STAFF MEMO

An improved composite indicator of systemic stress (CISS) for Norway

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An improved composite indicator of systemic stress (CISS) for Norway
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Norges Bank's advice on the countercyclical capital buffer is based on a broad set of qualitative and quantitative information. The European Systemic Risk Board (ESRB) recommends including a general indicator of systemic stress in the financial system in this decision basis. The composite indicator of systemic stress (CISS) measures the overall stress level in the financial system and has proved to be a good early warning indicator of a systemic banking crisis in real time or in the near future. It may therefore be a useful indicator to include in the decision basis for the countercyclical capital buffer. The levels of the CISS for Norway have been particularly high during international crises.

1 Introduction

In the event of a downturn and prospects for large bank losses, the countercyclical capital buffer can be reduced to prevent tighter bank lending standards from amplifying a downturn (Norges Bank (2013)). The ESRB recommends including a general indicator of systemic stress as part of the information basis for such a decision (ESRB (2014)).

The composite indicator of systemic stress (CISS), introduced in Holló et al. (2012), measures the overall level of stress in the financial system.[1] The indicator is based on five market segments that make up the core of the financial system. The computation of the CISS takes account of the higher risk to the financial system of periods in which stress prevails in several market segments at the same time compared with periods without such correlation. The CISS has proved to be a good early warning indicator of systemic banking crises in real time or in the near future (Detken (2014)).

This *Staff Memo* presents a revised CISS for Norway. Wen (2015) constructed a CISS for Norway that differed from Holló et al. (2012) in some respects. The revised indicator is based on the indicator presented in Wen (2015), but is more in line with the framework presented in Holló et al. (2012).[2] This makes the indicator more comparable with other countries' stress indicators, and international

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[1] A number of central banks have constructed composite indicators of systemic stress based on the framework presented in Holló et al. (2012), for example the European Central Bank (ECB), the central bank of Denmark, Nationalbanken, and the central bank of Sweden, Riksbanken.

[2] See Appendix C for a comparison of the revised CISS with the indicator presented in Wen (2015).

studies of the indicator will be more relevant for Norway. The revised version of the CISS could be included in the set of indicators used in the decision basis for the countercyclical capital buffer, in line with the ESRB's recommendation.

2 Structure of the revised CISS for Norway

The CISS aggregates the stress level in five market segments that represent the core of the financial system.[3] The five market segments are: money market, bond market, equity market, the financial intermediaries sector and foreign exchange and commodity markets. The stress level in each segment is measured by three subindicators (Chart 1). Each subindicator represents types of market stress, for example increased money market volatility, reduced equity market liquidity or a fall in market values in the financial sector. The subindicators should represent developments in an important part of the market segment, such as a broad equity index or an instrument used as a reference in the setting of prices for other instruments. They should not contain identical information, but be complementary and strongly correlated in periods when stress levels are high. The choice of subindicators in the Norwegian version of the CISS largely follows Holló et al. (2012), but is adapted to suit Norwegian conditions.[4]

The subindicators are mainly either computed as the difference between two interest rate series, a so-called interest rate spread, or using a simple measure of volatility. In periods of high stress, the interest rate spread between high-risk and lower-risk assets will often widen. If there is uncertainty about the price of a financial asset, price volatility will often increase. Wider interest rate spreads and higher volatility are both regarded as signals that the stress level in the financial system is rising. We follow Holló et al. (2012) and compute volatility as the weekly average of the daily absolute return.

To be able to compare the level of stress across market segments, the subindicators must first be transformed to the same scale. The subindicators are transformed by ranking each observation based on its empirical cumulative distribution. The observations are first ranked by size, from smallest to largest. Then a value is assigned to each observation corresponding to its place in the ranking and divided by the total number of observations. Thus, after transformation, all the observations will have been assigned a new value of between 0 and 1. A value of close to 0 denotes a low level of stress, characterised by low volatility and low risk premiums, while a value of close to 1 reflects a high level of stress.

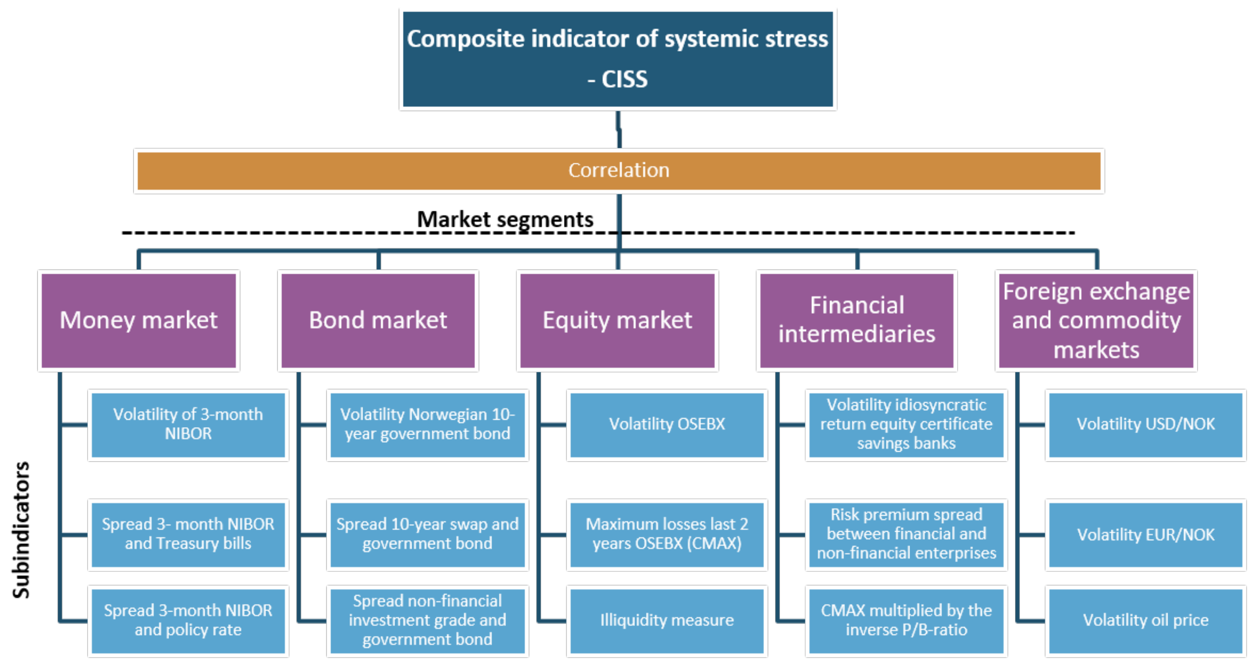
The observations can be ranked simultaneously or recursively, ie one at a time.[5] With simultaneous ranking, the ranking of historical data is updated for every new observation. However, we would not want observations indicating a high level of stress at a particular time to be changed later. For this reason, we rank the observations recursively, as do the ECB, the Riksbanken and the

[3] See Appendix B for a mathematical description of how the stress indicator is computed.

[4] We use the same subindicators as Wen (2015). For a more detailed description of these subindicators, see Appendix A.

[5] The difference between simultaneous and recursive ranking can be illustrated using the following example: Let us suppose we have observations [9, 0, 4, 3, 10]. We rank the first three observations simultaneously and the last two recursively, giving the following new values [3/3, 1/3, 2/3, 2/4, 5/5]. If all the observations had been ranked simultaneously, the ranking would have been as follows: [4/5, 1/5, 3/5, 2/5, 5/5].

Chart 1: Structure of the CISS



Nationalbanken.[6]

The level of stress in each market segment is computed as an average of the three subindicators. The stress level of the different market segments is then aggregated into a total level of stress for the financial system. In the aggregation, the market segments can be weighted in different ways. In Holló et al. (2012), the market segments are weighted according to their relative impact on industrial production growth in the euro area. This results in a weight of 25 percent for the equity market, 30 percent for the financial intermediaries sector and 15 percent each for money market, bond market and foreign exchange market.[7] The ECB and the Nationalbanken use these weights.[8] However, there are only small differences between a CISS computed using these weights or a CISS using equal weights for all the market segments.[9] We follow the example of the Riksbanken[10] and Wen (2015) and assign the same weight to all five market segments.

Finally, the CISS is computed by adjusting the aggregated stress level by the cross-correlation between the market segments. If the five market segments are perfectly positively correlated, the contribution from cross-correlation in computing the CISS will be 0. In cases where the market segments are not perfectly positively correlated, the contribution from the correlations will pull down the CISS.[11] This kind of situation is regarded as less of a challenge for the financial system

[6] To ensure that the indicator shows meaningful values from the start, all the observations for the first three years in the data set, ie from autumn 2003 to autumn 2006, are ranked simultaneously. The observations are then ranked one by one. Recursive ranking will not provide an identical real time assessment as potential revisions of the data are not taken into account.

[7] The weights are estimated based on a range of VAR models.

[8] See for example the ECB metadata page on the CISS and Nationalbanken (2014).

[9] See Holló et al. (2012), Figure A.2 on page 48.

[10] See Bonthron and Johansson (2013).

[11] The method is inspired by modern portfolio theory, where the correlation is included in order to compute total portfolio risk. The contribution from cross-correlation will generally be small when there is a high positive correlation

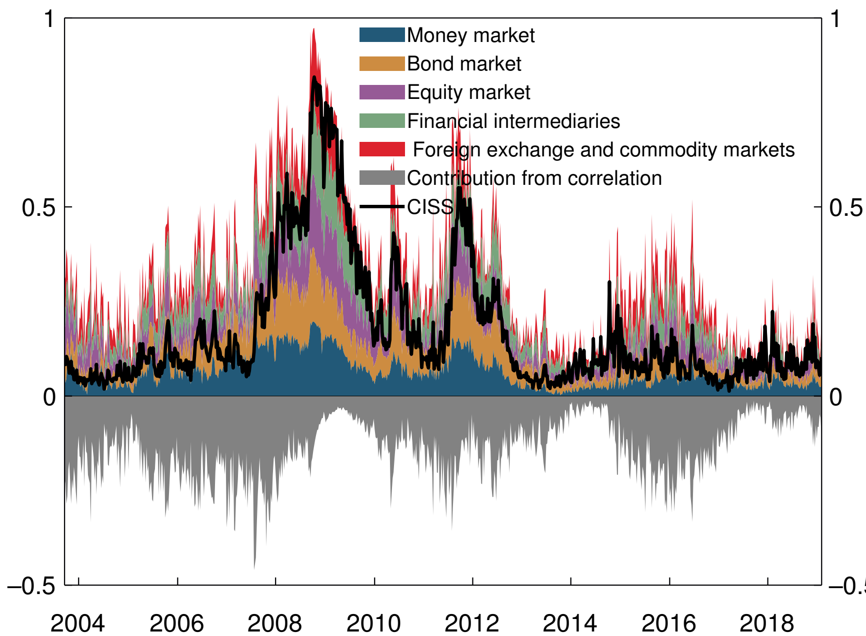
than periods of strongly positive correlation.

We follow Holló et al. (2012) and estimate the correlations recursively using an exponentially weighted moving average. This means that more weight is given to the last observations. The weight given to historical observations is determined by a smoothing parameter. As in Holló et al. (2012), we use a smoothing parameter of 0.93. The estimation of the correlations is described in more detail in Appendix B.

3 Presentation of the revised CISS for Norway

The revised version of the CISS for Norway has increased to high levels during crises (Chart 2), reaching its highest level so far in autumn 2008 during the financial crisis. All five market segments were experiencing elevated stress, and the positive correlation between the markets was high, as expressed by the grey area in Chart 2, which shows a contribution from correlation of close to zero. The CISS also spiked during the sovereign debt crisis, although it was considerably lower than during the financial crisis as the stress level in each of the market segments and the correlation between them were both lower. When oil prices fell in autumn 2014 and through the period of contraction that followed, the increase in the CISS was moderate as the stress level in each of the market segments and the correlation between them were both lower.

Chart 2: Revised CISS for Norway.[1] Weekly data. 15 September 2003–4 February 2019.



1)Estimated simultaneously autumn 2003–autumn 2006 and recursively thereafter.

Sources: Bloomberg, DNB Markets, Thomson Reuters Datastream and Norges Bank

High level of market turbulence and prospects for large bank losses can be indications that the

between the markets. A high degree of cross-correlation means that several market segments are above or below their theoretical average of 0.5. We are primarily interested in the first case as the stress level will then be relatively high in several markets at the same time.

buffer rate should be lowered. It is therefore important to be clear about what constitutes a high level for the CISS. One possibility is to compare today's stress level with historical periods of elevated stress, such as during the sovereign debt crisis and the financial crisis, when the CISS was between 0.5 and 0.8. Alternatively, a high level for the CISS could be estimated based on statistical criteria or econometric models. Detken (2014) estimates a threshold value of around 0.3 for signalling systemic banking crises in EU countries, although the robustness of the results is affected by the short time series underlying the analysis.[12]

Using different methods and applying different assumptions would affect the CISS. The choice of smoothing parameter to calculate historical correlations does not seem to be of great importance in normal time, but has some impact during crises (Chart 3a). With the smoothing parameter set at a higher level, peaks in the CISS have been slightly lower, as was particularly evident during the financial crisis. This is because in periods of high stress in all the markets, greater weight is given to historical correlations where markets have been less positively correlated. As a consequence, the contribution from the correlations during the financial crisis and the sovereign debt crisis was larger, resulting in a lower CISS.

Chart 3b shows that whether the observations are ranked recursively or simultaneously has little impact on the CISS. One exception is the increase in the recursive indicator ahead of the financial crisis occurred slightly earlier, reflecting the low level of stress in the pre-crisis years. When we select a specific point in time and rank observations recursively, we disregard observations after this point. Thus, an increase in the level of stress prior to the financial crisis led to a high level at that time compared with the preceding years. As a result, the CISS rose sharply. Simultaneously ranking resulted in a somewhat lower CISS as the ranking is based on the full data set, which will also include periods of high levels of stress such as the financial crisis and the sovereign debt crisis.

A number of countries' authorities have constructed a CISS based on Holló et al. (2012). As the methodology used is broadly the same, this indicator can be compared across countries, and events that lead to stress in all countries can be distinguished from those leading to stress in only one country. Historically, the CISS for Norway has been highly correlated with other euro area countries (Chart 3c), as international financial turbulence normally spreads rapidly to small open economies such as the Norwegian economy. Developments have diverged in periods, however. During the sovereign debt crisis, for example, the CISS for Norway was somewhat lower than for the euro area.

4 Conclusion

This *Staff Memo* The indicator is now more in line with the framework in Holló et al. (2012), as is the CISS developed by the ECB and several other central banks in Europe. This makes the indicator more comparable with other countries' stress indicators, and international studies of the indicator will be more relevant for Norway.

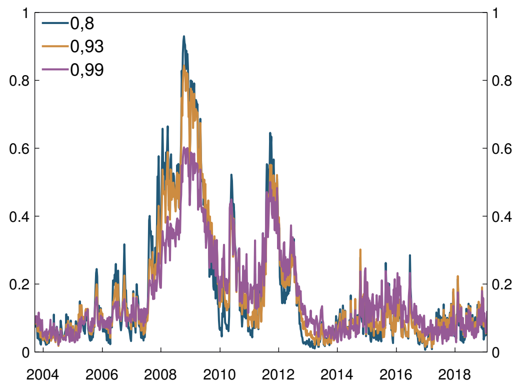
The composite indicator of system stress (CISS) measures the overall stress level in the financial system and has proved to be a good early warning indicator of a systemic banking crisis in real time

[12] Detken (2014) has data for the CISS for the period 1999 to 2014.

or in the near future. The revised version of the CISS could be included in the set of indicators used in the decision basis for the countercyclical capital buffer, in line with the ESRB's recommendation.

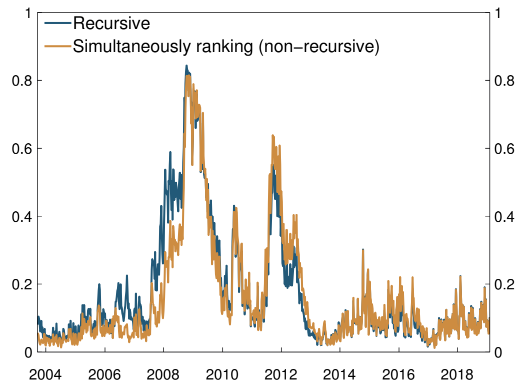
Chart 3

(a) Revised CISS for Norway using different smoothing parameters.[1] Weekly data. 15 September 2003 - 4 February 2019.



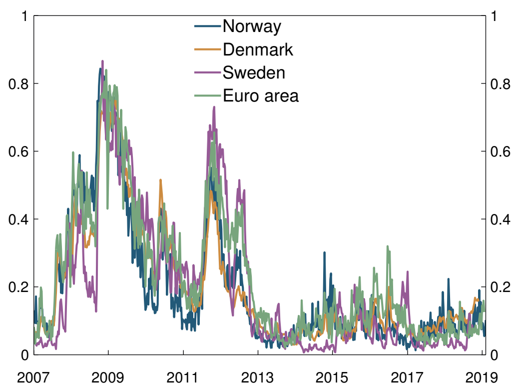
1)Estimated simultaneously autumn 2003–autumn 2006 and recursively thereafter.
Sources: Bloomberg, DNB Markets, Thomson Reuters Datastream and Norges Bank

(b) Revised CISS for Norway using recursive[1] versus simultaneous ranking of all observations. Weekly data. 15 September 2003 - 4 February 2019.



1)Estimated simultaneously autumn 2003–autumn 2006 and recursively thereafter.
Sources: Bloomberg, DNB Markets, Thomson Reuters Datastream and Norges Bank

(c) CISS for Norway, Sweden, Denmark and the euro area.[1] Weekly data.



1) As the methodology applied varies somewhat from country to country, minor deviations can be disregarded. The end date applied also varies.
Sources: Bloomberg, DNB Markets, ECB, Finansinspektionen, The Systemic Risk Council, Thomson Reuters Datastream and Norges Bank

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Appendiks A. A more detailed description of the subindicators included in the CISS

Money market

- Realised volatility of the three-month Nibor rate. The Nibor rate reflects the interest rate on unsecured interbank lending in NOK. Higher volatility therefore means increased uncertainty in the Norwegian interbank market and can be an expression of increased pressure on banks' liquidity management. Volatility is calculated as the weekly average of absolute daily changes in three-month Nibor. Source: Norges Bank

- Spread between three-month Nibor and the interest rate on three-month Treasury bills. This margin can be regarded as a risk premium required by a bank to lend to another bank as opposed to lending to the government. A wider spread indicates higher uncertainty in the money market. Source: Norges Bank

- Spread between three-month Nibor and the policy rate. In contrast to the interest rate on Treasury bills, which is influenced by supply and demand conditions, the policy rate is set by the central bank. Changes in the policy rate will in times of stability have a strong impact on three-month Nibor as they influence expectations with regard to the future interest rate level. In periods of stress, the spread between three-month Nibor and the policy rate can increase because of higher risk premiums in monetary market rates. A wider spread indicates higher money market uncertainty. Source: Norges Bank

Bond market

- Realised volatility of Norwegian ten-year government bond yields. Higher volatility can signal uncertainty among market participants regarding the future interest rate level. Volatility is calculated as the weekly average of absolute daily yield changes for Norwegian ten-year bonds. Source: Norges Bank

- Spread between ten-year swap rate and Norwegian ten-year government bond yield. The swap rate is the fixed rate in an interest rate swap agreement. Since banks are the main participants in the swap market, the swap rate will to a certain extent reflect credit risk in the banking sector. A wider spread between the swap rate and the yield on the corresponding government bond will therefore reflect a perception of higher credit risk in the banking sector. Sources: Thomson Reuters Datastream and Norges Bank

- Yield spread between bonds issued by investment grade non-financial enterprises in the utility sector and government bonds (five-year maturity). This spread gives an indication of credit and liquidity risk in the bond market. The spread normally increases in periods of financial stress when government bond yields fall owing to investors' search for safe investments and yields on bonds issued by non-financial enterprises increase because of higher credit and liquidity premiums. Sources: DNB Markets and Norges Bank

Equity market

- Realised volatility of the Oslo Børs Benchmark Index (OSBEX). Higher volatility signals greater uncertainty regarding the market value of the companies listed on Oslo Børs. High volatility can impair the functioning of the equity market and make it more difficult for companies to obtain financing. A higher value for this subindicator therefore indicates increased financial stress. This subindicator is calculated as the weekly average of absolute daily log returns. Source: Thomson Reuters Datastream

- Maximum losses over the past two years (CMAX) for the OSBEX. This subindicator provides an estimate of the maximum loss an investor may incur if shares were bought at a time in the past two years when prices were at their highest. A high value indicates that many investors have incurred large losses and may be vulnerable to further price falls in the equity market. It would also be costly for companies to issue new shares. Source: Thomson Reuters Datastream

- Illiquidity measure (Amihud illiquidity measure). A liquid market is a market where a large number of trades can be executed quickly without affecting price. This subindicator is intended to capture this aspect. It is calculated as the weekly average of daily absolute returns divided by daily trading volume. A higher value indicates larger price movements per unit trading volume and thus lower market liquidity. Sources: Bloomberg and Thomson Reuters Datastream

Financial intermediaries

- Volatility of the idiosyncratic equity return of equity certificate savings banks. This subindicator indicates the idiosyncratic risk associated with equity certificate savings banks listed on Oslo Børs. An increase in this subindicator indicates heightened uncertainty among investors with regard to the Norwegian banking sector. General market risk is already accounted for by the subindicator "Realised volatility of the Oslo Børs Benchmark Index (OSBEX)". The idiosyncratic risk is the residual from the following regression:

$$r_t^{OSEEX} = \beta_0 + \beta_1 r_t^{OSEBX} + \varepsilon_t \tag{A.1}$$

  where r_t^{OSEEX} is the return on the Equity Certificate Index and r_t^{OSEBX} is the return on the Oslo Børs Benchmark Index. Source: Thomson Reuters Datastream

- Risk premium spread between bonds issued by financial enterprises (banks) and investment grade non-financial enterprises in the utility sector (five-year maturity). This subindicator increases when risk premiums for the financial enterprises increase more than premiums for the non-financial enterprises. Source: DNB Markets

- CMAX multiplied by the inverse price/book ratio for the Oslo Børs index for the financial sector (OSE40GI). This subindicator is high if the equity market has been falling over time and book values for financial enterprises are high compared to market assessments. In such a situation, financial enterprises may already have incurred large losses, and investors can expect more losses ahead.

$$Int_t^{financials} = \sqrt{CMAX_t^{financials} * PB_t^{financials^{-1}}} \tag{A.2}$$

where $CMAX_t^{financials}$ is maximum losses over the past two years and $PB_t^{financials^{-1}}$ is the inverse price/book ratio for financial enterprises in the Oslo Børs index for the financial sector. Sources: Bloomberg and Thomson Reuters Datastream

Foreign exchange and commodity markets

- Realised volatility USD/NOK and EUR/NOK. The value of the Norwegian krone is influenced by macroeconomic and financial information. If uncertainty arises in financial markets, capital flows in and out of Norway can create increased volatility in NOK. With higher exchange rate volatility, managing exchange rate risk will be more difficult for firms and financial enterprises, which in turn can reduce their opportunities for obtaining funding in a foreign currency. Norwegian banks and covered bond issuers obtain a substantial share of their funding in foreign markets. Higher exchange rate volatility could therefore increase systemic stress in the financial system. The subindicators are calculated as the weekly average of absolute daily log changes in the exchange rate. Source: Norges Bank

- Realised volatility in the oil price (Brent Crude oil). Fluctuations in the oil price can have a substantial impact on the financial system and the Norwegian real economy. High oil price volatility can for example spread to share prices and exchange rates. This can also result in losses for investors exposed to the oil sector and higher risk premiums for other industries. A higher value for this subindicator therefore reflects a higher level of stress. The subindicator is calculated as the weekly average of absolute daily log changes in the oil price. Source: Thomson Reuters Datastream

Appendiks B. Technical calculations

Estimated volatility

About half of the subindicators are estimated based on a simple volatility measure:

$$\sigma_t^2 = \frac{1}{m} * \sum_{i=1}^{m} abs(r_i) \tag{B.2}$$

where m is the number of days in the week, abs is the absolute value and r is the raw series for subindicator i.

Ranking of observations

Suppose the following is the time series for variable $X : x_1, x_2, ..., x_n$, with n the total number of observations. This series is then ranked from the lowest to the highest value in a new series: $y_1, y_2, ..., y_n$, where $y_1 \leq y_2 \leq y_3 ... \leq y_n$. The ranked value, z_t, for observation, x_t, is calculated based on the empirical cumulative distribution function $F_n(x_t)$

$$z_t = F_n(x_t) = \begin{cases} \frac{r}{n}, & for \quad y_r \leq x_t \leq y_{r+1}, r = 1, 2, ..., n-1 \\ 1, & for \quad x_t = y_n \end{cases} \tag{B.3}$$

for $t = 1, 2, ..., n$. The empirical cumulative distribution function, $F_n(x^*)$, measures the number of observations that do not exceed a specific value, x^*, divided by the number of observations in the data set. In this formula, all the observations are ranked simultaneously. If recursive ranking is used on an expanding sample, the formula must be modified somewhat (see Holló et al. (2012)).

Estimation of correlations and computation of the CISS

The CISS at time t is computed as follows:

$$CISS_t = (w * s_t) C_t (w * s_t)^T \tag{B.4}$$

where $w = [w_1 \quad w_2 \quad w_3 \quad w_4 \quad w_5]$ is a vector of constant market segment weights, $s_t = [s_{1,t} \quad s_{2,t} \quad s_{3,t} \quad s_{4,t} \quad s_{5,t}]$ is the stress level in each market segment at time t, and * marks element by element multiplication of the vectors. C_t is the matrix of time-varying cross-correlation coefficients between market segments i and j:

$$\begin{pmatrix} 1 & \rho_{12,t} & \rho_{13,t} & \rho_{14,t} & \rho_{15,t} \\ \rho_{12,t} & 1 & \rho_{23,t} & \rho_{24,t} & \rho_{25,t} \\ \rho_{13,t} & \rho_{23,t} & 1 & \rho_{34,t} & \rho_{35,t} \\ \rho_{14,t} & \rho_{24,t} & \rho_{34,t} & 1 & \rho_{45,t} \\ \rho_{15,t} & \rho_{25,t} & \rho_{35,t} & \rho_{45,t} & 1 \end{pmatrix} \tag{B.5}$$

The time-varying cross-correlations, $p_{ij,t}$, are estimated recursively. The method used is an exponential moving average with covariance $\sigma_{ij,t}$ and volatility $\sigma^2_{i,t}$, approximated using the following formula:

$$\sigma_{ij,t} = \lambda\sigma_{ij,t-1} + (1-\lambda)\tilde{s}_{i,t}\tilde{s}_{j,t} \tag{B.6}$$

$$\sigma^2_{i,t} = \lambda\sigma^2_{i,t-1} + (1-\lambda)\tilde{s}^2_{i,t} \tag{B.7}$$

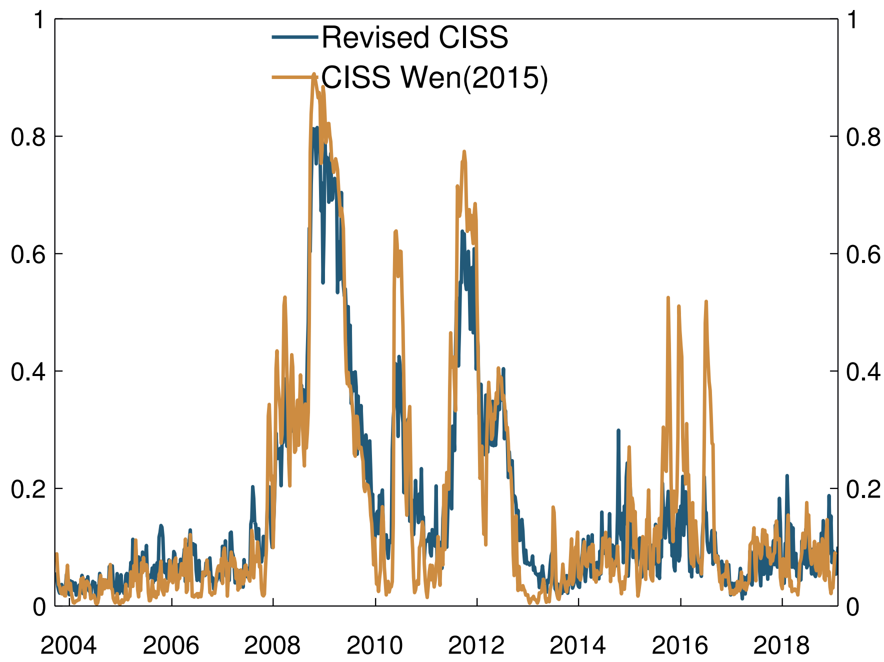
$$\rho_{ij,t} = \sigma_{ij,t}/(\sigma_{i,t}\sigma_{j,t}) \tag{B.8}$$

where $i = 1,\ldots 5$, $j = 1,\ldots 5$ and $\tilde{s}_{i,t} = (s_{i,t} - 0,5)$ show the stress level in each market segment minus their theoretical median of *0,5*. The smoothing parameter, λ, is, as in Holló et al. (2012), set at *0,93*.

Appendiks C. Comparison of the revised CISS for Norway with the indicator presented in Wen (2015)

We have updated the indicator in Wen (2015) with new figures and compared it with the CISS constructed in this *Staff Memo* (see Chart C.1). The indicators show fairly similar trends, although there are some differences, particularly in the period between autumn 2015 and summer 2016, when the updated CISS based on Wen (2015) was considerably higher, driven by a higher overall stress level and smaller contributions from the correlations. We have largely followed the framework presented in Holló et al. (2012). Wen (2015) used a different method in some areas: for example, GARCH models are used to estimate historical correlations and implied volatility for several of the subindicators.

Chart C.1: Revised CISS for Norway compared with the CISS presented in Wen (2015).[1] Weekly data. 15 September 2003 - 21 January 2019.



1) Ranking of all observations simultaneously.

Sources: Bloomberg, DNB Markets, Thomson Reuters Datastream and Norges Bank