
Staff memo

# SRISK in the Swedish banking system

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**Staff memo**

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# Summary

SRISK, a market-based systemic risk measure, captures a financial institution's expected capital shortfall in a crisis by combining information on its size, leverage and market sensitivity. In this staff memo, we estimate SRISK for the Swedish banking sector, including both listed and non-listed banks. We show that the capital shortfall for the Swedish banking sector under a market stress scenario is mainly driven by large banks and mortgage banks. The capital shortfall can increase fast during a crisis and is not always proportional to the severity of the market decline. Most small banks have generally close to zero capital shortfalls under a market stress scenario, however, there are some small banks, particularly consumer credit banks, showing higher relative levels of capital shortfalls to the size of their assets compared with large banks. Our findings highlight that systemic vulnerabilities are not limited to Sweden's largest banks and that monitoring smaller institutions can also be important from a financial stability perspective.

As a market-based risk indicator, SRISK is typically applied to listed banks. A key challenge in many countries, including Sweden, is that a large majority of banks are non-listed and thus lack market-valued equity. Although these non-listed banks are generally small and play a limited role in credit intermediation, their collective exposure to common shocks may still generate systemic risk. In this staff memo, we have applied the methodology of Engle et al. (2024), which extends the SRISK estimation to non-listed banks using observable balance sheet characteristics. In doing so, we contribute to a more comprehensive assessment of systemic risk in the Swedish banking sector by including both listed and non-listed banks in the analysis.

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# 1 Systemic risk in the Swedish banking system

Understanding systemic risk in the banking sector is central to financial stability analysis. Banks play an important role in the economy by channelling savings into investment, providing credit and facilitating payments. However, providing these services, they also take on risks and become vulnerable to shocks. When such shocks affect one or more institutions and spread to others, they can threaten the stability of the entire financial system. When this happens, the functioning of credit markets may be disrupted, and the real economy can be affected negatively. The societal and economic costs of financial crises are often severe and long-lasting, including higher unemployment, slower growth and substantial public spending to support the financial system. Monitoring systemic risk is therefore essential, not only to protect individual institutions but more importantly to prevent widespread financial instability that can have serious consequences for the economy as a whole. One particularly important dimension of systemic risk is banks becoming undercapitalized. Banks with insufficient capital buffers are not only more likely to become distressed in a market downturn, but they can also amplify the stress. When many such institutions are forced to deleverage at the same time, their actions could trigger fire sales and sharp declines in asset prices, reinforcing the initial stress. If several banks are simultaneously undercapitalized, the likelihood of widespread financial instability increases due to interlinkages and correlated exposures.[2] Studying undercapitalized banks is therefore central when it comes to identifying vulnerabilities that can both start and amplify financial crises.

While tools for monitoring systemic risk have become more sophisticated in recent years, much of the work focuses on large and publicly listed banks. A growing literature has developed quantitative, market-based measures of systemic risk that rely on stock price data to capture a bank's sensitivity to market wide stress.[3] These measures are useful for listed institutions, where market data is available in real time. However, applying similar methods to non-listed banks is not possible due to the absence of such data. This is particularly important in banking systems like Sweden's, in which smaller or specialized banks, such as non-listed consumer credit banks or mortgage institutions, also have a role in credit intermediation and other critical financial services. Moreover, large banks may be exposed directly or indirectly to these smaller institutions, which means that vulnerabilities among them may also propagate to the core of the financial system. Therefore, although these institutions may not be systemically important on their own, they can become systemically relevant in aggregate. When many smaller banks are exposed to similar risks, their joint distress can

[2] See for example Hanson, Kashyap and Stein (2011), who describe how simultaneous deleveraging and fire sales can amplify initial shocks and spread stress throughout the financial system, Acharya et al. (2017), who show that undercapitalized institutions contribute more to systemic risk when markets are under stress, and Montagna, Torri and Covi (2020), who analyse how network interlinkages and correlated exposures can transmit and amplify distress across banks.

[3] Examples include SRISK (Brownlees and Engle, 2017 and Acharya et al., 2012), ΔCoVaR (Adrian and Brunnermeier, 2016), marginal expected shortfall (Acharya et al., 2017) and the distressed insurance premium (Huang et al., 2009).

generate correlated losses and amplify instability in the system, a condition often referred to as being *systemic as a herd.*[4]

This staff memo replicates the methodology in the academic paper *Estimating systemic risk for non-listed euro-area banks* by Engle et al. (2024) and applies it to the Swedish banking system. Their approach involves establishing a functional relationship between a measure of systemic risk called SRISK and bank balance-sheet characteristics using a panel regression for the listed banks. Next, the estimated coefficients together with bank balance sheet characteristics for non-listed banks, are used to implicitly calculate SRISK for non-listed banks. By applying this methodology to Swedish conditions and institutional data, we make a first attempt to produce market-based systemic risk estimates for a broad set of Swedish banks, including smaller institutions that are typically outside the scope of standard market-based indicators for systemic risk.

Our results show that the potential capital shortfall in the Swedish banking system, as measured by SRISK, is primarily driven by large banks and mortgage banks, while small listed and non-listed banks overall contribute less to systemic risk. The SRISK estimates are consistently negative for small banks over time, indicating that the burden of recapitalization during severe market stress would fall mainly on the largest institutions. However, when examining the relative size of the capital shortfall, we find that smaller banks, particularly certain consumer credit banks, can stand out with relatively high levels of capital shortfall in relation to total assets. Even if these banks may not be the largest contributors to aggregate capital shortfall in absolute terms, this can be a signal of individual fragility. Persistent vulnerabilities at the individual bank level could, in turn, become relevant for financial stability if they were to trigger spillovers through, for example, funding markets, concentrated exposures or decreased confidence in the banking sector as a whole.

Taken together, our findings highlight the importance of monitoring systemic risk across the full universe of banks, not just the largest listed institutions. By extending the market-based systemic risk measure SRISK to non-listed banks, this staff memo provides a broader perspective of systemic risk in the Swedish banking system.

[4] See for example Liu (2011), Jain and Gupta (1987) and Hirakata et al. (2017).

# 2 A brief overview of the banking sector

As of June 2025, 125 banks were operating in Sweden[5]. Although the number of institutions is relatively large for a small, open economy, the Swedish banking system is highly concentrated and constitutes around 200 per cent of Swedish GDP. Only a few banks dominate the market and account for approximately 70 per cent of total lending to the public. These few banks are considered systemically important not only due to their size but also because of their interconnectedness, both with each other and with the broader financial system, domestically and abroad.

In parallel to the large institutions (often called universal banks, offering many types of financial services), a variety of smaller banks operate with more focused business models. These so-called *niche banks* or *specialized banks,* typically specialize in one or more market segments. Examples of these are mortgage banks, which provide loans to households, often secured by residential property; consumer credit banks, which offer unsecured loans and payment solutions, usually through digital platforms; security-trading banks, which mainly specialize in securities trading and fund and asset management. There are also banks with core activities focusing on product and sales financing.

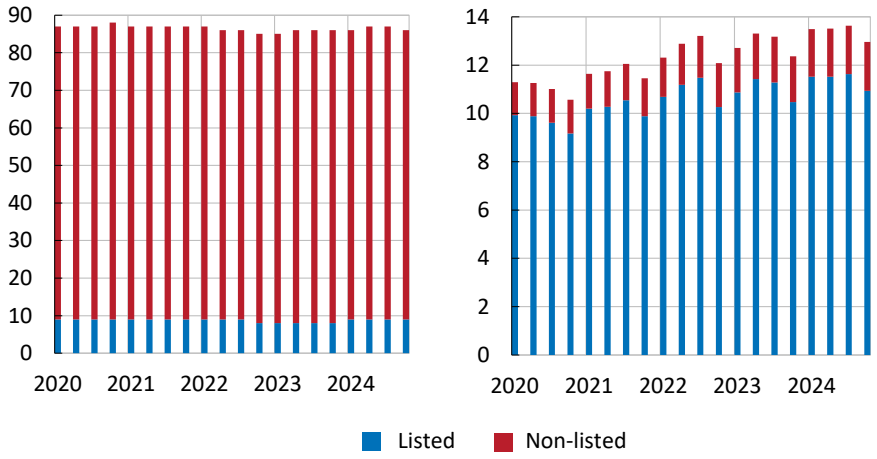
Most of the large banking institutions in Sweden are public companies traded on the stock exchange. This means that they have observable market valuations. The majority of banks, however, are not listed (see left pane Figure 1). As illustrated in the figure, out of the 88 Swedish banks, only nine are listed. This pattern is not unique to Sweden. In the euro area, non-listed banks make up around two-thirds of all supervised banks, and in the United States, the share is even higher. Being non-listed as a bank is hence not that uncommon. Still, this may create a challenge for systemic risk assessment. Many of the most widely used market-based measures of systemic risk, such as equity volatility, market beta, ΔCoVaR, SRISK or expected shortfall, rely on market data that are only available for listed institutions.[6] As a result, these tools cannot be applied to the vast majority of Swedish banks, limiting the scope of these monitoring frameworks and therefore the scope of systemic risk analysis.

[5] Of these, 88 are Swedish banks and the rest are foreign bank branches.

[6] In 2013, the Riksbank described and estimated different market-based methods to measure systemic risk, including SRISK, for the four major banks in Sweden. See Bengtsson et al. (2013), Identifying systemically important banks in Sweden – what can quantitative indicators show us?, *Sveriges Riksbank Economic Review,* 2013:2, the Riksbank.

**Figure 1. Number of Swedish banks and their total assets over time**

Number, SEK trillion




Note. The chart on the left represents the number of listed and non-listed Swedish banks. The chart on the right illustrates the share of total assets that belong to listed and non-listed Swedish banks in SEK trillion.

Source: The Riksbank and Finansinspektionen.

While listed banks dominate in terms of total assets and lending volumes, non-listed banks make up the majority in terms of the number of institutions (see Figure 1). Although these banks are individually "less significant", their collective presence means that they still play an important role in the functioning of the financial system. Empirical literature also suggests that systemic risk is not only about the failure of a single large institution, but it can also arise from the simultaneous distress of many smaller actors. This is commonly referred to as *systemic as a herd*.[7] From this perspective, smaller, or niche, banks may not be systemically important in isolation but may become so in aggregate if they are exposed to common risk factors. From a macroprudential perspective, it is therefore important to monitor risk exposures and vulnerabilities of the entire banking sector, listed or non-listed, big or small, to better understand where systemic risk may build up and how it might spread.

[7] See for example Adrian and Brunnermeier (2016), Acharya and Yorulmazer (2007) and De Bandt and Hartmann (2002).

# 3 SRISK is a market-based measure of systemic risk

### What is SRISK?

SRISK[8] measures the capital shortfall of a firm conditional on a severe market decline. Formally, the SRISK of a bank $i$ is defined as the expected capital shortfall ($CS$) at a future point in time *t+h* conditional on a severe downturn of a broad market index $R_{m,t+1:t+h}$ of size $C$ during the same time period:

$$SRISK_{i,t} = \mathbb{E}_t\left[CS_{i,t+h} \middle| R_{m,t+1:t+h} < C\right]$$

The concept builds on the idea that during a crisis, banks' equity prices tend to fall, often quite considerably, while liabilities remain largely unchanged in the short term. This means that a bank's leverage increases precisely when its ability to absorb losses is most stressed. SRISK estimates how large the gap would be between what a bank is expected to have in equity *after* a crisis, and what it *should* have to remain sufficiently capitalized. SRISK is a function of three key components: size, leverage and risk. It can hence be decreased by lowering any one of these components.

SRISK falls into the category of market-based measures of systemic risk. Being market-based means that the measure, wholly or partially, is based on information from financial markets, such a stock prices, rather than only on accounting or supervisory data. Market data change continuously and reflect investors' collective assessment of risk. In periods of stress, stock prices, for example, provide signals about how a bank is perceived in real time. Market-based measures can therefore help to detect early signs of distress before problems are seen in accounting data. A drawback to using market data is of course that they can sometimes behave erratically, especially during periods of stress. This means that risk can be over- or underestimated at times.

SRISK can be viewed as the market's assessment of banks' capital resilience. It can be compared to traditional stress tests of bank capital. Both start from a stress scenario defined in some way and they then assess the resilience of the bank or banking system. A difference between the two is while SRISK traces how a market shock propagates to the banking sector based on how individual banks' stock prices respond to market movements, stress tests analyse how a macroeconomic shock affects bank capital via credit losses and other balance sheet channels. Stress tests have the advantage of offering a more granular and detailed assessment compared to SRISK. A drawback is, however, the low frequency of accounting data used in stress tests. SRISK has therefore been discussed as a potential benchmark or complement to traditional supervisory stress tests, but with conflicting conclusions.[9]

[8] Introduced and further developed by Brownlees and Engle (2017), Acharya et al. (2012) and Acharya et al. (2017).

[9] For example, Acharya et al. (2012) have argued that SRISK can serve as a useful complement to regulatory stress tests, as it offers a simple, high-frequency estimate of banks' capital shortfalls under stress without

## Why is SRISK a measure of systemic risk?

As argued in the work of Acharya et al. (2012) and Engle and Brownlees (2017), what makes a financial institution systemically important is not only its size, but also its tendency to lose capital when markets fall and the rest of the financial system experiences stress. SRISK captures this by estimating the expected capital shortfall a bank would face in the event of a severe market downturn (which is not necessarily caused by the bank itself). Institutions with high SRISK are those that are expected to suffer large losses in equity during a crisis and may need to raise capital to meet prudential requirements and remain solvent. However, in a crisis, many banks with high SRISK are likely to be in this position at the same time. This can be a problem because the banks will now compete for capital at a time when markets are already stressed, and investors may be unwilling or unable to step in. This is what makes SRISK a measure of systemic risk. When the need for capital is widespread in the financial sector, individual institutions cannot rely on market solutions, and the burden of support may fall on the public sector. That is why it also matters when the capital shortfall occurs. A shortfall during "good times" may not be a problem, but a shortfall during bad times can make the crisis worse.

As described by Acharya et al. (2012), capital shortfall during a crisis can have ripple effects throughout both the financial system and the broader economy. In theory, a bank is therefore considered systemically risky if it is likely to face a capital shortfall when the financial system is already stressed. SRISK builds on this idea by providing a forward-looking market-based estimate of the capital shortfall a bank would face. It measures how much additional capital would be needed, according to the market's assessment of its capital resilience, to restore the bank's capital ratio to a predetermined level.

The strength of SRISK lies in its focus on conditionality. It assesses not just a bank's vulnerability, but whether that vulnerability would add to system-wide stress during a crisis. A high and positive SRISK indicates that the institution is likely to amplify the crisis, while a low or zero SRISK suggests it would not contribute significantly to systemic risk.

Like for many other measures of systemic risk, SRISK also has its weaknesses. First, it is model-dependent and relies on many assumptions about how markets behave during stress. SRISK is also sensitive to changes in equity prices and volatility. Because of this, it may signal large systemic risk simply because of temporary market turbulence, even if the underlying financial position of a bank remains solid. Similarly, it could underestimate risk during calmer periods.

requiring any particular credit risk modelling. Work by Homar et al. (2016), however, warns against using SRISK as a benchmark. This is because SRISK is highly sensitive to market leverage and equity valuations, and because it focuses only on the equity holder. In some cases, they argue, this can lead to low stress impacts for undercapitalized banks, precisely when the risks to financial stability are the most serious. Moreover, SRISK ignores the transmission mechanisms from macroeconomic scenarios to credit losses, which are central to regulatory stress tests. In summary, SRISK should not be seen as a substitute for regulatory stress tests but rather as a complementary market-based perspective that offers a high-frequency, forward-looking perspective.

## Estimating SRISK[10]

Given the book value of debt $D_{i,t}$, the capital shortfall of a bank is given by the following equation

$$SRISK_{i,t} = kD_{i,t} - (1-k)\mathbb{E}_t\left[W_{i,t}\middle|R_{m,t+1:t+h} < C\right]$$

where $k$ is a required percentage minimum of assets by the market, interpreted as the market's required capital ratio ("the required market leverage ratio" going forward), $W_{i,t}$ is the market valued equity, $C$ the severe market downturn and $R_{m,t+1:t+h}$ is the return of the broad market index.[11]

Before proceeding with the calculation, we need to put a value on the term $\mathbb{E}_t\left[W_{i,t}\middle|R_{m,t+1:t+h} < C\right]$. This represents how much equity is expected to be left given that the decline of the broad market index is larger than $C$.[12] This is captured by a variable called the *long-run marginal expected shortfall* (LRMES in short), defined as:

$$LRMES_{i,t} = -\mathbb{E}_t(R_{i,t+1:t+h}|R_{m,t+1:t+h} < C)$$

$LRMES$ quantifies how much a banks' stock price ($R_{i,t+1:t+h}$) is expected to fall conditioned on that the market return ($R_{m,t+1:t+h}$) is less than $C$ per cent over 6 months. This variable has to be estimated, using equity returns of both the bank itself ($R_{i,t}$) and a representative broad market index ($R_{m,t}$) as inputs. There is, however, a closed form approximation of it as well, as seen in the second equation below.[13] SRISK can now be rewritten and computed in the following way:

$$\begin{aligned} SRISK_{i,t} &= kD_{i,t} - (1-k)W_{i,t}\left(1 - \boldsymbol{LRMES_{i,t}}\right) \\ &= kD_{i,t} - (1-k)W_{i,t}\left(1 - \left(\mathbf{1} - \exp\left(\log(\mathbf{1}-\boldsymbol{C})\,\widehat{\boldsymbol{\beta_{i,t}}}\right)\right)\right) \end{aligned}$$

## SRISK is estimated weekly at NYU Stern V-LAB

The Volatility Institute of the NYU-Stern School of Business has developed a public platform called Volatility Laboratory (V-LAB) which provides real-time estimates of financial risk measures, including SRISK. These measures are estimated weekly and made public for major global financial firms. In our analysis, we use the SRISK estimates from V-LAB for the listed Swedish banks included in their database. For listed banks not covered by V-LAB, we compute SRISK independently using a consistent methodology.

[10] See full, step-by-step calculation and estimation details in the appendix.

[11] The market-based requirement *k* does not represent regulatory minimum levels, but rather the level of capitalization that investors are assumed to demand for the bank to remain viable under stress.

[12] The LRMES measures the expectation of the bank equity value multiperiod arithmetic return condition on the specified crisis event C.

[13] See appendix for the statistical details.

# 4 Estimating SRISK for non-listed banks

### Direct and indirect approach

As previously mentioned, the main challenge to apply a market-based approach to estimate SRISK is that most banks are not publicly traded. Therefore, one cannot use the method described in Chapter 3 to estimate the measure for the non-listed banks as it relies on the availability of market prices. Engle et al. (2024) have developed an analytical solution for this. It involves, first, mapping estimated SRISK measures for listed banks to some balance-sheet information, and, second, applying these mappings to the balance-sheet information of non-listed banks in order to calculate an indirect estimate of SRISK for these banks. Using this method, Engle et al. (2024) have estimated systemic risk for non-listed Euro-area banks and also validated the results with the losses in European bank stress-testing exercises.

Following Engle et al. (2024), we estimate SRISK for non-listed Swedish banks. We first establish the functional relationship between the measure and listed banks' balance-sheet characteristics using a panel regression. Second, we use the coefficients estimated in the first step together with the bank balance sheet characteristics for non-listed banks and calculate SRISK for these banks.

For the first step, Engle et al. (2024) have proposed two approaches: a direct and an indirect, that differ in terms of the sub-steps needed to estimate SRISK. The two approaches are described briefly below.

- **Direct approach**: estimate SRISK based on the following panel regression to establish a direct link between SRISK and the bank balance sheet characteristics

$$\widehat{SRISK_{i,t}^{direct}} = \hat{\delta} X_{i,t-1} + \widehat{\alpha_t} + \varepsilon$$

Here, $X_{i,t}$ is a vector of banks' lagged balance sheet characteristics including size (measured by the log total assets), equity-to-assets ratio, profit-to-assets ratio, CET1, and LCR, as well as the squared term of log total assets and equity-to-assets ratio to account for non-linearities. A one-quarter lag for all balance sheet variables is used to account for the reporting delay due to the fact that these financials are usually reported after the corresponding quarter. $\widehat{\alpha_t}$ represents the time fixed effect to control for factors that vary over time but affect all banks simultaneously. The coefficients are estimated using the sample of listed banks and then applied to the sample of non-listed banks.

- **Indirect approach**: estimate first the market value of equity $\widehat{W_{i,t}}$ and the beta $\widehat{\beta_{i,t}}$ for the bank using the below two panel regressions and then estimate SRISK using these variables as inputs.

$$\widehat{W_{i,t}} = \widehat{\delta^W} X_{i,t-1} + \widehat{\alpha_t^W} + \varepsilon$$

$$\widehat{\beta_{i,t}} = \widehat{\delta^\beta} X_{i,t-1} + \widehat{\alpha_t^\beta} + \varepsilon$$

Here, $X_{i,t}$ is a vector of banks' lagged balance sheet characteristics just like before. The coefficients estimated via the above two regressions for listed banks are used to derive the market value of equity and the beta for non-listed banks. Finally, the SRISK for non-listed banks can be computed using the SRISK definition formula as presented in Brownlees and Engle (2017):

$$\widehat{SRISK_{\iota,t}^{indirect}} = kDebt_{i,t} - (1-k)\widehat{W_{\iota,t}}\left(1 - \widehat{LRMES_{\iota,t}}\right)$$

$$= kDebt_{i,t} - (1-k)\widehat{W_{\iota,t}}\left(1 - (1 - \exp\left(\log(1-C)\,\widehat{\beta_{\iota,t}}\right)\right)$$

Following the original methodology of SRISK for European banks by V-LAB, the market crisis threshold $C$ is set to 40 per cent and the required market leverage ratio $k$ is set to 5.5 per cent, reflecting the observed market leverage ratios prior to the global financial crisis. It is important to point out that both these parameters can be changed according to needs, and they should not be interpreted as regulatory requirements. We consider different values for both of these parameters later on in a sensitivity analysis.

## Dataset

Table 1 provides a summary of the data sources used in our analysis. To estimate SRISK, we use two types of datasets. The first consists of SRISKs and betas for listed banks, primarily obtained from V-LAB. However, since three of the small listed banks (Resurs, Hoist and Nordnet) are not covered by V-LAB, we calculate SRISK and betas for these three banks independently, following the same methodology as V-LAB/Brownlees and Engle (2017). This approach is described in detail in Chapter 3 and in the appendix.

The second dataset consists of balance-sheet characteristics, which we collect from different data sources depending on the available length of the time series and variable coverage. For listed banks, we use hand-collected data from bank quarterly reports for the three large banks, and Bloomberg and Capital IQ financial data for the six smaller banks. For non-listed banks, we mainly rely on Capital IQ and complement it with the banks' standard reports obtained from the Swedish Financial Supervisory Authority.

**Table 1. Data sample and sources**

| | Banks | Data source |
|---|---|---|
| **Listed banks** | *Large banks:* SEB, Swedbank, and Svenska Handelsbanken | *SRISK and beta*: from V-LAB<br>*Market capitalization*: from Bloomberg<br>*Bank characteristics:* from banks' quarterly reports |
| | *Small banks:* Avanza, Norion, TF Bank, Resurs, Hoist, Nordnet | *SRISK and beta:* from V-LAB and self-computed<br>*Market capitalization:* from Bloomberg<br>*Bank characteristics:* from Bloomberg and Capital IQ |
| **Non-listed banks** | 4 mortgage banks<br>39 savings banks<br>9 consumer credit banks<br>3 security trading banks<br>5 other banks | *Bank characteristics:* from Capital IQ and banks' standard reports to the Swedish FSA |

In total, our dataset covers the nine listed banks and 60 non-listed banks[14], including four mortgage banks, 39 savings banks, nine consumer credit banks, three security trading banks, and five other banks. We combine all data sources and construct a panel dataset at a quarterly frequency until 2024-Q4, using the longest available historical time series for each bank type. For large listed banks, data is available as far back as 2004, while for smaller listed banks the same series are much shorter. For most non-listed banks, data coverage begins in 2015.

## Regression results

The direct approach regresses SRISK over total assets directly on banks' lagged balance sheet characteristics. The results are shown in Table 2. We use six model specifications with a different combination of balance sheet characteristics. The explanatory variables are the same as those in Engle et al. (2024). Consistent with the findings in Engle et al. (2024), our results show that bank size, measured by log total assets, has a positive and statistically significant coefficient, i.e. SRISK grows with the size of the bank. In contrast, both the equity-to-assets ratio and the profit-to-assets-ratio have negative and statistically significant coefficients, which aligns with the fact that lower profitability and less equity contribute to a bank's vulnerability to systemic risk and therefore its SRISK.

[14] All banks in our dataset are Swedish banks. Foreign bank branches and subsidiaries are not included in the analysis. Our dataset covers 69 out of 88 Swedish banks. The missing banks are mainly small saving banks. They are excluded due to missing data.

**Table 2. Direct SRISK estimation – regression results for SRISK over total assets**

| | SRISK-to-assets | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| *Log Assets* | 0.019*** | 0.143*** | 0.020*** | 0.094*** | 0.015*** | 0.017*** |
| | (0.001) | (0.019) | (0.001) | (0.024) | (0.001) | (0.002) |
| *Equity to Assets* | -0.379*** | -0.278*** | -0.735*** | -0.129* | -0.136 | -0.116 |
| | (0.081) | (0.082) | (0.228) | (0.074) | (0.089) | (0.084) |
| *Log Assets squared* | | -0.005*** | | -0.003*** | | |
| | | (0.001) | | (0.001) | | |
| *Equity to Assets squared* | | | 1.979 | | | |
| | | | (1.338) | | | |
| *Profit to Assets* | | | | -8.871*** | -8.197*** | -7.635*** |
| | | | | (2.128) | (1.900) | (2.204) |
| *CET1* | | | | | -0.114 | -0.256*** |
| | | | | | (0.078) | (0.074) |
| *LCR* | | | | | | 0.002* |
| | | | | | | (0.001) |
| *Constant* | -0.238*** | -0.990*** | -0.236*** | -0.655*** | -0.162*** | -0.168*** |
| | (0.018) | (0.115) | (0.017) | (0.151) | (0.026) | (0.033) |
| No of obs | 454 | 454 | 454 | 454 | 324 | 275 |
| Adj-R2 | 0.600 | 0.659 | 0.602 | 0.705 | 0.626 | 0.601 |
| Time fixed effects | YES | YES | YES | YES | YES | YES |

Note. The table shows the results from a regression based on the direct estimation approach of SRISK where SRISK in relation to total assets is regressed on seven balance sheet variables and a constant for listed banks. A one quarter lag is used for all independent variables. Details about the direct estimation approach can be found in Chapter 4.

When choosing the model specification to estimate SRISK, we follow the same criteria as Engle et al. (2024): (1) all explanatory variables must be statistically significant, (2) the model should have a better fit as measured by adjusted R-squared, and (3) a larger sample size is preferred. Based on these criteria, specification (4) in Table 2 is chosen for the direct estimation approach.

For the indirect estimation approach, the first step involves establishing a relationship between lagged balance sheet variables and two key components of the SRISK calculation: the market value of equity and the beta. The panel regression result for the log market value of equity is presented in Table 3. The large and statistically significant positive coefficient for the profit-to-assets ratio is consistent with standard asset pricing theory, where the market value of a firm reflects the discounted value of expected future cashflows, proxied by profitability. Also in this case, specification (4) is chosen for the indirect approach based on the same criteria as before.

**Table 3. Indirect SRISK estimation – regression results for the log of market value of equity**

| | Log(market value of equity) | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| *Log Assets* | 0.752*** | -0.138 | 0.739*** | 0.373** | 0.778*** | 0.755*** |
| | (0.010) | (0.113) | (0.010) | (0.166) | (0.012) | (0.019) |
| *Equity to Assets* | -1.077* | -1.799*** | 5.200*** | -3.328*** | -2.014*** | -2.246*** |
| | (0.632) | (0.635) | (1.913) | (0.578) | (0.695) | (0.668) |
| *Log Assets squared* | | 0.036*** | | 0.017*** | | |
| | | (0.005) | | (0.006) | | |
| *Equity to Assets squared* | | | -34.898*** | | | |
| | | | (10.659) | | | |
| *Profit to Assets* | | | | 90.919*** | 78.522*** | 81.098*** |
| | | | | (21.172) | (19.240) | (22.793) |
| *CET1* | | | | | 2.886*** | 4.182*** |
| | | | | | (0.581) | (0.574) |
| *LCR* | | | | | | -0.025** |
| | | | | | | (0.011) |
| *Constant* | 0.926*** | 6.304*** | 0.902*** | 2.861*** | 0.019 | 0.167 |
| | (0.160) | (0.679) | (0.147) | (1.081) | (0.223) | (0.299) |
| No of obs | 454 | 454 | 454 | 454 | 324 | 275 |
| Adj-R2 | 0.958 | 0.963 | 0.960 | 0.972 | 0.977 | 0.979 |
| Time fixed effects | YES | YES | YES | YES | YES | YES |

Note. The table shows the results from a regression of the first step in the indirect estimation approach of SRISK. The table shows regression results where the log market value of equity of listed banks is regressed on seven balance sheet variables and a constant. A one quarter lag is used for all independent variables. Details about the indirect estimation approach can be found in Chapter 4.

Table 4 presents the regression results for beta. Overall, the explanatory power and statistical significance of banks' balance sheet variables are lower compared to the other components of the SRISK estimation. The equity-to-assets ratio is negatively related to beta as well, suggesting that less capitalized banks tend to have higher market risk exposure. Again, based on the model selection criteria, specification (2) is chosen for the SRISK estimation. [15]

[15] A caveat could be that non-listed banks may have different risk exposures and business models compared to listed banks. This can be a challenge in the direct and indirect estimation methods. To take this into account, for each regression in both the direct and indirect approaches, we have tested different regression specifications by adding a dummy variable indicating bank type, and/or extra bank balance sheet variables that reflect banks' business models, e.g. loan-to-assets ratio, deposit-to-assets ratio and share of lending to households. However, the estimated coefficients for those variables are statistically insignificant, indicating that the concerns about different risk exposures and business models between non-listed and listed banks are likely negligible.

**Table 4. Indirect SRISK estimation – regression results for beta**

| | Beta | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| *Log Assets* | 0.041*** | -0.556*** | 0.029*** | -0.509*** | 0.049*** | 0.033** |
| | (0.007) | (0.098) | (0.007) | (0.121) | (0.011) | (0.016) |
| *Equity to Assets* | -3.605*** | -4.088*** | 2.179* | -4.229*** | -4.321*** | -4.942*** |
| | (0.382) | (0.381) | (1.175) | (0.433) | (0.581) | (0.613) |
| *Log Assets squared* | | 0.024*** | | 0.022*** | | |
| | | (0.004) | | (0.005) | | |
| *Equity to Assets squared* | | | -32.154*** | | | |
| | | | (6.196) | | | |
| *Profit to Assets* | | | | 8.351 | 14.921 | 25.412 |
| | | | | (12.068) | (13.026) | (16.086) |
| *CET1* | | | | | 0.070 | 0.113 |
| | | | | | (0.593) | (0.663) |
| *LCR* | | | | | | -0.020** |
| | | | | | | (0.009) |
| *Constant* | 0.816*** | 4.423*** | 0.794*** | 4.107*** | 0.696*** | 0.974*** |
| | (0.103) | (0.597) | (0.101) | (0.767) | (0.172) | (0.231) |
| No of obs | 454 | 454 | 454 | 454 | 324 | 275 |
| Adj-R2 | 0.554 | 0.594 | 0.579 | 0.594 | 0.632 | 0.664 |
| Time fixed effects | YES | YES | YES | YES | YES | YES |

Note. The table shows the results from a regression of the first step in the indirect estimation approach of SRISK. The table shows regression results where the beta of listed banks is regressed on seven balance sheet variables and a constant. A one quarter lag is used for all independent variables. Details about the indirect estimation approach can be found in Chapter 4.

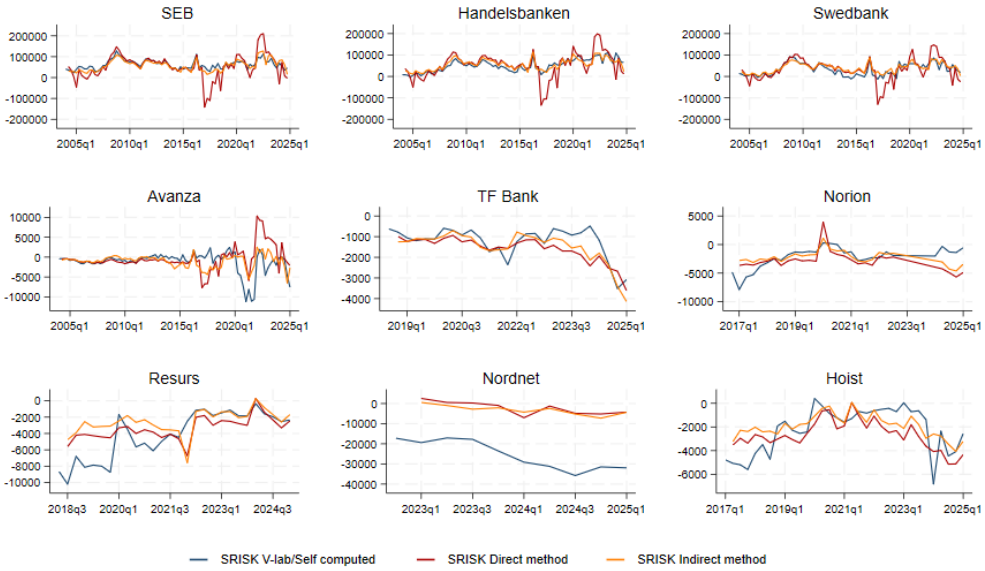
## In-sample estimation for listed banks

Before using the direct and indirect approaches to estimate SRISK for non-listed banks, we would like to test the performance of the two methods. Specifically, we conduct an in-sample fit test of the two estimation approaches described previously. We calculate SRISK for the nine listed banks using both the direct and indirect approaches and compare them with the SRISK computed by V-LAB (or ourselves for the banks not covered by V-LAB, see Table 1). If the two methods perform well, the calculated SRISK estimates for the listed banks should closely match the SRISK values obtained from V-LAB or own-calculations.

Figure 2 shows the observed and estimated SRISK measures for listed banks. Overall, both the direct and indirect estimation methods perform well, as they generate similar SRISK values that do not deviate much from the calculations by V-LAB or ourselves. The direct approach occasionally results in more volatile estimates for certain banks during specific periods, but the in-sample fit is generally strong compared to the SRISK values provided by V-LAB or our own calculations. An exception is Nordnet, which could be explained by the relatively short data history available for that bank.

**Figure 2. Observed and estimated SRISK for listed banks**

SEK million




Note. The graphs show the estimated SRISK values for the nine listed banks using the direct and indirect approaches, as well as those computed by ourselves or by V-LAB. Details about the direct and indirect estimation approaches can be found in Chapter 4.

## Out-of-sample estimation for non-listed banks

Figure 3 presents the out-of-sample estimation of SRISK for non-listed banks. It shows the average SRISK for banks in the corresponding bank group. Like the prediction for listed banks, both the direct and indirect approaches generate similar SRISK estimates for non-listed banks.

**Figure 3. Predicted SRISK for non-listed banks, average by bank group**

SEK million


Note. The graphs show the average predicted SRISK values for non-listed banks in each of five bank groups categorized by their business model. Predictions are based on the regression results in Tables 2-4. Details about the direct and indirect estimation approaches can be found in Chapter 4.

It is worth noting that, with the exception of mortgage banks and, in certain periods, consumer credit banks, the predicted average SRISK for other bank groups tends to be negative. Also, as illustrated in Figure 2, small listed banks exhibit persistently negative SRISK estimates over time. A negative SRISK value indicates a capital surplus under a stress scenario, according to the definition of SRISK. This suggests that potential capital shortfalls among smaller banks are generally limited, and that the burden of recapitalization under severe market stress would likely fall primarily on large banks and mortgage banks.[16]

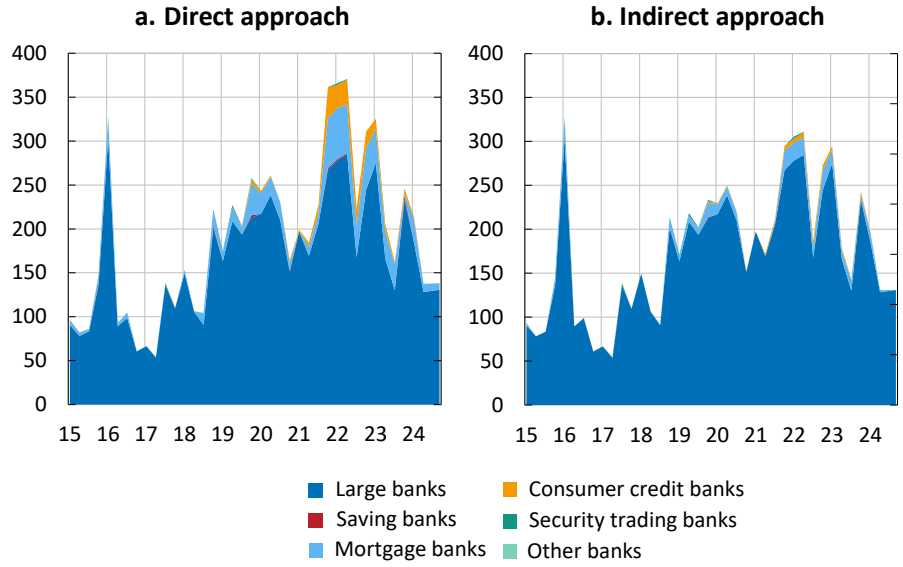
[16] We have done several robustness checks to validate the modelling approach. First, we extended the sample to include all listed Nordic banks to assess whether the results hold in a broader regional context. Second, we tested alternative model specifications when estimating the coefficients in the direct and indirect estimation approaches. Finally, for the three listed banks where SRISK was self-computed, we applied an alternative estimation method (OLS) to calculate beta and LRMES instead of the GARCH-DCC method, see details in the appendix. The results are similar and therefore not presented further in this staff memo.

# 5 Capital shortfall for the Swedish banking system under market stress

### Aggregate capital shortfall for the Swedish banking system

We combine the SRISK computed by V-LAB and ourselves using market data for the listed banks, and our results of the predicted SRISK for non-listed banks based on regression models, to generate an aggregate version of SRISK, i.e. the aggregate capital shortfall for the Swedish banking system. Here, we only take the positive values of SRISK when calculating the aggregate, as the negative values imply capital surplus under a market stress scenario with a 40-percent market decline in the coming six months with the 5.5-percent required market leverage ratio. Figure 4 presents the result over time.

**Figure 4. Predicted aggregate capital shortfall for the Swedish banking system**
SEK billion




Note. We only take the positive values of SRISK when aggregating the capital shortfall for the Swedish banking system. The negative values of SRISK can be viewed as a capital surplus during a crisis with a 40-percent market decline in the coming six months. Details about the direct and indirect estimation approaches can be found in Chapter 4.

As can be seen in the figure, the aggregate capital shortfall is mainly driven by the large banks, followed by mortgage banks and consumer credit banks. This is not surprising as size, leverage and market risk, as measured by the beta, are the three main ingredients for SRISK. Large Swedish banks are much bigger in size and have much lower leverage ratios compared to other Swedish banks, and therefore account for the majority of the aggregate capital shortfall. Mortgage banks are also relatively larger in size compared with the remaining bank groups and therefore become the second largest contributor to the aggregate capital shortfall. Given their relatively small size, saving banks, securities trading banks, and other banks contribute only marginally to the aggregate capital shortfall. This is reflected in Figures 2 and 3, where

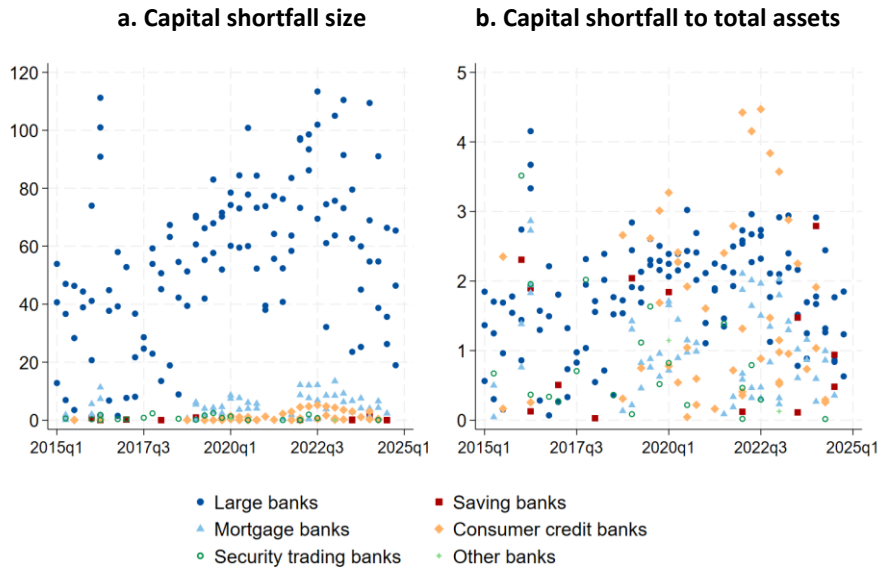
the predicted SRISK values for these bank groups remain consistently low or even negative over time.

## The size of capital shortfall for individual banks

Figure 5 presents the estimated capital shortfall for individual banks over time. As expected, the largest banks account for the highest absolute levels of capital shortfall. For these institutions, the shortfall typically ranges between 40 and 80 billion SEK in most quarters between 2015 and 2024, occasionally rising to around 110 billon SEK during periods of elevated market stress. In contrast, the capital shortfall for mortgage banks remains consistently below 15 billion SEK and for other bank groups less than 10 billion SEK throughout the period.

**Figure 5. Capital shortfalls for individual banks over time**

SEK billion, per cent




Note. Capital shortfalls (SRISK) are estimated under a stress scenario of a 40-percent market decline in the coming six months (the same as in V-LAB). Here, capital shortfalls for non-listed banks are estimated using the indirect approach. Figure 6a shows capital shortfalls for individual banks over time by the size of capital shortfalls. Figure 6b shows capital shortfalls for individual banks over time by the capital shortfall over total asset ratio.

However, examining the relative size of the capital shortfall, measured as the capital shortfall in relation to total assets, gives a different picture. Large banks are not always the ones with the highest shortfalls in relative terms. Smaller banks, particularly certain consumer credit banks, can stand out with high levels of capital shortfall in relation to total assets. For example, during the period 2022Q1-2022Q3, some consumer credit banks saw ratios as high as 4 to 4.5 of total assets, while the ratios for other banks are below 3 per cent. This indicates that while small banks contribute little to the aggregate capital shortfall of the Swedish banking system, the relative size of the shortfall can be substantial. This can pose a challenge for these banks to raise capital, especially when the shortfall is large relative to the required market leverage ratio of 5.5 per cent. Limited market access and higher refinancing costs as a result can amplify further if investors perceive small banks as riskier during periods of stress.

In such cases, deleveraging though asset sales or credit restrictions may reinforce negative feedback loops to the real economy. These banks, even if not considered systemic on their own, can become systemic as a group, either through correlated exposures, simultaneous funding pressure or collective procyclical behaviour.

# 6 Sensitivity analysis for capital shortfall

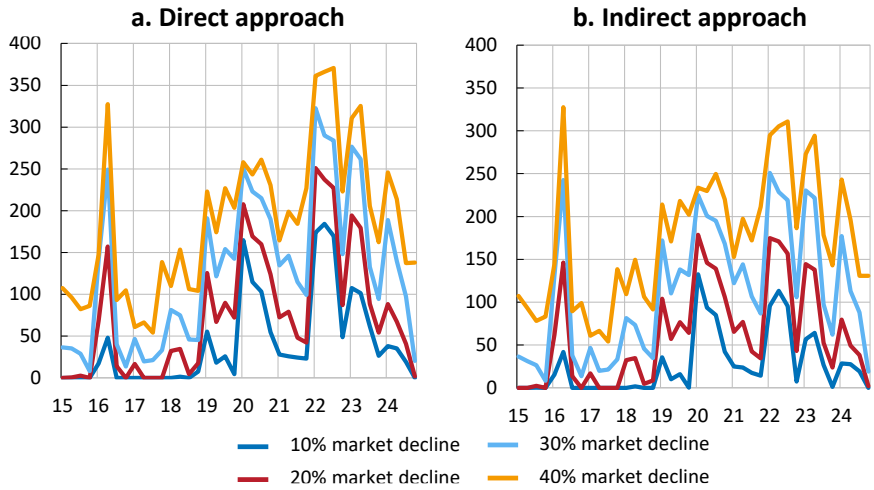
In the SRISK formula, the required market leverage ratio $k$ and the market stress scenario $C$ are the two key parameters that are pre-set by the users and can therefore affect the size of the estimated capital shortfall. Our baseline results, which are shown in Chapter 5, are estimated using the same parameter choices as those of V-LAB. By default, V-LAB sets the value of $C$ as 40 per cent, a market decline equivalent to the one during the global financial crisis. The default value of $k$ is set as 5.5 per cent for European banks, which reflects the observed market leverage ratios prior to the global financial crisis. These two parameters can in principle be chosen at any desired levels. In order to understand how alternative values of these two parameters can affect the result, we conduct a sensitivity analysis based on different choices of the two parameters.

## Capital shortfall under different market stress scenarios $C$

The aggregate capital shortfall presented in our baseline results is estimated under a market stress scenario involving a 40 per cent decline in the equity market over a six-month period. This is similar in magnitude to what occurred during the global financial crisis. However, such an extreme scenario may be rare going forward. A more likely situation could involve a more moderate market downturn. To examine this, we conduct a sensitivity analysis and estimate the aggregate capital shortfall for the Swedish banking system under a range of different market decline scenarios, from -10 to -40 per cent. The results are shown in Figure 6.

**Figure 6. Predicted aggregate capital shortfall for the Swedish banking system under different market stress scenarios**

SEK billion




Note. Capital shortfall is estimated under a stress scenario ranging from 10- to 40-percent equity declines over a six-month period. Details about the direct and indirect estimation approaches can be found in Chapter 4.

As expected, the estimated aggregate capital shortfall is much smaller under a more moderate scenario. For example, if the market decline is only 10 per cent in the coming six months, which is a reasonable scenario, the aggregate capital shortfall is zero for most quarters before 2019. During the peak of the third quarter in 2016, the capital shortfall is only around 50 billion SEK for the whole banking system under a 10-percent market decline scenario. This is equivalent to around 15 per cent of the level of 330 billion SEK under the 40-percent market decline scenario. It is worth noticing that the increase in capital shortfall can be fast and not necessarily proportional to the severity of market stress. For example, in the third quarter of 2016, a 20-percent market decline resulted in an estimated capital shortfall of 150 billion SEK, which is three times larger than the shortfall under a 10-percent decline scenario. This illustrates the non-linear nature of systemic risk and underscores how even a moderate worsening in market conditions can significantly amplify the pressure on banks' capital positions.

Moreover, when market uncertainty is high, for example, in the first quarter of 2020 (outbreak of the covid pandemic) and 2022Q1-Q3 (geopolitical conflict due to Russia's full scale invasion of Ukraine), a 10-percent market decline can lead to a relatively high level of aggregate capital shortfall.

## Capital shortfall under different required market leverage ratios $k$

The SRISK measure of capital shortfall is defined relative to a pre-set required market leverage ratio, denoted as $k$ in the SRISK formula. This ratio reflects the level of market capital required by investors. In our baseline analysis, we set $k$ to 5.5 per cent, which is also the default value used by V-LAB for European financial institutions.[17] However, the size of the estimated capital shortfall can vary depending on the chosen $k$, particularly during periods of market stress. To account for this, we do a sensitivity analysis and estimate SRISK using different levels of the required market leverage ratio $k$.

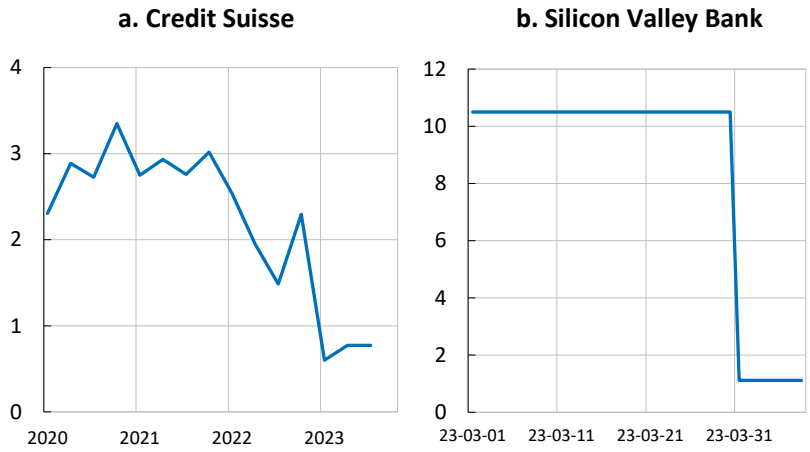
We consider two alternatives, a lower one (3 per cent) and a higher one (8 per cent), based on the observed pre-crisis market leverage ratios for two problematic banks Credit Suisse and Silicon Valley Bank. As shown in Figure 7, Credit Suisse had a market leverage ratio around 3 per cent during 2020-2021, before suffering significant losses caused by a bank run in 2022, which ultimately contributed to its collapse. For Silicon Valley bank, the market leverage ratio was 10.5 per cent before its failure. However,

[17] The default set of $k$ used by V-LAB is 8 per cent for non-European financial institutions, and 5.5 per cent for European institutions. The choice of 8 per cent is based on the observed market capitalization to asset ratios for major American banks in the pre-GFC period. During market stress, all banks should be subject to the same standard, so the required market leverage ratio should remain as 8 per cent. The differences in the required market leverage ratios between European and non-European institutions are attributable to the different accounting schemes, which can affect the valuation of book values of liabilities and therefore the total assets. In Europe, the IFRS accounting standard is primarily used instead of GAAP. Under GAAP, net derivatives are reported and thus derivatives represent a negligible fraction of the assets. Under IFRS, gross derivatives are reported. It has been estimated by Engle et al. (2015) that under IFRS, the assets of large US banks would increase by 40-60 per cent. To account for this difference in the accounting standards, a required market leverage ratio of 5.5 per cent is used for European firms. In a word, the default choice of 5.5 per cent for European institutions is due to the compensation of using the IFRS accounting standard. Otherwise, it would also be 8 per cent if European institutions use the GAAP accounting standard instead.

because Silicon Valley bank is a US institution and applies different accounting standards than European banks, we adjust its ratio to make it comparable. Following the adjustment applied by V-LAB and in line with Engle et al. (2015), US banks' asset valuations would increase by around 40-60 per cent under IFRS. Applying this adjustment, the 10.5-percent leverage ratio translates into roughly 8 per cent if Silicon Valley bank had reported under IFRS accounting standard rather than US GAAP.

**Figure 7. Market leverage ratio for Credit Suisse and Silicon Valley Bank**

Per cent

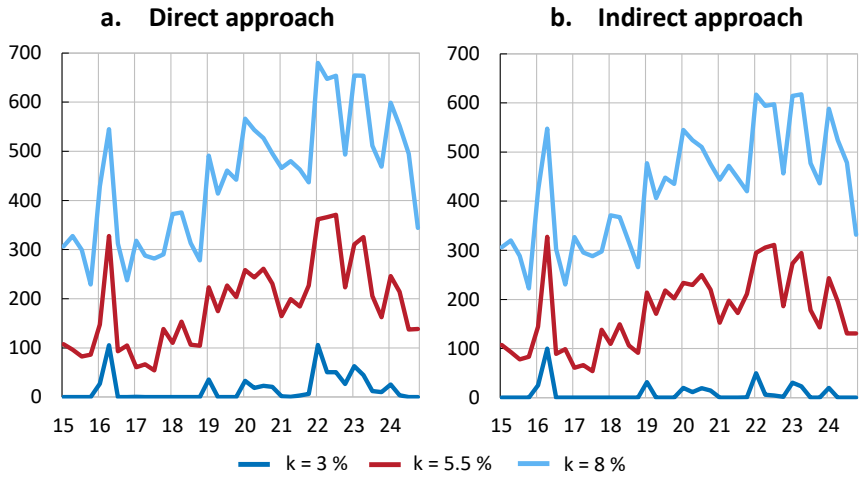



Note. Market leverage ratio is defined as the ratio between market capitalization and total assets.
Source: Bloomberg.

We now estimate the aggregate capital shortfall for the Swedish banking system under three different required market leverage ratios: 3 per cent, 5.5 per cent (our baseline), and 8 per cent. As expected, the estimated aggregate shortfall decreases when a lower required market leverage ratio is applied. With a ratio of 3 per cent, the aggregate shortfall is zero for most of the period between 2015 and 2014 under the 40-percent market decline scenario. By contrast, when the ratio is set to 8 per cent, the estimated capital shortfall for the Swedish banking system would be roughly twice as large as under the baseline ratio of 5.5 percent.

**Figure 8. Predicted aggregate capital shortfall for the Swedish banking system under different required market leverage ratios**

SEK billion




Note. K stands for the required market leverage ratio, a parameter in the SRISK calculation formula. The same market stress scenario of a 40-percent decline in the equity market over a six-month period is used for the prediction of aggregate capital shortfall under different required market leverage ratios.

This sensitivity exercise highlights how the choice of both the required market leverage ratio and the market stress scenario can have a large effect on the estimated capital shortfall, and hence on the assessment of systemic risk in the banking sector using SRISK. As discussed in Engle and Ruan (2018), the relevance of the results lies, however, not only in the size of the shortfall, but in whether it exceeds the maximum shortfall the system as a whole can absorb. When the required market leverage ratio is set at a low level, for example, the banking system copes well, with low or zero capital shortfall. When the ratio is set higher, the risk increases that banks cannot cover the shortfall without deleveraging significantly. Engle and Ruan (2018) therefore introduce the concept of SRISK capacity as the maximum shortfall that the system can bear, before the probability of a crisis exceeds 50 per cent. In this way, what matters is whether the capital shortfall implied by a given $k$ remains in this capacity or exceeds it. If exceeded, the probability of a financial crisis rises sharply.

# 7 Concluding remarks

In this staff memo, we use the market-based measure SRISK to estimate systemic risk in the Swedish banking sector, expressed as the expected capital shortfall that would arise in a crisis. Estimating SRISK requires information on market equity values. As most Swedish banks are not listed, we follow the methodology of Engle et al. (2024) to estimate SRISK for non-listed banks using observable balance sheet characteristics. By doing so, we are able to extend the coverage of the measure to the entire banking system and obtain a more comprehensive view of systemic risk, including potential vulnerabilities among smaller and non-listed banks that are typically not captured by market-based measures.

Over time, the estimated aggregate capital shortfall for the Swedish banking system under a market stress scenario tends to increase during periods of heightened market uncertainty, such as the covid-19 pandemic, Russia's invasion of Ukraine and the 2023 US banking turmoil. This pattern is expected, as SRISK is a market-based indicator and therefore reflects changes in market valuations and investor sentiment. During turbulent periods, banks may also face greater difficulties in raising capital, which can increase the estimated shortfall.

The primary contributors to the aggregate capital shortfall are large banks and mortgage banks. However, certain small banks, particularly consumer credit banks, can show elevated risk levels relative to their size compared with large banks. This suggests that these banks may face challenges in raising capital especially if investors perceive them as riskier during market stress. In such cases, deleveraging through asset sales or credit tightening could reinforce negative feedback loops to the real economy.

SRISK, as a market-based risk indicator, provides a useful tool to illustrate and quantify vulnerabilities at both the individual and system level. It can serve as an alternative or complementary measure in the monitoring framework to enhance our understanding of systemic risk in the Swedish banking system.

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# APPENDIX - Estimating SRISK

## Capital shortfall in general

SRISK measures a bank's expected capital shortfall conditional on a severe market downturn. The first step in estimating SRISK is therefore to define the capital shortfall of a bank. Brownlees and Engle (2017) define capital shortfall (CS) as the required capital given a bank *i*'s assets minus the same bank's market equity at time *t*. In other words, it is the difference between the capital a bank should hold (based on prudential requirements) and the capital it actually holds, defined as follows

$$CS_{i,t} = k \cdot A_{i,t} - W_{i,t} = k\big(D_{i,t} + W_{i,t}\big) - W_{i,t}$$

$$= kD_{i,t} - (1-k)W_{i,t}$$

where $W_{i,t}$ is the market value of equity, $D_{i,t}$ is the book value of debt, $A_{i,t}$ is the value of quasi assets, and the $k$ is the required market leverage ratio by the investors. $A_{i,t}$ is approximated by $D_{i,t} + W_{i,t}$ since the market value of assets is not easily observed. The equation of $CS_{i,t}$ hence tells us how much extra equity the bank would need in order to meet the capital requirement by the market *k.* If $CS_{i,t} < 0$ then the bank has more capital than required, if $CS_{i,t}$ is positive, the bank is undercapitalized.

## Capital shortfall conditional on a severe market downturn

The essence of SRISK is to extend the idea of capital shortfall and evaluate it at a time *t+h* conditional on a severe market downturn. Formally, the severe market downturn event is defined as follows:

$$R_{m,t+1:t+h} < C$$

where $R_{m,t+1:t+h}$ is the cumulative market return over the next *h* periods (for example *h* = 125 would equal a period of six months) and C is a so-called crisis threshold, or essentially the severe market downturn, the condition. For example, $C = 0.4$ should be interpreted as a situation where the market return declines by 40 per cent over a period of six months.

The SRISK of a bank is defined as the expected capital shortfall at time *t+h* conditional on a severe market downturn of size C:

$$SRISK_{i,t} = \mathbb{E}_t\big[CS_{i,t+h} \big| R_{m,t+1:t+h} < C\big]$$

Putting in the definition of CS and taking the expectations on the severe market downturn allows us to rewrite the above expression in the following way:

$$SRISK_{i,t} = k\mathbb{E}_t\big[D_{i,t+h} \big| R_{m,t+1:t+h} < C\big] - (1-k)\mathbb{E}_t\big[W_{i,t} \big| R_{m,t+1:t+h} < C\big]$$

Engle and Brownlees assume that in a short-term crisis, the book value of debt remains unchanged because it cannot be easily renegotiated, therefore the expression $\mathbb{E}_t\big[D_{i,t+h} \big| R_{m,t+1:t+h} < C\big]$ shortens to $D_{i,t}$ and the SRISK formula to:

$$SRISK_{i,t} = kD_{i,t} - (1-k)\mathbb{E}_t\big[W_{i,t} \big| R_{m,t+1:t+h} < C\big]$$

We now need to put a value on $\mathbb{E}_t\left[W_{i,t}\middle|R_{m,t+1:t+h} < C\right]$, which is how much equity is expected to fall during the severe market downturn[18]. This is captured by a variable called the *long-run marginal expected shortfall* (LRMES in short), defined as:

$$LRMES_{i,t} = -\mathbb{E}_t(R_{i,t+1:t+h}|R_{m,t+1:t+h} < C)$$

Hence, SRISK can be rewritten as:

$$SRISK_{i,t} = kD_{i,t} - (1-k)W_{i,t}(1 - LRMES_{i,t})$$

SRISK can thus be computed by knowing three variables: the book value of debt, market value of equity and the LRMES. Only the LRMES needs to be estimated statistically by means of stock price data.

## Estimating LRMES

The *long-run marginal expected shortfall* (LRMES) measures the expected percentage decline in a bank's equity value conditional on a severe market downturn. It answers the question *If the market drops sharply over a given horizon (say -40 per cent over six months), how much is bank i's equity expected to fall?* The LRMES therefore captures the bank's sensitivity to market-wide stress and is a key component of SRISK. LRMES can be estimated in different ways, two of which we describe briefly below.

The simple way to estimate LRMES is through a beta-based approximation which assumes that a bank's cumulative loss in a crisis is proportional to its exposure to the market, and that this exposure is captured by a beta $\beta_{i,t}$, which is estimated by regressing a bank's daily log returns on market log returns over a rolling window.

While the rolling beta approximation through OLS captures the time variation in market sensitivity to some degree, it does not take into account that volatility and correlations may also change over time, especially during periods of stress. To address this, LRMES can be estimated by means of a GARCH-DCC model[19]. First, the log returns of the market and bank *i* are modelled using a GARCH(1,1) process to capture how their respective conditional volatilities change over time. Then, a dynamic conditional correlation (DCC) model is used to estimate how the correlation between the bank and the market changes over time. Having estimated these three time-varying parameters, we can calculate a time-varying beta $\beta_{i,t}$. [20]

The LRMES can finally be approximated through the following closed-form expression[21]

$$LRMES_{i,t} = 1 - \exp\left(\log\left(1 - C\right)\hat{\beta}_{i,t}\right.$$

[18]The LRMES measures the expectation of the bank equity value multiperiod arithmetic return conditional on the specified systemic event.

[19] Brownlees and Engle (2017) specifically use a GJR-GARCH(1,1)-DCC model to construct the LRMES predictions. We also use this specification.

[20] $\hat{\beta}_{i,t} = \hat{\rho}_{i,m,t} \cdot \hat{\sigma}_{it,}/\hat{\sigma}_{m,t}$

[21] This is the way the V-LAB constructs the LRMES. We also use this approximation is our calculations. LRMES can, however, also be estimated through a simulation approach. The idea is to simulate market returns and use a GARCH-DCC model to obtain the corresponding bank returns. This distribution of returns is then used to estimate the bank's LRMES. This calculation is computationally heavy, therefore the closed-form expression is used when possible.


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