DISCUSSION PAPER

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LATVIAN FINANCIAL STRESS INDEX

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CONTENTS

ABBREVIATIONS

CAR – capital adequacy ratio
ECB – European Central Bank
ESRB – European Systemic Risk Board
EU – European Union
FCMC – Financial and Capital Market Commission
FRS – US Federal Reserve System
FSI – financial stress index
IMF – International Monetary Fund
JSC – joint stock company
MFI – monetary financial institution
NPLs – non-performing loans
PCA – Principal Component Analysis
ROA – return on assets
ROE – return on capital
US – United States

SUMMARY

The objective of this Discussion Paper is to develop a methodology for Latvian FSI. To this effect, the particular methodologies widely used in international practice for composite indicators applied in financial stability monitoring and the experience of selected countries were examined. The authors analyse the nature of financial stress and the related symptoms and offer their interpretation of the financial stress concept. The Paper provides the rationale behind the selection of the individual indicators (components) comprised in the FSI, evaluates various options for aggregating the FSI components as well as features a comparison between the methodology applied for the Latvian FSI and the practice pursued in other countries. The main conclusion presented in the Discussion Paper is that the dynamics of the FSI developed on the basis of the Bank of Latvia's methodology is quite an accurate measure of changes in the Latvian financial system's stress levels. It signals periods of elevated stress as well as periods of an excessively vigorous and imbalanced development of the financial system. The Bank of Latvia has been using the FSI as one of the elements of Latvia's financial system stability monitoring framework since 2009.

Key words: financial stability, financial stress, financial stress index, financial system stability monitoring

JEL codes: G01, G10, G20, E44, E58

INTRODUCTION

Three fundamental functions of a financial system – mediating payments, converting savings into funding and managing risk – have a decisive role in ensuring the functioning and growth of an economy. This leads to a logical conclusion that the financial system's stability is a mandatory prerequisite for sustainable economic growth (*Sveriges Riksbank* (2010)). Considering the close and versatile correlations between the stability of a financial system and economic growth, the assessment of the condition of the financial system and its monitoring becomes particularly important.

This issue has come under the spotlight in international practice and active work on improvement of the financial stability assessment and monitoring tools is always in progress. Thus, for example, one of the most important features of the current reforms of the EU financial supervision framework is the re-focussing from micro-prudential to macro-prudential supervision, creating the mechanisms for effective mitigation and prevention of the systemic risks jeopardising the stability of the financial system of the EU as a whole. One of the most important tasks of the ESRB established in 2011 is the shaping of an effective financial stability monitoring framework and the development of adequate analytical tools.

Historically, one of the traditional approaches is to monitor a set of selected financial indicators based on the regular financial reporting data of credit institutions. The most popular examples here are the financial soundness indicators (FSI) of the IMF[1] and the macro-prudential indicators (MPI) of the ECB[2]. These indicators comprise several variables characterising capital adequacy, liquidity, asset quality, profitability and other performance measures of financial institutions.

As well as many other individual indicators, they can be very useful when analysing particular functional aspects of a financial system. Nevertheless, none of the traditional individual indicators can provide a systemic or integrated overview of a financial system's stability, considering the complexity of its structure, multiple cross-sectoral links and the non-linear nature of the cross-sectoral transmission of potential shocks (Mörttinen, *et al.* (2005); White (2004)).

When indicators are aggregated into a system or a set (as practiced by, for example, the IMF or ECB) and structured on the basis of various features, the stability of a financial system can be assessed in several dimensions at a time (for example, based on the risk category). However, the nature of changes in variables is hardly ever perfectly homogenous (in terms of direction and timing), hence the monitoring of such a system (based on several variables) is complicated.

Therefore, the number of papers looking at the opportunities to construct a single composite indicator which would facilitate the monitoring of the condition of a financial system has increased significantly over recent years. This can be achieved by aggregating several indicators in a manner that would capture the interaction between individual indicators as completely as possible. The views of economists on this particular subject as well as the methodology applied differ quite considerably.

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[1] http://fsi.imf.org/.
[2] http://www.ecb.int/pub/pdf/scpops/ecbocp26.pdf.

The first step in search of a single quantitative measure of the condition of a financial system would be to find an adequate theoretical and conceptual framework. Consequently, a concept capable of being accurately defined and quantified is required.

Contrary to such concepts as, for instance, price stability, it is quite hard to find an accurate definition for the concept of financial stability.[3] Indeed, due to the complex nature of the financial stability phenomenon as well as the versatility and specifics of the indicators characterising the risks to financial stability, one feels motivated to look for an easier-definable and quantifiable concept. The coexistence of various terms used for financial stability indicators in international practice is a proof of the active search for such a concept. Alongside with the financial stability/instability indicators, one can also often come across financial fragility, financial vulnerability as well as financial stress indicators. The choice of the name for each specific indicator is determined by its conceptual and methodological peculiarities.

Section 1 of the Discussion Paper examines various approaches to the definition of the financial stress and the associated symptoms. It is proposed to treat financial stress as a category of the financial market participants' behaviour. In literature, financial stress is very often associated with the financial instability concept. Yet, contrary to financial stability, stress can be considered an easier definable and also quantifiable phenomenon. Therefore, Section 2 of the present Discussion Paper examines the options for the quantitative assessment of financial stress. Based on the analysis of the conceptual foundations of financial stress outlined in Sections 1 and 2, Section 3 explains the methodology used to estimate the FSI as a single composite stress indicator: it substantiates the selection of variables (components), analyses various approaches to their aggregation, explains the index interpretation. Section 4 analyses the dynamics of the Latvian FSI. Finally, conclusions are provided as to the accuracy with which the FSI reflects the changes in the financial stress levels of Latvia's financial system and identifies periods of elevated stress and of excessively vigorous and imbalanced development of the financial system.

1. OPTIONS FOR DEFINING FINANCIAL STRESS

The financial stress concept can be interpreted as a disruption in the normal functioning of financial markets (Hakkio, Keeton (2009)). Multiple definitions of financial stress can be found in the literature. Nevertheless, it is possible to highlight the most important symptoms or factors which, according to several authors, characterise financial stress. Many economists mention in their works three most important indications of elevated financial stress: **uncertainty**, large **expected financial losses** and **increased risk aversion** on behalf of the financial system players (for example, Illing and Liu (2003; 2006), Misina and Tkacz (2009), Hakkio and Keeton (2009)).

M. Illing and Y. Liu (2003) define financial stress as the force exerted on economic agents by the three above-mentioned factors or indications. M. Misina and G. Tkacz (2009) are of an opinion that financial stress is a situation in which large parts of the

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[3] For more discussions on options for defining financial stability and the definitions proposed by some national central banks see, for example, Bank of England (2007), ECB (2007), G.J. Schinasi (2004).

financial system (or to be more precise, sector) face the prospect of large financial losses. This highlights the systemic nature of the financial stress, i.e. the presence of stress in most segments of a financial system, instead of only individual segments. The FRS experts (Hakkio and Keeton (2009)) provide a more detailed explanation of the signs signalling financial stress:

1) increased uncertainty among lenders and investors about the fundamental values of financial assets. Such increased uncertainty typically translates into higher volatility in the market prices of the assets. In some cases, uncertainty about the fundamental values of assets reflects higher general uncertainty about the outlook for the economy as a whole and for specific sectors;

2) increased uncertainty about the behaviour of other investors;

3) increased asymmetry of information between lenders and borrowers or buyers and sellers of financial assets;

4) significantly decreased willingness to hold risky assets (flight to quality);

5) significantly decreased willingness to hold illiquid assets (flight to liquidity).

The IMF experts (Balakrishnan *et al.* (2009)) mention four fundamental characteristics: large shifts in asset prices, an abrupt increase in risk and/or uncertainty, liquidity droughts, and concerns about the health of the credit institutions.

Some authors also associate financial stress with macroeconomic instability. For instance, G. Dufrénot, D. Furceri and A. Zdzienicka (2011) define financial stress as a situation in which the economy faces a higher likelihood of experiencing financial turbulences associated with currency crises, balance of payment crises, sudden stops and capital outflows, stock market crashes, banking crises, default on servicing public debt, etc. D. Holló (2012) defines financial stress as a situation when disorders in the financial system unexpectedly influence the price and turnover of financial products, which may be accompanied by the default of systemically important financial institutions and the collapse of the financial resource allocation ability of the financial system, leading to an economic downturn.

K. Hubrich and R. J. Tetlow (2011) mention three channels through which financial stress affects the economy. Firstly, an increased financial stress raises the cost of borrowed funds for non-financial corporations and households. Secondly, in the circumstances of uncertainty and asymmetric information, credit institutions can become particularly cautious when evaluating the credit worthiness of their borrowers, constricting credit availability. Thirdly, higher financial stress can make the borrowers also more cautious and cause them to delay their asset purchase decisions, thereby reducing the demand for credit as well. This illustrates the negative impact of heightened financial stress on consumption and investment, and thereby also on the overall growth.

The results of a comparatively recent paper show that, of 113 financial stress episodes affecting 17 advanced economies within the period since 1980, 58 were followed by a significant economic slowdown or by recession. The remaining 55 financial stress episodes did not involve any significant macroeconomic consequences. Moreover, it was concluded that the losses caused by economic downturns that follow financial

stresses were, on average, significantly larger than those in the episodes of downturns caused by other factors (Cardarelli, Elekdag, Lall (2009)).

Based on the above conclusions about the indications and essence of financial stress, the authors of the present Paper propose to conceptually view the financial stress as a category of the financial market participants' behaviour. M. Blix Grimaldi (2010) defines financial stress as the product of vulnerable markets and of either exogenous or endogenous shocks. Stress can, indeed, be defined as a situation in the financial market which is determined by the response of its participants to shocks. Essentially, shocks may be either idiosyncratic (affecting only one market participant or a limited number thereof) or systemic (simultaneously affecting various market participants). Shocks may be domestic (arising in one or several segments of the domestic financial market) or external (arising in external financial markets or in macroeconomic environment).

In this context, the fact that financial crises (which can be defined as episodes of financial instability and stress) are very often analysed as a banking, debt and/or currency phenomenon rather than a phenomenon of a systemic nature is a drawback characteristic of several papers (Slingenberg, de Haan (2011)). When analysing the condition of a financial system, one has to take into consideration the correlations between its key elements (credit institutions, financial instrument markets etc.) and their vulnerability to domestic and external shocks. Problems in one of the system's elements may quickly spill over to other elements, thereby endangering the stability of the entire system. The combination of this interdependence and vulnerability determines the exposure of the particular financial system to the systemic risk (*Sveriges Riksbank* (2010)). The systemic nature of the risks to financial stability, interdependences between the segments and participants of the financial market, macroeconomic and financial environment should all be taken into account also when analysing the sources of the financial stress.

Important feature of the financial stress is also its level. A stress level which exceeds the long-term average signals financial instability and in some cases (when the stress level exceeds a pre-specified threshold) a financial crisis. A high stress level could be associated with large uncertainty, growing financial loss expectations and high risk aversion. A low level of stress could, in turn, signal stable development of the financial system. E. Hanschel and P. Monnin (2005) in their paper describe low stress periods as situations where stress is quasi-absent. Developing this concept of a quasi-absent stress further, it should be noted that financial stress is to be viewed as a constant phenomenon. That means that stress is always present in a financial system. Moreover, if the financial stress is persistently at a level significantly lower than the long-term average, this could imply that the market participants are overly optimistic (as manifested by, for example, a lending or investment boom), which, in turn, should signal imbalanced macro-financial development.

In this context, it is interesting to note the results of empirical research suggesting: the likelihood that financial stress will be followed by an economic downturn is associated with the extent to which housing prices and lending have increased in the pre-stress period. The steeper the increase, the higher the likelihood of a downturn. Moreover, greater reliance on financing from credit institutions by households and non-financial corporations is usually associated with a sharper downturn in the aftermath of financial stress (Cardarelli, Elekdag, Lall (2009)).

The level of financial stress depends primarily on the size of the shock hitting the system and the extent of accumulated imbalances in the financial system (e.g. a high degree of maturity mismatches, high leverage, high share of illiquid assets etc.). It is also dependent on the reactions of the institutions responsible for the promotion of financial stability to the above shocks as well as market participants' expectations in relation to such reactions (Holló (2012)).

The above-mentioned signs and conceptual peculiarities of the financial stress should be taken into account when developing a methodology for indicators characterising the financial stress.

2. OPTIONS FOR QUANTITATIVE MEASUREMENT OF FINANCIAL STRESS: INTERNATIONAL EXPERIENCE WITH SELECTION OF VARIABLES

The monitoring of a financial system's condition becomes substantially easier through the use of a single composite indicator. Financial stress can be measured using a single composite indictor called FSI whose extreme values can be considered a financial crisis (Illing, Liu (2006)). Essentially, the FSI is a dependent variable highly appropriate for applying in early warning models ((Illing, Liu (2006); Lo Duca, Peltonen (2011)). It is also suitable as a measure of the systemic stress level in cases when the normal functioning of the financial system and, through that, also of the entire economy is impaired. FSI can also be used to gauge the effectiveness of government measures directed towards mitigating systemic stress (Holló, Kremer, Lo Duca (2012)). The construction of a composite quantitative measure of financial stress also enables public institutions and financial market participants to better monitor the financial system's stability. It enables the identification of the sources and causes of financial stress (Gadanecz, Jayaram (2009)). This can be achieved through the so-called decomposition of the indicator, i.e. through analysing the contributions of separate components to the development of the aggregated indicator. Publishing the results of the analysis of the financial stress index movements also helps to communicate the views on changes affecting a financial system to the general public more effectively.

When developing the methodology for the composite indicator of financial stress, a very important feature of the financial stress, i.e. its continuity, has to be taken into account. The degree of stress in a financial system is constantly changing and, when monitoring the condition of a financial system, it is important to detect any episodes of heightened (as well as excessively low) stress. The literature often uses discreet or continuous measures for this purpose.

Discreet measures are typically in the form of binary variables which point to the start of a stress (instability or crisis) episode once a particular threshold value of some economic or financial variable has been breached (Frankel, Saravelos (2010)). A binary variables approach really makes it possible to detect episodes of financial stress. However, it only enables the identification of the start and end point of the episode and does not characterise the changes affecting the condition of a financial system during various stages of the episode. It does not allow for a measurement of the degree of financial stress (which could be defined as the distance to the long-term average) and its changes during as well as prior and after the crisis.

Considering the above-mentioned drawbacks, an alternative solution would be to use continuous measures. In order to reflect the systemic nature of the financial instability, a single composite indicator is required which would capture the behaviour of all or at least the most essential elements of the financial system.

The construction of a continuous composite financial stress indicator could serve as a basis for the development of a financial system monitoring framework. A logical solution in the construction of a composite indicator would be the aggregation of several individual indicators, each characterising an important factor or group of factors determining financial stress, into a single indicator with the help of various mathematical methods. Thus the first step in the development of such a composite indicator would be the selection of the individual indicators.

One of the potential approaches would be to use high-frequency (daily or weekly) financial market indicators. Market-based financial stress indicators have become very popular in practice, as the monitoring of market data capturing the behaviour and risk perception of market participants enables early detection of negative signals from the financial markets. The following examples could be mentioned: the composite indicator of systemic stress of the ECB (Holló, Kremer, Lo Duca (2012)), the financial stress index of the IMF (Cardarelli, Elekdag, Lall (2009)), the financial fragility indicator developed by the FRS experts (Nelson, Perli (2007)), the Bank of Canada's FSI (Illing, Liu (2006)) financial systemic stress index of the Bank of Greece (Louzis, Vouldis, (2011)), the new system-wide financial stress index of *Magyar Nemzeti Bank* (Holló (2012)) etc.

An alternative approach would be to combine the financial market data with the financial reporting data of financial institutions. This approach to the FSI construction is used, for example, by the Swiss National Bank (2006) and *Banque centrale du Luxembourg* (Rouabah (2007)). Alongside with balance sheet and performance indicators of credit institutions (changes in profitability, capital, asset quality and number of credit institutions' branches), market indicators (changes in the banks' stock prices and bond yields) and other indicators (interbank market data and information from supervisory authorities) are also used (Swiss National Bank (2006); Rouabah (2007)).

An interesting example is the so-called Financial Stability Conditions Index developed by the experts of *De Nederlandsche Bank*, which comprises not only the balance sheet and market data, but also some macroeconomic variables (real effective exchange rate of the euro and housing prices). Another specific feature of this index is that it supplements the data on credit institutions with the performance data on other financial institutions (insurance corporations and pension funds) (Van den End (2006)).

Česká národní banka also uses a banking stability index and publishes in its Financial Stability Report (Geršl, Heřmánek (2006)). Similarly as in Latvia and other Baltic countries, the opportunities to use financial market data for the construction of a financial stability index are limited in the case of the Czech Republic due to the relatively small number of listed shares and debt securities of domestic banks. This means that the index relies primarily on the data derived from the banks' balance sheets and supervisory data. A characteristic feature of the index developed by *Česká národní banka* is the main criterion for the selection of

variables to be comprised in the index: the variables should reflect the most important risks to financial stability.

The index comprises nine variables. CAR and two profitability ratios (ROA and ROE) characterise the buffer or the so called safety cushion against any potential risks. The ratio of NPLs to total loans as the asset quality indicator reflects the exposure to credit risk. The index also includes two liquidity ratios (quick assets to total assets and to non-bank deposits), one variable characterising interest rate risk (cumulative net balance sheet position to 3 months to total assets) and two indicators of foreign exchange risk (absolute value of open total position in foreign exchange to Tier 1 capital and absolute value of open balance sheet position in foreign exchange to Tier 1 capital) (Geršl, Heřmánek (2006)).

The motivation behind the attempts to include traditional financial stability risk indicators in a composite financial stability index is clear and logical. Nevertheless, the authors of the present Paper believe that the use of a similar approach in the Latvian circumstances is prejudiced by the cyclical movement peculiarities of some of the above-mentioned variables. Thus, for example, during the pre-crisis period the CAR in Latvia ranged between 10%–11% (see Chart 1), i.e. in stable and favourable circumstances characterised by a relatively low degree of stress in the financial system, the growth of capital in credit institutions overall did not outpace the increase in the risk-weighted assets. During and following the crisis, credit institutions actively injected capital in order to absorb the negative effect of bulging losses and boost their capital reserves, resulting in the CAR growing significantly and reaching its historical high in 2012. This highlights the issue of how to interpret the contribution of the CAR to the overall value of the financial stability index. The experts of *Česká národní banka* have tackled this problem by assigning the CAR the smallest weight in comparison with other index components. Nevertheless, the authors of the present Discussion Paper believe that, in Latvia's case, this argument does not offset the above-mentioned arguments strongly challenging the appropriateness of the CAR in the context of a composite financial stability indicator.

Chart 1
CAR developments in Latvia (Q1 2005–Q3 2012; %)

   ■ CAR
   ◆ Tier I capital ratio
   — Minimum capital requirement
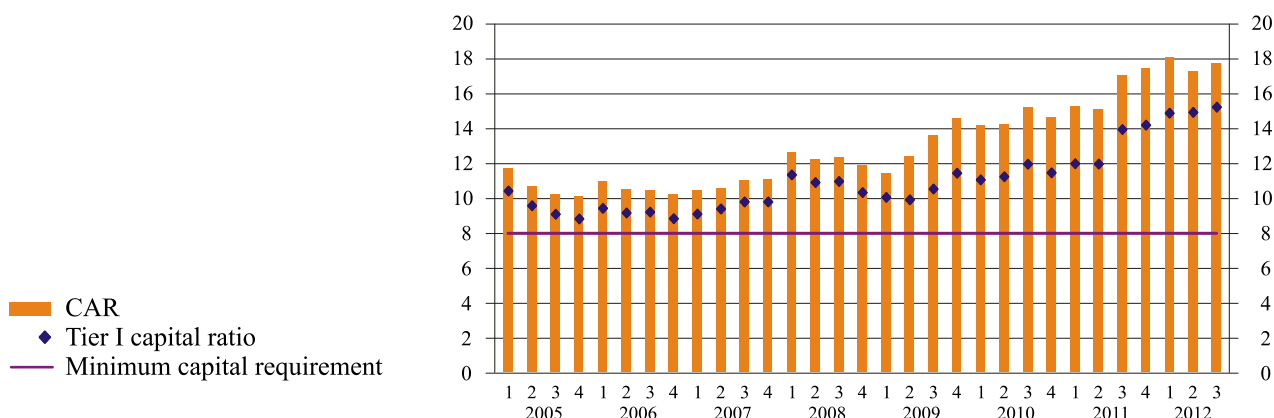
Source: FCMC.

Liquidity ratios represent another group of variables with specific dynamics depending on the particular stage of the business cycle. The dynamics of the FCMC

liquidity ratio traditionally used in Latvia (see Chart 2) is essentially similar to that of the previously examined CAR. In stable circumstances, when credit institutions engage in active lending and have a relatively high risk appetite, the liquidity in the credit institution system is lower than during a crisis, when credit institutions pursue prudential lending and investment policies, giving preference to liquid assets and thereby boosting the liquidity ratio.

Chart 2
FCMC liquidity ratio developments in Latvia (Q1 2005–Q3 2012; %)

FCMC liquidity ratio
Minimum requirement
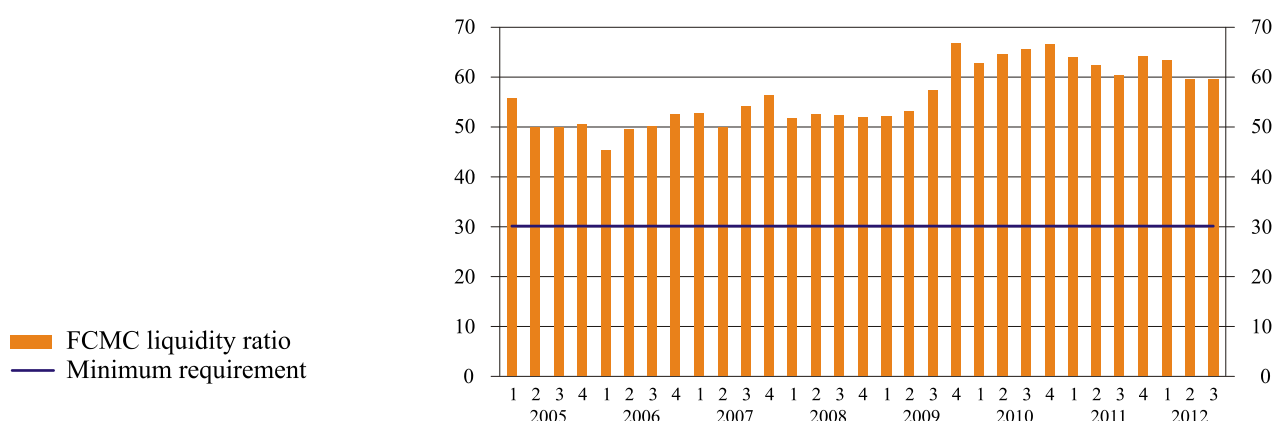
Source: FCMC.

In view of the ongoing regulatory reforms based on Basel III recommendations, the capital and liquidity requirements for credit institutions will be reviewed to incorporate anti-cyclical elements. Consequently, they would become factors mitigating the financial stress.

A large part of experts (including the above-mentioned approach by *Česká národní banka*) opt for constructing a composite FSI for specifically the credit institution sector, considering its central role in the financial system and thereby also in safeguarding the financial stability. This is particularly true in the countries where the credit institution sector dominates the national financial system.

Empirical research also suggests that the outbursts of financial crises associated with heightened stress particularly in the credit institution sector are more often related to episodes of deep and protracted economic downturns rather than to growing stress in the securities or foreign exchange markets. Recessions associated with elevated financial stress in the credit institution sector are on average at least twice as long as recessions triggered by other factors (Cardarelli, Elekdag, Lall (2009)).

Section 3 of the present Discussion Paper characterises the methodology for the construction and estimation of the FSI developed by the Bank of Latvia. For the sake of comparison, the index estimated based on the Bank of Latvia's methodology is compared with the one estimated based on *Česká národní banka* methodology in Appendix 1.

3. LATVIAN FSI: METHODOLOGY

3.1 Selection of FSI components

As mentioned before, when constructing an FSI, components should be selected that reflect the most essential symptoms of stress (uncertainty, large expected financial losses and heightened risk aversion) and the respective responses of financial market participants to domestic and external shocks (see also Section 1). As no economy, including its financial system, is deprived of its specifics, the selection of these components is always more or less subjective (this is also admitted by E. Hanschel and P. Monnin (2005), M. Illing and Y. Liu (2006), and A. Roubah (2007)).

When developing the Latvian FSI, preference was given to balance sheet indicators of credit institutions in combination with several indicators of some other sectors of the domestic financial market. The primary reasons behind this particular choice were the dominance of the credit institution sector in the financial system (the share of credit institution sector's assets in the aggregate assets of Latvia's financial system was 87.3% in 2011 (*Latvijas Banka* (2011)) and the relatively small market in financial instruments.

Thus the Latvian FSI combines various financial indicators (primarily of the credit institution balance sheets as well as characterising the money and securities market) whose movements reflect the following main symptoms signalling heightened stress in the financial system:

- decrease in the profitability of credit institutions;
- increase in loan loss provisions ratio;
- sharp decline in lending;
- deterioration of interbank lending;
- widening of credit spreads on the interbank market;
- deposit outflows;
- growing yields on government debt securities.

Uncertainty, large expected financial losses and heightened risk aversion affect the behaviour of stakeholders from the credit institution sector and other financial and non-financial sectors (investors, households, non-financial corporations) and they become extremely cautious. This, in turn, is reflected in the shifts of the above-mentioned variables (included in the Latvian FSI).

Deteriorating profitability of credit institutions represents the impact of losses on performance. Losses are caused by domestic and external shocks. Thus, for example, deterioration in the financial condition of borrowers (households and non-financial corporations) results in a rise of past-due loans, i.e. causes a credit risk shock. Credit institutions will be forced to build additional loan loss provisions, which implies the increase in their losses. There may be also other sources for losses, for example, revaluation of financial instruments held by credit institutions. Namely, foreign exchange shocks or other financial market shocks may impair the value of foreign exchange assets and securities held by the credit institutions. This, in turn, as a symptom of heightened stress will find its reflection in the deterioration of the credit institution's profitability and an increase of its provisioning ratio.

The shrinking of a credit institution's loan portfolio as a manifestation of excessive deleveraging is also to be considered a symptom signalling elevated stress, as it confirms that credit institutions are far more prudent in granting new loans during a crisis when uncertainty and risk aversion is considerably higher. In such circumstances, the amount of new loans by credit institutions becomes smaller than the loan portfolio's amortization amount, in response to the overall credit risk and external funding shocks.

Uncertainty with regard to the financial condition of the financial market participants and their ability to absorb the negative effects stemming from the above-mentioned shocks result in the so-called crisis of confidence. This can be observed, for instance, as mutual lack of trust among interbank market players. It deteriorates the liquidity conditions significantly and is reflected in growing money market risk premiums. The confidence shock results in a decrease of claims on and liabilities to MFIs, difficulties to draw funding from the interbank market and higher interest rate spreads. Households and non-financial corporations respond in a similar way by decreasing their deposits with credit institutions. Rising risk premiums on investment in sovereign debt instruments, in turn, point to the weakening of financial investors' confidence.

During low-stress periods, over-optimistic sentiments of market participants may result in surges of profitability, lending and deposit inflows, reductions of provisioning ratios and other symptoms (Latvia's experience in the pre-crisis years can be mentioned as an example here).

Table 1 features the variables included in the Latvian FSI broken down by the respective groups of variables.

Table 1
Description of variables included in the FSI for Latvia

Group	Variable	Variable included in the FSI	Transfor-mation	Impact
Balance sheet indicators of credit institutions	Profitability	ROA		−
	Provisioning ratio	Special loan loss provisions for resident loans to resident loans ratio	*dlog*	+
	Loans granted	Outstanding amount of resident loans	*dlog*	−
	Interbank lending	Outstanding amount of liabilities to resident MFIs	*dlog*	−
	Deposit developments	Outstanding amount of resident deposits	*dlog*	−
Money market indicators	Interest rates on the interbank market	Spread between 3-month RIGIBOR and EURIBOR		+
Securities market indicators	Yield on government debt securities	Spread between the average yields on 10-year Latvian and German government bonds		+

Source: Table designed by the authors.

The values of variables marked by a "−" sign in the column "Impact" of Table 1 were multiplied by a coefficient (−1) prior to aggregating (see more detail in Section 3.2), so that a positive value of those variables would signal a heightened stress period. Such a transformation means that, for example, positive growth of the credit institutions' loan portfolio would be interpreted as an indication of low stress and vice versa: the shrinking of the loan portfolio would be interpreted as an indication

of heightened stress. In cases when the stress is being determined by changes in variables instead of by their levels, logarithmic differences were calculated, which reflect the percentage changes in those variables.

The selection of specific variables or FSI components and of the reference period for the present Discussion Paper was based on the following conditions.

Firstly, the time series for the variable should be available as a minimum from the beginning of 1998. This is related to the authors' intent to construct an index for a period enveloping the most recent crisis as well as the previous episode of severe stress associated with the Russian financial crisis of 1998.

Secondly, despite the dominance of the credit institution sector in Latvia's financial system, the index would benefit from the inclusion of indicators characterising other segments of the financial system (money and securities market) in addition to those of the credit institution sector.

As the purpose of the Latvian FSI is to assess the stress levels of the domestic financial market, when selecting the balance sheet indicators of credit institutions, preference was given to those indicators characterising the behaviour of residents (see Table 1).

3.2 Aggregation of the FSI components: alternative approaches

The aggregation of the selected indicators or components into a single composite index (addressing the problem related to the weighting of variables) is the least theoretically grounded aspect of the FSI construction. The difficulty of assigning weights lies in the lack of a reference series upon which the selected weights could be tested (Illing, Liu (2006)). The following methodological approaches have been most often quoted in the literature:

1) aggregation with variance-equal weights;

2) aggregation using principal components analysis based weights;

3) aggregation of variables using equal or chained weights when the variables are transformed on the basis of their empirical cumulative distribution functions.

All three approaches were tested when constructing the Latvian FSI. For the sake of comparison, all the resulting indices were standardised by their sample means and standard deviation.

Aggregation with variance-equal weights**.** In this most frequently used stress index computation method, individual variables were first standardised[4] and afterwards aggregated in an index applying equal weights:

$$FSI_t = \sum_{i=1}^{k} \frac{X_{i,t} - \overline{X_i}}{\sigma_i}, \qquad\qquad [1],$$

where k – the number of variables combined in the index, $\overline{X_i}$ – sample mean of the variable X_i and σ_i – sample standard deviation of the variable X_i.

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[4] Dividing by the standard deviation transforms the original variables into to unit-free variables with variance is equal to one. Hence the term variance-equal weights.

Basically, for each of the index components, distance from its long-term average (measured in standard deviations) is calculated. Standardisation and equal weights ensure that "equal importance" is attached to all the variables aggregated in the index. If the variables were not standardised, the variables with a higher variance would make larger contributions to the index.

The assigning of equal weights is related to the desire to construct a stress index that would be easy to interpret. B. Gadanecz and K. Jayaram (2009) suggest that when different weights are applied the resulting index is a better representative of the financial system. Nevertheless, M. Illing and Y. Liu (2006) have found no significant differences between indices computed based on equal and on different weights. The results of computations based on different weights obtained by the authors of the present Discussion Paper also suggest that there are no material differences in comparison with the FSI estimated using equal weights (see description below).

PCA (Principal Components Analysis) based weights. PCA is a widely used method to reduce the dimensionality of the data space. The method allows to generate a small number of artificial uncorrelated variables (which are linear combinations of the initial variables) accounting for most of the variance of the initial multidimensional data set, thereby arriving at a condensed data representation with a minimal loss of information.

PCA was applied to the standardised[5] data.. The first principal component is used as an index. This corresponds to the aggregation of the standardised variables based on weights equal to the respective loadings of the first principal component[6]. A similar approach is applied by M. Illing and Y. Liu (2006) viewing this index as a measure of stress reflecting structural movements in the group of financial variables.

For the sake of comparison, Chart 3 illustrates two options for FSIs calculated using both the above-mentioned methods.

In the case of the Latvian FSI, the first principal component accounts for 61.4% of the variance in the set of observed variables. The difference between the FSI aggregating variables with PCA-based weights and the FSI aggregating variables with equal weights is minor[7].

Other options which are based on principal component analysis can also be found in the literature. Thus, for example, A. Rouabah (2007) applies the arithmetical average of the first six pre-standardised principal components (accounting for 90% of the variance in the observed components). The use of a similar approach in Latvia's case produced significantly worse results in comparison with the option applying the first principal component.

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[5] Pre-standardisation of data is used in the PCA in cases when the variables of the analysed data population have different units of measurement and scales. If the data were not standardised, the results would be highly dependent on the selection of the scale and the nature of the units of measurement.
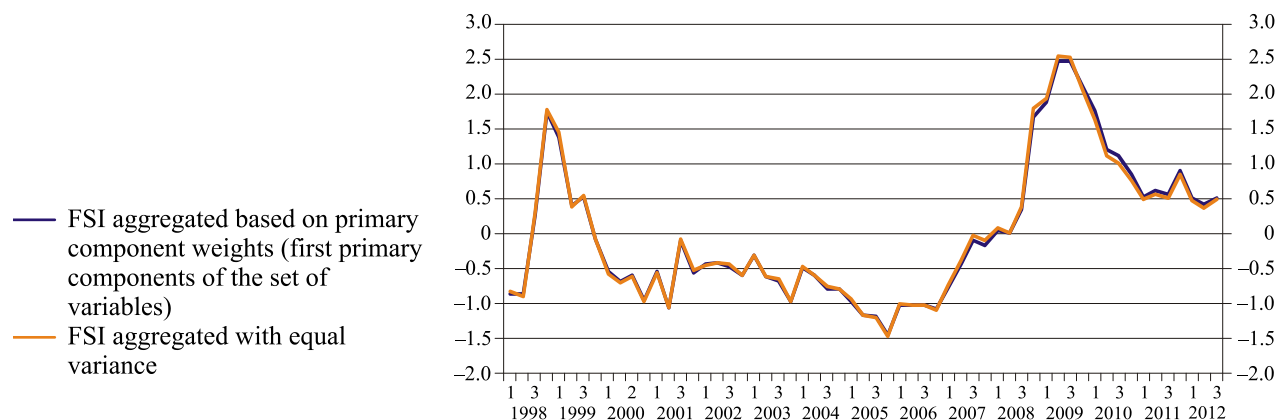
[6] The loadings of the first primary component are equal to the eigenvector corresponding to the highest eigenvalue of the variables correlation matrix.

[7] For the sake of comparison, the FSI aggregated with PCA-based weights was also standardised.

Chart 3
Aggregation based on primary component weights and equal variance
(Q1 1998–Q3 2012; in standard deviations)

Sources: Bank of Latvia, FCMC and authors' calculations.

Variable transformation based on empirical cumulative distribution functions. Standardisation of variables used in the previous two methods is very often criticised for the sensitivity of the sample mean and sample standard deviation to outliers. This may lead to sizeable index revisions if the index is based on short time series which do not cover severe stress periods.

An alternative way of standardisation, independent of the data distribution and less exposed to the impact of outliers, is based on the application of the empirical cumulative distribution function. According to this method, variable values are sorted in an ascending order and each observation is ranked. The observation is transformed into the respective percentile of the empirical cumulative distribution function $CDF^8(X_{it})$, the values ranging from 0 to 1.

The values is higher percentiles correspond to heightened stress, whereas those in lower percentiles to excessively low stress. The values around the median correspond to an average level of stress. Both types of standardisation yield similar results in the case of variables whose empirical distribution is close to normal.

The index is constructed by calculating the weighted average of the transformed variables based on chained weights:

$$I_t = \sum_i \frac{w_{it} + w_{it-1}}{2} CDF(X_{it}), \ t = 2,3,\dots,T, \tag{2}$$

where the weight of the variable *i* at time *t* is the share of the transformed value of the given variable within the simple sum of the transformed values of all the variables:

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[8] CDF is the empirical cumulative distribution function of the respective variable showing the share of the sample observations whose values are smaller than or equal to *x*:

$$CDF(x) = \frac{1}{T}\sum_{t=1}^{T} I\{x_{it} \le x\},$$

where $I\{x_{it} \le x\}$ is the indicator function: $I\{x_{it} \le x\} = \begin{cases} 1, & \text{ja } x_{it} \le x, \\ 0, & \text{ja } x_{it} > x \end{cases}$ of the event $\{x_{it} \le x\}$.

$$w_{it} = CDF(X_{it})/\sum_j CDF(X_{jt}).$$ [3].

In addition, a simpler version of the FSI can also be calculated as the arithmetic average of the transformed variables. For the sake of comparison, percentile-based FSIs were standardised. The results are featured in Chart 4 along with the FSI aggregated with variance-equal weights.

Looking at Chart 4, it is evident that the movements of the percentile-based FSI values are overall quite consistent with the stress levels resulting from the application of the first approach (aggregation with variance-equal weights). Despite the advantages of this transformation method (less revisions when updating the FSI calculation with new data), it is not deprived of certain drawbacks. Contrary to simple standardisation, transformation which is based on empirical cumulative distribution functions distorts the geometrical structure of the time series by artificially amplifying amplitude of small fluctuations of the variables. In fact, a large transformed value suggests that the value of the variable was extreme, yet failing to reveal the extent of this extremity (more detail about this problem has been provided in Appendix 2 based on an example of 3-month RIGIBOR and EURIBOR spreads).

Chart 4
FSI based on percentiles of variables as compared with FSI aggregated using equal variance (Q1 1998–Q3 2012; in standard deviations)

— FSI based on the sum of percentiles of variables
— FSI aggregated with equal variance
— FSI based on percentiles of variables with chained weights
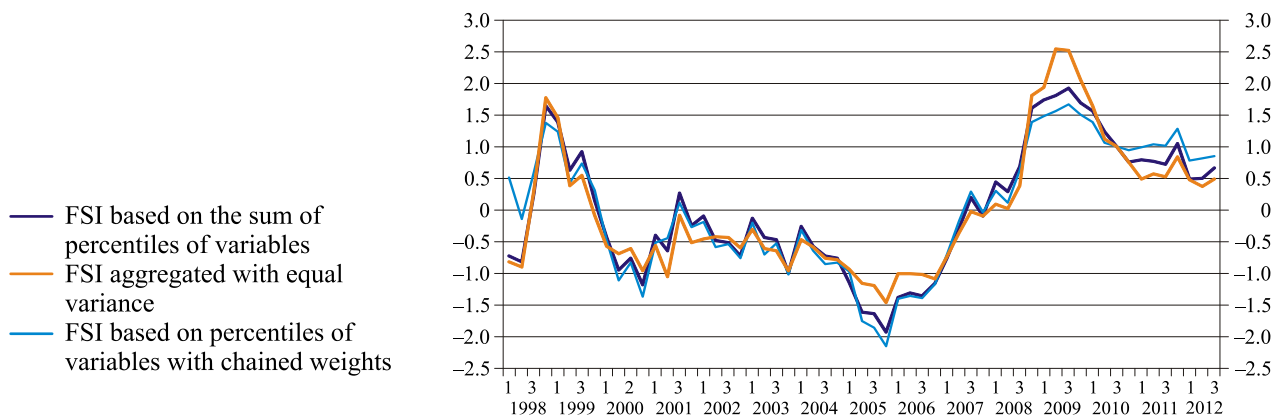
Sources: Bank of Latvia, FCMC and the authors' calculations.

3.3 FSI calculation and interpretation of values

All the explored versions of the FSI (see Section 3.2) are highly correlated, which suggests that the results are resistant to the selection of the weights and the type of standardisation. Nevertheless, the indices which were obtained by aggregating the components on the basis of principle component weights and equal variance yielded a more accurate assessment of the stress levels in comparison with the percentile-based index. Considering that the interpretation of the contributions of individual components is simpler in the case of the index computed by aggregating the data with equal weights, hereinafter specifically this version will be explored.

Prior to standardisation, all balance sheet indicators of credit institutions included in the FSI (see Table 1), with the exception of ROA, were expressed in logarithms and differenced. The transformed and remaining variables were standardised and added

up using equal weights on the basis of a formula [1]. The resulting index was also standardised in order to express it in terms of standard deviations from the mean. The index was estimated on a quarterly basis.

The following factors have to be considered when interpreting the resulting FSI values. The further the values of the observed variables deviate from their historical averages, the higher or lower the level of stress in the financial system (and, consequently, the FSI value). Positive index values signal a stress level which is higher than its historical average (equal to 0). The more intensive the heightened stress symptoms, the higher the value of the stress index. Conversely, negative index values represent periods when the stress is below the historical average. Periods in which an index value is persistently significantly below 0 may be interpreted as periods when imbalances are building up in the economy. This, in turn, could suggest a higher probability that the stress level would increase significantly in the periods to follow.

4. LATVIAN FSI: RESULTS

Chart 5 reflects the dynamics of the Latvian FSI from 1998 to the third quarter of 2012.

Chart 5
Latvian FSI (Q1 1998–Q3 2012; in standard deviations)
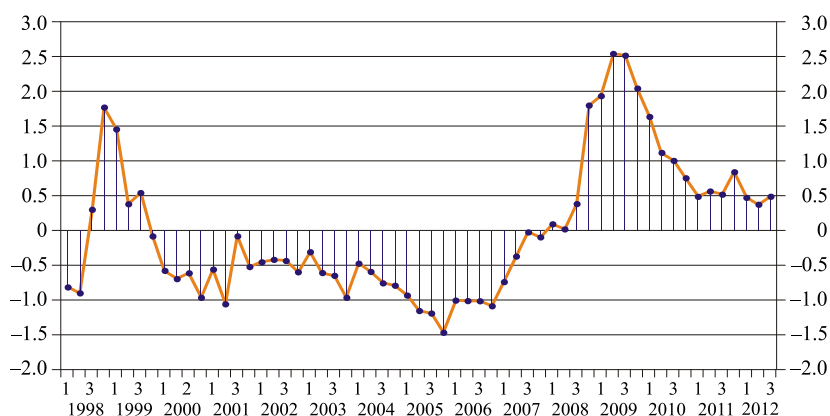
Sources: Bank of Latvia, FCMC and authors' calculations.

The FSI values point to two episodes when the stress was considerably higher than the historical average (over one standard deviation): from the fourth quarter of 1998 to the first quarter of 1999 and from the fourth quarter of 2008 to the third quarter of 2010.

The episode of heightened stress in Latvia's financial system at the end of 1998 and beginning of 1999 was primarily determined by the shocks associated with the impact of the Russian financial crisis 1998 on Latvia's credit institutions. Credit institutions suffered considerable losses from their investments in securities. Uncertainty, loss expectations and higher risk aversion on the part of financial market participants also resulted from a general short-lived economic downturn.

The period from 2004 to 2007 was characterised by buoyant development of the Latvian economy and the credit institution sector: strong investment inflows, lending
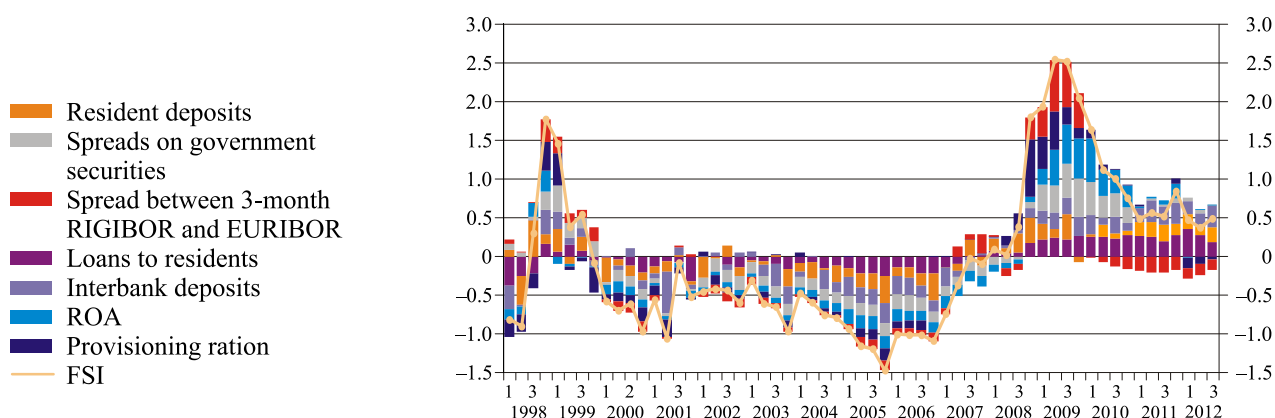
boom and a very high share of the non-performing loans in the loan portfolios of credit institutions. Therefore, the FSI value during this period was lower than the long-term average. In 2005 and 2006, the FSI value was below or close to one standard deviation. This period can be considered as a period of excessive optimism of the financial market participants and very low risk perception.

The period of imbalanced development of the macroeconomic environment ended with a significant increase in the stress level against the background of a deep economic crisis. In 2007, the stress level receded to the long-term average quite quickly, followed by a steep leap in the second half of 2008. The FSI value went above one standard deviation, pointing to the onset of a heightened stress episode, primarily as a result of weakening economic activity, credit squeeze, deposit outflows and growing tensions in the financial market. With the collapse of *Lehmann Brothers* and the subsequent liquidity squeeze and deterioration of the external economic environment, as well as with the uncertainty about the domestic economic outlook growing at the end of the year following the take-over of the JSC *Parex banka*, the financial stress level rose dramatically, reaching an all-time high in the second and third quarters of 2009.

The largest contributors to the outburst of financial stress during this period were the sharp rise in the loan-loss provisions and the related losses as well as in the spreads between the 3-month RIGIBOR and EURIBOR, and the contraction of the credit institutions' loan portfolio (see Chart 6).

Chart 6
FSI decomposition (Q1 1998–Q3 2012; in standard deviations)

Resident deposits
Spreads on government securities
Spread between 3-month RIGIBOR and EURIBOR
Loans to residents
Interbank deposits
ROA
Provisioning ration
FSI

Sources: Bank of Latvia, FCMC and authors' calculations.

The FSI dynamics since the second half of 2009 point to a gradual decline in the level of stress. It can be concluded that the situation is stabilising: part of the variables characterising the financial sector stress have returned to levels close to their long-term averages; a heightened level of stress, however, is still signalled by the high provisioning ratio, significant losses of the credit institution sector and the persistent shrinking of the loan portfolio.

In 2010, the value of the Latvian FSI dropped and fluctuated below one standard deviation thereafter. This suggests that the level of financial stress remained above the long-term average, although it was significantly lower than during the peak of the crisis.

The performance indicators of credit institutions stabilised in 2011 and it was no longer necessary to build large provisions. This, in turn, had a positive effect on profitability (except in the fourth quarter). Once the confidence in the market was restored, the spreads on the government debt securities also declined considerably. Nevertheless, there were also some factors preventing a further decline in the stress levels (see Chart 6). Credit institutions continued deleveraging, as suggested by the shrinking of the loan portfolio and debt repayments to parent banks. The profitability of the credit institution sector deteriorated at the turn of 2011 due to the JSC *Latvijas Krājbanka* losses, which also found a reflection in the increase of the FSI value. Nevertheless, the developments in the JSC *Latvijas Krājbanka* did not have a systemic impact on the credit institution sector (this is also confirmed by the FSI value in the fourth quarter: 0.84 which is below one standard deviation of the FSI). No significant changes in the FSI dynamics were observed during the first three quarters of 2012.

CONCLUSIONS

The present Discussion Paper describes the methodology for constructing the Latvian FSI, based on the analysis of the experience of various countries and the methodological features of composite indicators widely applied internationally in the field of financial stability monitoring. The Discussion Paper also provides a detailed overview of the concept of financial stress and the associated symptoms.

The FSI is useful as a measure reflecting the overall assessment of the condition of a financial system: various economic and financial market indicators often point to opposite tendencies, while an FSI can combine the trends of many factors into a single easy-to-interpret and comparable measure of the condition of the financial system. Thus the FSI can be considered a valuable addition to the set of analytical tools for macroprudential supervision.

The Bank of Latvia has been using the Latvian FSI developed by its experts as one of the elements of Latvia's financial system stability monitoring framework since 2010 (see (*Latvijas Banka* (2010); *Latvijas Banka* (2011); *Latvijas Banka* (2012)).

Latvian FSI aggregates various indicators of credit institution balance sheets as well as indicators characterising the money and securities markets whose developments reflect the major financial stress symptoms. The dynamics of the Latvian FSI, with a relatively high degree of accuracy, mirror the stress level changes in Latvia's financial system, enabling to identify episodes of heightened stress as well as episodes of an excessively rapid and imbalanced development of the financial system. This, in turn, provides an opportunity to develop an early warning system for Latvia's financial system stability by further elaborating the FSI forecasting model.

APPENDICES

Appendix 1. The comparison of the FSIs estimated based on the methodologies of *Česká národní banka* and the Bank of Latvia

In order to compare the FSI construction and estimation methodologies offered by the Bank of Latvia and *Česká národní banka*, two additional versions for the Latvian FSI were calculated on the basis of the financial stress indicators and calculation methodologies proposed by *Česká národní banka* (see Table P1 for a list of *Česká národní banka* indicators; see (Geršl, Heřmánek (2006)) for a description of *Česká národní banka* methodology).

Table P1
Variables aggregated in the Latvian FSI according to *Česká národní banka* methodology

Category	*Česká národní banka* variables	Impact	Variables aggregated in the Latvian FSI	*Česká národní banka* expert weights	Transformation
Capital adequacy	CAR (%)	+	identical	0.05	standardisation
Asset quality	Non-performing loans/total loans (%)	–	identical	0.25	standardisation
Profitability	ROA (%)	+	identical	0.25	mean of standardised values
	ROE (%)		identical		mean of standardised values
Liquidity	Quick assets/assets (%)	+	an adjusted quick asset definition was used	0.25	mean of standardised values
	Quick assets/client deposits (%)		an adjusted quick asset definition was used		mean of standardised values
Interest rate risk	Cumulative net balance sheet position to 3 months/assets (%)	+	identical	0.1	standardisation
FX risk	Absolute value of open balance sheet position in foreign exchange/Tier 1 capital (%)	–	excluded	0.1	
	Absolute value of open total position in foreign exchange/Tier 1 capital (%)		identical		standardisation

Source: Table designed by the authors based on (Geršl, Heřmánek (2006)).

When estimating the Latvian FSI, the set of variables used by *Česká národní banka* was adjusted depending on the availability of the statistical data required for the estimates at the time of writing the Paper. For this reason, one of the two variables of *Česká národní banka* characterising foreign exchange risk, absolute value of open balance sheet position in foreign exchange to Tier 1 capital, was excluded from the calculation. Only the absolute value of open total (balance sheet and off-balance sheet) position in foreign exchange to Tier 1 capital was used.

As regards the two liquidity ratios, an adjusted definition of quick assets characterising the liquidity risk[9] was employed. Quick assets were estimated as the total of the following liquid assets:

- vault cash of credit institutions;
- demand deposits of credit institutions with the Bank of Latvia, except minimum reserves;
- banks' demand claims on credit institutions and claims on credit institutions with residual maturity of up to 7 days;
- debt securities of the central governments of the Republic of Latvia and Zone A countries.

Other indicators used in the calculation of Latvia's FSI were identical to those used by *Česká národní banka.*

Since 2008, data on cumulative net balance sheet position of interest rate risk of credit institutions are only available at a semi-annual frequency. Therefore, interpolation was used to estimate the values of this indicator for the first and third quarter of the following year.

Due to problems with the availability of data about the whole reference period required for the calculation of some of the above indicators at the time of writing this Paper (see Section 3.1), a shorter period (from the first quarter of 2005 to the second quarter of 2012) was chosen for the estimation of the Latvian FSI based on *Česká národní banka* methodology.

To make the Latvian FSI calculated based on *Česká národní banka* methodology comparable with the one estimated in accordance with the Bank of Latvia's methodology, the values of variables marked by a "–" sign in the column "Impact" of Table P1 were multiplied by a coefficient (–1) prior to aggregation, so that a positive value of those variables would correspond to a heightened stress period.

Two types of the Latvian FSI were estimated in terms of the weights applied (see Chart P1): based on *Česká národní banka* weights provided in Table P1 (marked as *Česká národní banka* FSI in the Chart) and based on equal weights (marked as *Česká národní banka* FSI with equal weights in the Chart). For the sake of comparison, Chart P1 features also the FSI estimated based on the Bank of Latvia's methodology (marked as Bank of Latvia's FSI in the Chart) for the reference period (i.e. excluding the data on the period from the beginning of 1998 to the end of 2004).

Looking at the dynamics of the Latvian FSI estimated using *Česká národní banka* methodology, it can be concluded that both types (marked as *Česká národní banka* FSI and *Česká národní banka* FSI with equal weights) allow to identify the episode of growing financial stress from the end of 2008 to the beginning of 2010. However, a significant increase in the index value was only observed in the first quarter of 2009 and it remained at a relatively high level for four consecutive quarters only. Moreover, within the given reference period, only one index which was based on *Česká národní banka* weights (*Česká národní banka* FSI) exceeded one standard deviation which could be considered as a signal of the onset of a crisis. Equal-weights-based index (*Česká národní banka* FSI with equal weights), however, did

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[9] The definition of quick assets applied by Česká národní banka is available at: http://www.cnb.cz/en/general/glossary/q.html [cited 1 November 2012].

not exceed the threshold of one standard deviation during the crisis episode. Already in the second quarter of 2010, its value rapidly converged with the historical average of stress and remained below that level in the periods to follow. A mechanical interpretation of such dynamics of the index could lead to a rather dubious conclusion that the level of financial stress observed in Latvia during the last two years was even below that of the pre-crisis period. However, as 2011 should be considered the start of the recovery period from a severe crisis for Latvia's credit institution sector, this can hardly be characterised as a period of particularly low stress.

Chart P1
Comparison of the FSIs estimated based on *Česká národní banka* and the Bank of Latvia methodologies (Q4 2004–Q2 2012; in standard deviations)

Česká národní banka FSI
Česká národní banka FSI with equal weights
Bank of Latvia's FSI
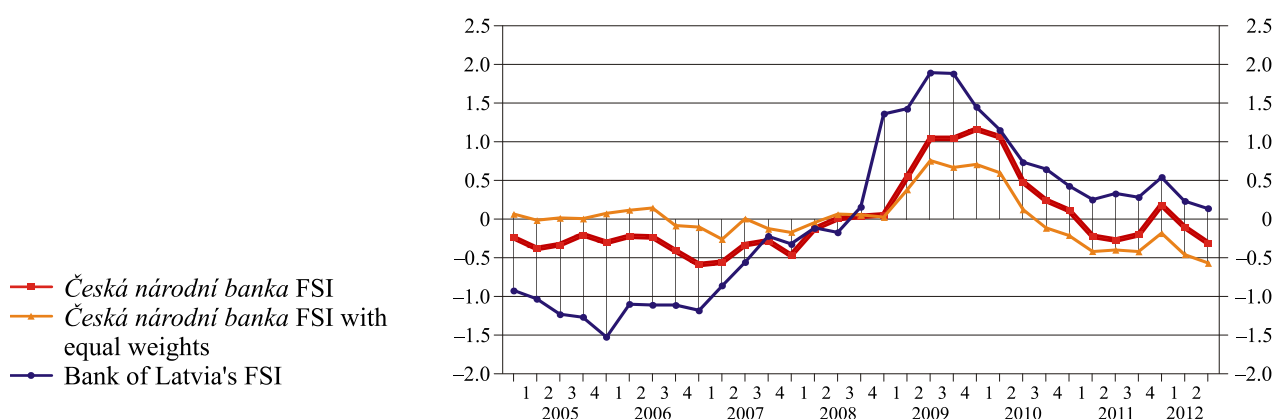
Sources: Bank of Latvia, FCMC and authors' calculations.

The development path of the index estimated based on the weights used by *Česká národní banka* experts (*Česká národní banka* FSI) also suggests that the stress remained below the historical average. Among other factors, it is determined by the specific behaviour of the CAR and the liquidity ratio depending on the particular stage of the business cycle (see more detail in Section 2).

Looking at the pre-crisis period, it has to be noted that the values of both *Česká národní banka* FSIs are below or close to the historical average. Overall, it is obvious that the movements of the index estimated based on *Česká národní banka* methodology do not signal the periods of the build-up of imbalances in the economy. Such a peculiarity is primarily determined by the specifics of the indicators selected for the index calculations, as they mainly characterise financial stability risks and are only partly capable of reflecting any build-up of imbalances in the economy associated with, for example, a lending boom or an excessive risk appetite. Looking from this aspect, the index calculated on the basis of the Bank of Latvia's methodology (marked as Bank of Latvia's FSI in the Chart) can be considered the most appropriate tool for accurate identification of such periods (see Chart P1).

As concerns the period of crisis, the Bank of Latvia's FSI again outperforms that of *Česká národní banka* in pointing out the period of heightened stress. The Bank of Latvia's FSI value increased sharply and exceeded the threshold of one standard deviation already in the fourth quarter of 2008: thus it reflects more accurately the growing tensions on the domestic financial market associated with the collapse of *Lehmann Brothers* and take-over of the JSC *Parex banka*. The Bank of Latvia's FSI value remains above one standard deviation threshold longer than that of *Česká*

národní banka (six consecutive quarters as opposed to four) and fluctuates above the historical average also afterwards. The value of *Česká národní banka* FSI for 2012 suggests that the stress in Latvia's financial market has fallen to the level of 2007, which, at least from a subjective point of view, could hardly reflect the real market situation.

The main advantages of the Bank of Latvia's FSI lie in its composition: the variables contained therein are better suited for assessment of the financial stress level in Latvia's circumstances in comparison with the indicators used in the calculation of *Česká národní banka* FSI. Another advantage is also the relatively low sensitivity of the Bank of Latvia's FSI to the component weights (see Section 3.2), which according to the authors of the present Discussion Paper is a proof of its robustness. The sensitivity of *Česká národní banka* FSI to the applied component weights, in turn, is higher (see the differences between *Česká národní banka* FSI and *Česká národní banka* FSI with equal weights in Chart P1). Thus, for example (as already mentioned in Section 2), due to the specific nature of the cyclical movements of the CAR, *Česká národní banka* experts have assigned the lowest weight to this component, thereby limiting the impact of the CAR on *Česká národní banka* FSI dynamics.

Overall, considering the differences in the composition of the variables aggregated in the Bank of Latvia's FSI and that of *Česká národní banka* and the differences in the selection of weights, the authors of the present Discussion Paper conclude that the Bank of Latvia's FSI is more appropriate for the use in Latvia's circumstances as it provides a better mirror of the stress level changes in Latvia's financial system.

Appendix 2. Example of an FSI constructed by transforming the variables based on empirical cumulative distribution functions

In order to illustrate the problems encountered when transforming the variables based on empirical cumulative distribution functions, let's look at the development of the spreads between 3-month RIGIBOR and EURIBOR. The standardised time series together with the percentiles time series based on the empirical cumulative distribution function are provided in Chart P2. The transformation based on the empirical cumulative distribution function "amplifies" the amplitude of small fluctuations, which results in almost identical transformed indicator values for 2007, 2009 and 2010, although, in fact, the spreads between the 3-month RIGIBOR and EURIBOR observed in 2009 and 2010 were twice as large as in 2007. These peculiarities of the observed transformation impair the comparability of the level of stress of different periods and are, therefore, considered undesirable by the authors of this Paper.

Chart P2
Comparison of a standardised time series of 3-month RIGIBOR and EURIBOR spread with a percentiles time series of the empirical cumulative distribution function
(Q1 1998–Q3 2012; in standard deviations)

Standardised time series
Percentiles time series of the empirical cumulative distribution function
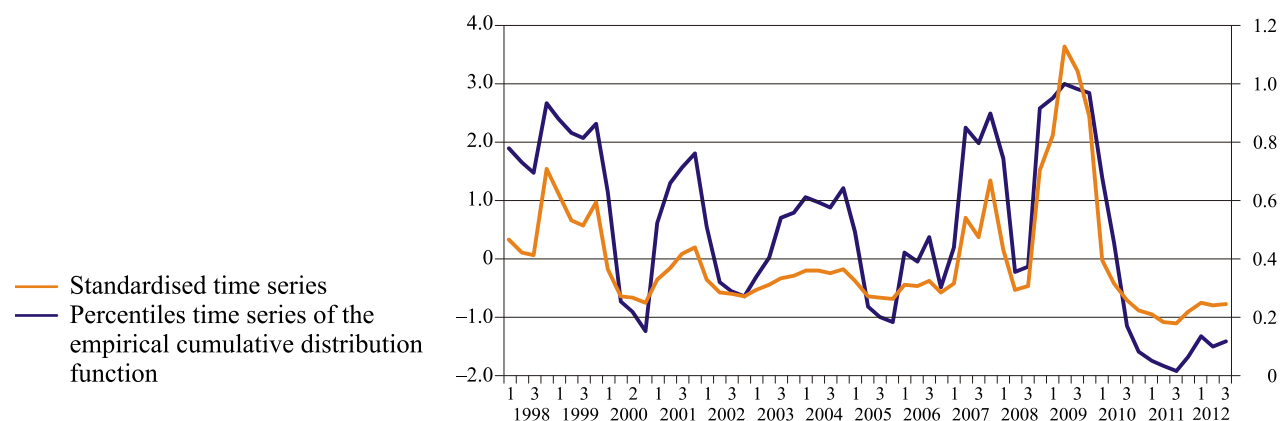
Sources: Bank of Latvia, FCMC and authors' calculations.

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