An index of financial stress for Sweden

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We have developed an index for financial stress that is intended for use as a tool in analysing developments on the financial markets. The starting point for our index is the financial markets that are important sources of funding for banks, companies and indirectly also for households. The four stress indicators we have chosen are directly or indirectly related to the funding costs prevailing in each respective market. The stress indicators are equally weighted and normalised[2] on the basis of the reference period January 1997 to July 2007. The tests presented in this article show that the choice of historical reference period and weighting may affect the analyses of the way the index develops. As the index is an average value of various indicators, it may provide an overall picture of the degree of financial stress on the financial markets. However, this may need to be supplemented with further information to provide a more complete picture. For instance, the analysis of sub-components may increase understanding of the symptoms of financial stress.

Difficult to assess the health of the financial system

The financial system is important as it provides fundamental services to the real economy. For instance, the financial system can facilitate economic growth through the efficient allocation of capital to companies and households. A particularly important part of the system is the markets where banks, companies and ultimately households have access to capital and manage their risks. Shocks to the system, which affect the functioning of some part of it may ultimately cause large costs to society. However, it is often difficult to determine how smoothly the financial system is functioning. One reason is that there are several sub-markets which can develop in different directions. This makes it difficult to assess the functioning of the system as a whole. One way of forming an overall impression of whether there are disruptions on markets is to construct and study an index for financial stress. This can provide an overall picture of developments on the financial markets, which

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2   This normalisation has taken the form of deducting the historical average from the individual observations. The results have then been divided by the historical standard deviation. The method is described in Appendix 2.

also makes it easier to compare different periods of stress. In this article we present such an index for Sweden.[3]

The following two sections present earlier literature and discuss how financial stress can be defined and measured. After that we present our index and the reasons for the choice of markets included. This is followed by a description of the data and the choice of historical reference period as well as the method used for weighting indicators. We also test how sensitive the index is to alternative choices of historical reference period and weighting method. The final section presents our conclusions. Our conclusion is that the index can provide indications of financial stress, but that changes in the index may also occur for other reasons. We also report the conclusion that the analysis of the development and level of the index may be affected by the choice of historical reference period and by the weighting method.

DEFINING FINANCIAL STRESS

It is difficult to define the concept of financial stress, and there is no real unequivocal or generally accepted definition for it. Illing and Liu (2006) discuss stress in the financial system in terms of a shock that may have negative effects on the real economy. Hakkio and Keeton (2009) instead define it as a period that is characterised by at least one of the following five circumstances: uncertainty over the fundamental value of financial assets, uncertainty over other investors' behaviour, information asymmetries, substantially increased demand for assets with very low risk (flight-to-quality) and substantially increased demand for assets with very good liquidity (flight-to-liquidity). Balakrishnan et al. (2009) also consider that financial stress is characterised by a number of circumstances similar to Hakkio and Keeton (2009), but also expressly take into account potential concern for the financial health of the bank system. Balakrishnan et al. (2009) also define financial stress as a period when the financial system is strained and its capacity to fulfil its mediation function is impaired.

EARLIER LITERATURE ON STRESS INDICES

Indices that show financial stress are quite common in academic research. An index can be constructed in different ways and contain different indicators. One simple method of weighing together indicators into one index is to normalise them and give them equal weight. This is how Danmarks Nationalbank's index is constructed (Hansen, 2006). This index aims to measure the risk premium in euro-denominated assets. The index uses indicators in the form of four differences between interest rates on high-risk and relatively risk-free assets, three measures of volatility and the difference between the yield on bonds

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3   Sveriges Riksbank regularly publishes two stress indices, one for Sweden and one for international circumstances. You can read about the two indices in the Economic Commentary "How has the stress on the financial markets developed? – An index-based discussion" published on 28 October 2009 and in the Box "Financial stress index" in the report "Financial Stability 2009:2" published on 26 November 2009.

and equity. Österholm's (2009) index for the Swedish market, which is used to measure the effect of the financial crisis in the late 2000s on the real economy, is also normalised and equally weighted.

Another means is to allocate weight to the indicators included in the index according to how much they contribute to systematic risk, that is, the risk that affects the entire financial system. One method of estimating this is to make a principal component analysis of the indicators, where the first component can be interpreted as the market's systematic component.[4] This method is used by Hakkio and Keeton (2009), who have a financial stress index for the American market. The index contains eleven indicators[5] which represent flight-to-quality, flight-to-liquidity and the uncertainty over fundamental values and other investors' behaviour.

A further means is to give the indicators different weights on the basis of a specific criterion. Illing's and Liu's (2006) Canadian index contains variables for the equity market, bond market and currency market, as well as the bank sector. They primarily choose to weight the indicators on the basis of the relative size of their respective markets as a percentage of the total credits in the economy.

In addition to the three named methods, there are a number of other possible ways of calculating the weights for the indicators in a stress index. For example, the European Central Bank's (ECB) (2009) global stability index is weighted on the basis of the indicators' variance.

A stress index for Sweden

The aim of our stress index is to try to reflect the degree of financial stress in a simple and comprehensive way. In this article we define financial stress as a disruption that impairs the financial markets' ability to act as an efficient intermediary between lender and borrower or buyer and seller. By efficient, we mean that there is good market liquidity and an even distribution of information between the agents in the market. Furthermore, financial stress may entail or lead to higher risk premiums and increased volatility. Our stress index is intended to function as an overall measure of these types of symptoms of financial stress.

When constructing a stress index, several considerations need to be made. These include which stress indicators to include, how to make these indicators comparable and how to weight them together into an index. We have chosen to include a total of four components from the capital market and the foreign exchange market. By normalising the indicators we relate them to their respective average levels during a reference period (January 1997 to July 2007) and make them comparable. We then allocate them equal weights in our index. This section describes the considerations we had when constructing the index.

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4   This is assuming that the first component is an approximately equally-weighted linear combination of the indicators.

5   Examples of indicators in their index are the TED spread (the difference between the interest rate on a non-secured interbank loan and the interest rate on a treasury bill), the 2-year swap spread (the difference between the interest rate on the fixed leg of an interest rate swap and the interest rate on a government bond), the risk premium on corporate bonds and implied volatility on the equity market.

STARTING POINT IS THE CAPITAL AND FOREIGN EXCHANGE MARKETS

One of the financial system's most important functions is to mediate capital, which can make it easier for companies and households to generate economic growth. The market that makes this funding possible is the capital market. It is therefore important that this market is not subjected to shocks that prevent it from functioning efficiently. As the capital market is central to the financial system, it forms a natural starting point for a financial stress index. The capital market can be divided up into the equity market and the credit market (consisting of the shorter money market and the longer bond market). Moreover, the foreign exchange market is important, as banks and companies to a great extent obtain funding in foreign currency.

We have chosen to use a few broad indicators as a base, to create a general and simple stress index. The index uses three stress indicators from the capital market – volatility in the equity market, the TED spread, a bond spread – and one indicator from the foreign exchange market – volatility. These indicators are described in more detail below.

The equity market

The equity market is an important source of funding for companies, either through IPOs or new issues where companies acquire their own capital. In addition to this, the equity market gives analysts and other interested parties important and useful information on investors' assessments and pricing of risk.

Choice of indicator for the equity market: volatility

There are several ways of measuring financial stress on the equity market. One of the most common is volatility. When investors are uncertain of the value of a share, they tend to react more strongly to new information when pricing the share than they would otherwise have done. This leads to increased volatility. If a price change is not supported by the company's ability to make a profit, the ensuing high volatility may be a sign of financial stress.

There are several theoretical models explaining the effects of volatility on the cost of equity capital. One of the most common is the Capital Asset Pricing Model (CAPM), which briefly states that the capital cost is positively related to the volatility. According to this theory, it becomes more expensive for companies to fund themselves on the equity market when volatility increases. Moreover, empirical studies show that periods of high volatility coincide with falling equity prices (see, for instance, Poon and Granger, 2003). The volatility thus becomes a natural starting point for the analysis of stress in the equity market.

There are different methods of measuring volatility. The most common entails calculating the historical volatility, measured as the standard deviation in price changes during a particular period of time. One disadvantage of this measure is that it is retrospective and thus not necessarily representative of the companies' capital costs at

the time of the measurement. Another method is to derive it from option prices and thus obtain an implied volatility that is based on market pricing of expected volatility.

The US equity market has the Chicago Board Options Exchanges index VIX, which measures 30-days' implied volatility on the S&P 500 index via option prices. The Swedish equity market does not have an index for implied volatility corresponding to the VIX index. We have therefore constructed one for the Swedish equity market.[6]

The credit market

The credit market can be divided up into two parts on the basis of the maturity of the loan: the short-term money market and the long-term bond market. The stress indicators on the credit market are calculated as the difference between the interest on a risky and a (relatively) risk-free asset. They thus represent the extra return that an investor requires over and above the risk-free interest in order to take a risk.

The money market

The money market includes loans with maturities up to one year. Both banks and companies seek short-term funding through the money market, for instance, through interbank loans or borrowing via certificates. As the money market constitutes an important source of short-term funding for banks and companies, disruptions to this market may rapidly lead to consequences for the financial system.

Choice of indicator in the money market: the TED spread

We have chosen to use the 3-month TED spread as an indicator of stress on the money market. The TED spread is the difference between the interest rate on an unsecured interbank loan (Stibor[7]) and the interest rate on a treasury bill with the same maturity. The spread thus shows the extra return that an investor requires to lend to a bank rather than lending to the state.

An investor who gives an unsecured interbank loan risks losing the deposit. There is also a risk that investors will need the money they have deposited before the loan matures. A treasury bill, on the other hand, is in principle free of both credit and liquidity risk as there is very little probability that the state will default on its payments and the bill is also very easy to convert into cash. Thus, the interest rate on a an unsecured interbank loan should be higher than the interest rate on a treasury bill. The TED spread thus compensates the investor for credit and liquidity risks. Something else that affects the spread is that investors want high-quality collateral in uncertain times, which increases the demand for, and leads to lower interest rates on, safer government securities (flight-to-quality and flight-to-liquidity). The TED spread thus also includes such effects of changes in supply and demand.

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6   See the Chicago Board Options Exchange (1999) for a technical description of the construction of the index, Demeterfi et al. (1999) for a derivation of the theoretical grounds for the index and also Dahlman and Wallmark (2007) for an application to the Swedish equity market.
7   Stockholm Interbank Offered Rate.

Times of financial stress may be linked to increased credit and liquidity risks, at the same time as a flight-to-quality and a flight-to-liquidity arise. At such times Stibor tends to rise at the same time as the interest rate on treasury bills tends to fall. Both of these variables can in this way contribute to the TED spread increasing, which makes it a good indicator of periods of financial stress.

The bond market

On the bond market, banks and companies borrow money for longer periods than one year. Together with bank loans, the bond market represents many companies' most important source of credit. Moreover, mortgage loans and other forms of consumer credits are funded via the bond market. This makes the market important for how demand develops in the economy.

Choice of indicator for the bond market: bond spread

We have chosen to represent the degree of financial stress in terms of an interest rate differential also for the bond market. In the same way as higher volatility in the equity market makes it more expensive for a company to fund itself in the equity market, a higher interest rate in the bond market makes it more expensive and more difficult to obtain funding there. We have chosen to use the difference between the interest rate on covered bonds and government bonds as an indicator of stress in the bond market.[8] In the same way as for the TED spread, periods of financial stress may be linked to a higher bond spread both because interest rates on covered bonds rise and because interest rates on government securities fall.

The credit risk relating to covered bonds can, unlike that for most corporate bonds, be regarded as very low. The value of covered bonds arises from the issuer's debt-servicing capacity and the collateral, which is mostly mortgage loans. These bonds constitute a central asset category in the Swedish financial system. This means that covered bonds, despite their very high credit quality, are regarded as a good indicator of the price of risk in the bond market in Sweden.

The foreign exchange market

Swedish banks and companies obtain a substantial part of their funding in foreign currency. It is therefore important for the Swedish economy that banks and companies have access to capital markets in other currencies on reasonable terms. This requires both smoothly-functioning foreign capital markets and a smoothly-functioning market for managing the financial risks that accompany borrowed capital in foreign currencies. If this risk management does not function efficiently, the access to foreign currency can deteriorate or

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8   Covered bonds were introduced into Swedish legislation in 2004. For the period prior to this, mortgage bonds are used instead.

the cost of this capital can increase. It is therefore valuable to include an indicator for the foreign exchange market in the financial stress index.

Choice of indicator for the foreign exchange market: volatility

When banks and companies choose to obtain funding in foreign currency, they take a foreign exchange risk. One means of managing this risk is to use derivative instruments. However, uncertainty over future exchange rates may lead to the price of such derivatives rising, which in turn may make it more expensive and more difficult for banks and companies to obtain funding in foreign currency.

There are several ways of estimating the uncertainty over future exchange rates. One means of estimating the price of foreign exchange risks is to use implied exchange rate volatility. We use implied volatility for the Swedish krona's exchange rate against the US dollar and the euro in the stress index. The reason for the choice of these two currencies is that Swedish banks and companies mainly use these currencies when obtaining funding in foreign currency.

DATA

The stress index is calculated on daily observations from 1 January 1997 to 30 June 2011 (see all of the indicators in Table B3). Where there are no observations, the previous data point has been used. All data has been gathered from EcoWin, except for the statistics for the index on implied volatility in the equity market, which have been gathered from Bloomberg and NASDAQ OMX. When calculating market weights, data on banks' and companies' funding has been gathered from Statistics Sweden (SCB).

The volatility on the foreign exchange market has been calculated as the mean value of the implied volatility for the Swedish krona relative to the US dollar and the euro respectively. As there is no data for the euro available prior to 1999, the volatility on the foreign exchange market between 1997 and 1999 is solely based on the krona's exchange rate against the US dollar.

Panel A in Table B1 shows the correlations between the indicators. The correlation is calculated for the entire period (1997-2011) and for two sub-periods, the historical reference period between January 1997 and July 2007 and the period between August 2007 and December 2009, which is characterised by the financial crisis of the late 2000s.

The indicators are mostly positively correlated, which is natural as the different parts of the financial system are affected by one another and by the same events. However, the TED spread in the historical reference period is negatively correlated with all of the other variables – although this changes during the crisis period when the TED spread is positively correlated with all variables.

METHOD

There are several methodological deliberations to make when constructing the index. Although advanced methods may have statistical advantages, they may also in general be more difficult to understand and interpret. We have therefore chosen to use a simple method where the indicators are allocated equal weight. A technical specification of the calculation of the index is contained in Appendix 2.

The stress indicators have been normalised to be able to express them in the same units and thus make them comparable with one another. The normalised stress indicators are then weighed together into an index. The index is also normalised, so that it has the mean value 0 and the standard deviation 1. The interpretation of the level of the index will thus be that when the value is equal to zero the index is equal to its historical mean value, and consequently the financial stress level should be regarded as low. This does not mean, however, that there cannot be individual markets that experience stress at the same time as other markets are stable. It is therefore interesting to also examine the level of the different components in the index to obtain a more detailed picture of the situation on the financial markets.

The Y axis in the figure shows the standard deviations from the historical mean value for the series. The standard deviation is a measure of variability for the distribution. In a normal distribution, one standard deviation covers around 68 per cent of the outcomes, two around 95 per cent and three standard deviations cover 99.6 per cent. One can thus say that when a series exceeds three standard deviations, it is an extreme situation that occurs very rarely, according to the normal distribution.[9]

Historical reference period

In general, the stress index is based on deviations from historical mean values. We use more than ten years' data, from January 1997 to the end of July 2007, to calculate the mean value used in the index. During this period Sweden experienced both upswings and downswings in its economy, which is necessary for the historical mean value to be representative. The period after this, up to the end of June 2011, is then compared with this historical mean value.

The choice of using data starting in the year 1997 can be discussed. Normally, longer time series entail more data points and thus better statistical properties. At the same time, the question arises of how relevant some historical data can be regarded to be for the current situation. The choice of time period should therefore be based on two factors: access to data and relevance of accessible data. As the method of the index is based on normalisation, it is very important that the historical mean values and standard deviations required for this are based on a period that can be regarded as representative.

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9   Financial data, of the type used in the stress index often do not follow the normal distribution, but instead tend to show a greater number of observations, which according to the normal distribution would be attributed a very low probability. This means that the normal distribution probably underestimates the probability of very unusual events. Thus, the probabilities implied by the normal distribution for certain outcomes should only be regarded as very indicative.

All of the indicators are limited by access to data to a different extent (see Table B3). Our index for implied volatility on the equity market has been calculated from the year 1992, which was the first year that NASDAQ OMX could supply data from. The TED spread and bond spread are accessible for slightly longer periods, from 1986 and 1990 respectively. However, the volatility in the foreign exchange market is based only on implied volatility in the exchange rate USD/SEK prior to 6 January 1999, because the implied volatility in EUR/SEK is not available prior to this date.[10]

The TED spread is an example of when one might discuss the relevance of the available data. Data for calculating the TED spread is available from 1986. However, one could argue that the TED spread for the period around the changeover to a floating exchange rate cannot be regarded as relevant to the index.[11] This is because interest rates tend to be more volatile under a fixed exchange rate regime than under a floating exchange rate regime, which may make it difficult to compare the interest rate differentials in different regimes.

It is interesting to check whether the conclusions would have altered significantly if we had chosen a different historical time period. We have therefore compiled a test where we calculate the index on the basis of two alternative time periods. The first alternative reference period is January 1992-July 2007, which means that it also includes the 1990s crisis in Sweden. The second is January 1992-June 2011, which means that it also includes the financial crisis of the late 2000s. Data on volatility in the foreign exchange market are not available prior to 29 December 1995. The extended history is therefore only based on the other three components prior to this point in time in the index.

Weighting of the indicators in the index

The advantage of weighing together the submarkets into one index is that this provides a collective overview of the level of stress on the market, as the significance of the individual factor is reduced. In our stress index we allocate equal weight to all stress indicators. In other words, the index is equally weighted. One justification for giving all of the sub-markets the same weight is that the index then becomes simpler and easier to understand. There are two main objections to using an equally-weighted index. The first is that the variables are not independent of one another (see Table B1). Equal weights can thereby risk overweighting an individual common factor among the indicators. The second is that it is debatable whether all sub-markets are of equally great significance for the economy.

To examine what effect the choice of weighting method may have on the results and to show the possible reasoning as to how the index can be constructed, we test two methods that offer alternatives to equal weighting. In the second alternative weighting (alternative method 1), we take into account the covariance between the indicators and carry out a principal component analysis, where the first component represents the market's systematic

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10 Implied volatility in USD/SEK is available from 29 December 1995.
11 Sweden switched to a floating exchange rate in 1992.

component. We also use a weighting method based on the relative size of the sub-markets in the economy (alternative method 2).

Alternative method 1: Weighting based on the covariance matrix

If the different sub-components are correlated and affected by a common factor, an index based on the components being allocated equal weight can lead to the degree of stress being overestimated or underestimated. One means of managing this is to use a principal component analysis (PCA). A PCA is a mathematical method whereby a number of correlated variables are converted into a number of uncorrelated variables that are known as principal components. These independent components capture similar movements or variations in the series examined. The first principal component captures as much of the variations in the data material as possible, and each ensuing component captures as much as possible of the remaining variations. If the series follow a common pattern, for instance a general market trend, the first principal component should be able to explain most of the common variation in the data material.[12] This first component therefore comprises our index and represents the common systematic risk in our variables. The first component uses around 63 per cent of the variation in the variables (see Table B2), which means that some information is lost in this method. The advantage is that the weights take into account the correlation between the variables, as the method uses the covariance matrix to calculate the weights. This means that the systematic risk is not overvalued in the index, which is a risk with the method using equal weights. However, one problem with applying the principal component analysis to indicators in the stress index is that these may have non-linear relationships to one another. As the method is based on linear relationships between the variables, the estimation of weights may disregard important information and thus be less suitable in this particular context.

Alternative method 2: Market weights

The second alternative method involves allocating the respective markets' weights based on their relative significance for the economy. One way of measuring the significance of a market is to take its size into account. However, one difficulty with this weighting is determining how to measure the size of a particular market. When calculating the weights we have used the banks' and companies' funding as a starting point.

With regard to the equity market, we have chosen to use the market value of equity in companies listed on Swedish marketplaces. This leads to a relatively large weight for the equity market, around 41 per cent in June 2011 which forms the end of the observation period, as a result of the non-financial companies' considerable dependence on this form of funding.

The weight of the money market is calculated by adding the total certificate borrowing of the Swedish MFIs in Swedish krona to the total value of their deposits in Swedish krona

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12 Several important assumptions are made in a principal component analysis, such as linearity and independence. For further information on PCAs, see Campbell et al. (1997).

with other MFIs, which gives a weight of 11 per cent at the end of the observation period. For the bond market we have chosen to use MFIs' total issued securities in Swedish krona, deducting certificate borrowing (which is included in the money market) and adding the total of the outstanding amount of bonds issued by non-financial companies on the Swedish bond market and the non-financial companies' debts abroad in Swedish krona. As a large percentage of bonded borrowing is in foreign currencies, the weight for the bond market amounts to around 16 per cent at the end of the observation period.

For the foreign exchange market we have chosen to base the weight on the MFIs' and non-financial companies' funding in foreign currency. This constitutes a large part of the total funding and of both the money market and bond market borrowing. The weight for the foreign exchange market is therefore around 31 per cent in the index at the end of the observation period.

One problem with this approach is that the markets with weights based on market value are given a lower weight during periods of stress. For example, as mentioned earlier, equity markets with falling equity prices often have a high volatility. This means that the value of the equity market falls, and its weight in the index declines, despite its importance for the economy remaining unchanged. Another problem arises if there are substitute markets that can replace the markets on which the index is based. One example of this is that the repo market can to some extent replace the unsecured interbank market, which is not captured by this index.
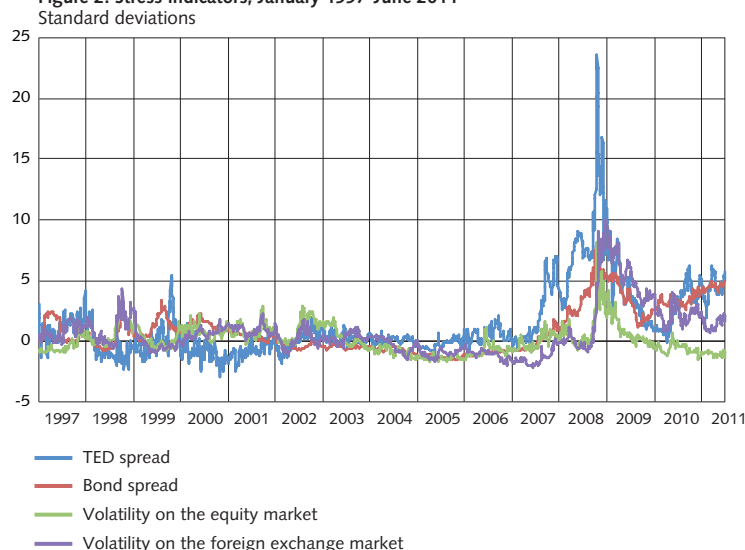
ANALYSIS OF THE INDEX

Figure 1 shows the equally-weighted index during the period January 1997 to the end of June 2011.

Figure 1. Stress index, January 1997-June 2011
Standard deviations
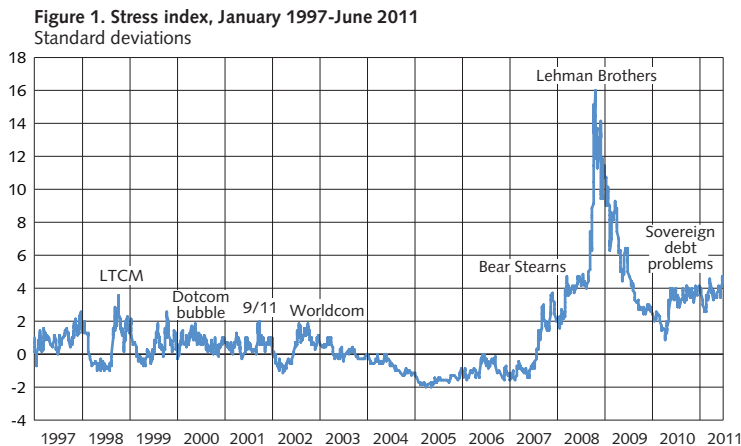
Source: The Riksbank.

The stress index captures a number of periods of increased global financial unrest, for example the LTCM crisis in connection with Russia's financial collapse in autumn 1998, the dotcom bubble of 2000, the terror attack in the USA on 11 September 2001 and the Worldcom scandal in 2002. From the middle of 2003, the index reflects the period of calm with low uncertainty and abnormally low risk premiums that prevailed until the autumn of 2007, when the financial crisis of the late 2000s began. The index reached a peak after the fall of Lehman Brothers in September 2008 and began to return to lower levels in 2009. Since the first half of 2010 the index has once again risen, parallel to the sovereign debt problems in several European countries.

Figure 2. Stress indicators, January 1997-June 2011
Standard deviations

- TED spread
- Bond spread
- Volatility on the equity market
- Volatility on the foreign exchange market

Source: The Riksbank.

To be able to analyse developments in the index, one must take into account the respective stress indicators. Figure 2 shows the development of the normalised stress indicators. For instance, we can see in the figure that all of the indicators contributed to a sharp rise in the index during the financial crisis of the late 2000s. Initially, it was only the TED spread that contributed to this increase, while there were only moderate increases in equity volatility on the equity market and the bond spread. However, as the crisis worsened the bond spread and share volatility began to increase. Volatility in the foreign exchange market also increased after September 2008 and remained at a high level for the rest of the year.

It is important to note that our stress index does not necessarily reflect financial stress. The symptoms of stress the index attempts to measure may be caused by other circumstances. A deviation in price from the historical mean value may be justified and may arise while the market is functioning efficiently. For example, the difference in the interest rate between a risky bond and a risk-free bond may rise above the historical average because the credit risk has risen. This could have the consequence that the index implies

financial stress, despite the actual market not being stressed. And a deviation from the historical mean value can for example also occur without an increase in the credit risk. This could then be a sign of financial stress. In practice, these two factors tend to covary, which can contribute to difficulties in separating them from one another. A further complication is that it is very difficult to assess what should comprise a normal level for the financial stress index. In our measure we use deviations from historical mean values as a base, but in actual fact this is not certain and the historical average level can be said to be normal.
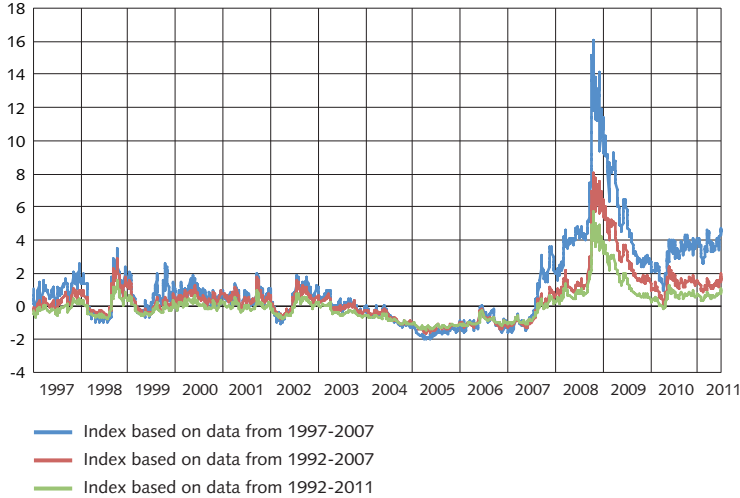
Market pricing of risk is also affected by the investors' willingness to take risk, that is, risk aversion. The investors' risk aversion determines what compensation they will demand to take on a particular risk in addition to the compensation for the actual risk. This further compensation is often called a risk premium. When risk aversion increases, the market demands higher compensation to take on the same risk. When analysing the stress index and the stress indicators included in it, it may be of great importance to distinguish between the risk and the price of the risk.[13]

Sensitivity to the choice of historical reference period

The three stress indices in Figure 3 follow one another closely over time. However, on a couple of occasions a tangible difference arises between the two alternative indices and our primary index. These are the middle of 2008 and then the first half of 2010, when our primary index increases much faster than the two alternative indices. This is largely due to the two alternative indices being partly based on a time period that includes the 1990s crisis. This means that the mean values and standard deviations for the two alternative indices are higher, which lowers the normalised values of the sub-components.

13 See, for example, Hull et al. (2005) and Espinoza and Segoviano (2011) who discuss this problem.

Figure 3. Stress index with different historical reference periods, January 1997-June 2011
Standard deviations

- Index based on data from 1997-2007
- Index based on data from 1992-2007
- Index based on data from 1992-2011

Source: The Riksbank.

The two alternative indices are also in general slightly lower than the one based on 1997 to 2007. The index based on the time period 1992 to 2011 has the lowest level, because it is based on a time period that includes both the 1990s crisis and the late 2000s financial crisis.

Sensitivity to choice of weighting method

Figure 4 shows the stress index constructed using a PCA together with the equally-weighted and the market-weighted indices. The PCA index shows roughly the same development as the equally-weighted index, despite the weights not being of equal size.[14] However, not all of the information from the indicators is used; the first principal component represents only around 63 per cent of the total variation in the Swedish indicators (see Table B2). All in all, a weighting with a PCA does not have any significant effect on the development of the index compared with using equal weights.

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14 The weights in the PCA are obtained from the condition that the total of the squared coefficients for each component totals 1.

Figure 4. Stress index, three weighting methods
Standard deviations

— Stress index, equal weights
— Stress index, PCA weights
— Stress index, market weights
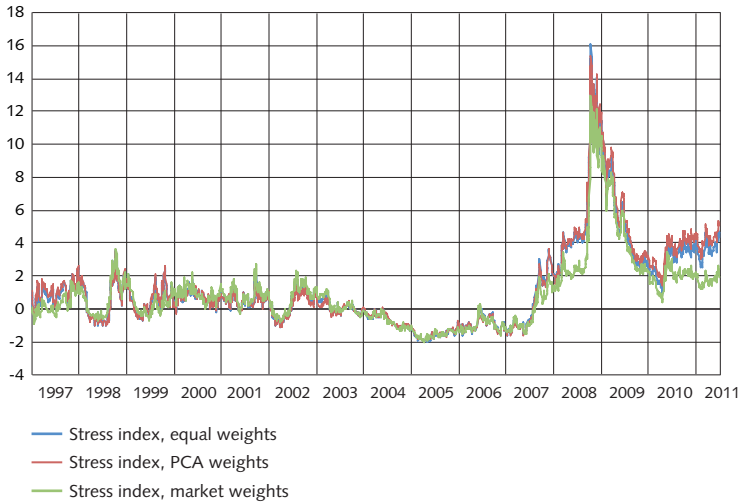
Source: The Riksbank.

Figure 4 also shows the equally-weighted index compared with an index that is weighted with market weights that change over time. The index with market weights deviates from the equally-weighted index on two occasions, namely in the middle of 2008 and since the first half of 2010. The reason for this is that on these two occasions it is primarily the TED spread and the bond spread that contribute to the increase in the index. These two indicators have been allocated relatively small weights in the market-weighted index. They therefore do not affect the index as much as the volatility on the equity market and volatility on the foreign exchange market. Otherwise, the indices follow one another fairly well.

Stress index – an overall picture of the financial markets

We have developed an index that is intended to function as a tool for analysing developments on the financial markets. We have based our index on the financial markets that are important funding sources for banks, companies and ultimately households. The stress indicators we have chosen are directly or indirectly related to the funding costs prevailing in each respective market. In times of financial stress these components tend to be affected, which may make it more expensive, and possibly more difficult, for banks, companies and households to obtain funding.

The indicators included in the stress index are normalised so that the level of each indicator at each point in time is related to the average level and the standard deviation during a reference period (January 1997 to July 2007). The indicators have then been weighed together into an equally-weighted index. In this article we test how the index is affected by alternative historical reference periods and alternative weighting. Our conclusion is that the development of the index is affected to some extent over time. The

differences in the way different variations of the index develop have however been few and temporary.

The construction of the index is simple and is intended to be easy to understand. Each change amounting to one unit in the index corresponds to a movement equivalent to a standard deviation, calculated on the basis of the historical reference period. When the level of the index is zero, the total of the four stress indicators correspond to the total of their historical mean values. However, there are a couple of aspects to take into account in the analysis of the index.

Firstly, the total of the four stress indicators may correspond to the total of their historical mean values without each stress indicator being equal to this mean value. This means that the analysis of the stress index may need to be supplemented with other information, such as the development of each individual stress indicator.

Secondly, it is not certain that the historical reference period (January 1997 to July 2007) is representative of any form of normal level. On 30 June 2011 the level of the stress index was 4.4. This can be compared with 4.5 on 30 June 2008 or -1.6 on 30 June 2005. However, it is not certain that the level of financial stress was lower on the dates 2005 and 2011 than the date 2008. What can be regarded as a normal level may change over time as a result of, for instance, structural changes in financial markets and changes in regulation. The level that our current construction implicitly regards as normal through the choice of historical reference period may thus need to be adjusted in the future and should not be unreservedly accepted.

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Appendix 1. Tables

Table B1. Correlations

Panel A: Indicators	TED spread	Bond spread	Volatility on the equity market	Volatility on the foreign exchange market
Total period (Jan 1997-Jun 2011)				
TED spread		0.68	0.29	0.48
Bond spread			0.31	0.69
Volatility on the equity market				0.52
Volatility on the foreign exchange market				
Historical reference period (Jan 1997-Jul 2007)				
TED spread		-0.11	-0.16	-0.14
Bond spread			0.45	0.50
Volatility on the equity market				0.63
Volatility on the foreign exchange market				
Crisis period (Aug 2007-Dec 2009)				
TED spread		0.60	0.68	0.19
Bond spread			0.62	0.65
Volatility on the equity market				0.59
Volatility on the foreign exchange market				

Table B2. Principal components based on the period January 1997-June 2011

Principal component	Value	Percentage	
PC 1	2.51	0.63	
	TED spread	Bond spread	Volatility on the equity market	Volatility on the foreign exchange market
Own vectors (loadings), PC 1:	0.50	0.55	0.40	0.54

Table B3. Variables included

	Source	Available from	Mean value	Standard deviation
3-month rate Treasury bills	EcoWin	03-01-1983	3.27	0.91
3-month interbank rate (STIBOR)	EcoWin	30-12-1986	3.46	0.90
5-year bond spread	The Riksbank	01-01-1990	44.50	18.76
30-day implied volatility index for OMXS30	The Riksbank	02-01-1987	26.36	8.42
3-month implied volatility, USD/SEK	EcoWin	29-12-1995	10.64	1.48
3-month implied volatility, EUR/SEK	EcoWin	06-01-1999	6.06	1.36

Note. The mean values and standard deviations are for the historical reference period (January 1997-July 2007) or from the date when they became available and until the end of July 2007.

Appendix 2. Technical specification of the calculation of the index

STAGE 1. CALCULATION OF THE HISTORICAL MEAN VALUE AND STANDARD DEVIATION FOR EACH RESPECTIVE STRESS INDICATOR IN THE INDEX

Based on a historical reference period, the arithmetical mean value is calculated as:

$$\bar{x} = \frac{1}{n} \times \sum_{i=1}^{n} x_i \qquad \text{Equation 1}$$

where n is the number of observations of the stress indicator. In our index the observation x_1 corresponds to the stress indicator's value as of 1 January 1997 while x_n corresponds to the stress indicator's value as of 31 July 2007. The historical standard deviation is calculated as:

$$s = \sqrt{\frac{1}{n} \times \sum_{i=1}^{n} (x_i - \bar{x})^2} \qquad \text{Equation 2}$$

STAGE 2. NORMALISATION OF THE STRESS INDICATORS

Each observation of the respective stress indicator is normalised using the historical mean value and the standard deviation. The observations are normalised as follows:

$$x_i^{norm} = \frac{x_i - \bar{x}}{s} \qquad \text{Equation 3}$$

STAGE 3. WEIGHTING OF THE INDICATORS

The stress indicators are weighed together into an index as follows:

$$index_i = w_a \times x_{i,a}^{norm} + w_b \times x_{i,b}^{norm} + w_c \times x_{i,c}^{norm} + w_d \times x_{i,d}^{norm} \qquad \text{Equation 4}$$

where w is the weight allocated to the respective indicators and the index a, b, c and d designate our four stress indicators. In our equally-weighted index $w_a = w_b = w_c = w_d = 0.25$.

STAGE 4. NORMALISATION OF THE INDEX

The index needs to be normalised so that the level of the index can be interpreted as the number of standard deviations from the mean value. Normalisation is carried out in accordance with Stages 1 and 2, with the difference that x is replaced by $index$.