ARTICLE – Stress tests of banks' capital

Stress tests of banks' capital are important tools for assessing banks' resilience to financial and economic unease. Different authorities use different methods. The Riksbank has also long used various forms of capital stress tests to assess the major banks' resilience and has also continuously developed the methods. However, there are many ways of conducting stress tests and each one has its strengths and weaknesses. This article provides an overall description of the Riksbank's current method and compares it with the stress test carried out by the European Banking Authority (EBA) in 2018. Given the same scenario, the results from the two stress tests differ, with significantly greater negative effects in the Riksbank's stress test. The results thereby clearly illustrate that different methods and approaches can lead to major differences in results. It is not obvious in advance which stress test method will result in the best description of what would happen in a stressed scenario. Different types of stress tests complement each other and it is therefore important to stress test banks using several methods.

The Riksbank conducts stress tests for several reasons

Using stress tests makes it possible to estimate how a bank's economic situation, and thus the bank's resilience, would be affected in a high-stress scenario. For example, it becomes possible to investigate how a bank's capital ratios would be affected during periods of financial and economic unease.

For many years, the Riksbank has conducted different types of stress tests to assess the resilience of individual banks and the banking system as a whole, and it has also continually developed the methods used. As the Riksbank is responsible for ensuring that the payment system is safe and efficient, such tests fulfil an important function. The banks are important participants in the payment system and also have a central role in the financial system in that they provide credit, accept deposits, mediate payments and help customers manage risk. Shocks to the banking system can lead to problems for these functions and in the payment system. At the same time, there are vulnerabilities in the Swedish banking system, and problems in one bank can rapidly spread to other banks (see "Vulnerabilities and risks in the financial system"). All in all, this can affect both financial stability and the conditions for monetary policy. The Riksbank therefore continually analyses the development of the banking system to discover threats and vulnerabilities at an early stage. The stress tests are part of this work.

The Riksbank can provide liquidity support to the banks in a financial crisis. One legal precondition, however, is that the bank receiving liquidity support has enough capital to be able to repay its debts, not just at the moment but also after a longer period of financial stress. In this context, also stress tests are important tools for assessing an individual bank's resilience.

There are different types of stress tests

Stress tests are based on a negative scenario

In most cases, a stress test is based on a scenario that describes a severe but plausible, development for different macroeconomic and financial variables. The idea is that the scenario describes a deep economic recession and/or financial crisis.

When authorities conduct stress tests, the stressed scenario usually assumes that no economic policy measures are adopted and that the banks do not make any changes to their business models. The banks' current ability to manage economic and financial problems without public support measures is thereby tested.

The type of stress test that the Riksbank conducts is known as a top-down stress test, which means that all calculations are made by the Riksbank. This differs from so-called bottom-up stress tests in which the banks themselves make the calculations under the monitoring of the supervisory authority. One example of the latter type of exercise is the EBA stress test implemented in 2018.

Second-round effects can be captured in top-down stress tests

In a top-down stress test, the same method is applied to all banks, making it easier to compare them. It can also be compared to the banks' own calculations. In addition, in a top-down stress test, it is possible to include mechanisms that take account of systemic risks that can arise due to for example second-round effects between banks. It is difficult to take account of this in bottom-up stress tests, as each bank makes its own calculations without considering the results of the other banks. One disadvantage of top-down stress tests is that they are usually based on less detailed data than bottom-up stress tests, which means that some characteristics of the risks in the credit portfolio are not captured to the same degree.

Bottom-up stress tests are based on loan portfolios
A bottom-up stress test can be conducted in many different ways. Internally, the banks work with various loan portfolios, for example the portfolio for mortgages. They also divide the loans into various risk classes. This division is usually made using internal models. Following this, the banks use the internal models to calculate what happens to the various loan portfolios in the stressed scenario. In addition, various restrictions for how the banks may calculate may be added, as is the case in the EBA stress test. Even though the stress tests are described as bottom-up, this does not mean that all calculations are based on each individual loan and every detail in the loan contracts, but rather from different loan portfolios. A bottom-up stress test is thus not as in-depth as the type of due diligence that normally takes place ahead the acquisition of a company, for instance.

Market-based measures are a good complement to stress tests
There may be reason to complement the stress tests that the banks themselves or the authorities conduct with various market-based measures. These measures provide an indication of market participants' confidence in the bank. The reason for this is that market information contains different participant' forward-looking assessment of the bank, such as expected credit losses. When the measures are based on market information, it is also possible to frequently update this type of assessment of the bank's repayment capacity and resilience. The market value of the shares in comparison with the book value of equity (price to book or P/B) and the expected probability of default (Expected Default Frequency or EDF[49]) are examples of such measures. These take consideration of the market participants' expectations of such things as a bank's future earnings and credit losses and can thus give an indication of a bank's capital strength or risks in its operations. The Riksbank also analyses measures of this type, even if these are not part of this article.

The Riksbank's stress test is based on models for both revenues and costs
The Riksbank's stress test of capital consists of a number of models that describe various parts of the banks' income statements and balance sheets and how these would be affected under stress. On the cost side, models are used for the banks' credit losses and for losses arising due to second-round effects. On the revenue side, models are used for the banks' net interest income and net commission income. All in all, the models make it possible to calculate the banks' capital ratios in different scenarios. A brief description of the models for credit losses, earnings and contagion effects is presented below.

The banks included in the stress test are Handelsbanken, Nordea, SEB and Swedbank.

Credit losses are an important variable in the stress test
The Riksbank's method for estimating credit losses is based on a model in which the level of earlier credit losses (credit losses as a proportion of lending to the general public) depends on the development of house prices, unemployment, interest rates,[50] corporate and household debt as a proportion of GDP, and the proportion of lending to non-financial corporations. In the model, housing prices, above all, play a decisive role.

The major banks' credit losses have historically been very small over long periods, before increasing heavily in crisis periods. This makes it difficult to estimate a model for credit losses that accurately captures the relationship between the level of credit losses and changes in factors such as GDP and house prices in both normal periods and crisis periods. The Riksbank's method for estimating credit losses in the stress test has therefore been developed to consider that levels in normal periods are close to zero but significantly higher in crisis periods.

The estimated credit loss level in the Riksbank's model closely follows the previous actual credit losses in both normal periods and periods of crisis (see chart 26).[51]

Earnings are important as a protection against credit losses
A bank's earnings must cover the bank's normal operating costs and can act as a buffer if credit losses arise. The two largest sources of the banks' earnings are net interest income and net commission income, which together are responsible for over 85 per cent of total earnings. In the Riksbank's stress test, there are separate models for net interest income and net commission income. The models explain the net interest income and net commission income using various macro variables and bank-specific variables. In the model for the net interest income, it is also assumed that a bank's funding costs increase as its capital situation deteriorates, as it is likely that investors will then make the assessment that there is a higher risk involved in lending to the bank. The net commission income is also assumed to be negatively impacted by the

[49] EDF is a market-based measure used by rating agency Moody's. It is calculated as the likelihood that the market value of the company's assets will be lower than the size of its debts.
[50] Two measures of interest rates are included in the model. These are the difference between the corporate lending rate and the 6-month Treasury bill, and the 5-year government bond yield.
[51] For more details on the model for calculating credit losses, see Buncic, D., Li, J., van Santen, P., Wallin, P. and Winstrand, J. (2019), The Riksbank's method for stress testing banks' capital, *Staff Memo*. Sveriges Riksbank

deterioration of a bank's capital situation. Lower asset prices are another source of a deteriorated net commission income.

Second-round effects can exacerbate stress

The major banks in Sweden are closely interconnected. They are exposed to similar risks and often obtain funding on the same markets. In addition, they have significant exposures towards each other as they own each other's covered bonds. This means that problems in one bank can rapidly spread to another bank, which reinforces different shocks that may arise in the financial system.[52] In the Riksbank's stress test, there are two mechanisms that take account of such second-round effects, one which captures that the direct links between the major Swedish banks themselves can give rise to credit losses, and one which captures general stress in the European banking sector.[53]

Deep economic recession in the scenario

A scenario for a stress test should reflect a severe but plausible development for different macroeconomic and financial variables. To calculate the results presented in this article, the Riksbank applies the scenario in the stress test carried out by the EBA in 2018.[54]

The scenario stretches over three years. For Sweden, it involves, among other things, a total fall in real GDP over the period of more than 10 per cent and in housing prices of almost 50 per cent (see table 2). The macro scenario is thus very severe. Together with the Riksbank's methods, which place great emphasis on systemic risks and housing prices, the scenario entails a hard stress test for the banks' Swedish operations. The banks also have operations in other countries and the assumptions of the EBA scenario is also used for these.

The banks' capital ratios fall in the stress test

Major credit losses

The level of credit losses is one of the key variables in a stress test. With a combination of the EBA scenario and the Riksbank's methods, the credit losses for the four major banks over one year are, at highest, about 4.5 per cent of lending, which is approximately the same level as during the crisis of the 1990s (see chart 27). This can be compared with a credit loss level of less than 1 per cent during the global financial crisis. The EBA scenario, however, is based on an economic development that is significantly worse than that of the global financial crisis.[55]

Table 2. Parts of the Swedish macro scenario in the EBA stress test 2018

Per cent

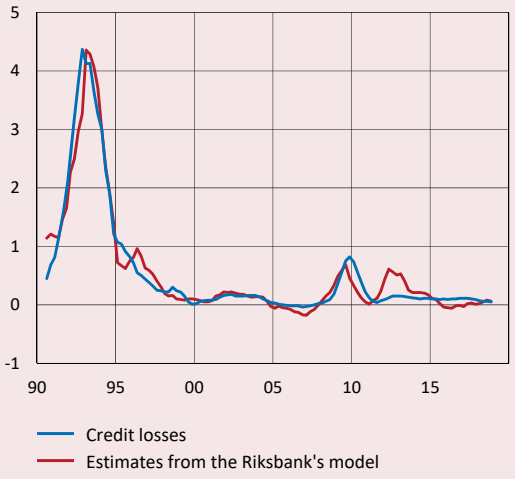
	Year 1	Year 2	Year 3
Real GDP	-3.1	-6.0	-1.7
House prices	-27.4	-28.0	-3.1
Prices of commercial properties	-23.8	-18.7	-7.7
Inflation	-1.4	-1.8	0.1
Unemployment	7.9	10.9	12.5
Equity prices	-26.4	3.1	6.6
Short-term interbank rate	0.3	0.8	1.2

Note. GDP, house prices, prices for commercial properties and equity prices are specified as annual percentage change. Inflation is specified as annual percentage change in the price index, and unemployment and the short (3-month) interbank rate are specified as percentages.

Source: EBA

Chart 26. The major banks' credit losses

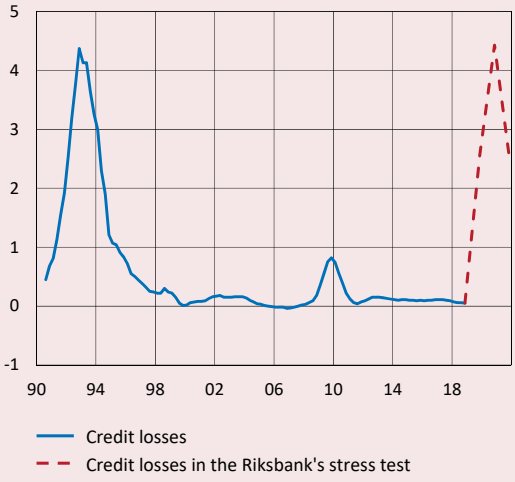
Percentage of lending to the public



Sources: Bank reports and the Riksbank

Chart 27. The major banks' credit losses in the Riksbank's stress test

Percentage of lending to the public



Sources: Bank reports and the Riksbank

[52] See the article Interconnectedness in the financial system. *Financial Stability Report* 2018:1 Sveriges Riksbank.

[53] For more information on the methods for capturing second-round effects, see Buncic, D., Li, J., van Santen, P., Wallin, P. and Winstrand, J. (2019), The Riksbank's method for stress testing banks' capital, *Staff Memo*. Sveriges Riksbank.

[54] For more information on the EBA's macroeconomic scenario, see *Adverse macro-financial scenario for the 2018 EU-wide banking sector stress test*, January 2018. European Systemic Risk Board (ESRB). For more information on the EBA's scenario for market risk, see *EU-wide Stress Test Market Risk Scenario,* January 2018. ESRB.

[55] During both the crisis of the 1990s and the global financial crisis, various support measures were adopted to mitigate the effects of the crises. This makes it difficult to compare the credit losses observed during these periods with the credit losses of the stressed scenario.

Most of the credit losses arising in the stressed scenario derive from lending to non-financial corporations (about 75 per cent of the credit losses). There are several factors that can explain why lending to companies in particular leads to such heavy credit losses in the scenario. Given the macroeconomic development in the scenario and the heavy fall in house prices, it is likely that households will significantly reduce their consumption and that demand for companies' goods and services will thereby fall heavily. At the same time, prices are falling for commercial properties, which affects property companies, who are major borrowers with the banks. All of this pushes up bankruptcies in the corporate sector and thereby also the banks' credit losses from lending to companies. In addition, losses arising as a consequence of second-round effects make up almost 12 per cent of credit losses.

Earnings fall

In the Riksbank's earnings model, the banks' earnings from net interest income and net commission income fall by 30 per cent over the three years of the scenario (see chart 28). The lower earnings mean that there is less scope for the banks to manage the credit losses.

One reason that earnings fall is that investors see a higher risk in lending to the banks when capital ratios are falling. This results in the banks' funding costs increasing, as investors demand compensation for the higher risk, and net interest income falling. In addition to this, lower asset prices also lead to the banks' net commission income falling.

The banks' capital situation deteriorates heavily

Chart 29 and chart 30 show how the banks' capital situation, measured using two different measurements, develops in the scenario, and how different parts of the stress test contribute towards the development. Chart 29 shows the banks' overall Common Equity Tier 1 ratio (CET1 ratio), which is to say their risk-weighted capital ratio measured as Common Equity Tier 1 (CET1) capital in relation to risk-weighted assets (see Equation 1).

Equation 1.

$$Common\ Equity\ Tier\ 1\ ratio = \frac{Common\ Equity\ Tier\ 1}{Risk\ weighted\ assets}$$

Chart 30 shows leverage ratio measured as Tier 1 capital in relation to total exposures (see Equation 2). Somewhat simplified, total exposures means total assets.

Equation 2.

$$Leverage\ ratio = \frac{Tier\ 1\ capital}{Total\ exposures}$$

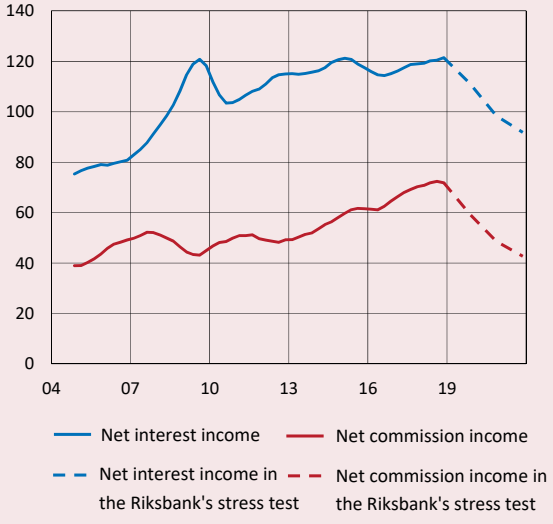
As the charts show, the banks' overall CET1 ratio is 16.3 per cent at the start of the scenario and the leverage ratio is 4.9 per cent. Due to the strongly negative development of the scenario, the banks' earnings deteriorate, but remain positive and thus make a positive contribution to the banks' capital ratios.

At the same time, the banks are making large credit losses, which affects the capital ratios negatively. In the stressed scenario, the credit losses become so large that the banks' earnings from net interest income and net commission income are not sufficient to cover the losses. This leads to the banks' operating earnings becoming negative over the entire scenario. The deteriorated economic conditions described in the scenario mean that parts of the banks' lending is deemed to be higher risk, with the consequence that the risk weights for this lending increase (so-called risk migration). All other factors being equal, this means that the risk-weighted assets increase and that the CET1 ratio thereby decreases. As the leverage ratio is not calculated using of risk-weighted assets, it is not affected by the risk in a bank's lending increasing.

A bank's Tier 1 capital (T1) consists of CET1 plus 'Additional Tier 1 capital' (AT1).[56] The part called Additional Tier 1 capital consists of debt instruments with long maturities and usually only makes up a small part of the bank's Tier 1 capital. When capital falls below a certain level, the debt instruments forming Additional Tier 1 capital are converted to CET1.[57] The conversion thereby

Chart 28. The major banks' earnings in the Riksbank's stress test

SEK billion

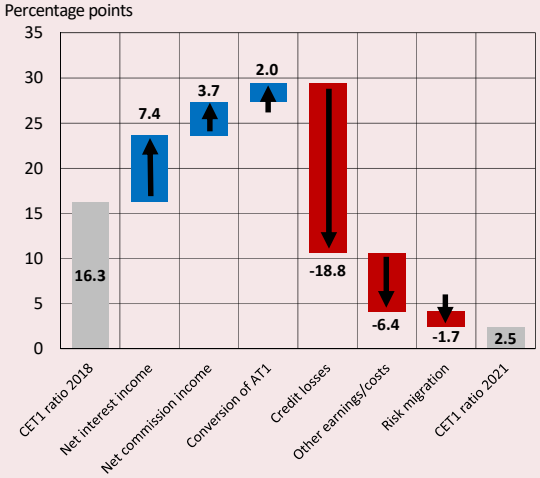


Sources: Bank reports and the Riksbank

[56] This means that T1 = CET1 + AT1.

[57] The terms for the debt instruments are designed so that they are converted to equity if the CET1 ratio falls below a certain level.

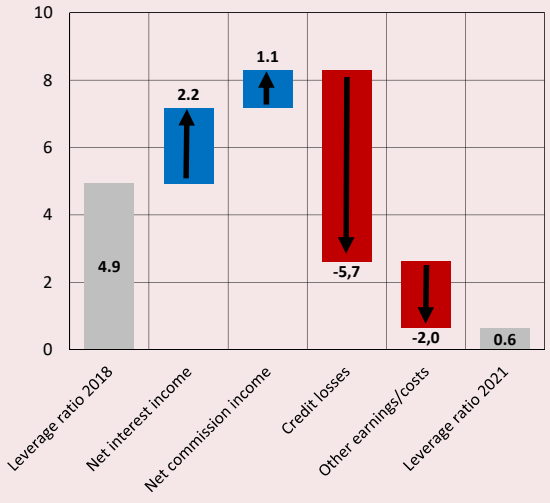
Chart 29. Change of the major banks' CET1 ratio in the Riksbank's stress test
Percentage points



Note. The credit losses affect the CET1 ratio both via CET1 and through a decrease in risk-weighted assets.

Sources: Bank reports and the Riksbank

Chart 30. Change of the major banks' leverage ratio in the Riksbank's stress test
Percentage points



Note. The credit losses affect the leverage ratio both via lower Tier 1 capital and through a decrease in total assets.

Sources: Bank reports and the Riksbank

has a positive effect on the banks' CET1, which increases the CET1 ratio.

The overall effect on the banks' capital situation in the stressed scenario is that the CET1 ratio falls from 16.3 per cent to 2.5 per cent and the leverage ratio from 4.9 per cent to 0.6 per cent.

Significant differences in results

As the stress tests of the Riksbank and EBA are based on the same macro scenario, it is interesting to compare the outcomes of the two exercises.

With the Riksbank's method, the credit loss level in the stress scenario reaches a maximum of about 4.5 per cent, which can be compared with just below 1 per cent in the EBA stress test. In total, over the three years, the banks' credit losses are SEK 771 billion using the Riksbank's method and SEK 155 billion with the banks' methods in the EBA stress test (see table 3).[58]

The Riksbank's method for estimating credit losses is sensitive to the variables included. The Riksbank has therefore made alternative calculations. The results of these show that the credit losses can be both higher and lower, depending on the variables included. The credit losses arising from different model specifications vary from being in the same magnitude as the credit losses for the Swedish banks in the EBA stress test to being just over SEK 1,000 billion. Models specified with house prices and short-term interest rates, but without variables indicating indebtedness in the economy, show credit losses in the lower part of the interval. Models specified so that indebtedness is included, or so that housing prices are given greater significance, show credit losses in the upper part of the interval. The selected credit loss model can explain historical credit losses well, at the same time as it gives a good balance between the number of variables and complexity. In addition, it takes consideration of risks that are significant to financial stability in Sweden. For example, the method attaches great weight to housing prices and indebtedness, which historically have played an important role in crises.

When it comes to net interest income and net commission income, the difference between the Riksbank and EBA stress tests is not quite as large. But the Riksbank's method cuts the net interest income and net commission income by a total of 30 per cent over the three years of the scenario, which can be compared to about 15 per cent in the EBA stress test. Over the three years of the scenario, the banks' earnings from net interest income and net commission income total about SEK 450 billion with the Riksbank's method while, in the EBA stress test, the corresponding figure is about SEK 500 billion.

The dates on which the stress tests start are different in the Riksbank and EBA stress tests, and thereby the starting values in the banks' capital ratios differ. However, both the stress tests run for the same length of time (three years), meaning that changes in capital ratios can be compared, despite the different starting values. The

[58] In the EBA stress test, the results are presented in EUR, and an exchange rate of SEK 10.3 to EUR 1 has been used here to convert the amount into SEK.

banks' operating earnings become heavily negative in the scenario using the Riksbank's methods, which results in the CET1 ratio falling by almost 14 percentage points and the leverage ratio by just over 4 percentage points (see charts 29 and 30). In the EBA stress test, the aggregate effect on the banks' CET1 ratios is relatively small, at the same time as the leverage ratio increases slightly.

Different methods affect the results

Even if the scenario in the Riksbank and EBA stress tests is the same, it is difficult to make direct comparisons of the results as there are relatively large differences in the methods used (see table 4).

In the Riksbank's stress test, all calculations are made by the Riksbank using mainly public data. In the EBA stress test, the banks carry out all calculations with the help of their internal models and largely non-public data. This means that both models and data are different in the Riksbank and EBA stress tests.

The Riksbank's data on the banks' credit losses stretches back to the end of the 1980s and thus includes the banking crisis at the start of the 1990s. The 1990s was a period in which the banks made significant credit losses and the Swedish economy had major and protracted problems. However, the financial system looks different today, with a variable exchange rate and another target variable for monetary policy. The Riksbank's methods for estimating credit losses works well for explaining historical credit losses but does not take full consideration of changes in the banks' risk management. However, the model takes into consideration that the proportion of lending to non-financial corporations has decreased since the 1990s. In the Riksbank's credit loss model, this means that, for a scenario identical to the crisis of the 1990s, the estimated losses today would be slightly lower than those observed in the crisis of the 1990s.

The banks' internal models often use historical data that is adjusted to make it representative of the banks' current situation, for example by taking greater account of the banks' risk management having changed.[59] As in the Riksbank's stress tests, this means that, even if the banks were to use a scenario identical to the crisis of the 1990s, the estimated credit loss level would be lower than that observed in the crisis.

If the Riksbank's method were to be used with data that excludes the crisis of the 1990s, the credit losses in the scenario would be significantly lower than they would be if the crisis of the 1990s had been included.

[59] In those cases where the banks lack historical loss data from the 1990s for their present exposures, the models are complemented by expert judgements.

Table 3. The Riksbank and EBA stress tests

	Riksbank	EBA
Total credit losses (SEK billion)	771	155
Total earnings (SEK billion)	452	501
CET1 ratio, starting value (%)	16.3	20.7
CET1 ratio, final period of scenario (%)	2.5	17.9
Leverage ratio, starting value (%)	4.9	5.0
Leverage ratio, final period of scenario (%)	0.6	5.2

Note. FI implemented a new method for the application of the risk-weight floor for Swedish mortgages at the turn of 2018, meaning that risk-weighted assets increased for the banks. This means that the starting value of the CET1 ratio for the Riksbank's stress test is lower than in the EBA stress test.

Sources: Bank reports, EBA and the Riksbank

Table 4. Overall comparison between the Riksbank and EBA stress tests

	Riksbank	EBA
General approach	Top-down	Bottom-up
Static or dynamic balance sheet	Dynamic, but without credit growth	Static
Data	Mostly public data	Largely internal data
Effect of including crisis of 1990s	Great effect on credit losses	Varies
Significance of second-round effects	Considerable	Relatively little
Model for credit losses	Empirical time series models	Internal models for probability of default and loss given default *
Models for net interest income and net commission income	Empirical time series models	Internal models based on repricing of assets and market risk

*Usually termed PD and LGD.

In addition, the Riksbank's stress test is designed to capture risks in the banking system in general. This means that what happens in one bank can affect what happens in another bank. This link is not captured in the same way in the EBA stress test. All in all, this results in there being large differences between the credit loss levels that the Riksbank estimates and those the banks estimate.

Different stress tests complement each other

The banks' ability to manage an economic crisis can be evaluated in several different ways. This article describes how the Riksbank's stress test for capital can be used as a method to measure the banks' ability to handle a heavily negative economic and financial development.

The results of the stress test shows that the effects may be significant for the four major banks in Sweden if the scenario the test is based on were to materialise. However, it should be pointed out that the scenario describes a very severe macroeconomic development and that the stress test does not take account of the measures to increase resilience that could be adopted by both the banks themselves and the authorities at an early stage. In a situation such as that described, the banks could attempt to issue new capital, for example. In addition, the

banks have eligible liabilities that could be converted into equity.[60]

The Riksbank's exercise shows that the choice of method may have major effects on the results of a stress test. The Riksbank's method includes both bank-specific risks such as systemic risks and also includes data from the crisis of the 1990s. In most cases, therefore, it will have a more negative outcome than a stress test using the EBA's methods. In addition, the Riksbank's alternative estimates for credit losses show a large variation. It is difficult to know in advance which stress test method gives the best description but the EBA and Riksbank stress tests can be used as two starting points. It is important to stress test banks using several methods and the Riksbank's method can be seen as a complement to the EBA method.

[60] In the Riksbank's stress test, Additional Tier 1 capital is converted to equity. In addition, under the European Bank Recovery and Resolution Directive (BRRD) and as part of the resolution, authorities can allow other parts of banks' liabilities to bear the losses by using the so-called bail-in tool. This means that some of the banks' lenders will have their claims written-down or converted into shares in the bank.