Further development of the index for financial stress for Sweden

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This article describes the Riksbank's new index for financial stress for Sweden. The index is a tool for analysing the development of the financial markets and financial stability. The index aims to provide an aggregate measure of the financial stress in the various sub-markets. One improvement compared with the previous stress index is that the stress on each sub-market is measured using several indicators. It is also important that the levels assessed as normal for these indicators can vary over time. Consequently, in the new stress index, the indicators are systematically ranked at the same time as the comparison period is extended. A further improvement is that the weighting of stress on the various sub-markets more clearly draws attention to periods in which financial stress is widespread. In this article, we show how the new stress index describes the degree of financial stress in Sweden between 1995 and 2013.

Why does the Riksbank use an index for financial stress?

The financial system performs central functions in the economy. One particularly important role is played by financial markets that contribute towards converting savings into investments. Furthermore, the financial markets make it possible for their participants to manage their risks by redistributing them to other market participants. Financial stress can be defined as a disruption that damages the financial markets' ability to efficiently fulfil their roles as intermediary between borrower and lender or buyer and seller.

Financial stress has several different symptoms. If a market is to function well, this requires buyers and sellers so that an asset can rapidly be sold for a fair price and this means that what is known as good market liquidity is required. In turn, this requires the market participants to have confidence in each other. It also requires that information be evenly distributed so that buyers and sellers can agree on fair prices for assets. In periods of unease, confidence among market participants can rapidly deteriorate and the value of a financial asset can suddenly become uncertain leading to a rapid deterioration of market liquidity. This can lead to funding becoming more expensive and more difficult to obtain as investors demand higher compensation for exposing themselves to the risk that they may neither get back what they have invested (meaning a higher credit-risk premium) nor have

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the opportunity to sell their investment in time should the need suddenly arise (meaning a higher liquidity risk premium).

In the Riksbank's work of maintaining financial stability, it is important to have tools to analyse symptoms of financial stress on the various parts of the financial markets. Financial stress can rapidly spread from one sub-market to another and it is thus important to consider stress from a systemic perspective. To make an overall assessment of symptoms of financial stress, the Riksbank regularly employs an index in its ongoing analysis of the financial markets. This index – which we call *the previous stress index* in this article – was prepared with the assistance of a method developed at the Riksbank (Forss Sandahl et al., 2011).

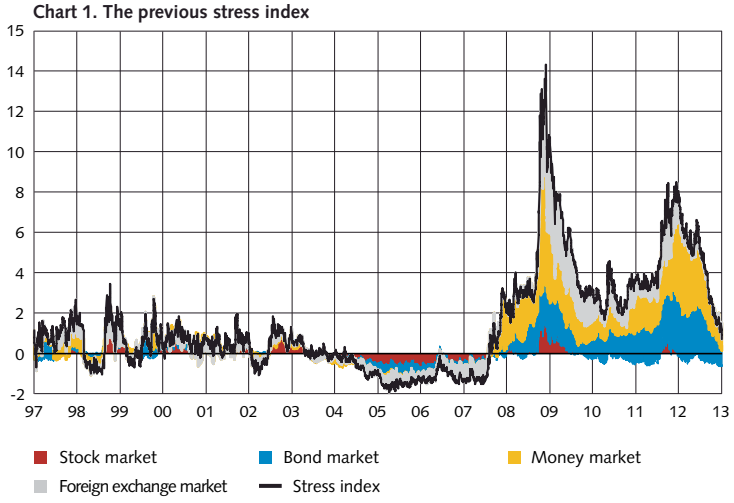
The stress index also makes it possible to compare different periods of financial stress with each other. For example, the Riksbank uses the stress index as an independent tool to summarise the development of the financial markets (Financial Stability Report, November 2012). Similarly, the stress index is included in discussions of signals that can be used to activate and deactivate countercyclical capital buffers[1] (Juks et al., 2012).

Why does the Riksbank's stress index need further development?

The previous stress index developed by the Riksbank in 2011 includes four sub-markets: the stock market, the bond market, the money market and the foreign exchange market. These, in turn, are summarised by *one* indicator per sub-market. The indicators are normalised to make them comparable and to give them equal weight in the formation of a stress index (Forss Sandahl et al., 2011). This stress index (see Chart 1) has proved to be easy to use and its results are relatively easy to interpret. However, at the same time, it has become apparent that some of its properties could be improved.

1 A countercyclical capital buffer is an extra capital buffer that varies over time. During economic upturns and periods of increased lending, the idea is that the banks will apply this extra capital buffer to better prepare themselves for less economically-favourable times.

Chart 1. The previous stress index



Sources: Bloomberg, Reuters EcoWin and the Riksbank

The stress index is intended to provide an aggregate measure of the financial stress in the various sub-markets. This is best done by measuring the stress on each sub-market with several indicators to reduce the sensitivity of one specific indicator. It also requires a sub-market's impact on the stress index not to be too great in comparison with other sub-markets. This also goes hand in hand with the stress index needing to clearly point out periods in which there is financial stress on many sub-markets, at the same time as it should tone down periods in which stress is not as widespread.

It should also be possible to use the stress index to measure how financial stress varies over time. As financial stress is defined as a disruption of normal market conditions, it is appropriate that the definition of normality should also be allowed to vary over time. Otherwise, long-term changes of specific financial indicators risk leading to incorrect conclusions of financial stress, even though the markets are functioning efficiently.

To meet these requirements and as a part of the continuous development of our internal models, we have created a *new stress index* that we present in this article. Many of the changes we have made are based on the method behind the CISS index (Kremer et al., 2012). This is an index for financial stress in the euro area that is used by, among others, the European Central Bank (Financial Stability Review, June 2010) and the European Systemic Risk Board (ESRB Risk Dashboard, September 2012).

The new stress index uses a greater number of indicators

To adjust the method to Swedish conditions, we select relevant Swedish indicators to be included in the stress index. It should be easy to interpret why each indicator is an appropriate measure of financial stress. Each indicator should also represent the development of a significant part of the sub-market (for example, a broad stock index) or

of an instrument used as a reference point for a sub-market (for example, a benchmark loan interest rate). In addition, it's also desirable to have indicators within a sub-market to measure different symptoms of financial stress. Furthermore, the longest time series possible should be used to include as many periods of financial stress as possible. Finally, the indicators should be published on a daily basis without significant delay so that the index can be used in the ongoing analysis of the financial markets.

In general, the new stress index is based around three different kinds of indicators of financial stress. When the pricing of a financial asset is uncertain, this tends to entail large and rapid price fluctuations – that is to say, volatility. One method for calculating volatility involves calculating the standard deviation of historical observations within a certain period of time. Throughout the new stress index, historical volatility is calculated as the standard deviation over the last 30 days. This results in a volatility indicator that is based on historical data and is thus a backward-looking estimate. However, data on implied volatility is used instead to the extent that this is available. 30-day implied volatility is calculated with the help of a pricing model for financial contracts with 30-day maturities, in which volatility is one of the model variables. Prices for these financial contracts and the values of the other model variables can be used to estimate volatility over the next 30 days, what is known as implied volatility. This volatility indicator is more forward-looking estimate.

However, volatility is a symmetric measure, which is to say that higher volatility can be linked with both unusually negative and unusually positive development. It is thus appropriate to complement it with some form of measure of level shift. Among other things, the new stress index uses a measure that sets an indicator at a certain date in relation to its highest or lowest level over the last two years.

By calculating the differences between various interest rates or expected returns, it is also possible to capture different types of risk premiums. For example, periods of financial stress are often characterised by a greater difference in expected return between higher risk assets and safer assets.

Considering these factors and the actual access to financial data, we have chosen to base the new stress index on the same sub-markets as the previous stress index. However, we have chosen to calculate the stress level for each sub-market on the basis of *three* indicators instead of *one* (see Table 1).[2] This means that the new index is not as sensitive to the outcome of one specific indicator, at the same time as it better captures different symptoms of financial stress. See Appendix 1 for a short description of each sub-market's significance in the financial system and an explanation of each indicator's significance for the analysis of symptoms of financial stress.

2 The CISS index is also based on three indicators per sub-market, but has an additional sub-market, financial intermediaries. As the amount of relevant financial data for the non-financial sector in Sweden is limited, we exclude this sub-market from our calculations, as the other sub-markets include indicators that are largely influenced by the financial sector.

Table 1. Sub-markets and indicators in the new stress index

SUB-MARKETS	INDICATORS
Stock market	Implied volatility
	Market value in relation to the highest in 2 years
	Estimated liquidity based on turnover data
Bond market	Difference between 5-year covered bond yield and 5-year swap rate
	Difference between 5-year covered bond yield and 5-year swap rate minus the 2-year equivalent
	Difference between 5-year swap rate and 5-year government bond yield
Money market	Difference between 3-month Stibor rate and 3-month treasury bill yield (TED spread)
	Historical volatility of TED spread
	Difference between 3-month Stibor rate and 3-month implied Stibor rate
Foreign exchange market	Implied volatility of USD/SEK
	Implied volatility of EUR/SEK
	30 day change in the value of the krona against a basket of currencies (TCW index) in absolute terms

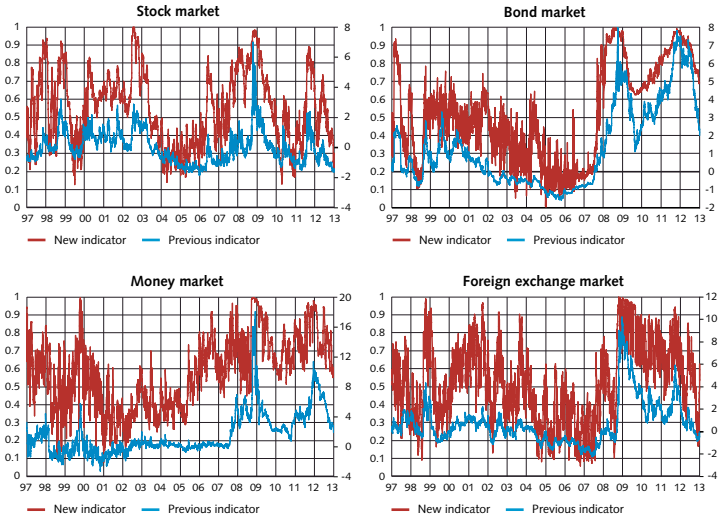
The new stress index uses a variable reference period

In the new stress index, we use ranked indicators instead of absolute indicators to improve the stress index's ability to account for new information, possibly involving long-term changes of the indicators. Each observation is ranked by magnitude in relation to earlier observations, so that an observation receives a value that is greater than zero but smaller or equal to one. See Appendix 2 for a technical explanation of this method.

The ranked indicators for each sub-market are then weighed together using equal weights. This means that each indicator makes up one-third of the sub-market in which it is included. In this case, each sub-market indicator receives a value between zero and one, like the ranked indicators.

Ranking the indicators and placing different measures of symptoms of financial stress along the same relative scale makes their influence on the stress index more evenly distributed (see Chart 2). This also means that the historical reference period is continually extended, making it easier to distinguish symptoms of financial stress from normal market conditions.

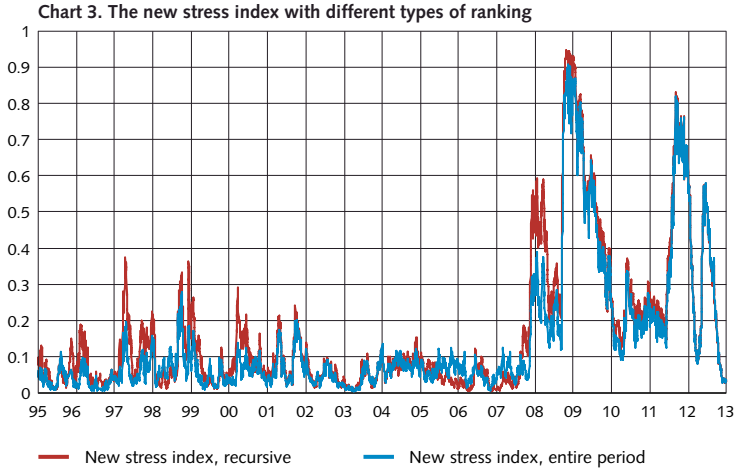
Chart 2. Comparison of sub-market indicators
Values for new indicators are specified on the left-hand axis and values for previous indicators are specified on the right-hand axis.



Sources: Bloomberg, Reuters EcoWin and the Riksbank

Consequently, when we rank an observation at a certain point in time, we disregard observations after this point (recursive ranking). However, it is important that an observation defined as high financial stress on one occasion is not reassessed at a later stage. To ensure this, the new stress index using recursive ranking can be compared with an equivalent stress index calculated with the help of a ranking that takes the entire period 1995-2013 into account (see Chart 3). Both stress indices give a similar result. However, the recursive ranking emphasises the IT crash in 2000 and the early stage of the financial crisis in 2008 more clearly. All in all, we assess that the recursive ranking provides reliable estimates of financial stress over time.

Chart 3. The new stress index with different types of ranking



Sources: Bloomberg, Reuters EcoWin och the Riksbank

The new stress index emphasises widespread financial stress

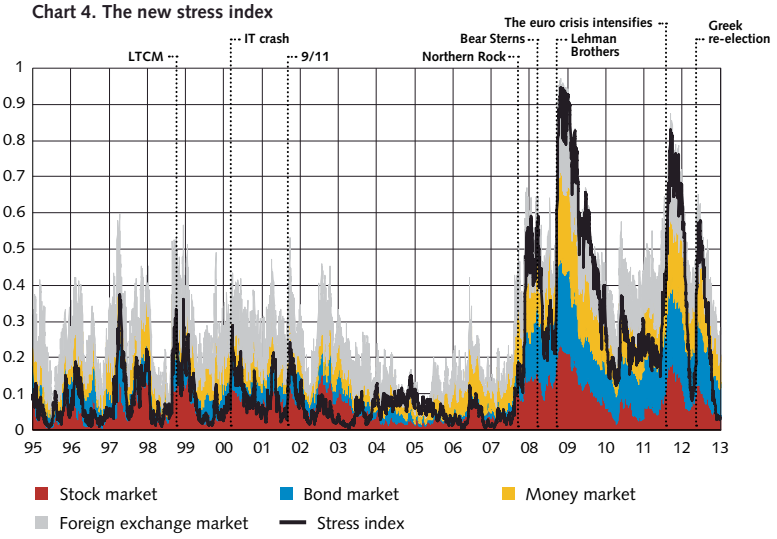
The new stress index is calculated as an equally-weighted[3] mean value of the sub-market indicators that is squared and adjusted with regards to the correlations between the sub-market indicators (see Appendix 2). The aim of taking these correlations into account is to emphasise periods of widespread financial stress on the financial markets.[4]

A high level of correlation shows that several sub-market indicators simultaneously *exceed or fall below* their theoretical mean values of 0.5. We are most interested in highlighting the first case in the stress index. Charts 4 and 5 show how the correlation effect increases during the financial crisis and the euro crisis. This is because all sub-market indicators show high levels of financial stress and thus a high correlation. The overall stress level thereby becomes relatively higher. When only a few markets show financial stress, as during the IT crash, the correlation is lower, which dampens the overall stress level. A case in which there is high correlation due to the sub-market indicators simultaneously showing a low level of financial stress clearly occurs in the period 2004-2005. Then the value of the stress index increased at the same time as the indicators decreased due to an increased correlation.

3 The CISS index uses what are known as relevance weights, in which the significance of each sub-market is based on its effect on productivity growth in the European manufacturing industry. However, it also emphasises that the difference between the CISS index calculated with relevance weights and the CISS index calculated with equal weights is marginal.

4 A parallel can be made with classical portfolio theory in which the correlation between assets is included to calculate the aggregate portfolio risk (see Appendix 2). Here, a high level of correlation between assets is interpreted to mean that strong linear connections exist between the assets that risk reducing the diversification effect for the portfolio and increasing the portfolio risk. As regards the stress index, it is the linear connection we wish to consider, above all because this is a result of all sub-market indicators showing financial stress simultaneously.

Chart 4. The new stress index

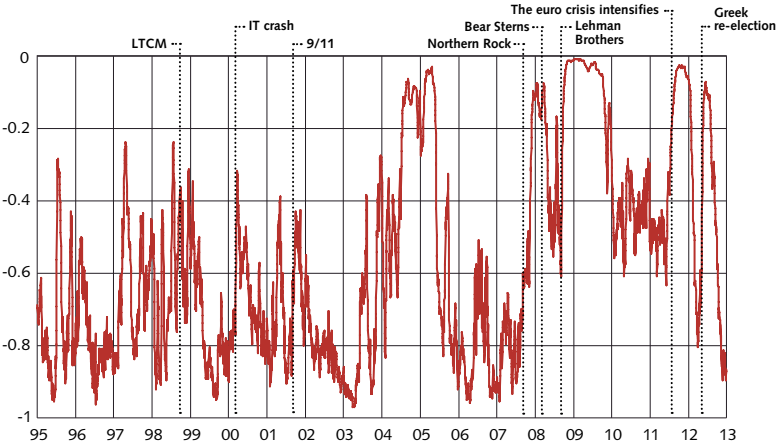


Note. The sum of the sub-markets in the figure actually refers to the squared, equally-weighted mean value of the sub-market indicators.

Sources: Bloomberg, Reuters EcoWin and the Riksbank

Chart 5. Correlation effect

Percentage difference between the stress index and the sum of the sub-market indicators in Chart 4.

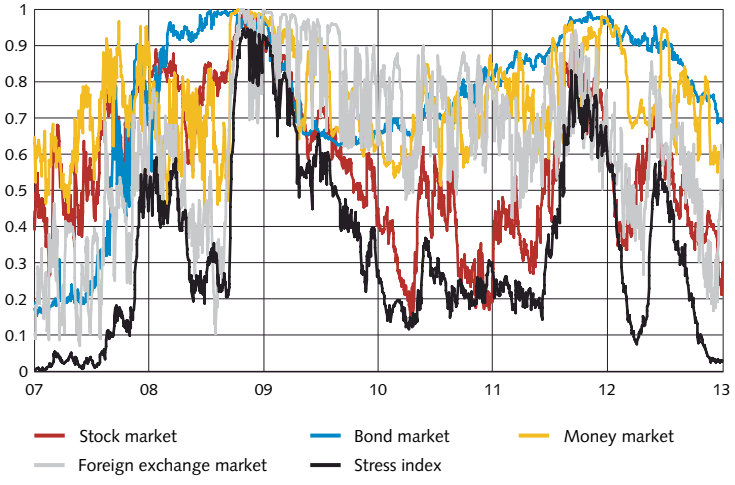


Sources: Bloomberg, Reuters EcoWin and the Riksbank

To further illustrate the factors determining the correlation effect in practice, we focus on Charts 6 and 7 in the period 2007-2013. During this period, the indicators for the money market and the bond market, above all, have been above their theoretical mean value of 0.5 (see Chart 6). This means that the correlation between the bond and money markets has been high (see Chart 7). The indicators for the two other sub-markets, the share market and the foreign exchange market, thus form the factor that has most affected the

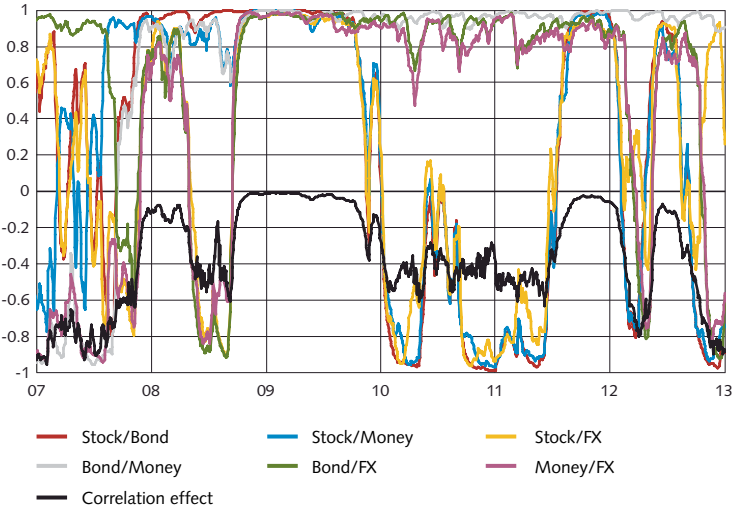
overall correlation effect. For example, the correlation effect decreased in the autumn of 2012 (it approaches -1 in Chart 7) and the stress index level decreased rapidly due to both of these sub-market indicators falling below their theoretical mean values (see Chart 6).

Chart 6. Sub-market indicators in the new stress index



Sources: Bloomberg, Reuters EcoWin and the Riksbank

Chart 7. Estimated correlations in the new stress index

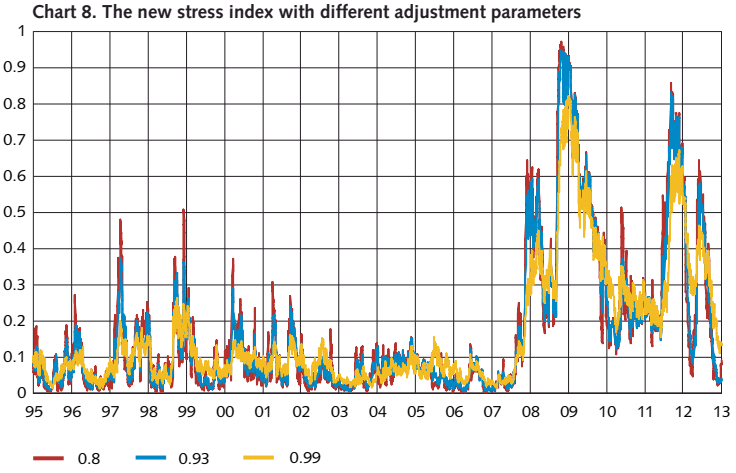


Sources: Bloomberg, Reuters EcoWin and the Riksbank

In the new stress index, we estimate the correlations between the sub-market indicators with the use of an exponentially weighted moving average (see Appendix 2), in line with the CISS index (Kremer et al., 2012). This means that the correlations are updated at each point in time with the starting point in earlier data where most weight has been

placed on the latest observations.[5] Formally, the latest correlation estimate is given the weight β where β is an adjustment parameter. Depending on the choice of parameter, the correlation estimates and thus the stress index change at a different rate. We have chosen an adjustment parameter of 0.93, in line with the CISS index (Kremer et al., 2012), which means that the stress index rapidly responds to situations in which most sub-market indicators exceed their theoretical mean values, at the same time as certain short-term fluctuations are smoothed out. However, regardless of the choice of adjustment parameter, the stress index shows the same pattern (see Chart 8).

Chart 8. The new stress index with different adjustment parameters



Sources: Bloomberg, Reuters EcoWin and the Riksbank

The new stress index is a better measure of financial stress

We have further developed an index that is intended to function as a tool for measuring financial stress on the financial markets. The stress index should thus give an aggregate measure of a disruption that negatively impacts the financial markets' normal role as intermediary between lender and borrower and seller and buyer, respectively.

This role is central to the functioning of the financial system. It is therefore important that the Riksbank carries out ongoing analyses of the financial markets to safeguard financial stability, not least when high financial stress has shown itself to be related to major real economic costs (see for example Bjellerup et al., 2012 and Kremer et al., 2012). The aim of this article is to describe how the stress index has improved as a measure of financial stress to increase its reliability as both an independent tool and a component of a broader analysis.

5 The CISS index is based on weekly sub-market indicators, while the new stress index is based on daily sub-market indicators. All else being equal, the correlation estimates will be updated more rapidly over time with the new stress index.

In the new stress index, three times as many indicators are used as in the previous stress index. As these indicators can be explained by economic factors and provide supplementary information, the new index better captures the overall level of stress on the financial markets.

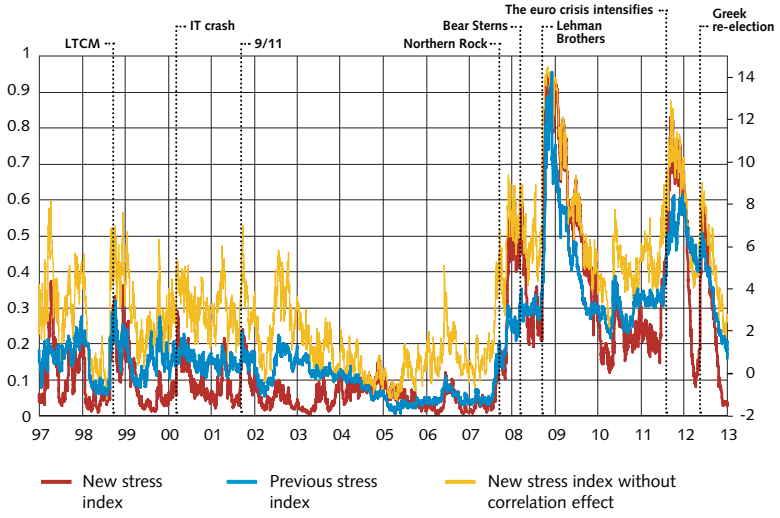
In addition to this, the new stress index is not dominated by individual sub-markets to such a great extent. This is a consequence of the recursive ranking that means that the sub-market indicators are given the same scale and affect the stress index's outcome in a more uniform manner. Structural changes are also continually phased into what the ranking classes as a normal condition, as the reference period is continuously updated and based on all historical data.

Finally, the correlation of the sub-market indicators is taken into account. This means that the new stress index more clearly highlights periods in which several sub-markets show high levels of financial stress simultaneously.

In Chart 9, we make a concrete comparison of the new and the previous stress index which are placed side-by-side so that their highest and lowest levels are about the same (see Chart 9). Even though the methods of calculation of both stress indices differ significantly, they look quite similar. However, the normal level of the new stress index is lower and the historical crises consequently have relatively greater impact. This is because the index is adjusted to take account of the relationship between the sub-market indicators and their theoretical mean values (the correlation effect). As the correlations are rapidly updated over time, the new stress index can rapidly vary between high and low levels. Without the correlation effect. the difference between the previous and the new stress index would be smaller.

However, the difference is also because the ranking of the indicators in the new stress index takes account of a variable reference period, which reduces the dominance of certain sub-market indicators on the earlier stress index. These two factors explain, for example, why the new index more clearly shows financial stress at the start of the financial crisis in 2008, but also shows lower stress in 2010. It also explains why the new stress index highlights the different phases of the euro crisis more clearly, which can largely be said to be defined by the timing of the various policy measures adopted by the European Central Bank: 3-year LTRO loans in late 2011/early 2012 and the announcement of the OMT programme for the purchase of government bonds in the late summer of 2012.

Chart 9. Comparison of stress index
Values for the new stress index are specified on the left-hand y axis, while values for the previous stress index are specified on the right-hand y axis.

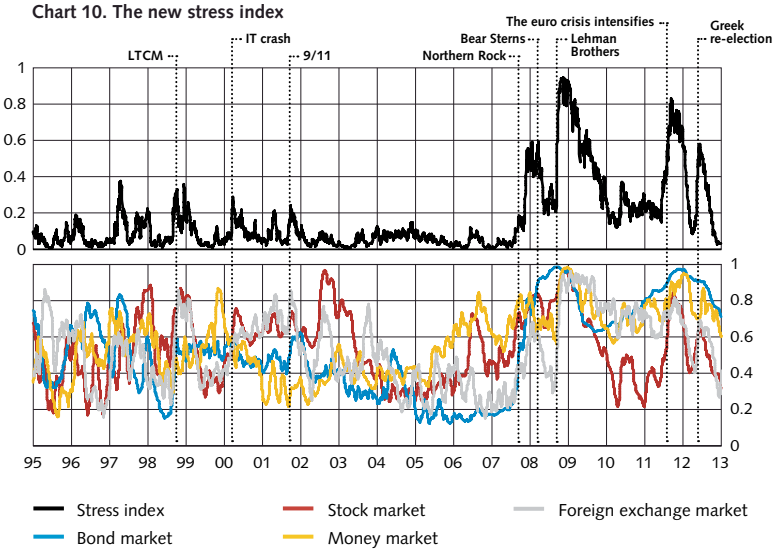


Sources: Bloomberg, Reuters EcoWin and the Riksbank

When the new stress index is interpreted, it should be borne in mind that this is a relative index. The stress level at any point in time is given in relation to historical data on financial stress since 1995 and receives a value of between zero and one, depending on the relative degree of stress. Secondly, the stress index is a non-linear function of the sub-market indicators. It is calculated as a squared average and adjusted to take account of the relationship between the sub-market indicators and their theoretical mean values (the correlation effect). Consequently, it cannot simply be interpreted as the mean of the sub-market indicators. As the sub-market indicators have the same scale in the new stress index, understanding of the index can hopefully be improved when it is presented in combination with the individual sub-market indicators (see Chart 10). This will clearly show the factors driving the stress index and that it does highlight periods in which all sub-market indicators are above their theoretical mean values.

To sum up, the analysis of the new index and its sub-components shows that it provides a useable overall measure of financial stress.

Chart 10. The new stress index



Note. The sub-market indicators in the figure have been smoothed out through the application of an exponentially-weighted moving average with the adjustment parameter 0.93, similarly to how the correlations are estimated in the stress index.

Sources: Bloomberg, Reuters EcoWin and the Riksbank

References

Amihud, Yakov (2002), Illiquidity and stock returns: cross-section and time-series effects, *Journal of Financial Markets 5, pp. 31-56*

Baba, Naohiko and Packer, Frank (2008), Interpreting deviations from covered interest parity during the financial market turmoil of 2007-08, *Working Paper* no. 267. Bank for International Settlements

Bjellerup, Mårten and Shahnazarian, Hovick (2012), The Interaction between the Financial System and the Real Economy, *Report from the Economic Affairs Department at the Ministry of Finance*. Ministry of Finance

Dahlman, Maria and Wallmark, Madeleine (2007), The Swedish expected volatility index – Construction and properties, *master's degree essay*. Stockholm School of Economics

ESRB Risk Dashboard, September 2012. European Systemic Risk Board

Fabozzi, Frank (2010), *Bond markets, analysis and strategies*. Pearson

Financial Stability Review, June 2010. European Central Bank

Financial Stability Report November 2012. Sveriges Riksbank

Forss Sandahl, Johannes, Holmfeldt, Mia, Rydén, Anders and Strömqvist, Maria (2011) An index for financial stress for Sweden, *Sveriges Riksbank Economic Review*, 2011:2. Sveriges Riksbank

Hakkio, Craig and Keeton, William (2009), Financial stress: What is it, how can it be measured, and why does it matter? *Economic Review*, second quarter. Federal Reserve Bank of Kansas City

Juks, Reimo and Melander, Ola (2012), Countercyclical capital buffers as a macroprudential instrument, *Riksbank Studies*, December 2012. Sveriges Riksbank

Kremer, Manfred, Holló, Dániel and Lo Duca, Marco (2012), CISS – A composite indicator of systematic stress in the financial system, *Working Paper* no. 1426. European Central Bank

Packer, Frank, Stever, Ryan and Upper, Christian (2007), The covered bond market, *BIS Quarterly Review*, September 2007. Bank for International Settlements

The Swedish Financial Market 2012. Sveriges Riksbank

Appendix 1. Sub-markets and indicators in the new stress index

THE STOCK MARKET

The stock market is an important source of funding for companies which can obtain capital there through initial public offerings and new issues of shares. At the same time, the stock market makes it possible for investors to get exposure to the risks and returns entrepreneurship entails, at the same time as they can sell shares relatively rapidly through widespread secondary market trading.

Implied volatility

A high level of stock market volatility implies the existence of great uncertainty over the pricing of shares among market participants. This can lead to market liquidity deteriorating and the functioning of the stock market becoming impaired. The Riksbank previously created an index[6] that measures 30 days' implied volatility of the OMXS30[7] price index. It was used in the previous stress index and is also included in the new one.

Market value in relation to the highest in 2 years

A low relative market value means that it is relatively expensive for companies to obtain equity funding as they must surrender a larger equity stake in return for new capital. At the same time, it means that investors' wealth is relatively low which can reduce their risk propensity. This can impair companies' access to equity funding. MSCI Sweden[8] is used for this indicator, as it is one of few relevant stock market indices with enough historical information of dividends. Since dividend payouts decrease the value of shares, it's important to use a total return index where the dividends are reinvested to minimize this effect.

Estimated liquidity based on turnover data

The liquidity of the stock market is linked to both price volatility and market value. However, capturing the liquidity aspect more clearly is relevant, particularly as the stock market is one of the few sub-markets with enough turnover data for liquidity to be directly estimated. To accomplish this, a method is used (Amihud, 2002) that divides daily absolute returns with turnover and where a high value indicates low market liquidity.

6 It is based on an application (Dahlman et al., 2007) of the Chicago Board Options Exchange's methodology for the VIX index on the Swedish stock market.
7 A return index of the 30 most frequently traded shares on the Stockholm stock exchange.
8 A return index of the largest companies' shares on the Stockholm stock exchange, which represents 85 per cent of the market value available for public trading. This is equivalent to about 35 shares.

THE BOND MARKET

The bond market is the market for fixed income securities with a longer maturity than one year. Its primary role is to bring together market participants who administer long-term investments with banks, companies and institutions that need to borrow money over the longer term. Moreover, mortgage loans and other forms of consumer credits are funded via the bond market.

Difference between 5-year covered bond yield and 5-year swap rate

Covered bonds[9] form one of the main sources of funding for the Swedish banks. To estimate the relative funding cost via bonds, bond yields are often compared to swap rates[10], rather than government bond yields, since there are several practical advantageous of swap rates even though they are not completely risk-free and involves small risk premiums (Fabozzi, 2010). The difference between a bond yield and a swap rate of the same maturity is thought to reflect several different risk premiums as compensation for the anticipated differences in properties of the two financial instruments, where credit risk and liquidity risk are thought to explain a large part of the difference (Fabozzi, 2010). In this case, the difference is primarily due to a liquidity risk premium as the investor of the covered bond ties up capital which is not done to the same extent in a swap whereas the credit risk premium is small due to the collateral pool. Certainly, the covered bond may be sold on the secondary market before the maturity date, however, the investor may incur a loss doing this. A larger liquidity premium may indicate increased uncertainty among covered bond investors which may impair the role of the covered bond market.

Difference between 5-year covered bond yield and 5-year swap rate minus the 2-year equivalent

This indicator should be interpreted as the difference in liquidity risk premium for tying up capital for 5 years compared to tying up capital for 2 years in covered bonds. If an investor suddenly needs to sell these covered bonds on the secondary market before the corresponding maturity dates, there is a larger risk for a loss on the bond with the longer maturity due to the greater inherent interest rate risk. Similarly to the previous indicator, if this difference increases, it may indicate an increased uncertainty among investors which may impair the role of the covered bond market. Also, it may cause banks to issue covered bonds with shorter maturities which increases their refinancing risk.

9 In the event of a bankruptcy, covered bonds give the bond owner special preferential rights to a collateral pool consisting of credit associated with liens on real property. Covered bonds were introduced into Swedish legislation in 2004. For the period prior to this, mortgage bonds are used instead. Both products have similar characteristics, however.

10 The swap rate is the fixed interest rate in an interest rate swap that is exchanged against a floating interest rate and that gives the swap a market value of zero for both counterparties when they enter into the swap contract.

Difference between 5-year swap rate and 5-year government bond rate

As a slightly simplistic but still illustrative comparison, the 5-year swap rate may be seen as the expected average 3-month Stibor rate during the next 5 years and the 5-year government bond yield may be seen as the expected average 3-month treasury bill yield during the next 5 years. Therefore, this indicator reflects a credit risk premium as well as a liquidity risk premium (Fabozzi, 2010) similar to the TED spread (see below) and should be viewed as another indicator of uncertainty on the bond market.

THE MONEY MARKET

The money market is an important market for banks' and companies' short-term funding. It covers the market for fixed income securities with maturities of up to one year. If the money market does not function well, there is a risk that this will rapidly lead to negative consequences for the liquidity management in the financial system.

Difference between 3-month Stibor rate and 3-month treasury bill yield (TED spread)

The 3-month Stibor rate is the most commonly used reference rate on the money market and corresponds to the average interest rate the Swedish banks charge one another for lending for three months without collateral. The difference between the 3-month Stibor rate and the 3-month treasury bill yield (TED spread) can be seen as the risk premium a bank requires for lending to another bank, compared with lending to the government for the same maturity. This premium corresponds to a credit risk premium as the probability of a bank encountering problems in repaying a loan is greater than the probability that the government would encounter such a problem. Unlike interbank loans, treasury bills can also be traded on the secondary market which means that the premium also involves a liquidity risk premium. This indicator can thus be considered to signal uncertainty on the money market (The Swedish Financial Market 2012) and has therefore also been used in the previous stress index.

Historical volatility of the TED spread

This indicator represents an additional dimension of uncertainty on the money market. Increased volatility in the TED spread can signal a lack of consensus among the banks over a fair interbank rate or increased uncertainty over the pricing of Swedish treasury bills. Together with the size of the TED spread, this indicator can signal how well the money market is functioning.

Difference between 3-month Stibor rate and implied Stibor rate

The covered interest-rate parity condition says that currency risk hedged funding in foreign currency converted to domestic currency should be obtained at the same cost as funding directly in domestic currency (The Swedish Financial Market, 2012). However, it

has become apparent that this parity condition is not valid in periods of financial stress. In particular, such periods have entailed higher costs and less availability for swapping funding in Swedish kronor for US dollar. Studies (Baba et al., 2008) have found that this can be explained by an increasing credit risk premium for funding in Swedish kronor. An increase of this indicator may thus be a sign of declining confidence in the Swedish banking system and the impaired functioning of the Swedish money market.

THE FOREIGN EXCHANGE MARKET

On the foreign exchange market, banks and companies can exchange Swedish kronor for foreign currency and vice versa to match revenue and disbursements in different currencies. These payments are traditionally seen as a consequence of trade in goods and services as well as financial assets. Transactions of this type create a need for foreign exchange risk management.

Implied volatility of USD/SEK and implied volatility of EUR/SEK

The variable value of the Swedish krona can be considered to reflect the capital flows in and out of Sweden that are largely influenced by new macroeconomic and financial information. As there is uncertainty on the financial markets, the capital flows can give rise to increased volatility of the krona's value. This need not mean a deterioration of the possibilities for trading on the foreign exchange market, but it could indicate financial stress in one or more areas of the financial markets.

However, one direct negative aspect of the increased volatility is the increased expense of managing foreign exchange risks through derivative instruments, which, in turn, may impact the conditions of companies for obtaining funding in foreign currency. The two most important foreign currencies for Swedish banks and companies are the euro and the US dollar. The implied volatility for the exchange rate between the Swedish krona and these currencies captures the uncertainty surrounding future exchange rates and gives an indication of the companies' costs for protecting themselves against exchange rate fluctuations. These two indicators have also been included in the previous stress index.

30 day change in the value of the krona against a basket of currencies (TCW index) in absolute figures

A considerable increase in the value of the Swedish krona over a slightly longer period may reflect a change in fundamental economic factors, possibly also affecting other sub-markets. As volatility only provides information on fluctuations of the krona's value, changes of the krona's value on absolute figures compared with a basket of other currencies (TCW index) over 30 days are a good complement to the other indicators.

Appendix 2. Technical calculations

RANKING OF INDICATORS

Assume that we have a time series $x_1, \ldots, x_n$ and that these observations are ranked according to size and create a new series of observations, $y_1, \ldots, y_n$, in which y_1 is the smallest observation and y_n is the largest. The ranked value z_n of the latest observation x_n is calculated as follows:

$$z_n = f(x_n) = \begin{cases} \frac{r}{n} \, for \, y_r \leq x_n < y_{r+1} \, and \, r = 1, 2, \ldots, n-1 \\ 1 \, for \, x_n = y_n \end{cases}$$

If a value occurs several times, the ranked value is set as the average ranked value. If, for example, we have 10 observations in which the tenth value has already occurred once and this value has been given the ranks 3 and 4 of the 10 values, the ranked value of the tenth observation will be (3+4)/2/10 = 0.35.

The ranking originally starts with the observations over the first four years being ranked in light of all observations during this period, before then going over to using historical data alone. This is done to increase the initial stability of the ranking.

PARALLEL TO PORTFOLIO THEORY

Assume that a portfolio consists of two assets with the standard deviations σ_1 and σ_2, correlation ρ_{12} and portfolio weights w_1 and w_2 in which $w_1 + w_2 = 1$. The portfolio risk (variance) can then be expressed as follows:

$$\sigma_P^2 = (w * \sigma) \, C \, (w * \sigma)^T = \begin{bmatrix} w_1 & w_2 \end{bmatrix} \begin{bmatrix} \sigma_1 \\ \sigma_2 \end{bmatrix} \begin{bmatrix} 1 & \rho_{12} \\ \rho_{12} & 1 \end{bmatrix} \left[\begin{bmatrix} w_1 & w_2 \end{bmatrix} \begin{bmatrix} \sigma_1 \\ \sigma_2 \end{bmatrix} \right]^T$$
$$= w_1^2 \sigma_1^2 + w_2^2 \sigma_2^2 + 2 \, w_1 w_2 \sigma_1 \sigma_2 \rho_{12}$$

The same principle is applied to calculate the new stress index, in which the standard deviations for the assets in the above illustration, σ_1 and σ_2, are replaced by the stress level among the sub-market indicators, and the correlation between the assets, ρ_{12}, is replaced by the correlation between the sub-market indicators.

CALCULATION OF STRESS INDEX AND ESTIMATION OF CORRELATIONS

The new stress index at the time t is calculated as follows:

$$Stress\ index_t = (w * s_t)\ C_t\ (w * s_t)^T$$

in which $w = [w_1\ w_2\ w_3\ w_4]$ is a vector of constant sub-market weights, $s_t = [s_{1,t}\ s_{2,t}\ s_{3,t}\ s_{4,t}]$ is the sub-market indicators at time t and $*$ marks the element-wise multiplication of vectors. C_t is a matrix of correlation coefficients at time t, $\rho_{ij,t}$, between sub-market i and j:

$$C_t = \begin{bmatrix} 1 & \rho_{12,t} & \rho_{13,t} & \rho_{14,t} \\ \rho_{12,t} & 1 & \rho_{23,t} & \rho_{24,t} \\ \rho_{13,t} & \rho_{23,t} & 1 & \rho_{34,t} \\ \rho_{14,t} & \rho_{24,t} & \rho_{34,t} & 1 \end{bmatrix}$$

The time-varying correlation coefficients are recursively estimated on the basis of an exponentially-weighted moving average of covariances $\sigma_{ij,t}$ and variances $\sigma_{i,t}^2$ respectively of the different sub-market indicators i and j:

$$\sigma_{ij,t} = \beta\sigma_{ij,t\text{-}1} + (1-\beta)\ z_{i,t}\ z_{j,t}$$

$$\sigma_{i,t}^2 = \beta\sigma_{i,t\text{-}1}^2 + (1-\beta)\ z_{i,t}^2$$

$$\rho_{ij,t} = \sigma_{ij,t} / \sigma_{i,t}\sigma_{ij,t}$$

for $i = 1,\ldots,4$, $j = 1,\ldots,4$ and $z_{i,t} = s_{i,t} - 0{,}5$ where 0,5 is the sub-market indicators' theoretical mean value. The adjustment parameter β is constant at 0.93 (Kremer et al., 2012). For the first observation, which is to say where $t = 1$, the initial values for $\sigma_{ij,0}$ and $\sigma_{i,0}^2$ are set to the estimates of covariance and variance over the first four years.