of risk and higher credit growth.	Average of corporate bond spreads in the US and the EU based on Bank of America Merrill Lynch Euro and US Corporate Index, option adjusted spread.	-	Level	1997Q1	Thomson Reuters
	Global cross-border bank credit/ GDP	Higher cross-border bank credit can signal easing of global financial conditions which can have spillovers effects on domestic credit conditions.	BIS reporting banks' total cross-border claims on all sectors in all countries relative to GDP in all recipient countries.	+	Gap (pct. point)	1980Q4	BIS

Table 7: Non-financial sector (1/3)

Components	Indicators	Rationale	Description	Dir. of incr. risk	Data trans.	Start Date	Sources
Households: Leverage	Credit to households/GDP	Captures increases in leverage relative to a long-run trend and signals periods of sustained and large increases in leverage. Periods of heightened levels of leverage can signal higher credit risk and lead to lower demand reflecting potential debt overhang effects, and has been a good predictor of financial crises.	Credit (C2) to households (mainland) (1995Q4-2017Q2), chained back in time using total C2 households (1987Q4-1995Q3) and using growth in households' total loan debt (1975Q1-1987Q3). Credit series is divided by gross domestic product for mainland Norway.	+	Gap (pct. point)	1975Q1	IMF, Statistics Norway and Norges Bank
Households: Debt service	Debt service ratio (interest expense + amortization relative to after-tax disposable income)	Measure of debt service affordability that is closely related to leverage. High values can signal unsustainable levels of indebtedness and higher exposure to shocks. High household debt burdens can lead to an increase in bank losses on loans to households and a cut back in demand.	Households' debt service ratio is calculated following Drehmann et al. (2015) and is defined as the ratio of interest and principal payments to after-tax income. The details of the calculation for Norway is documented in Norges Bank Monetary Policy Report (4/15).	+	Level	1980Q1	Statistics Norway and Norges Bank
Households: Credit growth	Growth in real credit to households	Episodes of higher growth in real credit could signal lower lending standards and tends to result in higher leverage in the future.	Year over year growth in credit (C2) to households deflated by 4-quarter moving average of CPI., 4-quarter moving average.	+	Gap (pct. point)	1980Q1	Statistics Norway and Norges Bank
	Net lending/ Disposable income	Low levels of net lending can signal higher credit growth (relative to income) and unsustainable trends in consumption. It also implies that households are more vulnerable to potential funding or income shocks, resulting in a larger cutback in consumption.	Net lending of households and non-profit institutions serving households as a share of disposable income. Both net lending and disposable income exclude income from dividends and disposable income includes adjustments for household pension funds. Data prior to 2002Q1 is based on annual data and is converted to quarterly data using linear interpolation.	-	Level	1980Q1	Statistics Norway and Norges Bank
	Change in credit demand for mortgages	Higher credit demand can lead to higher credit growth and larger financing needs.	Based on Norges Bank's Quarterly Bank Lending Survey. 10 largest financial institutions are asked whether credit standards have changed "a lot", "a little" or are "unchanged" relative to the previous quarter. 9 largest financial institutions were asked before 2017Q2 and 8 largest financial institutions ranked according to the annual change in lending to households and to non-financial corporations were asked before 2015Q2. A higher value in this variable indicates higher credit demand.	+	Level	2007Q4	Norges Bank

Table 7: Non-financial sector (2/3)

Components	Indicators	Rationale	Description	Dir. of incr. risk	Data trans.	Start Date	Sources
Non-financial corporations (NFCs): Leverage	Credit to NFCs/GDP	Captures increases in leverage relative to a long-run trend and signals periods of sustained and large increases in leverage. Periods of heightened levels of leverage can signal higher credit risk and potential debt overhang effects, and has been a good predictor of financial crises.	Credit (C3) (includes credit from mainland and foreigners) to mainland non-financial enterprises (1995Q4-2017Q2). It is chained back in time using growth in total C3 non-financial enterprises (1987Q4-1995Q3) and growth in enterprises' total loan debt (bank loans, bonds and notes) (1975Q1-1987Q3). Credit series is divided by gross domestic product for mainland Norway.	+	Gap (pct. point)	1975Q1	Statistics Norway and Norges Bank
Non-financial corporations (NFCs): Debt service	Debt service ratio (interest expense + amortization as a share of disposable income + dividends paid)	Measure of debt service affordability that is closely related to leverage. High values can signal unsustainable levels of indebtedness and higher exposure to shocks. It has been shown to increase significantly before financial crises and improve the performance of credit gap in the context of multivariate signaling models.	NFCs' debt service ratio is calculated following Drehmann et al. (2015) and is defined as the ratio of interest and principal payments to disposable income plus dividends paid.	-	Level	1980Q1	Statistics Norway and Norges Bank
	Total debt/ Liquid assets	Lower financial buffers increases vulnerability to different shocks and reduce their capacity to service debt.	Liquid assets include cash, listed stocks and bonds, mutual fund shares and money market funds. Total debt includes all loans and debt securities. Includes all enterprises and is based on the financial accounts data (2017Q1-1995Q4). The series were chained back to 1975Q1 using the database Findatr. 4-quarter moving average	+	Level	1975Q1	Statistics Norway and Norges Bank

Table 7: Non-financial sector (3/3)

Components	Indicators	Rationale	Description	Dir. of incr. risk	Data trans.	Start Date	Sources
Non-financial corporations (NFCs): Debt service	Share of foreign credit	Financing provided by non-residents can be more volatile and expose NFCs to funding shocks and affect their balance sheets through exchange rate fluctuations if there are currency mismatches on their balance sheets. These could negatively impact their debt servicing capacity and the domestic financial system. An important caveat is the fact that some of the foreign liabilities of NFCs include inter-company loans which would not be subject to the same set of vulnerabilities.	Share of foreign credit in total C3 credit (mainland + foreign). 4-quarter moving average.	+	Gap (pct. point)	1980Q1	Statistics Norway and Norges Bank.
Non-financial corporations (NFCs): Credit growth	Growth in real credit to NFCs	Episodes of higher growth in real credit could signal lower lending standards and tends to result in higher leverage in the future.	Year over year growth in credit (C3) to non-financial enterprises deflated by 4-quarter moving average of CPI. 4-quarter moving average.	+	Gap (pct. point)	1980Q1	Statistics Norway and Norges Bank
	Net lending/GDP	Low levels of net lending can signal higher credit growth (relative to income) and unsustainable trends in investment, low profitability or cash flow problems. It also implies that NFCs are more vulnerable to potential funding or income shocks, resulting in a larger cutback in investment and employment.	Calculated as NFCs' net lending (adjusted by dividends paid) divided by gross domestic product.	-	Level	1980Q1	Statistics Norway and Norges Bank
	Private investment in non-oil sector/GDP	Strong growth in private investment could signal an unsustainable boom which could be associated with higher credit risk.	Gross fixed private capital formation excluding housing and oil (4-quarter moving sum) divided by gross domestic product for mainland Norway (4-quarter moving sum).	+	Gap (pct. point)	1978Q1	IMF and Statistics Norway
	Private investment in oil sector/GDP	Strong growth in private investment could signal an unsustainable boom which could be associated with higher credit risk.	Gross fixed private capital formation in extraction and transport via pipeline (4-quarter moving sum) divided by gross domestic product for mainland Norway (4-quarter moving sum).	+	Gap (pct. point)	1978Q1	IMF and Statistics Norway
	Change in credit demand	Higher credit demand can lead to higher credit growth and larger financing needs.	Based on Norges Bank's Quarterly Bank Lending Survey. 10 largest financial institutions are asked whether credit standards have changed "a lot", "a little" or are "unchanged" relative to the previous quarter. 9 largest financial institutions were asked before 2017Q2 and 8 largest financial institutions ranked according to the annual change in lending to households and to non-financial corporations were asked before 2015Q2. A higher value in this variable indicates higher credit demand.	+	Level	2007Q4	Norges Bank

Table 7: Financial sector (1/3)

Components	Indicators	Rationale	Description	Dir. of incr. risk	Data trans.	Start Date	Sources
Banking sector: Leverage and asset growth	Equity ratio	An increase in banking system leverage could increase the vulnerability of the banking system to shocks by reducing buffers and signals excessive growth in lending.	Ratio of banks' and mortgage companies' (excluding foreign branches) equity to total assets. Accounting statistics of Reporting of banks, mortgage companies, state lending institutions and finance companies accounts to the public authorities (ORBOF) was used for the period 1987Q1-2017Q2. The series were chained back to 1980Q1 using linearly interpolated annual data from OECD banking statistics.	-	Level	1980Q1	OECD, Statistics Norway and Norges Bank
	Total assets/GDP	A large increase in the size of the banking system can signal higher risk taking, credit risks and increasing complexity.	Total assets of banks and mortgage companies in Norway as a share of mainland GDP based on the accounting statistics of ORBOF. The series were break-adjusted for the inclusion of mortgage companies into the ORBOF database in 1996Q1. The series was chained back to 1980Q1 using linearly interpolated annual data from OECD banking statistics.	+	Gap (pct. point)	1987Q1	OECD, Statistics Norway and Norges Bank
	Loans to domestic sector/GDP	As a broad measure of lending to the domestic sector, this indicator provides a more comprehensive measure of domestic leverage.	Total claims of banks and mortgage companies in Norway on all domestic sectors in Norway (i.e. including lending to public sector) as a share of mainland GDP based on the accounting statistics of ORBOF. The series was break-adjusted for the inclusion of mortgage companies into the ORBOF database in 1996Q1. The series was extended back to 1980Q1 using linearly interpolated annual data from OECD banking statistics.	+	Gap (pct. point)	1978Q1	OECD, Statistics Norway and Norges Bank
Banking sector: Funding	Wholesale funding ratio	Higher share of wholesale funding exposes the banking system to potential funding risks as wholesale funding can be more volatile and dry up more quickly during periods of stress. A higher share of wholesale funding can also signal periods of financial excess, high credit growth and increasing connectedness between banks (for example reflecting higher interbank lending).	Wholesale funding (total liabilities less customer deposits and equity) as a share of total liabilities for all banks and covered bond mortgage companies in Norway, excluding branches and subsidiaries of foreign banks. The data are based on the sum of individual company balance sheets, and are from 2007Q4 adjusted for intragroup receivables and payables. Accounting statistics of ORBOF was used for the period 1987Q1-2017Q2. Linearly interpolated annual data are used in the period 1975Q4-1986Q4.	+	Gap (pct. point)	1975Q4	Statistics Norway and Norges Bank

Table 7: Financial sector (2/3)

Components	Indicators	Rationale	Description	Dir. of incr. risk	Data trans.	Start Date	Sources
Banking sector: Funding	Loan to deposit ratio	Higher loan to deposit ratios implies greater maturity transformation and potential vulnerabilities to liquidity risks in the banking system.	Ratio of loans to deposits (customer deposits) of all banks and mortgage companies in Norway based on the accounting statistics of ORBOF. The series were break-adjusted for the inclusion of mortgage companies into the ORBOF database in 1996Q1. The deposit series was break-adjusted for the inclusion of Postbanken into the ORBOF database in 1992Q4. The series were chained back to 1980Q1 using linearly interpolated annual data from OECD banking statistics.	+	Gap (pct. point)	1987Q1	OECD, Statistics Norway and Norges Bank
	Foreign liabilities of domestic banking system/Total Liabilities	Financing provided by non-residents can be more volatile and expose banks to fluctuations in exchange rates if they are not hedged.	Liabilities of banks and mortgage companies in Norway to non-residents as a share of their total liabilities where liabilities include deposits, debt securities and loans). 4-quarter moving average. Based on the financial accounts data (2017Q1-1995Q4). The series were chained back to 1975Q1 using the database system Findatr.	+	Gap (pct point)	1975Q1	Statistics Norway and Norges Bank
Banking sector: Connectedness and Concentration	Claims on foreigners/Total Assets	Rising share of claims on non-residents could expose the domestic financial system to shocks originating abroad and could also increase exposure to exchange rate fluctuations if they are not hedged.	Claims of banks and mortgage companies in Norway (excluding foreign bank branches in Norway and Nordea but including the claims of Norwegian banks' foreign branches) on foreigners as a share of their total assets based on the accounting statistics of ORBOF. Claims on foreign central banks are excluded. 4-quarter moving average. The series were break-adjusted for the inclusion of mortgage companies into the ORBOF database in 1996Q1.	+	Gap (pct. point)	1987Q1	Statistics Norway and Norges Bank
	Claims on other domestic financial institutions/Total assets	A more interconnected financial system can amplify financial shocks and increase the severity of a crisis.	Claims of all banks and mortgage companies on other domestic financial institutions as a share of their total assets based on the accounting statistics of ORBOF. 4-quarter moving average. The series were break-adjusted for the inclusion of mortgage companies into the ORBOF database in 1996Q1. See Norges Bank Staff Memo No 13/2016 for more information on the construction of this indicator.	+	Level	1987Q1	Statistics Norway and Norges Bank
	Share of banking system bonds held by non-banks	This indicator captures interconnectedness between the banking system and non-banks concentrating on the liability side of banks' balance sheets. A more interconnected financial system can amplify financial shocks and increase the severity of a crisis.	Total bank and mortgage company bonds held by non-banks (finance companies, mutual funds, money market funds, state-lending institutions, insurance companies and pension funds excluding the government pension fund) as a share of total bonds issued by banks and mortgage companies. 4-quarter moving average. Based on the financial accounts data (2017Q1-1995Q4). The series were chained back to 1975Q1 using the database system Findatr.	+	Level	1975Q1	Statistics Norway

Table 7: Financial sector (3/3)

Components	Indicators	Rationale	Description	Dir. of incr. risk	Data trans.	Start Date	Sources
Banking sector: Connectedness and Concentration	Exposures to Housing Market	Housing constitutes an important collateral for the banking system and has the potential to affect the real economy given its predominant role in household balance sheets. Increasing concentration in banks' exposures to the housing market could increase the severity of a crisis and could lead to correlated losses in the financial system. It could also contribute to higher connectedness in the financial system.	Share of lending that consists of mortgages to wage earners and benefit recipients and lending to non-financial corporations in the real estate sector as well as banks' holdings of covered bonds issued by other Norwegian banks. Based on accounting statistics of ORBOF. The loan series were break-adjusted for the inclusion of mortgage companies into the ORBOF database in 1996Q1. 4-quarter moving average.	+	Gap (pct. point)	1987Q1	Statistics Norway and Norges Bank
Non-Bank Sector	Private sector credit/ GDP	Credit provided by non-banks contributes to overall leverage in an economy and their share of credit could increase over time (for example reflecting regulatory arbitrage). If credit provided by non-banks increase substantially, it could signal potential credit risks for the whole financial system.	Total claims on the domestic non-financial sector by finance companies, mutual funds, money market funds, state-lending institutions, insurance companies and pension funds (excluding the government pension fund) in Norway as a share of mainland GDP. Based on the financial accounts data (2017Q1-1995Q4). The series were chained back to 1975Q1 using the database system Findatr.	+	Gap (pct. point)	1975Q1	Statistics Norway and Norges Bank
	Total assets/GDP	A large increase in the size of the non-bank financial system can signal higher risk taking, credit risks and increasing complexity.	Total assets of finance companies, mutual funds, money market funds, state-lending institutions, insurance companies and pension funds (excluding the government pension fund) in Norway as a share of mainland GDP. Based on the financial accounts data (2017Q1-1995Q4). The series were chained back to 1975Q1 using the database system Findatr.	+	Gap (pct. point)	1975Q1	Statistics Norway and Norges Bank

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