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A Swedish Financial Stress Index

Abstract: In this thesis we develop a daily index that aims to reflect the functionality of the Swedish financial system. We extend previous research about systemic financial stress by introducing the Swedish Financial Stress Index (SFSI), a market data based measure consisting of 14 indicators aggregated into five subindices that reflect different parts of the financial system. Each component is chosen by its connection to key phenomena of financial stress as suggested by research consensus. The subindices are weighted by their time-varying cross-correlations to reflect the detrimental impact of systemic stress on the financial system. We validate our results and choose aggregation methods based on a comparison of the output of different specifications to the results of an academic expert survey. The SFSI peaks in periods classified as highly stressful by the academic experts. A threshold vector autoregression (TVAR) model is utilized to estimate the level of financial stress at which it starts to impact economic growth. The SFSI is constructed to become a macroprudential policy tool for the Riksbank.

Keywords: Financial stress index, Financial crises, Systemic risk, Financial stability, Financial system

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1. Introduction

Financial crises have been a long standing by-product of organized financial markets (Reinhart and Rogoff, 2008) and have caused some of the deepest and longest lasting economic downturns in history such as the Great Depression starting in 1929. The condition of the financial system has increasingly become the focus of public attention as the global financial crisis of 2007-2009 and the subsequent European sovereign debt crisis threaten global wealth and stability.

Typically, the culmination of major financial crises can be attributed to specific trigger events such as the 2008 bankruptcy of Lehman Brothers. However, we cannot think of financial crises as only binary variables. Frictions in the financial markets exist at almost all times, but they rarely have impacts so severe that the entire economy is affected. We refer to disruptions in the functioning of the financial system as financial stress.

In order to understand high stress occurrences in a financial system, it is necessary to evaluate financial stress quantitatively. Such a quantification may help to understand the severity of an episode of financial stress in a historical context, to compare the different stages of a single crisis and, ultimately, to understand the impact of a crisis on the real economy (Louzis and Vouldis, 2011).

In this paper we create the Swedish Financial Stress Index (SFSI), a daily index that aims to reflect the functionality of the financial system. It is an extension of the Swedish stress index as suggested by Forss Sandahl et al. (2011) and is meant to serve as a complementary tool for the macroprudential analysis at the Swedish Riksbank. For this purpose, the SFSI should provide a quick, clear and intuitive assessment of the current state of the financial system. We provide a precise description of financial stress, identify phenomena of financial stress that critically impact the trading behavior of investors and determine individual market indicators that proxy these behavior patterns. Subsequently, we aggregate all identified indicators to a single index. We derive the parameter choices for the aggregation by aligning our results to assessments of past stress episodes by academic experts on financial stress. We also aim to highlight system-wide stress by additionally weighting our index by the cross-correlation structures of our indicators.

We expect that only high stress values will have a negative impact on the growth of the real economy. In the last part of our paper, we test this hypothesis by showing that the interdependence between the financial stress index and growth in industrial production shifts once a certain level of stress is surpassed.

1.1 Definition of Financial Stress

There is substantial debate about how to define the term financial stress (e.g. Louzis Vouldis, 2011). As Hakkio and Keeton (2009) state, in most general terms one can think of financial stress as an interruption to the functioning of financial markets. More concretely, we will adopt the approach by Forss Sandahl et al. (2011) and consider financial stress to be a disruption in the financial markets' functioning as an efficient intermediary between borrowers and lenders and buyers and sellers. We will also extend our evaluation to the entire financial system by including institutionalized financial intermediaries.

We are mainly interested in financial stress because of its potential adverse effect on the real economy. While elevated levels of financial stress are not always followed by a downturn in the real economy, we still consider a threat to the growth of the real economy as a defining feature of high financial stress. If systemic financial stress levels can be detected at an early stage, fiscal and monetary policy measures can be taken to mitigate the potential impact on the economy. We will refer to an extreme level of financial stress as a financial crisis.

Others researchers have focused more on describing the circumstances that typically accompany financial stress or the consequences of stress. Grimaldi (2010) describes it as "the product of vulnerable markets and of shocks". Reinhart and Rogoff (2009) argue that a "lack of confidence" is the unifying element of all episodes of financial stress, while Holló et al. (2010) define stress in the financial sector as the amount of systemic risk that has materialized. Furthermore, Group of Ten (2001) define systemic risk as the risk that an event will trigger a loss of economic value or confidence in the financial system with significant adverse effects on the economy. The adverse real economic effects from systemic problems are generally seen as arising from disruptions to the payment system, to credit flows, and from the destruction of asset values.

Illing and Liu (2006) address the different causes for extreme financial stress and distinguish between banking crises, currency crises, equity crises and debt crises. However, they also point out that while financial crises are often rooted in just one segment of the market, stress tends to spread across the entire financial system. Often, such an event signifies that there is also a contagion risk for the real economy. For this reason we will pay special attention to "systemic stress" in our analysis.

In their financial stress index Hakkio and Keeton (2009) focus on the key features, or phenomena, of well-known financial crises that determine the trading behavior of investors. Each observed period of increased stress in the financial markets has different characteristics, implying varying relative importance of the factors. However, each crisis seems to involve at least one and

often all phenomena. The five key features of financial stress as defined by Hakkio and Keeton (2009) are

(i) increased uncertainty about fundamental value of assets,

(ii) increased uncertainty about behavior of other investors,

(iii) increased asymmetry of information,

(iv) decreased willingness to hold risky assets (flight to quality) and

(v) decreased willingness to hold illiquid assets (flight to liquidity)

We adopt this approach as it provides a clear guideline of how to observe financial stress empirically. The characteristics also fit our notion of financial stress as a disruption in the financial system. All of the stated phenomena either impede the ordinary functioning of financial markets and intermediaries (such as increased uncertainty about asses values, increased asymmetry of information) or indicate that market and intermediaries react to stress (e.g. by reducing their own exposures to risk to ensure that their capitalization remains stable as an example of (v)). We will discuss below how conditions (i) to (v) may adversely affect the development of the real economy.

1.2 Sources of Capital for Non-Financial Companies

The primary function of any financial system is to enable the allocation and deployment of economic resources, both spatially and temporally, in an uncertain environment (Merton, 1995). Some of the negative effects of financial stress may include an increase in adverse selection and moral hazard phenomena and consequently, a malfunctioning of financial intermediation (Louzvis and Vouldis, 2011). In this section, we will describe more in depth the mechanism of how disruptions in the financial system have the potential to adversely affect the development of the real economy.

Companies need to access the financial system for a variety of reasons, most notably to finance new investments (that provide the fundament for growth) and day-to-day operations when internal financing is unavailable or disadvantageous. Parts of the financial markets, especially the derivatives markets, are relevant for the risk management of companies while foreign exchange markets need to be accessed for any operations outside of Sweden or transactions with counterparties abroad.

The most common classification of financing possibilities distinguishes between equity and debt financings, but for our purpose the distinction between seeking financing from public (or in some cases, private) markets and institutionalized financial intermediaries (such as banks) is similarly important.

We reflect the different possible paths of capital to companies by creating a number of subindices. We adopt the approach by Illing and Liu (2006) and Forss Sandahl et al. (2011) and develop subindices for the equity, bond, foreign exchange and money markets. Illing and Liu (2006) note these correspond to the major channels for capital in Canada, an assumption we can also make for Sweden. Additionally, we follow the approach by Holló et al. (2010) and introduce a dedicated financial intermediaries index (comprising different asset classes). An independent subindex for financial intermediaries has the advantage that it is more suitable for capturing financial stress that emanates from institutional capital providers. In section 4.2 we provide an exact description of the composition of the subindices and a list of individual indicators that we consider to be representative of the different markets.

The only major source for financing we do not explicitly consider is internal financing by retaining earnings. Asymmetric information between firms and suppliers of external finance create a wedge between the cost of external and internal financing. Many small companies, even companies with promising growth prospects find it difficult to raise outside capital at reasonable terms, implying that they almost exclusively finance their growth internally (Carpenter and Peterson, 2002). Intuitively, an increased ability to finance investment opportunities with retained earnings may decrease the threat level to the real economy from a "credit crunch" in the financial markets. The possibility to finance internally also seems less dependent on (i) to (v) than the financing capabilities of intermediaries and financial markets. Therefore, an argument can be made for including a corresponding proxy to our financial stress index. However, the closest proxy would be the level of corporate cash reserves, which is only available in quarterly reports and not on a daily level.

Furthermore, the argument for using total corporate cash reserves is weakened by the likely assumption that the firms building large cash reserves are less reliant on frequent access to the capital markets. Other internal financing proxies such as dividends-to-earnings ratios or utilizations of revolver facilities would be for similar reasons noisy and possibly skewed. We will therefore not consider internal financing capabilities.

Another financing source we do not consider is equity received from institutional alternative asset managers such as private equity or venture capital firms. These types of firms usually raise (fixed size) funds from institutional investors that are called upon and invested in the subsequent 3 – 5 years. The setup is noteworthy in our context because these firms typically have the capacity to invest large amounts of equity during market downturns (sometimes they are even obliged to do so as they receive a penalty when failing to invest committed capital). Private equity could therefore - potentially - smooth the flow of capital to the real economy. However, the

opposite has been the case historically (EVCA, 2011) as most private equity firms also rely on substantial deal-by-deal debt financing that is often unavailable when the access to capital markets is strained. Consequently, anecdotal evidence (such as during the subprime crisis) suggests that private equity investments go down during times of financial stress. Due to the ambivalent impact of private equity, the relatively small size of the sector and data availability constraints we do not consider it further in this paper.

1.3 The Chain Reaction of Financial Disruption: Impact on the Real Economy

We are mainly interested in financial stress due to the potential adverse impact on economic growth. If financial intermediaries and financial markets stop functioning ordinarily, companies are no longer able to raise financing for investments that drive forward economic growth. Consequently, inefficiencies emanate as profitable investments that could be undertaken when financial markets function normally cannot be financed.

This leads to a lower total number of available efficient investment opportunities (e.g. for subcontractors) because of the lower overall economic activity, a second and indirect effect that further slows down growth. The mechanism is aggravated by market participants' anticipation of this development. It is not necessary that access to financing is actually blocked, but firms may already start to voluntarily curtail investments based on the negative economic outlook. It is therefore conceivable that the slowdown in economic activity by far exceeds the immediate impact of firms unable to receive financing. The concept that it is advantageous for economic agents to act in the same way as they expect other agents to act is referred to as strategic complementarity (Cooper and Corbae, 2002). In this context it means that financial crises may turn into a vicious cycle and that smaller trigger events may lead to bigger system wide crises.

Lastly, heightened uncertainty about growth in the economy makes it rational for lenders to become hesitant about providing credit as the value of the available collateral of borrowers becomes harder to determine, thereby exacerbating the downward process (Bernanke and Gertler, 1995, and Kiyotaki and Moore, 1997).

While there are many ways for financial stress to spread to the real economy, Holló et al. (2010) point out that observers are ultimately left in the dark with regard to the "systemic" impact of a financial crisis. Many influencing factors – such as market psychology – cannot be observed. We only observe the development of economic activity indicators such as total industrial output, but need to hypothesize about the degree to which real economic developments are linked to the financial sector.

1.4 Distinguishing Financial Crises from Other Market Downturns

The five key features as defined by Hakkio and Keeton (2009) do not give an explicit definition of financial stress, they only describe the consequences typically observed during periods widely considered to be financial crises. The advantage of this approach is that the five phenomena can be observed with indicators available in the financial markets, which facilitates an empirical analysis. However, it remains unclear if we can deduce financial stress merely from the occurrence of the phenomena. It may be possible that the features also occur when there was no disruption that emanated in the financial markets.

A bank failure can be considered a classic example for a disruption originating in the financial sector. Asymmetric information and overall uncertainty over consequential potential losses for other market participants may already lead to several symptoms of financial stress (e.g. (iv) – a decreased willingness to hold risky assets) and ultimately cause a mechanism that harms economic growth such as described in section 1.3. Similarly, currency crises often have a root cause in the financial sector itself.

It is less clear in which way we can intuitively think of other crises and market downturns as having a "financial" nature. The dot-com crash in April 2000 as well as other asset price bubbles were not the result of a financial disruption in the classic sense, but rather a drastic reassessment of future earnings expectations. As company and asset valuation is a part of finance, we may also refer to the immediately resulting stress symptoms as "financial stress". Nonetheless, there is a need for us to distinguish between downturns constricted to single asset types or single industries from financial crises with a "systemic" nature and a malfunctioning of the entire financial system. While such a systemic meltdown of the financial sector did not occur in 2000, we need to consider that the financial crisis peaking in 2008 also began with the burst of an asset price bubble in the US real estate market.

Sharp declines in asset prices will often also put a strain on the financial sector, which may cause it to stop functioning properly. Banks typically have an exposure to prices of assets such as equities or mortgage backed securities. A drop in the prices of these assets will then decrease their capital ratios which may cause counterparties to doubt their abilities to service own liabilities. Such a mechanism took place in 2007 when many US households were forced to default on their mortgages, thereby transferring a large part of the losses related to declining real estate prices to banks. From this perspective it makes sense to think of asset price bubbles as risks factor that may spread and trigger a system-wide financial crisis.

Similarly, even crises that did not start out in the financial sector may take on a financial aspect – examples may be terrorist attacks such as 9/11 or political uprisings. Non-financial

disruptions may lead to an increased uncertainty about fundamental values of assets and therefore have the potential to cause a chain reaction in the financial system. However, a change in the business environment resulting from the described non-financial events may single-handedly cause an economic slowdown as well, with a strain on the financial system only as a secondary effect.

From this perspective, it is often difficult to make a clear distinction between a financial crisis in the sense that we use the term and other downturns in the economy that also affect the financial sector. Ideally, the goal of an aggregated stress index is therefore to assess the strain on the real economy that can only be attributed to the financial sector.

2. The Swedish Financial System

The financial crisis had a significant impact on Sweden's financial sector. Both domestic and foreign funding markets were seriously strained, and several Swedish banks encountered severe funding issues due to concerns about their exposure to the Baltic markets and a high dependence on short-term wholesale funding. The non-banking financial sector was also affected, with a significant fall in insurance companies' solvency ratios from declining stock prices and record high covered bond spreads. The crisis did not only affect the financial sector, it also had a severe impact on Sweden's economy. A deep recession followed, with GDP contracting 7.5 per cent between the second quarter of 2008 and the second quarter of 2009 (IMF, 2011a). In the remainder of this section we will discuss the Swedish economy in an international context, with emphasis on how Sweden could be affected to such an extent by a financial crisis originating in the U.S. mortgage market.

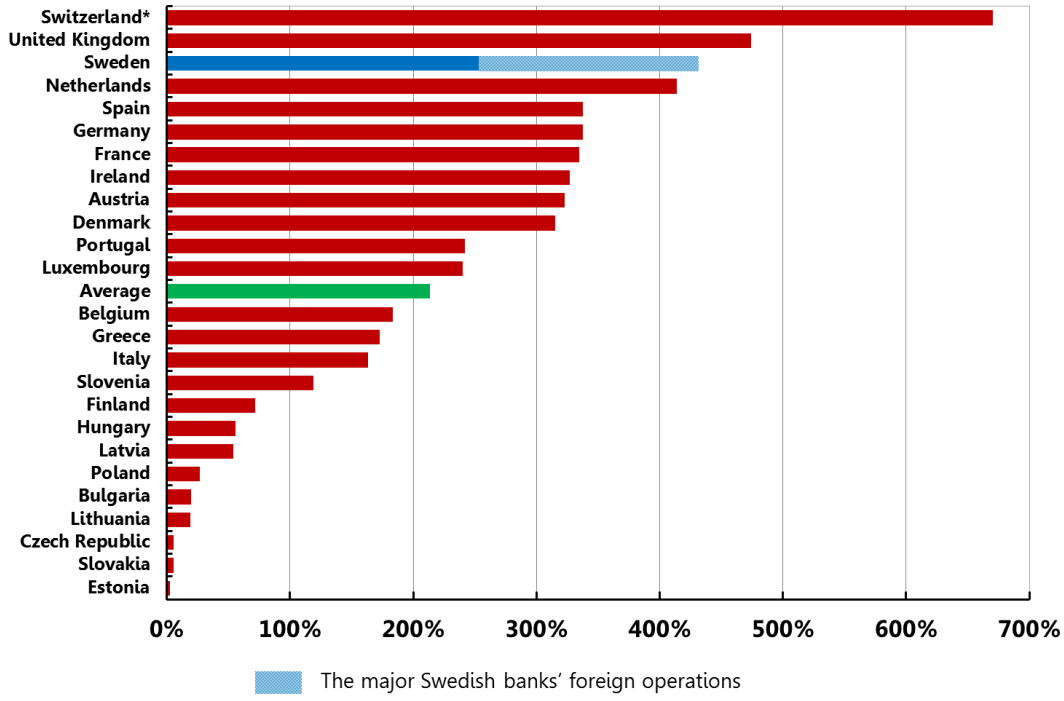
2.1 Swedish Banking

Four major banks dominate the Swedish market; Handelsbanken, Nordea, SEB and Swedbank. Together, these four banks account for about 75 per cent of deposits from and lending to the Swedish public. The banks are largely exposed to each other, mainly through interbank loans and covered bonds. Risks arising in one bank can thereby easily spread through spillover effects, posing a serious contagion threat to the entire Swedish financial system (Ingves, 2011). This became evident in the 2008-2009 financial crisis when markets were particularly concerned about the asset quality in Swedish banks' Baltic operations, with share prices of all major Swedish banks dropping sharply. Several Swedish banks had difficulties rolling over their debt obligations, demonstrated by a sharp increase in in the Swedish interbank market risk premium. Naturally, the

most exposed banks took the hardest hits, however even Handelsbanken with no significant exposure to the Baltic crisis was affected by increased counterparty risks. Funding and currency swap markets were impaired when the banks hoarded liquidity, leading up to a potentially systemic "liquidity squeeze". However, Sweden suffered little damage from financial disruptions compared to many other developed countries, partly due to the timely and effective reactions of the Swedish Riksbank to the temporary halt of interbank and short term credit markets. The measures taken by the Riksbank together with the SNDO and the Swedish Ministry of Finance most likely avoided a detrimental credit crunch for Sweden (Goodhart and Rochet, 2011).

With total assets in the Swedish banking sector amounting to more than 4 times Sweden's GDP, the Swedish banking sector is large compared to the size of the Swedish economy (Sveriges Riksbank, 2011a). This is a result of a decade of rapid expansion in the Nordic and Baltic regions, continuously increasing domestic housing prices (and mortgage demand) and the Swedish corporations' dependence on intermediary funding rather than market funding. The latter will be developed further in section 2.2. The concentrated and interlinked banking sector combined with its large relative size implies that the failure of a major Swedish bank would have very serious implications for the functioning of the Swedish financial system.

Fig. 1. Total domestic banking sector assets as a percentage of GDP (2010)



Source: Slides to Financial Stability Report 2011:1 *Financial Stability Report 2011*

Over the last decade, Swedish banks have increasingly relied on global wholesale funding to support the expansion in their credit operations. Credit demand has by far outpaced the amount of deposits, and today Swedish banks obtain half of their funding from the financial markets, of which approximately half is denoted in foreign currencies (IMF, 2011b). The foreign currency funding is needed to meet lending needs and reduce total lending costs, and can also serve as an efficient way to spread financing risks. However, foreign lending increases the dependence on an efficient currency swap market and more importantly increases the contagion risk from other economies. Worth noting is that the Swedish banks have major foreign operations, which to some extent can serve as a foreign funding rationale (Sveriges Riksbank, 2011a).

Systemically important banks around the world have almost always been bailed out by their respective governments when threatened by bankruptcy, which has led to banks being able to reduce capital ratios without punishment by their lenders in terms of higher interest rates (Sveriges Riksbank, 2011b). Ingves (2011) points out that the markets presume an implicit state guarantee even for the Swedish banks, as the subsequent huge implications from a bank failure makes them too big for the state to let them fail. Hence, the banks are considered less risky and can obtain cheaper funding than comparable institutions with less systemic relevance.

To avoid costly bailouts of systemically important banks and increase stability in global banking, the Basel committee has proposed a new set of capital regulations, the Basel III, increasing the ratio of core capital the banks will need to hold. Sweden is required to adopt these rules as a minimum, however Finansinspektionen, the Swedish Ministry of Finance and the Riksbank have jointly proposed higher capital requirements for the largest[1] Swedish banks, due to their vast size and domestic importance. Swedish banks will be required to hold 10 per cent common equity by 2013 and 12 per cent common equity from 2015. This can be compared to the 7 per cent common equity requirements[2] proposed by the Basel committee. (Finansinspektionen, 2011). The new rules will reduce the funding discount of systemically important banks, hence increasing their total cost of capital. In section 2.2 we will discuss the implications of the new capital requirements for the funding of Swedish non-financial corporations.

2.2 Financing of Swedish Non-Financial Corporations

In an international context, the Swedish non-financial corporate bond market can be characterized as underdeveloped. Total outstanding amount of corporate bonds were SEK 376bn at the end of 2010, compared to more than SEK 2,000bn in credit institution loan financing. The

[1] The rules will primarily apply to the four major banking groups, Handelsbanken, Nordea, SEB and Swedbank
[2] Excluding the countercyclical buffer

Swedish high-yield bond market is close to non-existing. The Swedish model with barely any market debt funding can be explained by a tradition for relationship banking in Sweden and a reluctance to the relatively high bond market entry costs (e.g. credit rating costs and issuance fees). In addition to that, a small market is self-fulfilling. Investors demand a premium for the additional liquidity risk of bonds, which further increases the costs of market funding, thereby reducing attractiveness of this alternative. The proportion of bond issues to bank financing is slowly increasing. However, it is obvious that the Swedish non-financial companies are particularly dependent on financial intermediary funding (Gunnarsdottir and Lindh, 2011).

The higher capital requirements of systemically important banks as discussed in section 2.1 will probably increase total funding costs for banks, with three probable scenarios (or a combination of the three): (i) a reduction in shareholders' return on equity, (ii) higher borrowing costs for Swedish corporations and households due to shareholders preserving return on equity targets, and (iii) a reduction in the supply of lending to shrink the banks' balance sheets and thereby avoiding an equity injection (Härle et al., 2010). Higher borrowing costs or decreased loan supply may give Swedish corporations an incentive to try market funding, leading to a faster increase in the ratio of bonds to intermediary financing than we observe today. This will in turn increase Swedish bond markets' significance for the stability of the Swedish financial system.

For the construction of our index we conclude that the relevance of financial intermediaries is disproportionally high in Sweden, while the corporate bond market is small in international comparison. The banking sector is also highly concentrated with four major institutions, another factor that could increase contagion risk in the intermediaries sector.

2.3 Export Oriented Economy

The Swedish economy is heavily exposed to the world markets, with the combined value of exports and imports totaling approximately 100 per cent of its GDP. The trade balance has been consistently positive over the last 20 years, and about half of total imports are related to the export-industry (SCB, 2011). The largest share of Swedish exports is directed towards advanced economies. With cyclical industries such as electronic equipment and machinery industries as main contributors, it is apparent that growth in the Swedish real economy is dependent on foreign demand for industrial manufacturers and commodities (Jochem, 2010). This became evident during the recent financial crisis, when the openness of the Swedish economy and the Swedish financial markets resulted in a quick contraction of the economy.

As a small open export-oriented country outside the euro area, the Swedish economy is subject to risks related to price movements in the foreign exchange markets. Certain mitigation of

these risks can be achieved with the use of currency swaps, however increased volatility in exchange rates decreases the predictability of future earnings for important Swedish corporations.

3. Existing Financial Stress Indices

3.1 Overview

The interest in creating composite indicators of financial stress has increased significantly post the recent global financial crisis. However, there were a few studies on the subject prior to this as well. Gadanecz and Jayaram (2009) point out that the literature was derived from previous studies on early warning indicators for banking crises and financial stress. This overview of previous literature does not include all financial stress indices created so far, our intention is rather to describe the development in previous literature from basic equally-weighted raw stress indicators to advanced measurements of systemic risk.

Bordo et al. (2001) pioneered the financial stress literature by constructing a financial conditions index with a number of yearly standardized raw stress variables. The purpose of the study was to determine the frequency of financial crises in historical data from 1790-1997. The index uses yearly data, hence it is not an optimal approach for a real-time financial stress measure. However, later researchers have adapted the authors' ideas and methodology. Hanschel and Monnin (2005) created a stress index for the Swiss banking sector using quarterly data. Individual indicators were standardized and weighted equally. The index was evaluated by comparing output to events commonly known as stressful.

lling and Liu (2006) enhanced the literature on financial stress indices by introducing a daily data stress index for the Canadian financial system. The index comprises four individual indicators, each representing one market identified to be of particular importance for the stability of the financial system. The authors test several indicator aggregation approaches, including factor analysis (principal components), econometric benchmarking and generalized autoregressive conditional heteroskedasticity (GARCH) modeling. The preferred approach of credit weights is then chosen because the results are best aligned to responses of an internal Bank of Canada survey on periods of financial stress.

Cardarelli et al. (2009) constructed a variance-equal weighted FSI for 17 advanced economies. This broad perspective limits the authors to focus on raw stress variables available in all advanced economies. Episodes of financial stress were identified as events where the FSI deviated positively more than one standard deviation from its mean value. Similarly, ECB (2009)

constructed a FSI for the 29 main economies in the world. Indicators were statistically standardized, log-transformed and grouped into each of the three markets fixed income, equity and foreign exchange. A novelty about ECB's index was the development of the Global Index of Financial Turbulence, a weighted average of the stress in the world's major economies.

Hakkio and Keeton (2009), constructing the monthly Kansas City Federal Reserve FSI, selected stress indicators intended to best capture the five key phenomena of financial stress, a methodology we adopt for the SFSI. The authors utilize a principal component analysis (PCA) approach to individual stress indicator aggregation. The index is evaluated by comparing it to known periods of financial stress. Hatzius et al. (2010) adopted the PCA approach, combining an unbalanced panel of 44 monthly financial stress indicators to a single financial conditions index for the United States. The authors evaluated the index based on its ability to forecast real economic output, with results suggesting a tighter link with future economic activity than existing stress indices.

Holló et al. (2010) introduced a new indicator of contemporaneous financial stress in the euro area, with a main focus on "real-time" properties and index robustness. The authors present a methodological innovation by incorporating findings of modern portfolio theory. The authors weight their subindices (consisting of equal weighted transformed indicators) with their time-varying cross-correlation structures to better capture the "systemic" component of stress. Louzis and Vouldis (2011) adopt this approach, while PCA analysis and log-transformations were implemented for indicator to subindex aggregations. Furthermore, the authors compare the index with the results of a survey conducted among financial experts.

3.2 The FSI of the Riksbank

The SFSI builds upon previous research from the Swedish Riksbank. Forss Sandahl et al. (2011) created a financial stress index for the Swedish markets with the aim to "reflect the degree of financial stress in a simple and comprehensive way." Financial stress was defined as a disruption impairing the financial markets ability to act as an efficient intermediary between lender and borrower or buyer and seller. The authors chose four indicators of financial stress, each representing a different marketplace.

Equity market: One of the most common measures of stress in the equity markets is volatility. Volatility can be measured as realized volatility over a certain time period, for instance intra-day or 30-day close-to-close realized volatility. An alternative is to determine the implied volatility through option prices such as VIX, the implied volatility of a 30-day S&P 500 index option. As there is currently no official measure of implied volatility on the OMX stock

exchange, Sveriges Riksbank has created such a measure (SVIX) to better understand uncertainty in the equity markets. The authors use the SVIX as a measure of stress in the equity markets.

Money market: The money market includes loans with maturities up to one year and is important for the short-term funding of banks and non-financial corporations. The TED spread is chosen as a stress indicator in the money market. The TED spread denominates the difference between the daily average interest rate on unsecured interbank loans (STIBOR) and the interest rate on treasury notes of the same maturity. The spread is a measure of the credit and liquidity risk on the interbank lending market.

Bond market: In addition to intermediary funding, the bond market is an important source of finance for several of the largest Swedish companies. In addition to that, the bond market is an important market place for collateralized mortgage loans, other forms of customer credits and other asset-backed securities. The bond market risk measure is the covered bond spread, defined as the difference between covered bonds and Swedish government securities of the same maturity.

Foreign Exchange market: A substantial part of the funding for Swedish banks and corporations is obtained in foreign currency. Therein lies a currency risk which most companies prefer to hedge. If this risk management does not function efficiently, the access to foreign currency funding can deteriorate or the cost of this capital can increase. The majority of foreign currency funding is denominated in US dollar or euro, thus the authors chose the mean of the SEK/USD and SEK/EUR implied option volatilities as the indicator of foreign exchange risk.

Subsequently, the four indicators are statistically standardized (demeaned and divided by their standard deviations) over the historical reference period. To complete the index, the four indicators are combined into a single time series through equal weighting and the simple arithmetic mean. Finally, a verbal analysis of the index discusses the spikes in the index in the most known periods of financial stress over the past 14 years.

4. An Adapted SFSI - Choice of Components

4.1 Objectives of the SFSI

The interest in financial stress increased after the financial crisis. Several central banks and independent researchers have created daily data financial stress indices. The high level of interest shown by central banks in this area is not surprising. A stress index can serve as a good indication of the overall level of financial stress in the system, and potentially as a complementary tool for

central banks' macroprudential analysis and monetary policy decisions. A stress index is also a useful graphical display that can be presented to the public to emphasize the need for policy change.

When constructing an index of stress in the Swedish financial system we have four main objectives: to (i) consider the five identified key phenomena of financial stress in the selection of stress variables, (ii) follow the developments in previous literature by measuring "systemic" risk, (iii) construct an index tailored to the Swedish system, and finally to (iv) determine the impact of high SFSI stress levels on the real economy.

(i) In section 1.1 we name five key features of financial stress as defined by Hakkio and Keeton (2009). If one or several of these phenomena are observed, we risk a disruption to the ordinary functioning of the financial system. A substantial part of previous research does not clearly make the connection between their definition of financial stress and their respective stress indicators. From an academic point of view we see this connection as crucial, in particular due to the lack of a dependent variable on which the index can be tested. Hakkio and Keeton (2009) is an exception, as they are stating how each stress indicator is related to their definition of financial stress. When constructing the SFSI we aim to relate the choice of raw stress indicators to one or several of the five key features of financial stress.

(ii) In constructing the SFSI, we are particularly interested in "systemic" events, where the regular functioning of the financial markets and thereby the real economy is threatened. In section 3.1 we describe the developments in the financial stress index literature, clearly shifting from easily interpretable weighted averages to methods designed to emphasize systemic stress. We want to take advantage of these developments by incorporating a systemic factor in the aggregation of the SFSI. This could make the methodology and hence interpretation more complex, but the systemic factor is too important to be overlooked. Additionally, we believe that the aggregation methodology can be developed further by testing different approaches on the results from an expert survey on financial stress.

(iii) We want to optimize the SFSI for the Swedish financial system. First, we consider the conditions of the Swedish system as described in section 2. When constructing a financial stress index for Sweden, Forss Sandahl et al. (2011) discuss four markets in which stress can be observed in Sweden. This discussion can be developed further, e.g. by including financial intermediaries as an additional sector due to their importance for funding Swedish companies. However, these markets are not necessarily equal in significance. Relative importance can be determined by their respective predictive power on economic activity or with a proxy, for instance the size of credit in each market. Second, we want to include stress parameters that

precisely reflect one or more of the key phenomena of financial stress, but that have been omitted or overlooked in previous stress indices. An example is CDS spreads, which are a good measure of perceived bond market credit risk. CDS spreads have not been included in past FSIs due to the lack of historical data. Consequently, we can add value by creating two indices, one long index for methodology testing, and a short index with additional indicators having the potential to outperform other FSIs in the future.

(iv) We are interested in financial stress mainly due to its potentially negative impact on the real economy. When evaluating the index, most previous literature graph the index and compare it qualitatively to periods known as stressful. We do not disagree with this approach; however, we are ultimately interested in the performance of the index compared to real economic growth. In addition to a qualitative discussion of stressful events, we aim to test the performance of the index by comparing it with economic activity.

4.2 Construction of Five Subindices

The SFSI is constructed to capture the amount of stress in the five most important market segments of the Swedish financial system, following the approach of Holló et al. (2010). The five market segment indices are composed by indicators in: the money market, bond market, foreign exchange market, equity market and banking sector. As pointed out in section 1.2 our subindices are constructed to take into account all elements of risk related to capital flows within Sweden and between Sweden and other countries.

Our goal is for the SFSI to measure the stress in the financial system in real time, hence we are only looking for indicators available on a daily basis. This limits us to data from the financial markets, as macro indicators and balance sheet data which otherwise would have been interesting to include are generally only available with a lower frequency and longer publication lags. Due to data availability constraints for certain indicators we construct two financial stress indices, a "short" SFSI and a "long" SFSI. The short SFSI has the base date 01 July 2003 and includes all indicators, while the long SFSI has the base date 01 November 1993 and includes only the stress indicators with sufficient historical data. In both cases we also calculate the indices for initiation periods of approximately six months each, but we do not include these values in our analysis as both indices behave too unstable initially. We aim to use the long SFSI for testing and propose the short SFSI as the future stress index due to valuable added information. If an indicator is not included in the long SFSI it will be stated when describing the indicators below. We used Datastream to download all time series, except the SVIX, mortgage bond index and STINA swap rates, which were provided by the Riksbank.

In the remainder of this section we provide a thorough description of the five subindices and their respective stress indicators before we, in Table 1, link these indicators to the five key features of financial stress, (i) to (v).

4.2.1 Money Market

The money market is a primary source of liquidity and short-term financing for financial and to some extent also non-financial corporations. The main products include interbank loans or borrowing via certificates (Forss Sandahl et al., 2011). We include the money market in the SFSI as higher risk premiums reflect increased counterparty risk and borrowing costs for banks, hence higher cost of capital for corporations dependent on intermediary funding. As borrowing via bank loans is the dominating source of funding for Swedish non-financial corporations, disruptions in the money market could have serious implications for their growth and consequently exert a negative effect on the real economy. We have chosen two indicators to measure the overall stress level in the money market:

3 month basis spread: The Swedish basis spread is defined as the interest rate spread between the STIBOR and a STINA (STIBOR tomorrow/next average) swap, where the STINA-swap can be considered as an approximation of the expected repo-rate over the specified time-period.

Previous researchers have used the TED spread as a risk indicator for the interbank market, with the TED spread in Sweden defined as the difference between the STIBOR and Treasury notes with the same maturity. We argue that this is not the best measure of interbank risks. If we consider the UK market, the TED spread can be decomposed into LIBOR-OIS and OIS-Treasury notes. LIBOR rates should typically be the average expected overnight interbank interest rate over the loan period plus a term premium. However, the rate can also include an additional premium for counterparty default risk and in particular stressful scenarios a market liquidity premium. The OIS (overnight indexed swap) rate reflects the expected geometric average of the overnight rate over the contract period, plus a pure term premium with negligible risk and liquidity premium (Brunnermeier, 2009). The additional OIS-Treasury spread will vary due to Treasury market specialness and is stripped out when using OIS rate as the benchmark (Schwarz, 2010). There is no OIS rate available for the Swedish market. The closest instrument available in the Swedish market is the STINA swap rate, serving as a good proxy of the OIS rate. STINA is calculated as an average of the shortest interbank rate, overnight rate of tomorrow, over the specified term (three months in this particular case). Sveriges Riksbank (2008) use STINA as an expected repo rate, and state that the basis-spread is a better measure of the interbank market risk premium than the TED spread.

The basis spread was previously considered as a relatively clean credit risk measure, however at the beginning of the 2007-2009 financial crisis the widening of the spread was largely associated with non-credit factors such as banks hoarding liquidity (Bank of England, 2007). If lending banks have difficulty determining which borrowing banks are more or less risky, an adverse selection problem could also arise. Due to data limitations the basis spread is only available for the short SFSI. Hence, we include a proxy, the TED spread, in the long SFSI.

STIBOR Volatility: We use realized volatility of the STIBOR rate as the second money market indicator. Increased STIBOR volatility is often related to reluctance among banks to lend to each other, and was particularly apparent during the financial crisis. In a tranquil financial environment banks tend lend to each other at very similar interest rates, but with increased and differing liquidity needs there is not a single interest rate anymore, increasing uncertainty and hence STIBOR volatility.

4.2.2 Bond Market

In section 2.3 we argued that in Sweden the bond market is less important for funding non-financial corporations than in many other developed countries. Nonetheless, bonds are not at all irrelevant for the stability of the Swedish financial system. The mortgage bond market is one of Europe's largest and government bonds are an important source of funding for the state's current expenditures. Additionally, some of Sweden's largest and most important corporations fund themselves via the bond market. Thus, the bond market includes some of Sweden's most secure investments and is important for monitoring demand in the economy. As we are currently experiencing with the euro-crisis, bond market stress can turn into a systemic crisis, affecting the entire financial system.

Covered bond spread: The covered bond spread is defined as the difference between Swedish covered bonds and government bonds with the same maturity. The Swedish mortgage bond market for housing finance is the fifth largest in Europe, with outstanding stock of mortgage bonds close to SEK 1,100bn, approximately twice the size of the nominal government bond market (Danske Markets, 2011). The value of covered bonds is dependent on both the issuer's debt servicing capacity and the collateral, where the latter mainly consist of mortgage loans. Covered bonds are considered a safe investment compared with corporate bonds and are important for the stability of the Swedish financial system due to the sheer market size. The mortgage institutions suffered significant credit losses after the early 1990's Scandinavian housing bubble, leading up to one of the most stressful periods in Swedish banking history. However, a major part of the credit losses were related to commercial mortgages and not household mortgages. Credit losses in mortgage institutions have been minor since then, mainly a result of

the steady rise in real estate prices over the past two decades. While housing prices rose by 40 per cent from 1995 to 2010, household debt doubled during the same period, making Swedish households among Europe's most indebted (IMF, 2011a). If housing prices decline the covered bond market could be vulnerable due to the excessive lending, and the bonds might be less safe than previously assumed.

The benchmark of the covered bond spread is the government bond. The government bond is assumed to carry very small risk, and is the closest to a risk-free investment of all Swedish bonds. The covered bond spread is a measure of both credit and liquidity risk in the bond market, as government bonds generally are seen as both safer and more liquid investments. Asset backed securities are also susceptible to increases in the asymmetry of information between buyers and sellers. Issuers typically have an incentive to securitize high-quality loans to preserve their reputation, however in uncertain times some issuers may be tempted to securitize lower-quality loans while keeping higher-quality loans on their balance sheets (Hakkio and Keeton, 2009).

Realized volatility of Swedish government bonds: The covered bond spread is using Swedish government bonds as a risk-free benchmark. However, as we recently have witnessed in Europe, government bonds are not necessarily without risk anymore. Hence, there might be credit risks in the bond markets not captured by the covered bond spread. CDS spreads might seem like the best way to capture government bond risk, but since Swedish government bonds were perceived as risk-free prior to the recent crisis the market was small with sporadic demand and supply, resulting in volatile spreads and therefore noisy data. A volatile indicator during stable times is not optimal when creating an index of overall stress in the market.

When the market considers government bonds as a risk-free asset it is basically an interest rate investment in a highly liquid reserve asset perceived as a store of value. The rate should be a proxy of the expected repo rate with a term premium and low volatility. However, as investors begin to view the debt as a credit instrument with a risk premium, this debt can quickly trade with a volatility and liquidity that is fundamentally at odds with an asset perceived as risk-free (BlackRock, 2011). We use realized volatility as a measure of government bond risk, calculated as the 20 trading-days rolling realized volatility of absolute changes in 5-year Swedish government bond yields.

5-year swap spread: The swap spread is the difference between the fixed rate in an interest rate swap and a treasury security of the same maturity. The floating-rate payments in the swap are based on a short-term STIBOR rate. The positive swap spread can be decomposed into two of the phenomena of financial stress. First, as argued for the basis spread, the STIBOR rate exceeds

the rate on a treasury security of the same maturity mainly due to credit risk, but to some extent also liquidity risk. Second, the claim of the fixed-rate payments is significantly less liquid than a Government bond with the same term, which can be sold on short notice in the secondary markets. These explanations suggest that an investor will demand compensation for the credit and liquidity risk. Hence, the swap spread will increase when counterparty risk increases and liquidity becomes important, which is particularly the case in stressful markets (Hakkio and Keeton, 2009). The liquidity component is more important in the swap spread than in the other bond market indicators.

4.2.3 Equity Market

The stock market is an important source of funding for companies all over the world. It reacts effectively to new information about individual companies, macroeconomic activity and monetary policy. Equity crises are usually defined as a sharp decline in the overall stock market index. This decline can be indicative of increased expected loss, higher dispersion of expected loss (higher risk), or greater uncertainty about firm returns (Illing and Liu, 2006). In an uncertain environment investors require an extra risk premium to invest in the equity market, as it is considered a much more risky investment than the bond markets. An increased risk premium implies a higher discount rate, reducing the total value of companies and thus depressing stock prices. Stress in the financial system does not only affect stock prices negatively, it usually also increases market volatility as investors become less certain about the fundamental value of the assets.

Stock market volatility: Volatility of asset prices describes the extent of price fluctuations over a given period. Stock market volatility is not constant over time, and from an investor's point of view, volatility is a proxy for uncertainty. Technically, volatility is a symmetric measure that can increase during periods of both rising and declining stock prices; however, the latter is obviously considered more stressful by investors (Deutsche Bundesbank, 2005). A key concept of portfolio theory is that investors will require compensation for increased variances and thus uncertainty about asset prices. Whether uncertainty leads to volatility or volatility leads to uncertainty is not necessarily always easy to determine or even relevant, but the former is probably more often related to periods of increased stress in the financial system.

To measure stock market volatility we use the SVIX, a measure of expected volatility in the Swedish stock market created by the Riksbank. The SVIX is derived through option prices similarly to the VIX, often referred to as the "investor fear index". The SVIX takes advantage of the relationship between volatility and option prices to derive the implied stock market volatility, and is thus a more current measure than realized volatility.

Sudden decline in OMX30: The volatility index is the most commonly used measure of stress in the equity market, with the great advantage that it is unrelated to previous values of the stock index. As mentioned above however, volatility can even increase in good times without necessarily being related to financial stress. To account for this and reduce the noise in the equity market index, we add a complementary measure of declining stock prices. We use the CMAX method, developed by Patel and Sarkar (1998) to identify stock market crashes by measuring the maximum cumulated loss over the past two years. In other words, we compare the OMX30-index with its peak value over the two previous years:

$CMAX_t = 1 - \frac{x_t}{\max[x \in (x_{t-j} | j=0,1,\ldots T)]}$; where T=500, assuming 250 trading days per year.

4.2.4 Foreign Exchange Market

The literature on currency crises is heavily weighted towards episodes related to fixed or tightly managed exchange rates. In countries with such regimes, stress can lead to significant official reserves losses, increased interest rates, and if severe enough, a currency collapse. All of these phenomena could be observed in the period leading up to the ERM crisis in Sweden in 1992, which ended with a devaluation of the Swedish krona. Stress can also occur with floating exchange rates, where a depreciation represents a loss to domestic currency holders and increased volatility affects liquidity and therefore market efficiency (Illing and Liu, 2006). Currency movements are not necessarily negative however; several empirical studies suggest that exchange rate changes act as a safety valve that absorbs macroeconomic shocks that might otherwise have had a larger impact on an economy's output level. Even when exchange rate movements help to stabilize the economy, they can be destabilizing for individual business sectors that are particularly sensitive to exchange rate changes (HM Treasury, 2003).

In section 2 we argue that Sweden is both heavily exposed to and dependent on stability in the foreign exchange markets for two key reasons. First, the Swedish economy is export-oriented, with exports consistently larger than imports and the sum of exports and imports larger than GDP. An appreciation of the Swedish krona reduces the competitiveness of the important export-oriented industries, possibly slowing real economic growth. Second, the banking sector and to some extent non-financial corporations obtain significant funding in foreign markets. Hence, stability in the foreign exchange market is important for financial sector profitability and Swedish real economic growth.

SEK/USD and SEK/EUR volatility: Foreign currency funding adds a currency risk factor for Swedish companies, a risk often managed with derivative instruments. Exchange rate risk is not easy to measure. However, volatility is a good approximation of market uncertainty (Forss

Sandahl et al., 2011). As mentioned above, large foreign exchange movements resulting in increased volatility may reflect macroeconomic shocks and not market uncertainty. This does not necessarily invalidate exchange rate volatility as a stress measure however. Even if financial stress does not emanate in the foreign exchange market, fluctuations in this segment may indicate other types of financial stress that cause the macroeconomic shocks. We use the implied volatility of SEK/USD and SEK/EUR 30-day options as foreign exchange volatility indicators in the short SFSI. For the long SFSI we use 20-day realized volatility of the respective exchange rates due to data limitations for exchange rate options. The USD and EUR benchmarks were chosen as a majority of trade and foreign funding is denominated in one of the two currencies.

4.2.5 Financial Intermediaries

Lastly, we introduce the banking index. As Bank of England (2011) points out there is a tendency among banks to get overexposed to risk in the upswing of a credit cycle. After all, the banks are driving the cycle. As they become more confident about lending against collateral, such as the illiquid property market, more funds are available to investors. This leads to rising asset prices and increased confidence of all parties involved. History has shown that banks are particularly vulnerable to asset bubbles, and many banking crises have originated from one.

It can be difficult to define a banking crisis, the analysis relies to a large extent on qualitative information (Illing and Liu, 2006). Many studies that identify banking crises avoid explicitly defining the term and rely on judgment, although a few address the issue directly. An example is Bordo (1986), who defines a banking crisis as a period where actual or incipient bank runs or failures lead to suspended convertibility of their liabilities. For the purpose of this thesis it is not necessary to define a banking crisis however, as we are creating a continuous index and do not rely on a binary variable.

In contrast to the other subindices, the banking index does not reflect a particular marketplace. Hence, the indicators in the banking index are constructed with instruments found in the other marketplaces. It still makes sense to include a separate banking index, as financial intermediaries contribute a majority of the funding to Swedish non-financial companies. Additionally, due to the size and concentration, the banking sector plays a fundamental role for the functioning of the Swedish financial system. Hence, stress or even perception of stress in the banking sector can rapidly contaminate other parts of the Swedish economy through decreased lending activity or increased borrowing costs for companies, indirectly affecting economic activity as described in section 1.3. It is difficult to measure lending activity and borrowing costs from financial intermediaries, as balance sheet data is only available on a quarterly basis and borrowing

cost is private information. Consequently, to create a subindex that reflects the amount of stress in financial intermediaries we use several market measures discussed below.

Inverted yield curve: We use the inverted yield curve as a proxy for interest rate shocks. The yield curve is the relation between interest rates and time to maturity for a given borrower. Yield-curves are usually upward-sloping, due to a term premium on longer maturity securities. One of the banks' major income sources is converting short-term liabilities (deposits) into longer-term assets (loans). With a negative yield curve, namely when short-term rates exceed long-term rates, bank profitability is seriously threatened (Illing and Liu, 2006). Treasury securities are generally considered to be risk-free, and we use the difference between 3-month Swedish treasury-bills and 5-year government bonds as our inverted yield curve measure. One could argue that the slope of the yield curve reveals more about the stance of monetary policy than about financial stress (Hakkio and Keeton, 2009), but that does not necessarily disqualify it as an indicator of financial stress. We are not looking for the causal effect of stress in the financial system, but merely the best way to measure and detect stress that potentially could impact the real economy. In addition to the yield curve's importance for banks' net interest income, it is widely known as one of the best recession indicators. According to Harvey (2010), an inverted yield curve has forecasted the last seven U.S. recessions. We have not found any similar studies on the Swedish economy, but there should be a similar relationship between the yield curve and the real Swedish economy.

Financial yield spread: The financial yield spread is defined as the difference between bond yields of financial and non-financial companies with the same credit rating and maturity. An increased financial yield spread reflects sector specific risk by implying a decreased willingness to hold financial assets. Besides deposits, the bond market is the main funding source for banks. Increased bond yields on outstanding debt heighten new borrowing cost with a decreased profitability as a probable outcome. At worst it can be detrimental for the refinancing possibilities of financial intermediaries and threaten the stability of the financial system. Furthermore, increased funding costs for banks can easily spread to companies dependent on intermediary funding, as banks may have to lend at higher rates to maintain profitable. As components in the financial yield spread we use indices of European AAA-rated financial 5-year bonds and European AAA-rated non-financial 5-year bonds. Unfortunately there are no equivalent Swedish indices available, but risks in the European financial system are a good proxy for Sweden due to its interlinked nature, contagion risk and the Swedish banking system's possession of large amounts of European assets. The components of the financial yield spread are available from 1999, hence this indicator is only included in the short SFSI.

Bank CDS spreads: As a novelty in the literature of financial stress indices we introduce credit default swap (CDS) spreads as a measure of credit risk in the Swedish banking sector. A CDS is a credit derivative used as insurance against bond defaults. Creditworthiness or default risk is a critical issue for all business firms and households. The prospect of default on investor-held debt of a non-financial corporation may have little impact on that firm's ability to serve its main economic function. In contrast, for financial intermediaries whose main economic functions include issuing contingent payment contracts to their customers, creditworthiness is the central financial issue. The possibility of intermediary default on contracts to its customers can significantly reduce the efficiency and value of those contracts in the future, consequently reducing the effectiveness of the main economic function served by the intermediary (Merton, 1995).

Given constant recovery rates, CDS spreads are clean measures of bond default risk and, unlike yield spreads, are not dependent on a benchmark index (Schwarz, 2010). As Tang and Yan (2007) point out, there may be an additional liquidity premium similar to that of bonds if the CDS market is not very liquid. However, due to the size of the major banks in Sweden the CDS market is relatively liquid and has become more so in recent years now that bank debt is considered to carry a higher risk than previously perceived. The main reason for why CDS spreads have not been used in previous financial stress indices is probably the lack of historical data. Data series of CDS spreads for Swedish banks start in the beginning of 2003, hence we can include it in the short SFSI only. This obviously constitutes a problem for testing the relevance of including CDS spreads, however we argue that it conceptually adds value to add a more 'pure' measure of credit risk in the banking sector. To create the bank CDS spread measure we calculate the average of the CDS spreads on senior debt for the four largest Swedish banks, weighted by yearly total lending activity in Sweden. Lending is the principal economic function of the banks, and total lending activity is therefore a good measure of each bank's importance in the Swedish financial system.

Sudden decline in financial sector stock index: To conclude the banking index, we include a measure of financial sector risk in the equity markets. The CMAX method, previously described for the equity market index, is adapted to the Swedish financial sector stock index. In times of financial stress we expect the financial sector stocks to decline, hence increasing the absolute value of the CMAX measure.

Table 1: Individual indicators and their connection to the 5 features of financial stress

Stress indicator	**Subindex**	**Key features of financial stress represented by indicator**
Basis spread / Ted spread	Money market	(iv) Flight to quality, (v) flight to liquidity, (iii) increased asymmetry of information
STIBOR Volatility	Money market	(i) Uncertainty about fundamental value of assets, (ii) uncertainty about behavior of other investors, (v) flight to liquidity
Bond spread	Bond market	(iv) Flight to quality, (iii) increased asymmetry of information
Government bond volatility	Bond market	(i) Uncertainty about fundamental value of assets, (ii) uncertainty about behavior of other investors
Swap spread	Bond market	(v) Flight to liquidity, (iv) flight to quality
Stock market volatility (SVIX)	Equity market	(i) Uncertainty about fundamental value of assets, (ii) uncertainty about behavior of other investors
Sudden decline in stock markets (CMAX)	Equity market	(iv) Flight to quality, (i) uncertainty about fundamental value of assets, (ii) uncertainty about behavior of other investors
SEK/USD and SEK/EUR volatility	Foreign exchange	(i) Uncertainty about fundamental value of assets, (ii) uncertainty about behavior of other investors
Inverted yield curve	Financial intermediaries	(iii) increased asymmetry of information, (iv) flight to quality, (v) flight to liquidity
Financial yield spread	Financial intermediaries	(iv) Flight to quality, (iii) increased asymmetry of information
Bank CDS spreads	Financial intermediaries	(iv) Flight to quality, ((v) flight to liquidity)
Sudden decline in financial stocks (CMAX)	Financial intermediaries	(iv) Flight to quality, (i) uncertainty about fundamental value of assets, (ii) uncertainty about behavior of other investors

5. An Adapted SFSI - Methodology

5.1 Construction of the SFSI

The combination of individual stress indicators is arguably the most difficult aspect of constructing an index measuring the amount of stress in the financial system (Holló et al, 2010). The difficulty in constructing the SFSI lies in the lack of a dependent variable upon which different approaches could be tested. Therefore, the majority of previous researchers use qualitative arguments and intuition to determine the preferred weighting method. Illing and Liu (2006) perform an expert survey with results interpreted as a binary crisis variable to approach this problem. The authors test the outcome of several different indicator aggregation methods, including factor analysis (principal components), credit-weights and equal weights on the binary crisis variable, counting the number of type I (failure to recognize a crisis) and type II (falsely signifying a crisis) errors for each. The crisis threshold value in the stress index is assumed to be one standard deviation higher than the index' mean. Illing and Liu conclude that credit weights is the preferred weighting method for the Bank of Canada index. We do not adopt the credit weights approach directly for the reason that our methodology is different from Illing and Liu's approach in other key areas. However, we have adopted and further developed their idea of conducting an expert survey. Our methodology is explained in section 5.3. We also use the survey results to determine the optimal aggregation method for the SFSI. We consider two alternative approaches for indicator to subindex aggregation and two alternative approaches of weighting the respective subindices to the final SFSI. Hence, we test the performance of four different specifications on the survey results to determine the optimal properties for the SFSI. In the succeeding sections we present and discuss the statistical properties of the SFSI.

5.1.1 Transformation of Stress Variables

The individual indicators as described in section 4.2 must be transformed in an appropriate way to account for the large differences in absolute values and distributions. The most common method in previous literature is statistical standardization of variables, a procedure where each individual indicator is demeaned and divided by its standard deviation. There are several limitations to this approach. First, a practical shortcoming is the transformation's sensitivity to the arrival of new information. Every time the stress index is updated with additional observations, the mean and standard deviation of the indicators will be revised, hence recalculating past values of the indicators (Holló et al., 2010). This implies that the stress index value today may change in the future. Forss Sandahl et al. (2011) avoid this by defining a mean

and standard deviation 'reference period', which keeps historical values constant in future updates of the index. Secondly, a statistical drawback of the approach is the implicit assumption of normally distributed indicators. The stress index is comprised of indicators from several different markets and with different compositions. We question the implicit assumption that bond spreads share the same distribution as CDS spreads or a volatility measure. Our assumption of time-varying volatility alone violates the definition of normality.

In order to alleviate the problems described above we follow the approach of Holló et al. (2010) and transform our indicators to make them more robust. Each indicator is replaced by its recursive ordinal value and divided by the total number of observations to that date. The transformed indicators are therefore unit-free, measured on an ordinal scale and defined within the interval (0,1]. Consequently, indicator values are compared to historical values only, preserving the real-time nature of the individual indicators.

The recursive ordinal transformation of indicators is less affected by extreme values and different distributions. Critics could argue that an ordinal approach diminishes the impact of extreme events on the stress indicators, making the model less suitable of detecting systemic events. However, we argue that systemic events are not detected in the individual indicators, but in the finalized SFSI. Furthermore, the problem becomes less severe as we add more historical data, thereby increasing the range of past observations. We will discuss the detection of systemic events in section 5.1.3 in which we discuss the aggregation of the subindices to a composite indicator.

5.1.2 Indicator Aggregation

Following the transformation described above, we have two to four indicators ranging in the interval (0,1] within each defined subindex. The next step is determining the method for combining these in single time series for each subindex. There are two common approaches in previous research: (i) principal component analysis (e.g. Stock and Watson, 2000; Hakkio and Keeton, 2009; Louzis and Vouldis, 2011) and (ii) equal weighting of indicators (e.g. Holló et al., 2010).

Principal component analysis: Principal component analysis is often considered to share characteristics with factor analysis. The central idea of principal component analysis is to reduce the dimensionality of a data set consisting of a large number of interrelated variables, while retaining as much as possible of the variation present across the variables. This is achieved by transforming to a new set of uncorrelated variables, ordered so that the first principal component retains most of the variation present in all original variables (Joliffe, 2002). The purpose of the technique is to reduce the number of variables (to one index in our case) and detect the structure

in the relationship between variables. In a two-variable example, the principal factor is the least-squared regression line between the two. If extended to multiple variables, the first principal component is extracted by rotating the scatter plot of observations to best fit the criteria described above (Illing and Liu, 2006). The underlying assumption of using the first principal component is that variables belonging to the same subindex include the common information content (Louzis and Vouldis, 2011), while the noise from individual observations is filtered out.

Previous applications of principal components in financial stress indices take a non-recursive approach to the principal components methodology. This implies that the coefficients, and hence the principal component scores, are recalculated when updating the stress index. Thus, the SFSI would lose its "real-time" nature, with past events subject to reclassification. This is not a desired property for the SFSI, as the index is supposed to serve as a graphical tool. Changing past values would make the graph less recognizable and clear. The discussion of stress levels in a historical context would also become more difficult as there would be no constant high stress benchmark values. Therefore, we adapt a recursive principal component approach to time series as suggested by Voegtlin (2004). This implies that the principal component scores are recalculated every day to only take into account historical values of the raw stress indicators, hence avoiding them to change with future updates of the index. As can be seen graphically in Appendix D, the SFSI is very robust to the choice of recursive or non-recursive principal components, which further strengthens our case. The output from a principal component analysis will contain both positive and negative values, with zero-mean properties for a non-recursive approach. The recursive principal components will not necessarily have a mean of zero, but our subindices will include both negative and positive values. Due to the quadratic properties of the SFSI (which will be further explained in section 5.2), we can not allow negative subindex values. Hence, we scale each subindex linearly, in such a way that each of them always takes on values between 0 and 1.

Equal weighting: The most commonly applied method to transformation is statistical standardization, while the most common approach to aggregating the indicators is the simple arithmetic mean of the transformed indicators (Holló et al., 2010). The obvious advantage of this approach is easy construction and interpretation of variations in the index and the underlying indicators. Additionally, in contrast to the principal component approach, equal weighting of individual indicators does not require rescaling of subindices as they hold the desired [0,1] properties.

To determine the best approach for the SFSI, we test the performance of both suggested aggregation methods in section 5.3 by comparing results to the outcome of an expert survey.

5.1.3 Weighting of Subindices

After merging the individual indicators into five subindices, the next step in creating the SFSI is to determine the subindex weights. We adopt the approach by Holló et al. (2010) and apply portfolio theory to the weighting of subindices. We expect that an elevated level of financial stress will manifest itself in all indices. While it is possible to analyze these individual indicators or subindices of financial stress by themselves, it is much more difficult to understand to what degree the stress is actually of a systemic nature. Ultimately, however, it is most dangerous when the stress is present throughout the entire financial system, hence when stress is evident in all subindices for the SFSI. The stress index should therefore emphasize periods in time in which several or all of the subindices increase together.

In the context of portfolio risk management, it is not the idiosyncratic volatilities of individual assets that are of importance, but the co-movement of the individual assets. Assuming that these co-movements vary over time, the portfolio is most risky when expected correlation is high. As this is similar to our definition of systemic stress, we can use theories of portfolio management in constructing the SFSI. The subindices are thus combined in a similar way to the aggregation of individual asset risks to overall portfolio risk. This implies that the subindices are weighted by two factors. First, we create the time-varying cross-correlations, reflecting the systemic risk of the financial system. Second, similar to asset weights in an asset portfolio, weights are determined based on each subindex' importance in the financial system. We will describe each step in detail below.

Time-varying cross-correlations $\rho_{ij,t}$ are estimated recursively with exponentially-weighted moving averages (EWMA) of respective covariances $\sigma_{ij,t}$ and volatilities $\sigma_{i,t}^2$:

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

$$\sigma_{i,t}^2 = \lambda\sigma_{i,t-1}^2 + (i-\lambda)\tilde{s}_{i,t}^2$$

$$\rho_{ij,t} = \frac{\sigma_{ij,t}}{\sigma_{i,t}\sigma_{j,t}}$$

Where $i = 1, \dots, 5$, $j = 1, \dots, 5$, $i \neq j$, $t = 1, \dots, \mathrm{T}$, where $\tilde{s}_{i,t} = (s_{i,t} - 0.5)$ represents the demeaned subindices $s_{i,t}$, obtained by subtracting each subindex with its approximate median of 0.5. The decay factor λ is constant over time with a value of 0.97 as suggested by the RiskMetrics technique to measure risks in market portfolios (J.P. Morgan and Reuters, 1996).

Subsequently, we define C_t, as the time-varying cross-correlation coefficient matrix of the five subindices:

$$C_t = \begin{pmatrix} 1 & \rho_{12,t} & \rho_{13,t} & \rho_{14,t} & \rho_{15,t} \\ \rho_{12,t} & 1 & \rho_{23,t} & \rho_{24,t} & \rho_{25,t} \\ \rho_{13,t} & \rho_{23,t} & 1 & \rho_{34,t} & \rho_{35,t} \\ \rho_{14,t} & \rho_{24,t} & \rho_{34,t} & 1 & \rho_{45,t} \\ \rho_{15,t} & \rho_{25,t} & \rho_{35,t} & \rho_{45,t} & 1 \end{pmatrix}$$

Even though this approach is similar to applied portfolio theory, it is important to stress that we are not applying this to predict future co-movement risk between the subindices. We are simply interested in a descriptive statistic measuring the real-time co-movements between the subindices to better capture events when stress in the financial system becomes 'systemic'.

After having created the time-varying correlation matrix, we introduce a vector of the subindex weights $w = (w_1, w_2, w_3, w_4, w_5)$. Our initial idea was to define w as the real impact weights of the subindices on industrial production, solved with a constrained regression of the lagged (d) subindices (s) on industrial production (IP): $\min_w \sum_{t=1}^{T} (IP_t - w' s_{t-d})^2$. This would give some economic meaning to the weights. However, due to noisy data and a high level of multicollinearity between the subindices, it was impossible to obtain sensible weights with this approach alone. Illing and Liu (2006) suggest an approach in which the variables are weighted by the relative size of credit in each market. The intuition is clear considering the main function of the financial system as described earlier in this thesis. The financial system provides funding to Swedish companies and households, and it seems reasonable that the markets that provide most of this funding are most important for stability in the financial system. Hence, similar to the real impact weights, assigning weights based on the size of credit in each market has some economic meaning. There are obstacles with this approach however, for instance it is not clear how to determine the 'credit size' of the foreign exchange market. Additionally, the money market is merely contributing approximately 2 per cent to the total credit in Sweden. This is mainly due to market specifics, with a high turnover ratio and interbank netting agreements. However, the money market is clearly very relevant as the interbank market and short-term funding are important for financial intermediaries and thus important for the entire financial system.

Based on previous literature and our own assessment, we are left with two alternatives after dismissing real-impact weights as an alternative; (i) equal weights, (ii) weighting based on a qualitative discussion of market importance.

Equal weights: Assigning equal weights to the subindices is the most common approach in previous literature. Equal weighting is easy to interpret, and it is probably used to such an extent due to the lack of a proven better alternative. One could argue that the correlation-matrix takes care of the systemic risks, and hence we would be less interested in the actual 'asset weights'. The

obvious disadvantage of this approach is the potential loss of information in the SFSI as some markets are arguably more important than others.

Market relevance: Our alternative approach is assigning weights based on a qualitative discussion of quantitative facts about market importance. For instance one could base a qualitative assessment on combined information from credit size and the earlier proposed real impact weights. The purpose of the equity market, bond market and financial intermediaries is similar in the sense that they provide most of the credit to Swedish corporations. Hence, the importance of these can be determined with credit weights. The foreign exchange market and money market are important for different reasons, and weights for these could be determined qualitatively. The real impact weights regression suggests that stress in the bond market and financial intermediaries have larger impact on economic activity than the other subindices. Thus, we decide to assign larger weights to those. Additionally, the equity market is responsible for the largest amount of company funding in Sweden, hence we weight it with medium importance. The money market is very important for financial intermediares in Sweden, and therefore for the entire financial system, however the associated risks should be captured by the financial intermediary subindex to some extent. Due to high level of multicollinearity between the respective indices and that our real impact approach suggests that the financial intermediary subindex is a better predictor of economic activity, we choose to weight the money market less. The assigned weights are: equity market, 20%; bond market, 30%; financial intermediaries, 30%; foreign exchange market, 10%; money market, 10%. In our further analysis we will refer to these weights as "relevance weights".

In order to finalize our index, we will test the proposed subindex weighting methods combined with the two proposed approaches of individual indicator aggregation on the survey results in section 5.3.

5.2 Aggregation to a Single Index

After determining subindex weights we then define $\mathbf{y_t}$ as the vector of weighted stress subindices, $y_t = (w \circ s_t)$, where $s_t = (s_{1,t}, s_{2,t}, s_{3,t}, s_{4,t}, s_{5,t})$ is a vector of the five subindices, and $w \circ s_t$ is the Hadamard entrywise product of w and s_t.

The SFSI is defined as a cross-correlation weighted aggregation of the subindices.

SFSI = $y_t \, C_t y_t'$

5.3 Analyzing and Implementing the Results of the Expert Survey

The construction of the SFSI was carried out in line with previous research about financial stress with some modifications to the Swedish financial system and minor changes due to data availability considerations. We chose our indicators based on their connections to the five features of financial stress as identified by Hakkio and Keeton (2009). The methodology therefore has a theoretical foundation, but so far we have no empirical indication that the SFSI in fact captures financial stress.

We are not aware of any data that displays financial stress itself and that we could utilize for a comparison with our index. Naturally, if such data were to exist and be published without a considerable time lag, it would make our effort to create an index that replicates this time series somewhat redundant.

We have identified a negative impact on the real economy as a defining component of extreme financial stress, so the examination of such a relationship is a natural approach to evaluate our index. However, such a measure does not let us make any inferences about situations in which financial stress does not become so intense that is causes a slowdown in the economy. For this reason, we will only come back to this idea in section 7. At this stage, we instead utilize an expert survey to verify our results. To this end, we compare high stress events identified by academic experts to periods of high stress as indicated by the SFSI.

Furthermore, we use the survey results to test the performance of the different specifications we have suggested. While we could derive our choice of indicators from the definition of financial stress, we were so far unable to determine the best method to aggregate our indicators into subindices and a single SFSI.

Twelve researchers in finance, macroeconomics and financial accounting at Stockholm School of Economics and Linköping University agreed to participate in our survey. The participants held the academic positions assistant professor, associate professor and professor. All of our participants except for one were of Swedish nationality. For a sample of the survey, please see appendix H.

We identified 20 time spans from 1991 to 2011 associated with events widely considered to be financially stressful. We then asked for assessments of these time periods on a scale from 1 to 7 where 1 denotes "Not stressful" and 7 "Extremely stressful". We deliberately did not ask for the causal impact of a certain event on financial stress as such an effect would most likely be spread over time and be difficult to isolate in our index. Furthermore, we asked about overall stress levels instead of stress only associated with a particular event because our index can only measure the overall condition of the financial system. At certain times, stress caused by different

events may overlap with each other, such as during the fall 2008 when numerous stressful events occurred within a short time frame.

In the financial stress literature, there is no consensus about which methodology to use when constructing a survey on financial stress and subsequently analyzing it by comparing it to an index directly derived from observed market data. Louzis and Vouldis (2011) and Illing and Liu (2006) divide their survey results and SFSI values into only two groups, high stress and low stress. We favor this approach as well as we want to avoid the comparison of low stress events to each other. As we will discuss more in depth in section 7.1, a modest increase of our index on a low level may sometimes not be associated with an actual problem in the financial system but rather represent noise as the stress indicators can be influenced by other factors than financial stress.

We then evaluate our index based on a calculation of type I and type II errors. Type I errors signify failures to recognize a crisis. Type II errors are instances in which the index falsely signals a crisis. To this end we aggregate the values for the long SFSI to a monthly level and derive from the survey the months that can be considered to be stressful. The first month of a crisis is often easy to identify as it usually includes the trigger event. The index should ideally already signify a crisis in the month of the trigger event, as we would like it to react swiftly to new developments that cause stress in the financial system. As an example, we consider it to be a type I error if a specification only recognizes stress in October 2001 instead of September 2001 for the 9/11 terrorist attacks.

We are more lenient with regard to diverging identified ending dates for the crises. We did not ask our academic experts for the points in time when stress subsided again, as they presumably would have agreed it is difficult to pinpoint specific dates. Consequently, we also do not consider it to be type I or type II errors if our specifications deviate from each other at the end of crises. The deviations also do not tend to be very large and there is no general trend of one index identifying longer time periods as stressful, which is why we the think that this approach should not lead to any problems.

Another difficulty is defining the threshold between high and low stress levels. In order to allow for more nuanced assessments of the different episodes, we asked in our survey for classifications on a range of seven increments, while the SFSI is scaled from 0 to 1. Every threshold chosen is somewhat arbitrary, so we adopt definitions that have led to satisfactory results for other researchers. We follow Louzis and Vouldis (2011) and identify the events as stressful that received average expert assessments in the upper half of the scale of the questionnaire. In our survey these were the following dates and events (shaded rows are events

that could not be used for a benchmark against the SFSI as they occurred before the beginning of our index):

Table 2: Survey results

Rank	Event description	Date	Stress Value
1	Lehman Brothers bankruptcy	September 2008	6.3
2	ERM crisis, GBP Black Wednesday	September 1992	5.7
3	Iceland collapse	October 2008	5.7
4	Swedish banking solvency issues	Fall 1991	5.6
5	Bear Stearns collapse	March 2008	5.2
6	SEK devaluation	November 1992	5.0
7	Bailout of Latvia	February 2009	5.0
8	Euro Crisis[3]	Fall 2011	4.7
9	Northern Rock Bank Run	Aug./Sep. 2007	4.6
10	Dot-com bubble burst	April 2000	4.6
11	Gota bank and Nordbanken equity injection and nationalization	Late summer 1992	4.5
12	Collapse of U.S. sub-prime mortgage industry	March 2007	4.5
13	Greece bailout by the EFSF	May 2010	4.4
14	Russian crisis and LTCM	Fall 1998	4.2
15	9/11: US terrorist attacks	September 2001	4.1
16	WorldCom bankruptcy	July 2002	3.9

Illing and Liu (2006) also evaluate their index based on type I and type II errors. They choose a specification of two standard deviations over the mean as a stress cut-off value for their quantitative index. This describes about 5 per cent of their sample data as indicative of financial stress. Such a cut-off rate does not work well for us as our sample period (1993 – 2011) was arguably more affected by financial crises than their sample from 1980 to 2005 for Canadian data. Instead, we define the top 30 per cent monthly SFSI values as periods of high financial stress. This is a somewhat arbitrary choice, but it balances well between type I and type II errors and reflects that c. 30 per cent of the sample time span is identified as stressful by our expert survey. We now have all the necessary parameters to evaluate our specifications:

[3] Until the end of August 2011

Table 3: Methodology evaluation – Aggregation methods

	Type I errors (false negative rate)[4]	Type II errors (false positive rate)
1. Recursive principal components of single indicators, equal weights of subindices	9 (13.6%)	8 (5.3%)
2. Recursive principal components of single indicators, relevance weights of subindices	8 (12.3%)	8 (5.2%)
3. Equal weights of single indicators, equal weights of subindices	9 (12.7%)	3 (2.0%)
4. Equal weights of single indicators, relevance weights of subindices	7 (10.3%)	4 (2.7%)

The main source for type I errors for our specifications is the belated recognition of the subprime crisis. We deduce from the survey results that the crisis was already under way in March 2007 when the US subprime mortgage industry collapsed. We agree that an "early warning" would have been desirable here. Furthermore, some of the indices exhibit a certain time lag in other instances too and only reach elevated levels a month after the beginning of the Greece crisis in April 2010 and the Russian and the LTCM crisis in August 1998. Sources for type II errors are more diverse. Some appear to stem from minor events such as uncertainty about interest rate changes by the ECB and the Federal Reserve in summer 2006 (three of the four specifications indicate a crisis) while we are unable to explain others that may simply result from noise.

Overall, the fourth specification with equal weights of subindicators but relevance weights of subindices appears to perform best. Arguably, we should not consider type II errors to be of more importance than type I errors. In lack of a better alternative, Illing and Liu (2006) weight both error types equally. Intuitively, we are not more concerned about "false warnings" than about failures to recognize a crisis. Consequently, we adapt specification 4 for our further analysis.

Finally, we test if our additional weighting technique that incorporates the time-varying cross-correlations performs more in line with the assessments of the experts than only relevance weights. To this end, we create a modified version of our identified preferred specification that does not include the cross-correlation structure and compare the results.

[4] False negative and false positive rates may still deviate when an identical number of errors occurs as the specifications identify different ending dates for crises.

Table 4: Methodology evaluation – Cross-correlation matrix

	Type I errors (false negative rate)	Type II errors (false positive rate)
Incorporation of time-varying cross-correlation structures	7 (10.3%)	4 (2.7%)
Only relevance weights	7 (11.5%)	11 (7.0%)

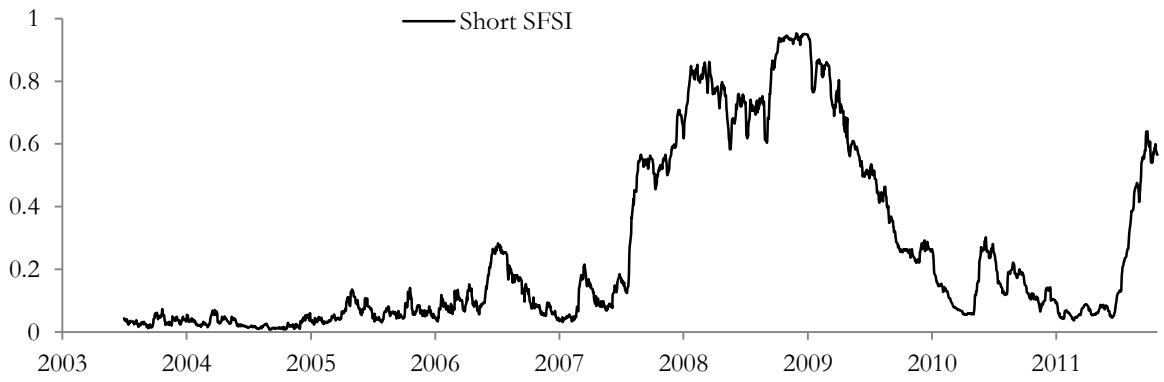
The results indicate that the two indices recognize crises approximately equally well. However, the index without the cross-correlation structures has more type II errors, i.e. instances in which the index falsely signifies a crisis. These "false positives" mainly stem from early 2001, a point in time that admittedly marks the onset of a recession but is generally not associated with the term financial crisis. Intuitively, it makes sense that we see a higher type II error rate as we have created the cross-correlation structure for the purpose of recognizing only "systemic" events. Outliers in single indicators that are not related to crises in the entire financial system therefore have a lesser impact on the cross-correlation structure method. We therefore proceed with the specification that weights all indicators equally when aggregating to subindicators and utilizes relevance weights and a time-varying cross-correlation matrix to calculate the SFSI.

6. Results

6.1 The SFSI

Having determined the aggregation and weighting method, we present the SFSI in Fig. 2 below. Illustrated is the "short" SFSI, including all variables and starting in July 2003.

Fig. 2. The short Swedish Financial Stress Index



From studying Fig. 2, we note a first spike in mid-2006, at a time of worldwide uncertainty about potential interest rate increases. The Bear Stearns failure in March 2008 and Lehman Brothers bankruptcy constitute the two major peaks of the index. Furthermore, we note a clear spike in the SFSI when Greece applied for the Financial Support Mechanism in April 2010. Lastly, we see the impact of the Euro-crisis on the amount of stress in the Swedish financial system.

6.1.1 Identification of Stressful Events

Financial crises are infrequent events. As Reinhart and Rogoff (2008) point out, episodes of severe financial stress occur globally on average about every five years. Considering the economic history from 2003 until 2007 we know that this period was tranquil from a financial stress perspective. Having such a small sample of stressful events is obviously not optimal for back testing. Hence we used a "long" SFSI for testing the different indicator aggregation methodologies and will use it again in section 7 to test the impact of extreme financial stress on the real economy. Fig. 3 compares the short and long version of the SFSI, denoted with well-known financial events.

Fig. 3. Short and long SFSI

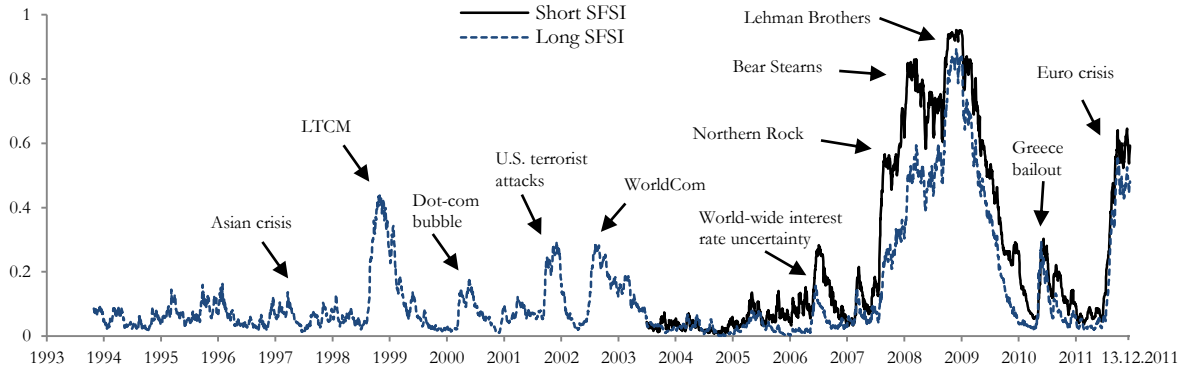


Fig. 3 illustrates that all major spikes in the SFSI occur around well-known events that in most cases have been considered stressful for the Swedish financial system. None of the pre-2007 events come close to the values observed during the financial crisis and the European debt crisis we are currently experiencing. After a small spike in March 2007, the index recognizes the severity of the financial crisis in August 2007, at a time where the subprime crisis escalated and just prior to the Northern Rock bank run. This is supported by Brunnermeier (2009) who concludes that the first "illiquidity wave" on the interbank market started on August 9. At that time default and liquidity risks of banks rose significantly, driving up interest rates in the

interbank market. Subsequently, the SFSI reached a new record level when Bear Stearns failed, and finally its peak so far shortly after Lehman Brothers filed for bankruptcy in September 2008.

Unfortunately, data limitations make us unable to construct a meaningful index that includes the 1991-1992 Scandinavian banking crisis, otherwise that would have served as an interesting benchmark to the global financial crisis. As indicated by the expert survey, we expect that the banking crisis would have ranked as similarly severe.

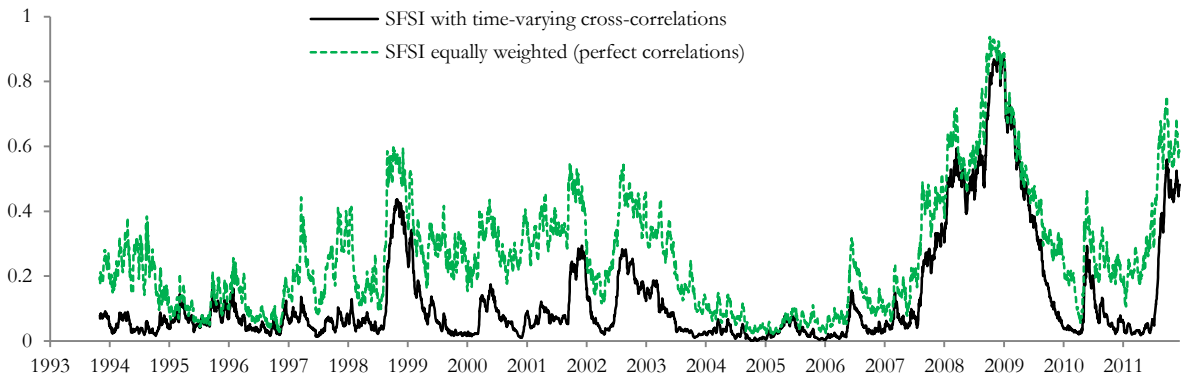
The events recognized as most stressful in the SFSI were also all identified by the survey, with a majority ranked among the most stressful by the academic experts. Therefore, we conclude that we have succeeded in constructing a financial stress index that graphically captures well-known stressful events in the Swedish economy. The performance of the SFSI in predicting real economic growth, another key feature of such an index, will be evaluated in section 7.

The short SFSI is initially more pronounced and volatile than its long counterpart, which is primarily a consequence of our statistical approach. The recursive ordinal methodology compares current indicator values with historical values only, preserving the real-time property of the SFSI and avoiding reclassification of past events. One could argue that the new index is still in an initiating phase pre-Lehman, in particular the mid-2006 spike is arguably too pronounced. This is supported by our survey results, indicating that mid-2006 was not a particularly stressful period for the Swedish financial system. Similarly, the Long-Term Capital Management (LTCM) default and the Russian crisis in 1998 are seemingly over-emphasized in the long SFSI, and the index appears much better adjusted after that event. Interestingly, the short and the long index follow each other closely after the financial crisis, indicating that both indices are adjusted properly as both include many observations in more and less stressful times. At the same time, the short index contains additional, and in our view more accurate, indicators of financial stress, hence we argue that the short index should be the preferred SFSI in the future.

6.1.2 The Systemic Factor

In section 5.1.3 we describe the inclusion of a "systemic stress" measure by weighting the subindices with the time-varying cross-correlations. Fig. 4 illustrates the effect of the time-varying correlations matrix, by comparing the SFSI to an equal-weighted or "perfect correlations" scenario. In the perfect correlation scenario all values in the time-varying cross-correlations matrix are set to 1, while the cross-correlations matrix utilized for the SFSI range between -1 and 1. This matrix is then weighted with the respective subindices as described in section 5.2, hence the SFSI will always take on a lower or in rare cases of perfect correlations the same value as the equally-weighted index.

Fig. 4. The systemic factor – Impact of time-varying cross-correlations



We are particularly interested in systemic stress, and according to our definition an event becomes systemic when stress is prevalent in several or all of the defined market places simultaneously. The effect of the time-varying cross-correlations weighting is clearly evident during the Asian crisis in 1997, when the equally-weighted index far exceeds the SFSI. The implicit interpretation of such an event is that one or two subindices might have been affected while overall stress in the Swedish financial system was low or moderate. According to our theory such an event should have a less negative impact on economic activity than an event in which all markets experience stress, implying credit constraints throughout the financial system. As expected, the co-movement between the subindices is high during the subprime crisis in 2007 and throughout the financial crisis, illustrated by the narrow gap between the equal weighted index and the SFSI. From studying Fig. 4 it is arguably clear that the inclusion of the "systemic factor" reduces noise in the SFSI and underlines the periods that we and the academic experts consider to be most stressful for the Swedish financial system. The visual inspection therefore confirms our findings from the expert survey (section 5.3).

A limitation of this approach, however, is that detection of stressful events may be lagged if one or two of the subindices are leading indicators of financial stress. Mitigation of that problem can be achieved by identifying such leading indicators and study that particular indicator or subindex in further detail. As Illing and Liu (2006) point out, the financial stress index captures the current level of stress and can not be expected to have strong predictive power for future crises or particularly stressful events. Leading indicators of these events, which may include individual components of the SFSI, can be identified from models using the SFSI as the dependent variable. However, that lies outside the scope of this thesis.

6.1.3 Comparison to the Existing Swedish Financial Stress Index

In section 3.2 we describe the method of Forss Sandahl et al. (2011) in constructing the existing FSI for Sweden. The methodology differs considerably from that of the SFSI, and a qualitative and quantitative evaluation of the two indices seems appropriate in order to discuss their abilities to measure financial stress.

Fig. 5. Comparison of the long SFSI and the old financial stress index for Sweden

Fig. 5 compares the SFSI with the FSI of Forss Sandahl et al. (2011) scaled on different axes. The SFSI will always take on a value between 0 and 1, while the value of the previous Swedish FSI is interpreted as the number of standard deviations from its pre-financial crisis mean. From a visual inspection we can see that the two indices follow each other relatively closely. This is not a surprise as we constructed the SFSI as an extension of the existing index. We cannot compare stress levels directly from a quantitative perspective due to the different scales. However, we can evaluate the rank correlation. Spearman's ρ gives us a value of 0.65, suggesting a moderately high correlation that nonetheless justifies a closer examination of the deviations.

Fig. 5 highlights periods in which elevated stress levels can only be observed in one of the stress indices. First, the SFSI emphasize the LTCM bankruptcy, the dot-com bubble crash, the U.S. terrorist attacks and the WorldCom bankruptcy more than the old index. Small spikes can be noted in the old FSI as well, but they can be more difficult to distinguish from previous index values and could easily be interpreted as noise. According to our academic experts, these four periods were at least somewhat stressful for the Swedish economy. We also argue that the properties of the SFSI are preferable for graphical presentation, as stressful periods should be easily recognizable for the reader.

Bear Stearns and Lehman Brothers' bankruptcy, together with the euro crisis that we are currently experiencing, are recognized as very stressful periods by both indices. The most notable difference after the financial crisis is the period from May 2010 to July 2011. Following the Greece bailout in May 2010 the SFSI declines to a low level before it spikes in early August 2011.

In this period the old Swedish FSI remains constant at a relatively high level, implying continuously high levels of stress in the Swedish financial system. Considering the enormous challenges in the euro area today, it is easy to argue in hindsight that this period was particularly stressful. However, we argue that the stress in the Swedish financial system was not systemic during this period, with the SFSI keeping a low level due to the time-varying cross-correlations, or "the systemic factor". The sentiment of investors in Sweden were, in our view, generally positive over this period, backed up by a substantial increase in equity prices (OMX30 gained c.15 per cent) and a 5 per cent growth in industrial production from July 2010 to July 2011. With the escalation of the euro crisis in August 2011, stress reaches all markets and the SFSI spikes, implicitly stating that economic growth is threatened. This interpretation of the economic situation is supported by the views of the Riksbank. As late as in July, they stated that growth in the Swedish economy has been very strong and occurring at a faster rate than in many other countries, with good conditions for "continued strong growth in the years ahead" (Sveriges Riksbank, 2011c). In the corresponding October report the view was different, with weaker outlooks for the second half of 2011 and expectations that growth will "be slightly slower than normal next year" due to financial sector uncertainty and an expected slowdown in foreign demand (Sveriges Riksbank, 2011d). Furthermore, 2012 GDP growth forecasts were revised from 2.2 per cent to 1.5 per cent from the July to the October report.

From May 2010 to July 2011 the old SFSI mostly ranges between 3 and 4 standard deviations above the "historical average", with the historical average calculated for the pre-crisis period. Thus, it is implicitly assumed that the index will return to its "normal" values around 0 in future tranquil periods. This might not be the case however, as investors have a different view on exposure to credit risks and instruments previously perceived as risk-free after the financial crisis (BlackRock, 2011). We can not be sure if this is a structural or only a temporal shift, however that is less crucial for the SFSI with the recursive ordinal approach, taking into account all historical data and not only a pre-defined normal period.

6.1.4 Application of the SFSI Methodology to German Data

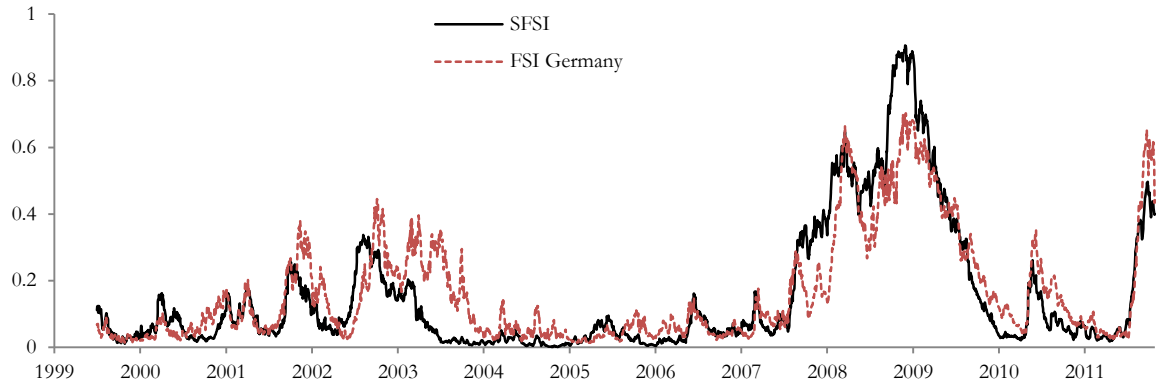
As an additional validity check of our results we conduct an international comparison of stress levels over time. As a benchmark we choose Germany as the largest national economy in Europe. We apply the methodology of the SFSI to German data in order to qualitatively evaluate any material differences. There is an inherent tradeoff between accurately measuring stress levels for individual countries and ensuring international comparability. The German financial system might arguably be more suited for other parameter and weighting choices. However, in order to

enable a comparison to Swedish SFSI values, we follow the SFSI methodology as closely as possible.

We obtained the equivalents of the individual indicators we used for the long SFSI from Datastream. As a counterpart for the Swedish covered bond spread we calculated the spread between the German 5-year Pfandbriefe index and German 5-year maturity government bonds. For the volatility measure, we calculated realized volatilities of EUR/USD and EUR/GBP. For weighting and aggregation, we used the same approach as for the SFSI.

Due to data availability constraints, we were only able to calculate the German index from 1999 to 2011. In order to ensure comparability to our Swedish index, we also calculated an SFSI with 01 July 1999 as a base date.

Fig. 6. Comparison of the SFSI and an equivalent German financial stress index



A graphical evaluation of the two indices confirms that stress levels for the two countries are similar during most periods and that the trigger events for high stress appear to be identical. This result is not surprising as there were no major national financial crises in either Germany or Sweden between 1999 and 2011. The last major national event was the Swedish banking crisis of the early 1990s. Of course it would have been especially of interest to compare the respective stress levels during that period, but due to data availability limitations we were unable to calculate either index from such an early starting point.

However, there are several periods during which the two stress indices noticeably diverge. The WorldCom bankruptcy in July 2002 and the ensuing accounting scandal caused an increase in both indices, but the stress lingers approximately 6 months longer in the German system. A likely explanation is that the event coincided with a recession and a stock market downturn that both were more intense and long lasting in Germany than in Sweden. While the OMX 30 reached its post dotcom-crash low in October 2002, the German equity index DAX 30 only bottomed in February 2003.

Conversely, stress levels appear to be even higher for Sweden than for Germany after the September 2008 bankruptcy of Lehman Brothers. The interpretation is less clear as we would expect that the event was highly stressful for both countries. The respective stress levels align again in early 2009. It is possible that the magnitude of the domestic problems became apparent later in Germany, with the nationalization of real estate financing firm *Hypo Real Estate* by the government vehicle *SoFFin* only occurring in April 2009.

We expect that the European sovereign debt crisis had a larger impact on Germany, as it is part of the euro area. We observe slightly higher values following the EFSF bailout of Greece in May 2010 and again in fall 2011. In fact, the German index recently experienced stress levels very close to its peak in the aftermath of Lehman Brothers' bankruptcy. However, the data suggests that the Swedish financial system also reached the second highest stress levels since 1993 in October 2011.

An obvious limitation of applying a stress index of another country as a benchmark to the SFSI is that they are both country-specific, hence the raw-stress indicators are only compared with their own previous peaks. This implies that an event affecting the Swedish economy more severely than the German economy could be classified as equally stressful in their respective FSIs if Sweden historically has experienced higher stress levels. Nevertheless, a benchmark index can help with the identification of financial stress as country-specific or of an international nature.

7. Evaluating the Impact of Financial Stress on the Real Economy

7.1 Theory

In the introduction we stated that our interest in financial stress stems from its potential adverse impact on the real economy. In this section, we evaluate this relationship with the help of our financial stress index and monthly data on industrial production in Sweden, our proxy for the development of the real economy.

We expect that low and medium levels of financial stress have little impact on the real economy as minor disruptions in the financial system typically do not lead to any of the effects described in section 1.3. It is likely that any correlation between low levels of the SFSI and industrial production stems from our incorporation of indicators that reflect expectations of future developments of industrial production (such as equity prices) into the SFSI. Therefore, in periods of low financial stress the SFSI may follow anticipated developments in the real economy rather than the other way around.

In order to observe the effects described in section 1.3, a higher level of stress is necessary. Our hypothesis is that financial stress needs to surpass a certain threshold before an impact on the real economy can be observed. We expect to observe a variety of negative effects such as lowered investment levels, lower consumption and/or lower capacity utilizations.

In the next section we will test econometrically if the link between financial stress and the real economy depends on the value of the stress index. While we can test if such a threshold exists, there is one restriction to our approach. It is not possible for us to detect actual causality, that is whether high financial stress actually causes a slowdown in the economy or if it is caused by another unobserved factor. This is especially problematic when financial stress is caused by a real world event such as e.g. the WorldCom bankruptcy. In such a case it is difficult to answer if it is the financial sector that is affected by the bankruptcy and in turn affects the real economy or if the real economy is immediately affected by the event and the stress in the financial markets is merely a by-product. While it would still be possible to conclude an association between financial stress and economic downturns, it would not be possible to make any conclusions for policymakers. Attempts to mitigate financial stress in such instances would then only combat a symptom of a crisis instead of the underlying cause. Fortunately, we do not face this problem for all crises as many of them (such as LTCM or the subprime crisis) have their origin in the financial sector.

7.2 TVAR - Tsay Test

We adopt the approach by Holló et al. (2010) and apply a bivariate threshold vector autoregression model (TVAR) to identify stress levels that may trigger a slowdown in the real economy. The model assumes that the regime that can be utilized to describe the development of the real economy depends on the value of an observable threshold variable. We make use of this specification to show that extreme levels of financial stress correlate differently with the real economy than low levels of stress. It also enables us to make an estimate of which stress level is required to trigger such a shift. We choose the following specification for our bivariate TVAR model:

$$x_t = \alpha^L + \beta_1^L x_{t-1} + \beta_2^L x_{t-2} + e_t^L \qquad \text{if } SFSI_{t-d} < \tau \qquad (1)$$

$$x_t = \alpha^H + \beta_1^H x_{t-1} + \beta_2^H x_{t-2} + e_t^H \qquad \text{if } SFSI_{t-d} > \tau \qquad (2)$$

We define x_t as the vector of the logarithm of the year-over-year Industrial Production rate and our financial stress index $(Ind\_Prod_t\ SFSI_t)$. Due to data availability constraints for the industrial production factor we need to convert the SFSI to a monthly index by taking simple arithmetic means. This has the advantage that short-lived jumps in the SFSI have a less

pronounced impact. We define d as the time lag between observed financial stress and the possible impact on industrial production and τ as the (as of yet unknown) threshold value of the SFSI that marks the level where the interdependence shifts. We estimate intercepts α^S and slope coefficients β^S for x_{t-1} and x_{t-2} for possible stress states $S = L$ (low) and H (high). We also allow different distributions for the variance covariance matrices for the error terms e_t^S depending on the stress state. Furthermore, we refer to $k = 2$ as the dimensions of the endogenous time series x_t, to $p = 2$ as the number of explanatory variable vectors x_{t-1} and x_{t-2} and to $h = \max(p, d) = 2$.

At this stage we will only conduct a test for the existence of one threshold even though it is possible that more than two stress regimes exist. However, due to the rare occurrences of episodes of high financial stress it is difficult to test if the relationship between financial stress and the real economy shifts more than once depending on the stress level. While we have a long sample of daily data, most of the captured high stress values belong to few individual episodes. From our expert survey we can only identify about 12 single episodes of stress in the Swedish financial system during our sample period from 1993 to 2011. While it is possible that within our sample different interdependencies between stress and industrial production reappear once a certain stress levels reappears, we would not be able to conclude that we have identified three or more stress regimes with generally valid patterns if we are only able to attribute two or maybe three crises to the different regimes. Such a conclusion is less difficult if we only try to distinguish between low and high stress states.

We can apply the same reasoning for the possibility of a univariate vector autoregression model (such as an autoregressive Markov switching model as utilized by Holló et al., 2010) that evaluates if the SFSI data appears to stem from different distributions. Such a conclusion would suggest that there is in fact something like "systemic stress", a situation in which different stress indicators start to reinforce each other. The occurrence of such an event would be especially visible in our index due to the cross-correlation weighting method. However, as stated above, the interpretation would be difficult due to the limited amount of data to our disposal. Furthermore, it would be difficult to derive any real world implications, as we still would not be able to make any statements about the real economy.

We test for a threshold separately for a time lag of $d = 1$ and $d = 2$, indicating that we anticipate an effect on the real economy either one or two months after an elevated level of stress. The level of industrial production is expected to trail after the financial stress index as it is less influenced by people's expectations for future economic development but more related to past order intake. At the same time, we consider that the SFSI itself arguably has a lag of a few

days or weeks until it fully incorporates financial stress (due to e.g. the more slowly adapting cross-correlation matrix). In order to keep degrees of freedom low (and statistical power high), we also limit our model to data from the past two months to explain our vector x_t as we expect that we will only have a low number of observations that can be attributed to the high stress regime.

In a first step, we apply the test developed by Tsay (1998) to test for evidence that a threshold τ is required to accurately depict the relationship between financial stress and industrial production. Such a threshold would suggest that the impact of "systemic" stress on the real economy is fundamentally different from the interdependence between the SFSI and the real economy during periods of low stress levels.

For the Tsay test, we rearrange the data for equation (1). We do not sort the data from $t = 1, \dots, n$, but ascendingly by their values for $SFSI_{t-d}$ (note that the equations themselves don't change by this procedure). Furthermore, we formulate as a null hypothesis that τ is not required (or 1), implying that we can capture the relationship between stress and industrial production for all possible stress levels with only one equation and without a dummy variable for elevated financial stress.

The Tsay test then makes use of the property that the residuals of the estimated equation (1) should only represent white noise if there is no misspecification. However, if there is a threshold, the residuals of our estimates will exhibit a correlation to the regressor, the values for industrial production and the SFSI for *t-1* and *t-2*. This is because our estimator will be biased. We can evaluate the residuals in the following way:

We run an OLS regression for equation (1) without a stress threshold, but only take into account the data points that are associated with the m_0 smallest $SFSI_{t-d}$ values. m_0 has to be chosen somewhat arbitrarily and needs to be balanced between a stable starting estimation and good power in testing. We follow Tsay's (1998) suggestion and pick $m_0 = 5 * \sqrt{N}$, where *N* is the number of observations, in our case 212 (months). This leads to an m_0 of 73. We refer to the vector $[\beta_1\ \beta_2]$' as $\mathbf{Z}$, to its OLS estimate obtained from m data points as $\hat{\mathbf{Z}}_m$ and to $[x_{t-1}\ x_{t-2}]$ as $\mathbf{X}$'.

We then use the estimator to predict the SFSI and Industrial Production indicators for *m+1* and calculate the corresponding residual:

$$\hat{e}_{t(m+1)+d} = y_{t(m+1)+d} - \hat{\mathbf{Z}}_m{}'\mathbf{X}_{t(m+1)+d}$$

In the next step we rescale the error term:

$$\hat{\imath}_{t(m+1)+d} = \hat{e}_{t(m+1)+d} \,/\, [1 + \mathbf{X}'_{t(m+1)+d}\mathbf{V}_m{}'\mathbf{X}_{t(m+1)+d}]^{0.5}$$

where

$$\mathbf{V}_m = \sum_{i=1}^{m} [\mathbf{X}_{t(i)+d} \mathbf{X'}_{t(i)+d}]^{-1}$$

We now repeat this process for $m = m_0 + 1 \ldots n - h$. We then describe $\hat{\imath}$ as a function of the explanatory variables.

$$\hat{\imath}_{t(m+1)+d} = \mathbf{X'}_{t(l)+d} \Psi + \mathrm{w'}_{t(l)+d} \qquad l = m_0 + 1, \ldots, n - h$$

We can now reformulate our null hypothesis to $H_0: \Psi = 0$ versus the alternative $H_a: \Psi \neq 0$.

Tsay's test statistic is:

$$C(d) = [n - h - m_0 - (kp + 1)] * \{[\ln(\det(S_0) - \ln[\det(S_1)]\}$$

$$S_0 = \frac{1}{n - h - m_0} \sum_{l = m_0 + 1}^{n-h} \hat{\imath}_{t(l)+d} \, \hat{\imath}'_{t(l)+d}$$

$$S_1 = \frac{1}{n - h - m_0} \sum_{l = m_0 + 1}^{n-h} \hat{\mathrm{w}}_{t(l)+d} \, \hat{\mathrm{w}}'_{t(l)+d}$$

Under the null hypothesis, C(d) asymptotically follows a chi-squared distribution with $k(pk + 1) = 10$ degrees of freedom. For the different values of d, C(d) takes on the following values and corresponding p-values:

Table 5: C(d)-values and confidence levels for Tsay test

	$d = 1$	$d = 2$
C(d)	17.44	23.53
p-value	0.065	0.009

We can therefore reject the null hypothesis for $d = 2$ and conclude that we require a coefficient threshold switch in our VAR model to describe x_t in terms of its own two trailing values. The state of the threshold switch depends on the level of $SFSI_{t-2}$. We are not able to make the same conclusion for the existence of a switch that would be triggered by $SFSI_{t-1}$. Therefore, we will continue with our analysis with $d = 2$.

7.3 Estimating the Threshold Value

So far we have only established that we require a threshold τ to avoid a biased depiction of our data in a VAR model. Now we evaluate which threshold fits our data best. To this end, we perform OLS regressions for the equation system (1) – (2) for $d = 2$ for all possible values of τ on the [0,1] interval and choose the specification that minimizes the Akaike Information Criterion (AIC):

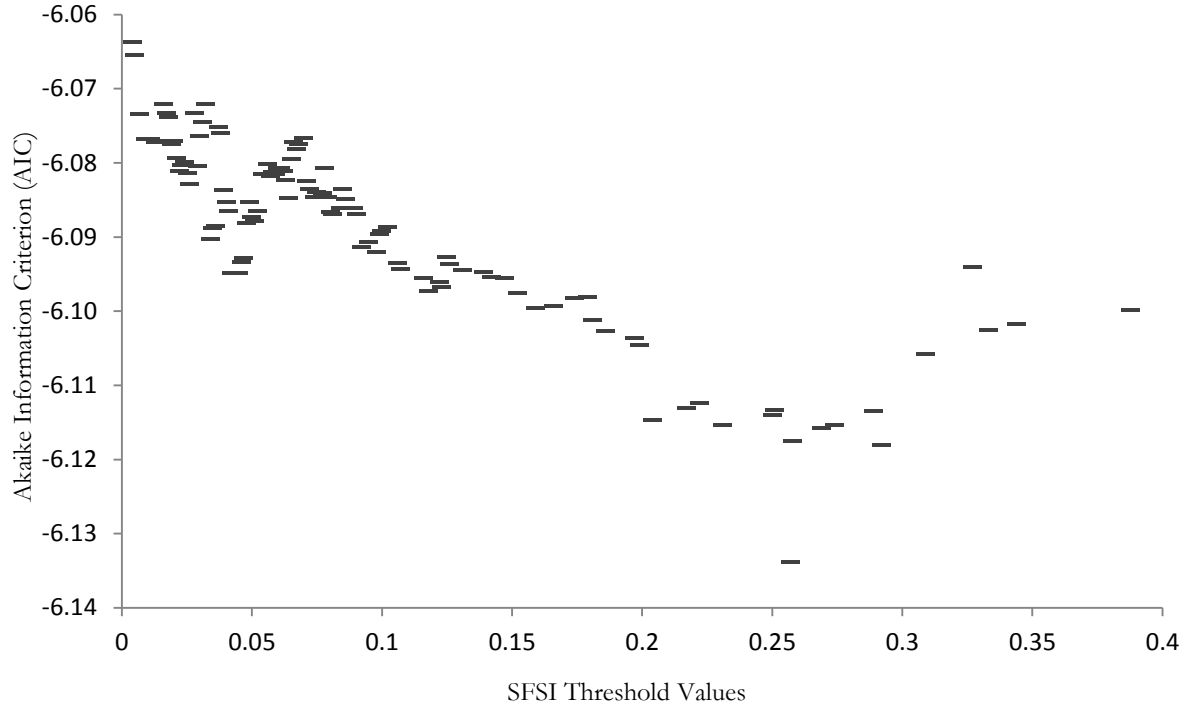
$$AIC = \log(EVE) + \frac{2}{N} * v$$

$$Error\ variance\ estimator\ (EVE) = \sum_{t=1}^{N} \frac{r_t^2}{v}$$

$$r = residuals \qquad v = number\ of\ independent\ variables$$

We observe a pattern of AIC values that reaches a low at 0.257. As we increase the threshold, the development of the AIC values becomes less granular and somewhat less well behaved. This is because fewer observations change regimes as the threshold increases. A high threshold implies that only extreme stress values such as during the 2008 financial crisis would be attributed to the stress regime.

Fig. 7. Output from threshold estimations based on AIC values for TVAR(2)



We now determine if the observed growth rates in industrial production after severe financial crises fit our expectation. We do this exemplarily for $\tau = 0.257$, the threshold that describes the observed data best.

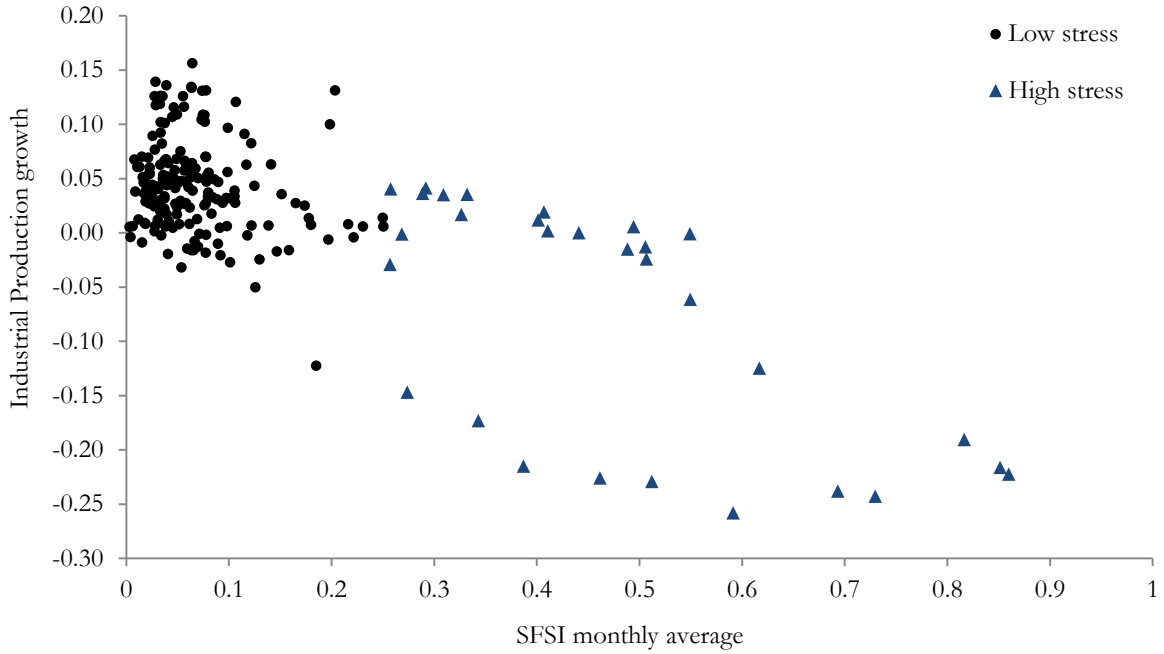
Table 6: Average industrial production growth and SFSI β values below and above threshold

	If $SFSI_{t-2} < 0.257$ (S = L)	If $SFSI_{t-2} > 0.257$ (S = H)
Mean Ind_Prod_t value	0,043	-0,081
Observations	183	29
$\beta_{SFSI(t-1),IndProd(t)}$ (p-value)	-0.092 (0.06)	-0.162 (0.002)
$\beta_{SFSI(t-2),IndProd(t)}$ (p-value)	0.046 (0.40)	0.018 (0.74)

As we had expected, log average growth rates for Ind_Prod_t are lower after periods of elevated financial stress. Furthermore, we can see in the β values that only the one-month trailing SFSI in the high stress state has a significant (and negative) impact on the Industrial Production rate. This fits our expectation that only high financial stress will negatively affect the growth of the industrial production. It may seem counterintuitive that we do not have a significantly negative $\beta_{SFSI(t-2),IndProd(t)}$ value for the high stress state even though the Tsay test suggested $d = 2$. However, both $d = 1$ and $d = 2$ entail that x_{t-1} and x_{t-2} are used as explanatory variables for x_t. $d = 2$ only means that $SFSI_{t-2}$ determines whether we are in a high or low stress state in t and should use β^H or β^L. Naturally, there is also high multicollinearity between x_{t-1} and x_{t-2}.

We need to be cautious when interpreting table 6 as it only provides anecdotal evidence. In the analysis, we used a cut-off value of 0.257. However, this is merely our best guess for the "true" cut-off value that signifies the level where financial stress may begin to impact the economy. From the Tsay test we can only conclude that some cut-off value is required and as demonstrated in Fig. 7, 0.257 maximizes our explanatory value. However, we cannot determine if this is within a certain proximity to the true value, just as we cannot determine if there are in fact only two different stress regimes or possibly more. Such an evaluation would require substantially more data.

Fig. 8. Scatter plot of two months lagged SFSI values against Y-o-Y log industrial production growth. Threshold for high-stress and low-stress regimes determined by output from TVAR-model



8. Conclusion

We have developed a daily data financial stress index for Sweden. After reviewing previous research on the nature of financial stress we identified 14 individual indicators that reflect the state of the financial system and are available on a daily frequency level. Subsequently we aggregated the indicators to subindices and eventually a single index by weighting them by their relevance for the financial system and their time-varying cross-correlation structures. This method served to accentuate stress that becomes "systemic" – stress states where the entire financial system is similarly affected, a condition that is characteristic of major financial crises.

The major difficulty when constructing a financial stress index is that there is no observable counterpart of financial stress that we can use to test the validity of our index. Instead, we resorted to verbally discussing the depiction of well-known financial crises, comparing our index to the results of an expert survey and showing that extreme values of our index cause a shift in the relationship between our index and growth in industrial production. The SFSI has performed satisfactorily for all evaluation methods.

The SFSI was designed as an extension of the Swedish stress index as suggested by Forss Sandahl et al. (2011) and is meant to become a policy tool at the Swedish Riksbank. It gives a

quick, clear and intuitive assessment of the state of the Swedish financial system and is therefore well suited for internal and external communication purposes. A more ambitious application for financial stress indices would be to utilize them to perform further research on the functioning of the financial system. As Goodhart and Rochet (2011) point out, the Riksbank and central banks in general had a crucial role in avoiding a major economic depression after the subprime crisis in 2008. Financial stress indices can potentially be another step in understanding financial crises and evaluating how fiscal or monetary policy measures can mitigate or avoid them.

Stress values indicated by the SFSI can only be interpreted by comparing them to past values generated by prior stress episodes. The SFSI's information content and precision will rise automatically as more historical data is added. More sample data may also help to further pinpoint parameters that we chose by exercising judgment and aligning our results to experts' opinions on financial stress.

Another possibility to enable further econometric analysis would be to exploit the cross section dimension by comparing Swedish data to the stress levels of other countries. This would also facilitate the identification of crises as national, European or global phenomena. We did a first step in this direction by applying the SFSI methodology to German data.

A limitation for our SFSI is that we constrained it to data that is available on a daily level. Arguably, some parts of the financial system could be portrayed more accurately if we had also included monthly or quarterly data. Balance sheet data from financial institutions would allow for less noisy evaluations of their financial positions than the high frequency indicators such as bond and equity prices that we now use.

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Appendix

Appendix A – Comparison of Tested Aggregation Methods of the SFSI

Fig. 9-11 show the four different aggregation specifications we compared with the results from the expert survey. All four specifications follow the same pattern, underlining the robustness of our statistical approach to different aggregation methods.

Fig. 9. Impact of different subindex weights with equal weighted indicators

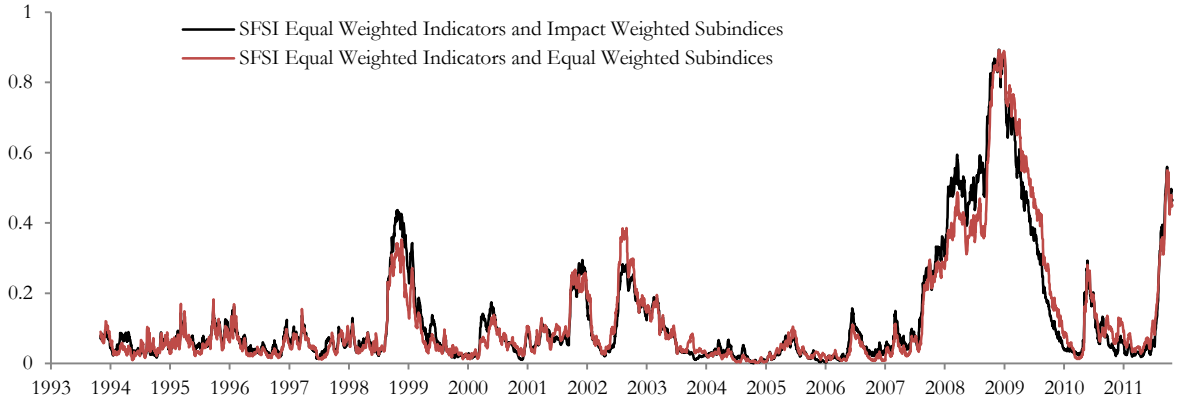


Fig. 10. Impact of different subindex weights with Principal Component indicator aggregation

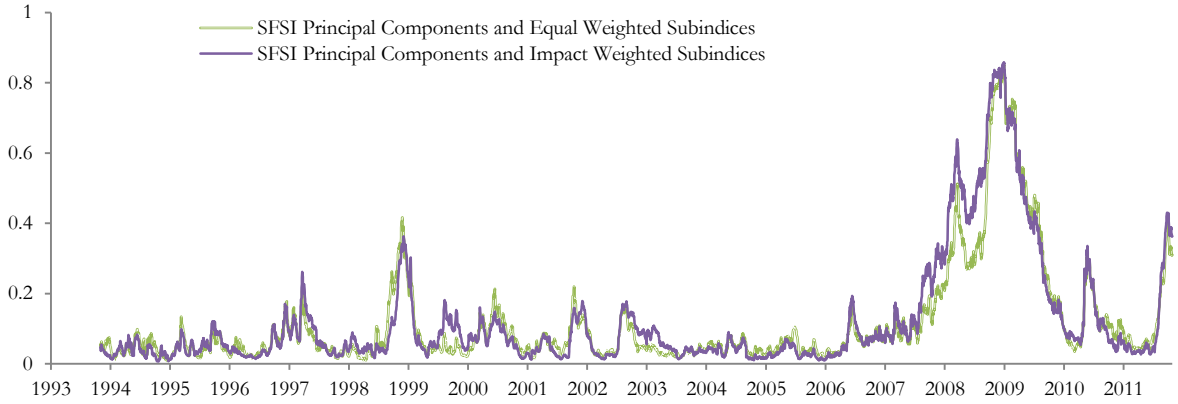
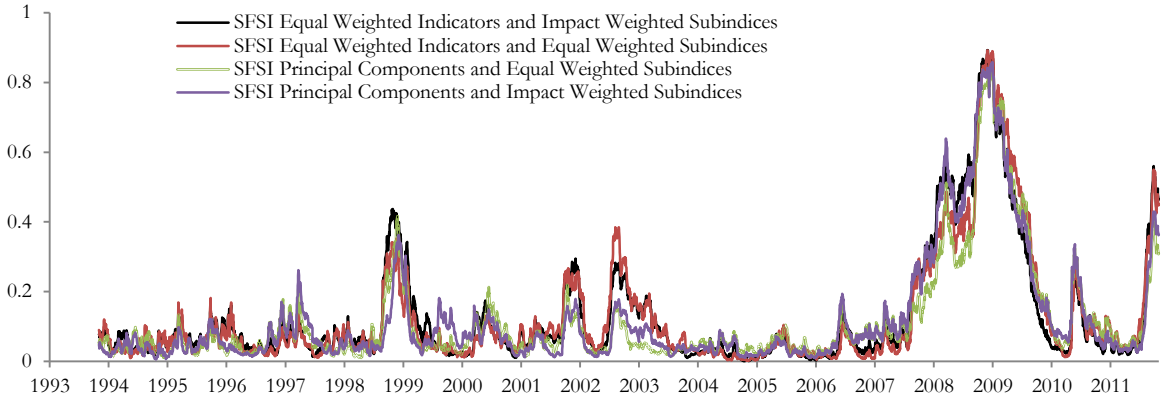


Fig. 11. Comparison of the four weighting methodologies



Appendix B – Histogram of SFSI Observations

Fig. 12. Histogram of SFSI stress level observations

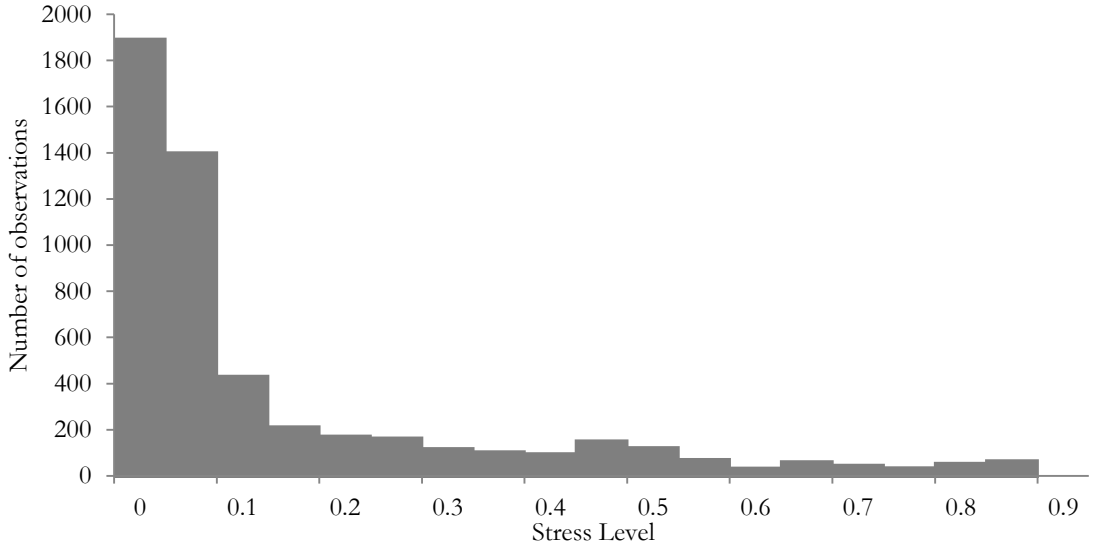


Fig. 12 shows the distribution of stress index observations, and as expected there is a clear overweight of low observations. This is result of the SFSI's quadratic properties and time-varying cross-correlations, keeping the SFSI at a low level in tranquil times. More interesting is the increase in the number of observations close to 0.5 and at the highest observed stress levels between 0.8 and 0.9. This does not look like a "normal" quadratic transformation, and might imply that we have a larger number of relatively high stress level observations than one would expect. This may result from the tendency of financial stress to spread across asset classes and markets, which is further accentuated in our index by our use of time-varying cross-correlation matrices.

Appendix C – Recursive and Non-Recursive Indicator Transformation Comparison

Fig. 13. Recursive vs. non-recursive ordinal approach

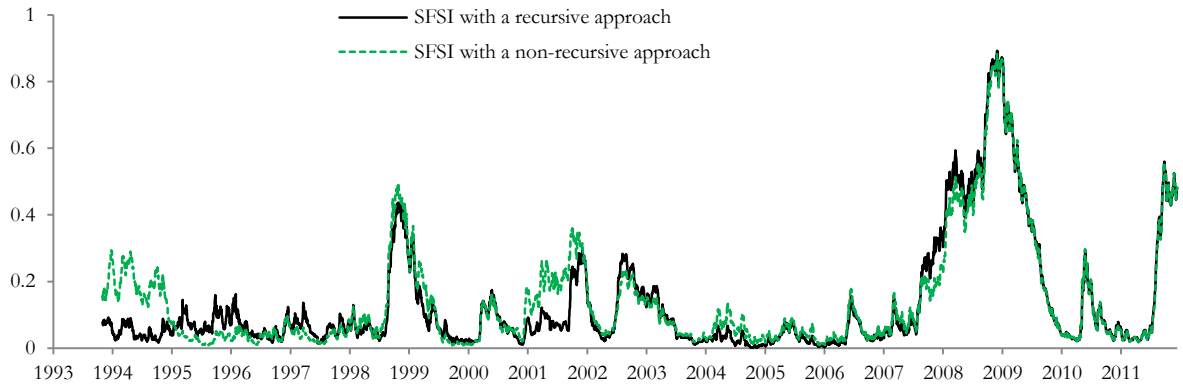


Fig. 13 compares the recursive ordinal approach we have utilized for the SFSI with an index created using a non-recursive ordinal approach. The recursive transformation of raw stress variables compares the respective value at time t with values only prior to t, while the non-recursive transformation compares values at time t with the entire dataset. When more historical values are added to the recursive approach the two indices converge as we would expect. As we can see in Fig. 13 the two indices experience very similar values from 2002 until today, further underlining the robustness of our approach. The values of all subindices will be exactly the same for both approaches at the last index date, however the SFSI stress level may differ slightly due to small differences in the time-varying cross-correlations.

Appendix D – Comparison of Recursive and Non-Recursive PCA approach

Fig. 14. Recursive vs. non-recursive Principal Component approach

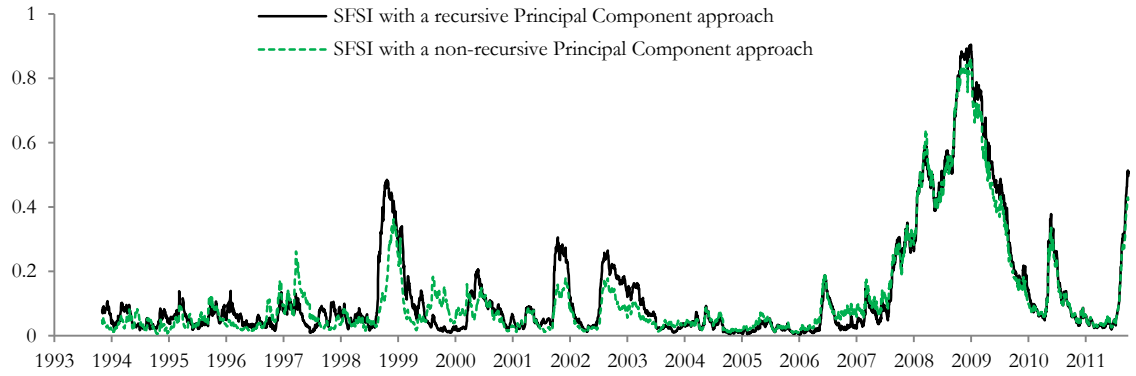


Fig. 14 compares the recursive principal component analysis approach that we use in this paper (although not in the final specification of the SFSI) with a non-recursive principal component analysis approach. The non-recursive approach includes information includes all information when calculating a stress value, while the recursive approach only use information available at each date (implying that the index would look exactly the same if calculated at that date). Again, the two indices follow each other relatively closely, and the recursive approach has the advantage that we do not risk reclassification of past events.

Appendix E – Time-Varying Cross-Correlations

Fig. 15 and Fig. 16 present the time-varying cross-correlations of the short and long SFSI respectively. This is the "systemic" component of the SFSI, where theory implies that cross-correlations should increase in particularly stressful periods.

Fig. 15. Time-varying cross-correlations, short SFSI

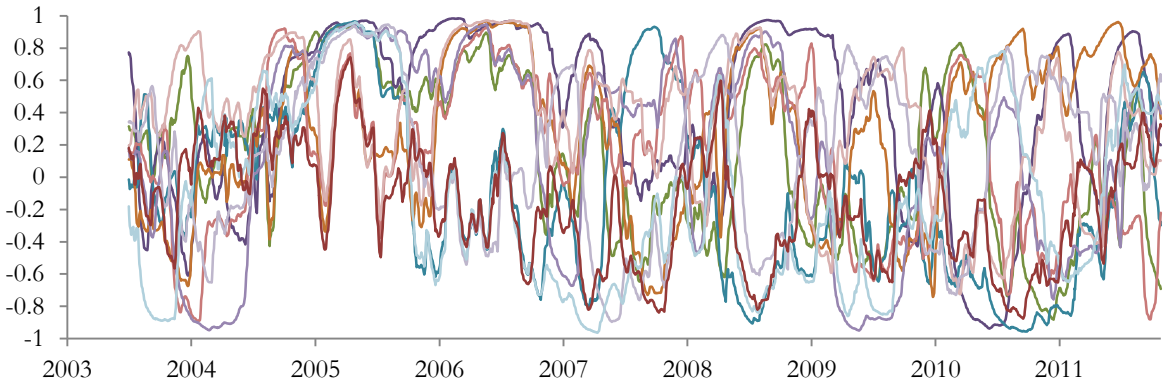
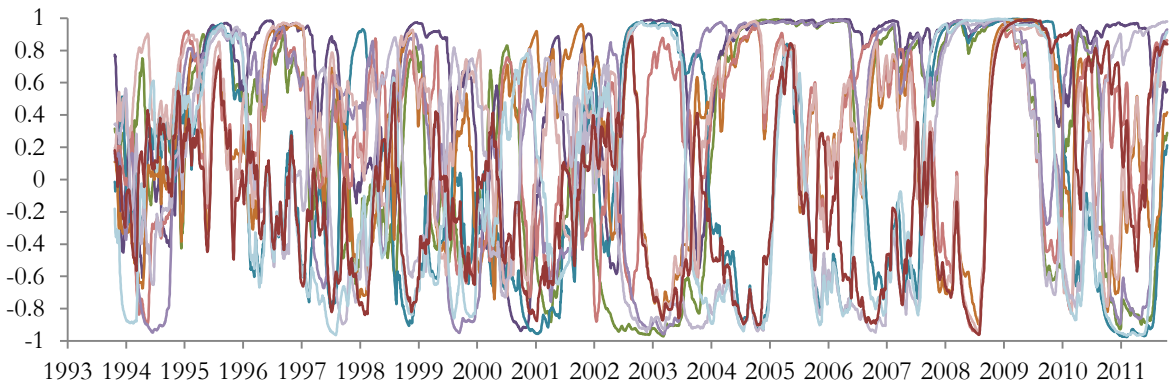


Fig. 16. Time-varying cross-correlations, long SFSI



Appendix F – Decomposition of the SFSI

Fig. 17-21 show the five subindices of the short SFSI while Fig. 22-26 present the same subindices for the long SFSI. In particular the money market and foreign exchange subindices have remained at consistently high values after the financial crisis, but due to stress in other subindices decreasing, and thus reducing the value of several of the cross-correlations, the value of the SFSI was low until it detected the euro crisis in August 2011. This does not imply that there was no stress in the markets in this period, but that the level of stress was not systemic.

Fig. 17. Equity subindex of the short SFSI

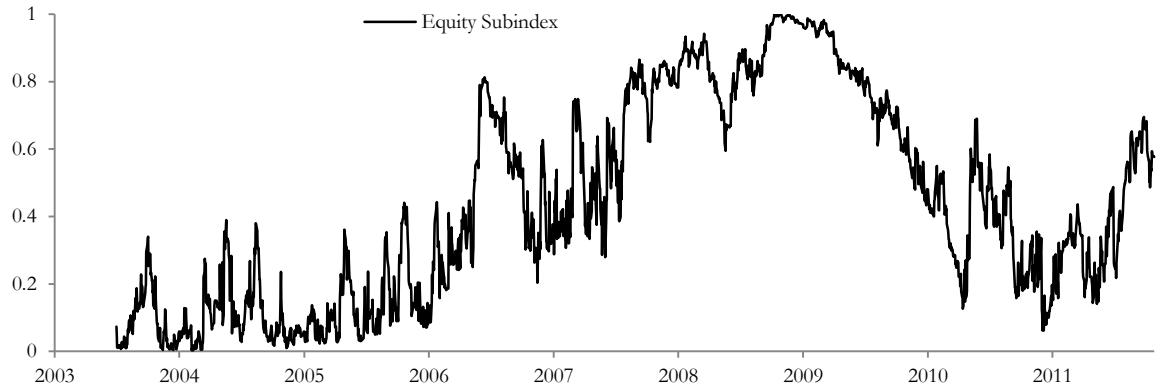


Fig. 18. Bond subindex of the short SFSI

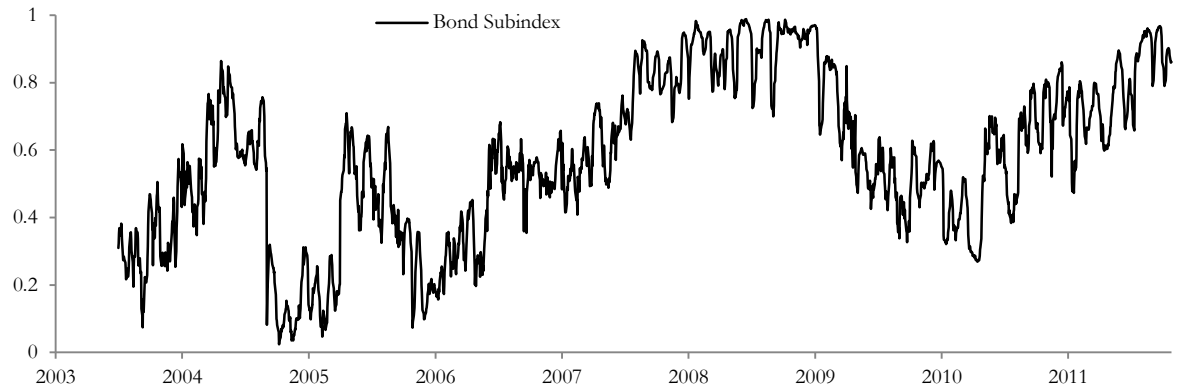


Fig. 19. Bank subindex of the short SFSI

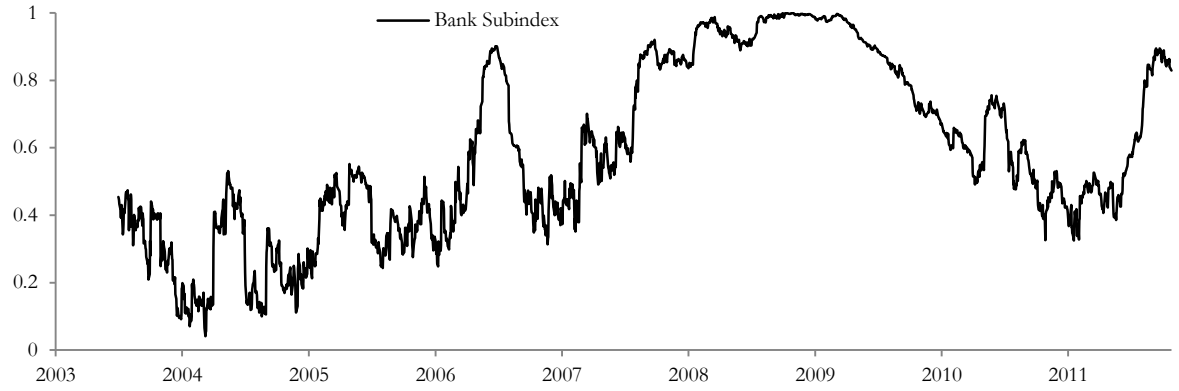


Fig. 20. Money Market subindex of the short SFSI

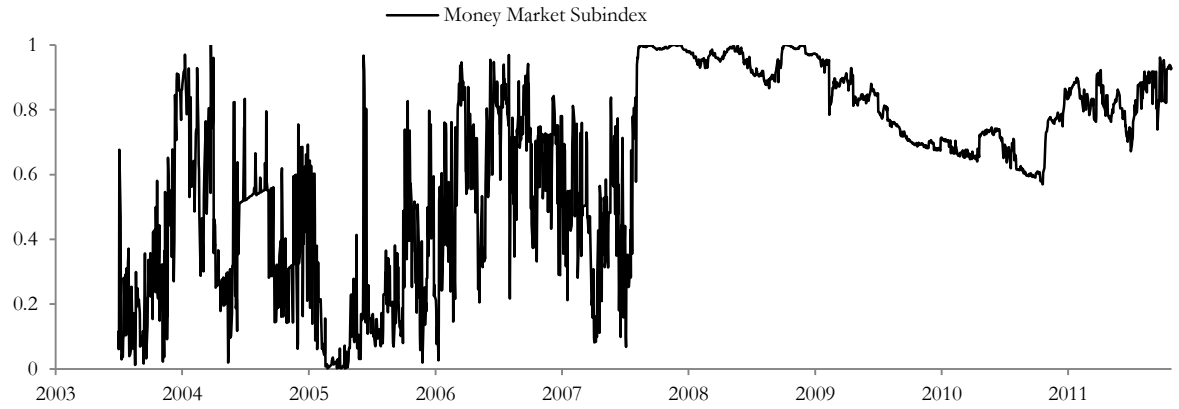


Fig. 21. Foreign Exchange subindex of the short SFSI

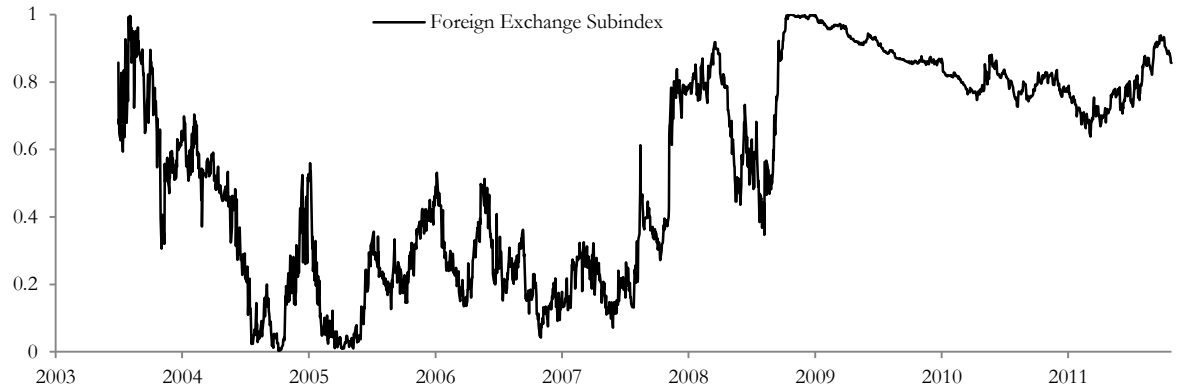


Fig. 22. Equity subindex of the long SFSI

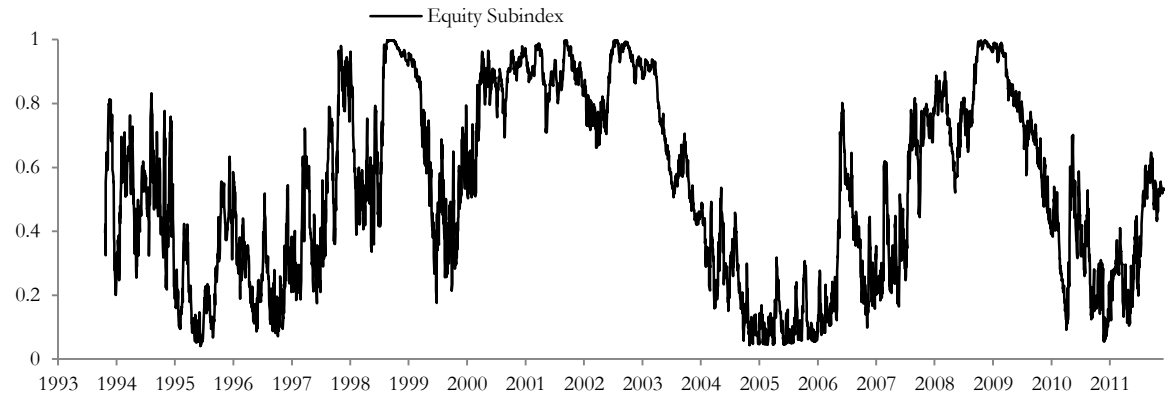


Fig. 23. Bond subindex of the long SFSI

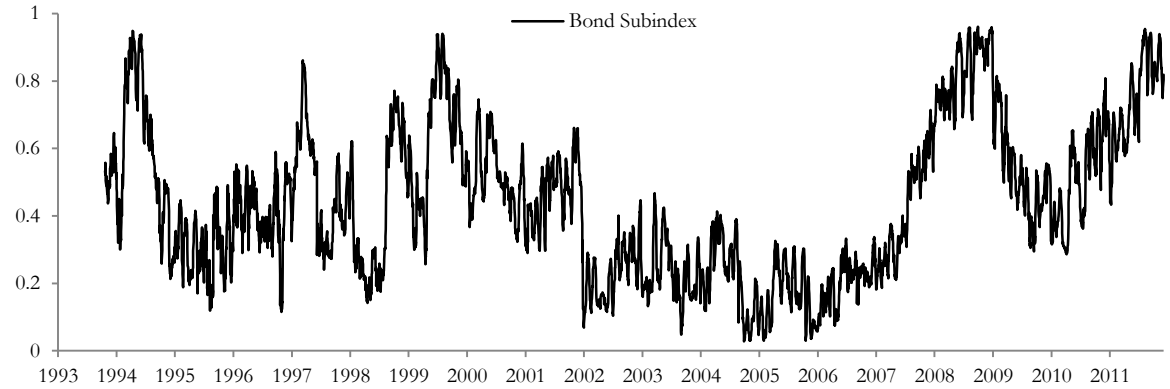


Fig. 24. Bank subindex of the long SFSI

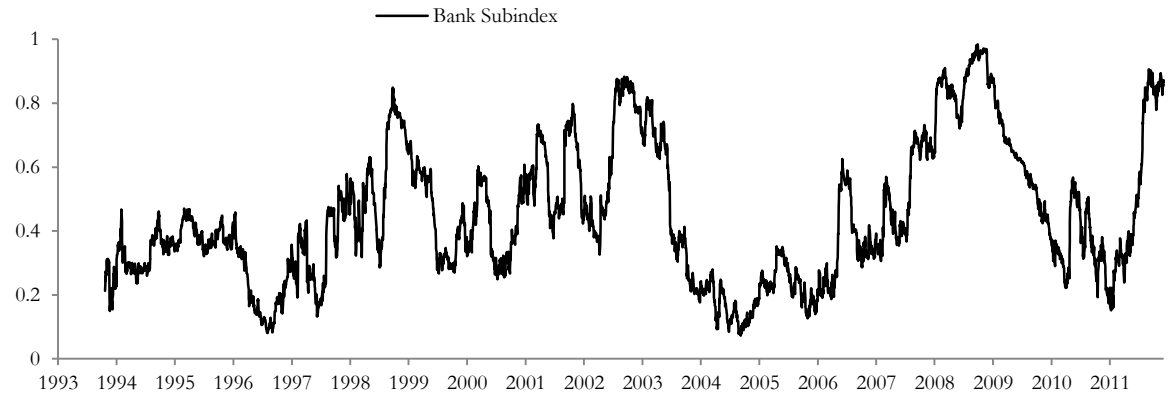


Fig. 25. Money Market subindex of the long SFSI

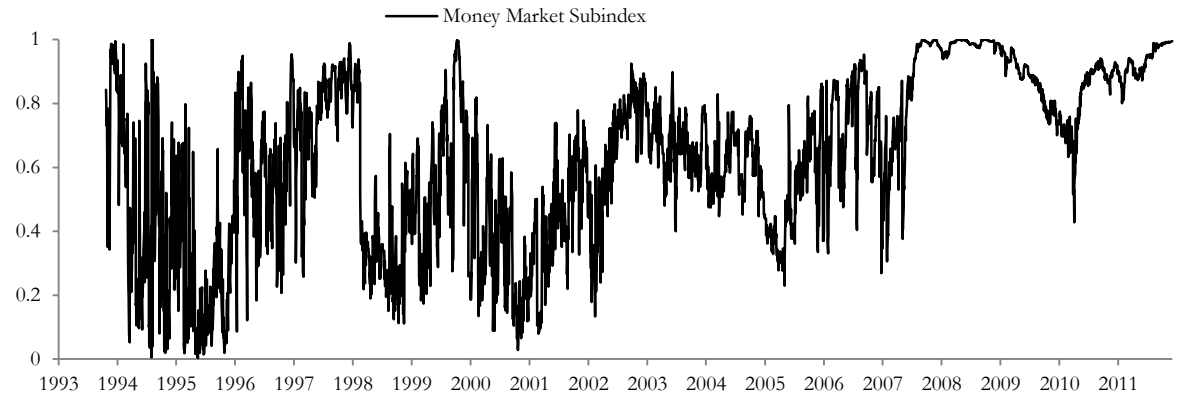
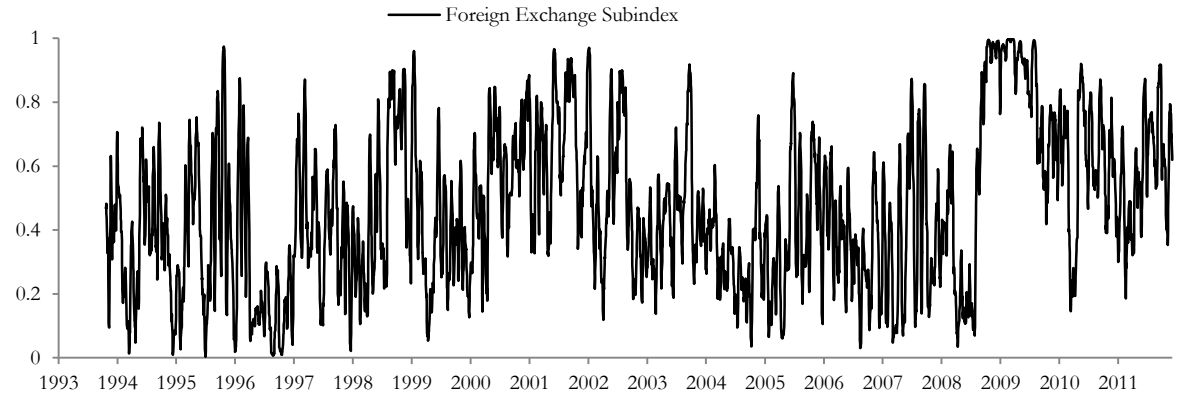


Fig. 26. Foreign Exchange subindex of the long SFSI



Appendix G – Transformation of Raw Stress Indicators

Fig. 27.1 – 27.16 show the ordinal transformation of all raw stress indicators included in both the long and the short SFSI. The figures include both recursive and non-recursive tranformations.

Fig. 27.1-16. Quantile transformations of raw stress indicators – computed both recursively and non-recursively

Fig. 27.1. SEK/EUR realized volatility

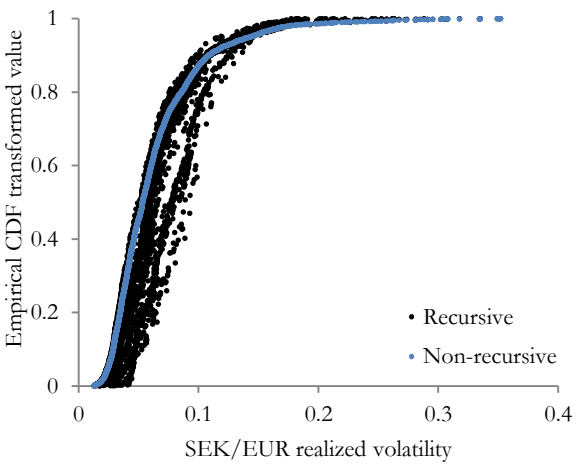


Fig. 27.2. OMX30 CMAX measure

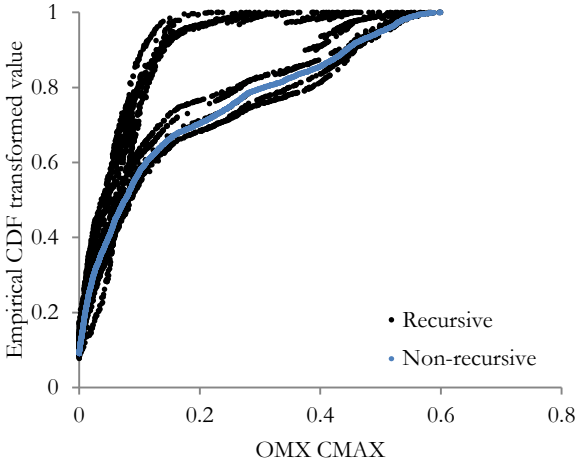


Fig. 27.3. Covered bond spread

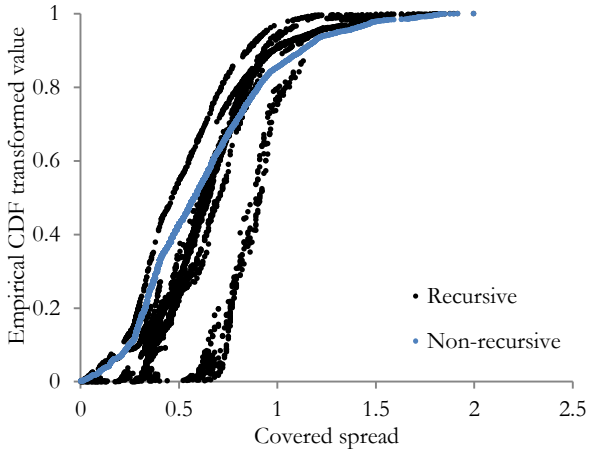


Fig. 27.4. SEK/EUR realized volatility

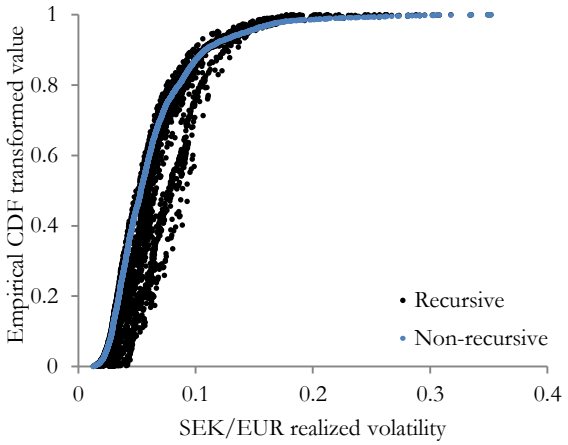


Fig. 27.5. 5-Year Government Bond volatility

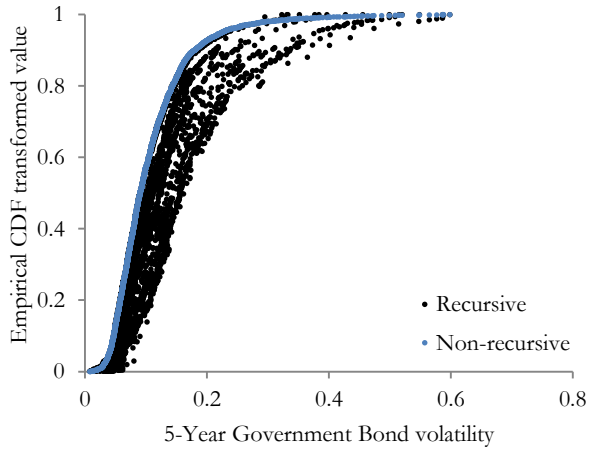


Fig. 27.6. STIBOR volatility

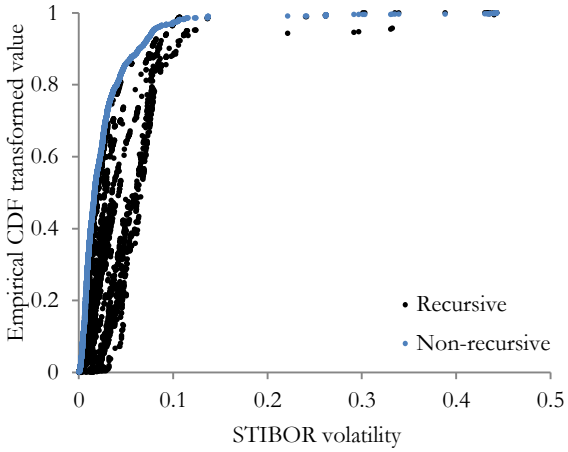


Fig. 27.7. SVIX (implied stock market volatility)

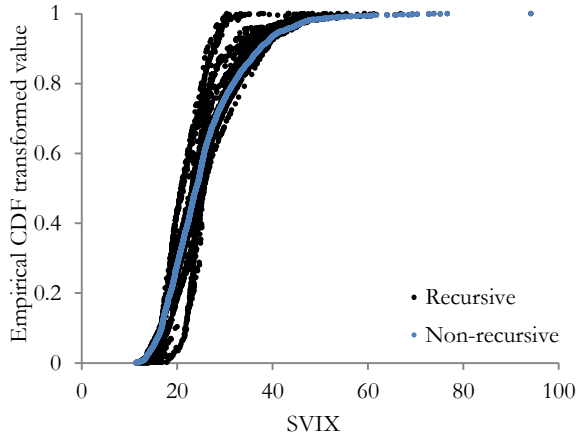


Fig. 27.8. Swap spread

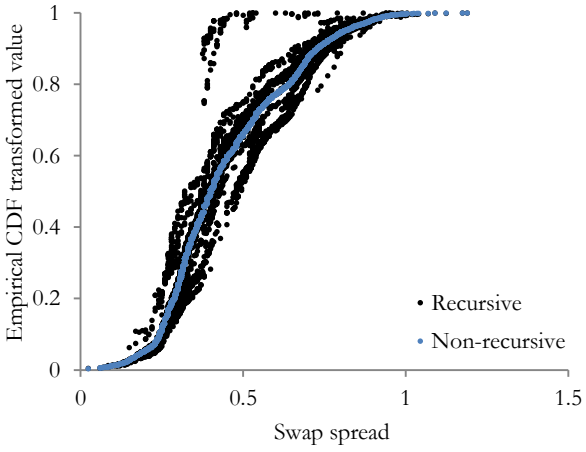


Fig. 27.9. TED spread

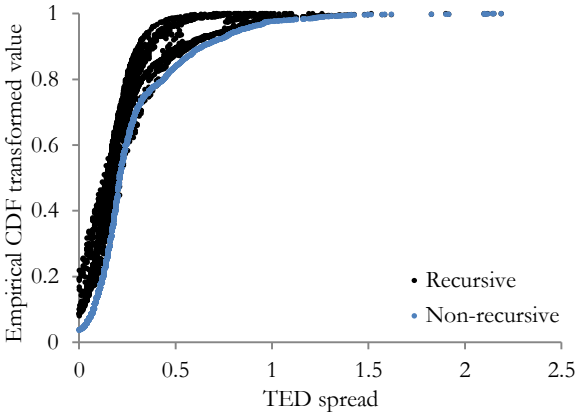


Fig. 27.10. SEK/USD implied volatility

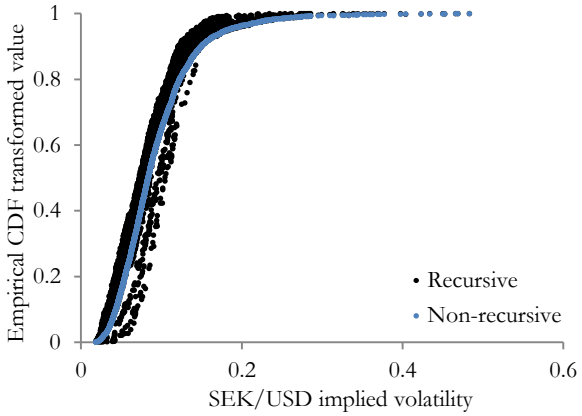


Fig. 27.11. Banking sector CMAX measure

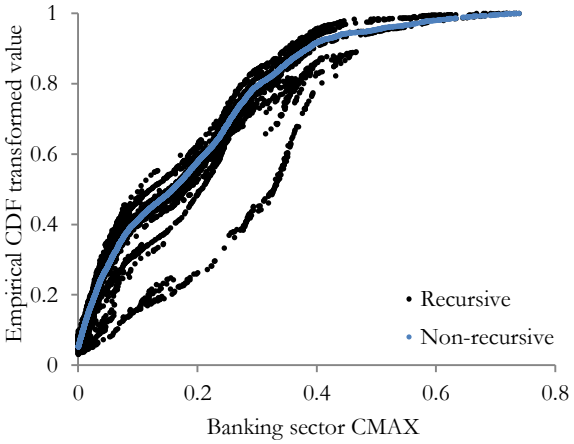


Fig. 27.12. Inverted yield curve measure

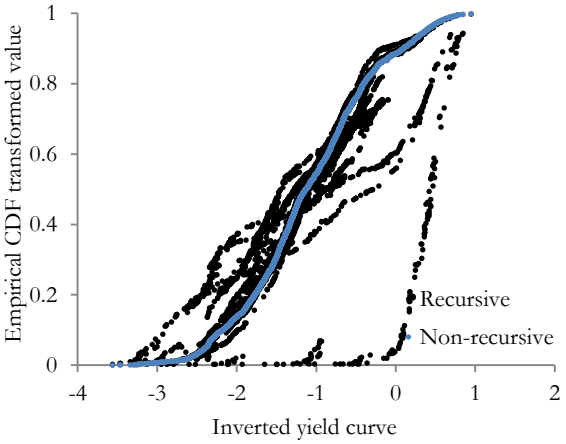


Fig. 27.13. Basis spread

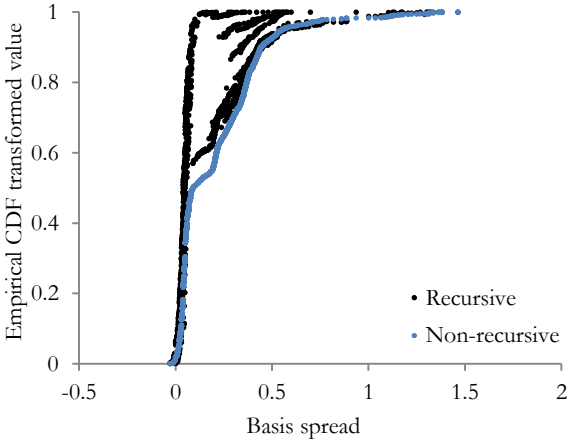


Fig. 27.14. Bank CDS spreads

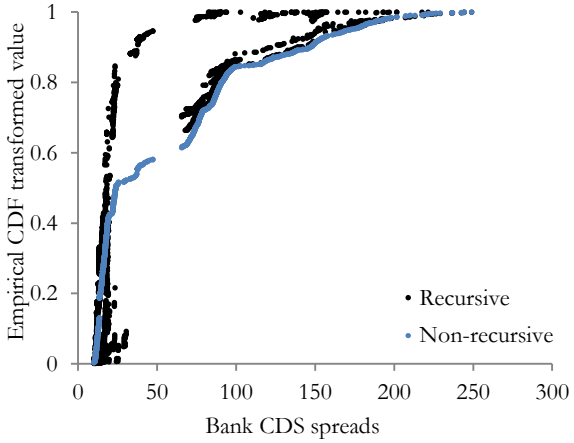


Fig. 27.15. SEK/EUR implied volatility

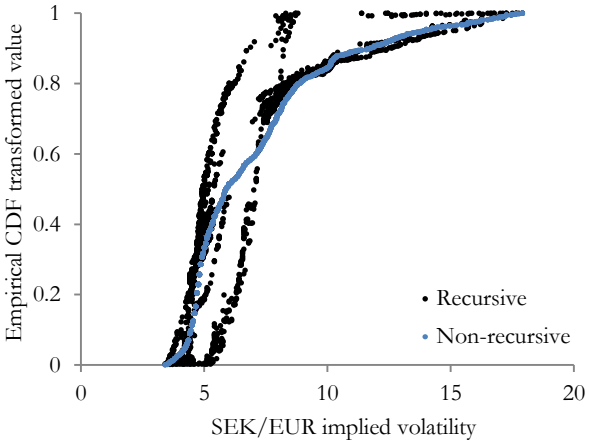
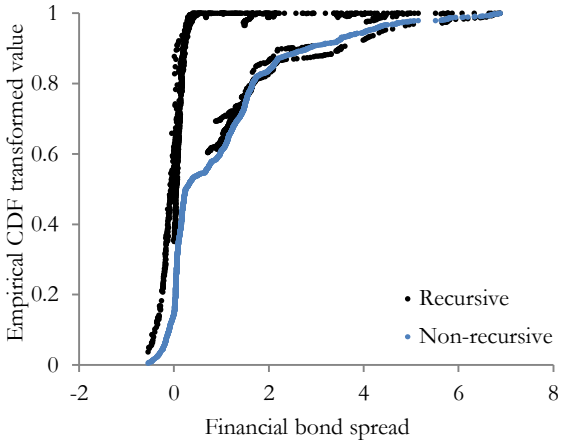


Fig. 27.16. Financial bond spread



Appendix H – Expert Survey on Financial Stress

Below is a copy of the survey we conducted with a number of leading academic experts on financial stress in Sweden.

SURVEY ON FINANCIAL STRESS IN SWEDEN

We are two students at the Stockholm School of Economics, currently writing our master's thesis about financial stress in the Swedish financial markets.

We are currently experimenting with methods of measuring/predicting financial stress in the Swedish financial markets with markets based data. We would like to know how our quantitative measures correspond to your expert's view of a number of historical events that may have been perceived as stressful for the Swedish financial markets.

We consider financial stress a disruption in the financial system's functioning as an efficient intermediary between borrowers and lenders, thereby threatening real economic growth. Episodes of financial stress can often be associated with the following key features of investor behavior:

- Increased uncertainty about fundamental value of assets
- Increased uncertainty about behavior of other investors
- Increased asymmetry of information
- Increased risk aversion (flight to quality)
- Decreased willingness to hold illiquid assets (flight to liquidity)

We would like you to assess and rank the stress level in Swedish financial markets at the particular time of the events below. Some of the events may be considered parts of extended single crises. Please try to assess the overall level of financial stress at the time the events occur and not only the stress that was an immediate consequence of the referenced event. Please circle the number to the right that best fits your judgment of the amount of stress in the Swedish financial markets.

Please be aware that we will make the results of this survey anonymous before we use it. We will only release aggregated findings, drawing only a distinction between the academics' perspective and policy makers' perspective.

Thank you very much for your participation.

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Sören Haefcke
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Tel. 072 733 09 47

1: Not stressful for the Swedish financial markets
7: Extremely stressful for the Swedish financial markets
DK: Don't know

Date / Event	Scale							
	Not stress-ful			Somewhat stressful			Extremely stressful	
Fall 1991: Swedish banking solvency issues, leading to equity injection in Nordbanken and a state loan guarantee for Första Sparbanken to fulfill its capital requirements	1	2	3	4	5	6	7	DK
Late summer 1992: Nationalization of Nordbanken and later Gota Bank	1	2	3	4	5	6	7	DK
September 1992: ERM (Exchange rate mechanism) crisis, GBP Black Wednesday	1	2	3	4	5	6	7	DK
November 1992: Devaluation of the Swedish krona	1	2	3	4	5	6	7	DK
December 1994: Mexican crisis following the devaluation of the Mexican peso	1	2	3	4	5	6	7	DK
July/August 1997: Asian crisis: Devaluation of the Thai Baht and IMF rescue package	1	2	3	4	5	6	7	DK
August/September 1998: Russian crisis and subsequently the fail of hedge fund LTCM which led to a bailout of several financial institutions	1	2	3	4	5	6	7	DK
April 2000: Dot-com bubble burst	1	2	3	4	5	6	7	DK
September 2001: US terrorist attacks	1	2	3	4	5	6	7	DK
July 2002: Worldcom bankruptcy	1	2	3	4	5	6	7	DK
May 2006: Worldwide uncertainty regarding interest rate increases from Fed and ECB	1	2	3	4	5	6	7	DK
March 2007: Collapse of U.S. sub-prime mortgage industry	1	2	3	4	5	6	7	DK
August/September 2007: Liquidity stress and bank run of Northern Rock	1	2	3	4	5	6	7	DK
March 2008: Bear Stearns collapse leading to a J.P. Morgan takeover	1	2	3	4	5	6	7	DK
September 2008: Lehman Brothers filing for bankruptcy	1	2	3	4	5	6	7	DK
October 2008: Collapse of Iceland's banking sector	1	2	3	4	5	6	7	DK
February 2009: Bailout of Latvia	1	2	3	4	5	6	7	DK
April/May 2010: Greece applies for the Financial Support Mechanism	1	2	3	4	5	6	7	DK
October 2010: The winding-up of the Riksbank's loan facilities	1	2	3	4	5	6	7	DK
July/August 2011: The intensification of the Euro crisis and the downgrade of U.S. government debt	1	2	3	4	5	6	7	DK

Are there any other events in your opinion that are missing and how will you grade this with the same scale as above:

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