Financial stress indicators for small, open, highly euroized countries: the case of Croatia

MIRNA DUMIČIĆ, MSc*

Review article**
JEL: E44, E50, G10
doi: 10.3326/fintp.39.2.3

* Special thanks go to Ana-Maria Čeh and two anonymous referees for exceptionally useful suggestions and comments. The views stated in this work are the viewpoints of the author and do not necessarily express the stance of the Croatian National Bank.
** Received: June 1, 2014
Accepted: February 10, 2015

The article was submitted for the 2014 annual award of the Prof. Dr. Marijan Hanžeković Prize.

Mirna DUMIČIĆ
Croatian National Bank, Trg hrvatskih velikana 3, 10000 Zagreb, Croatia
e-mail: mirna.dumicic@hnb.hr

FINANCIAL THEORY AND PRACTICE
39 (2) 171-203 (2015)

Abstract

The main objective of this paper is to construct high-frequency composite indicators of financial stress for Croatia that will enable the monitoring of the total level of financial stress and its components on the domestic financial market. Emphasis is put on the choice of variables appropriate for small, open, highly euroized economies characterised by bank-centric financial systems dominantly owned by foreign banks, shallow financial markets and dependence on foreign capital.

Keywords: financial stress, financial stability, financial markets, systemic risk, composite index, Croatia

1 INTRODUCTION

Many research papers refer to the strong and negative relation between stress episodes on the financial markets and financial and macroeconomic stability, and emphasize their adverse impact on overall economic activity (Hubrich and Tetlow, 2012; Kliesen et al., 2012). In developing an analytical framework for monitoring financial markets, the objective is to encompass all of the most important stress sources that might cause the materialization of systemic risks. For this purpose, individual indicators could be used. Nevertheless, in order to reduce the volume of data from financial markets, while obtaining information about the total level of stress in the financial system, these indicators are often aggregated into composite indices. The stronger the initial shock, the higher the correlation among the different segments of the financial system. This makes the use of aggregated data, reflecting developments in various segments of the financial system, the starting point for an analysis of financial stress and systemic risk (Kota and Saqe, 2013).

The main goal of this paper is to construct high-frequency financial stress indicators for Croatia, which will enable the monitoring of the level of overall financial stress in the domestic financial system, as well as in particular segments of the financial market, and which will provide timely indication of possible stress episodes and systemic risks materialization. In addition to the analysis of stress periods, there is an emphasis on the importance of information that indices can provide in tranquil periods on the financial markets.

In a review paper about the measurement of financial stress, Kliesen et al. (2012) show that most of the composite financial stress indicators are constructed for highly developed financial markets with diversified financial instruments and numerous financial indicators. However, by adjusting the set of variables included in the index, they can also be useful for the analysis of developments in less developed financial systems. The main focus of this paper is thus not on development of a methodology for computing composite indices, but on the identification of variables that reflect financial stress in small, open, highly-euroized economies, characterized by bank-centric financial systems dominated by foreign banks, shal-

low financial markets and dependence on foreign capital because of het shortfall in domestic savings. Apart from that, the focus is on the transmission mechanism of financial market shocks to these countries. Particular attention is directed to cases in which the main transmission channel of monetary policy is the exchange rate, and in which there is no classical reference interest rate. In such situations, the domestic money market is not necessarily a relevant source of bank funding, and the interest rates in this market segment have a negligible impact on the borrowing costs for domestic sectors as they depend on trends in world financial markets and levels of risk premiums for the country and the parent banks of domestic banks. Therefore, the analysis of variables that reflect financial stress in a small open economy is the most important contribution of this paper. Its practical contribution inheres in the potential use of the FSIs for economic policy makers and financial market participants.

The paper is divided into five main parts. After an introduction there is a detailed explanation of the theoretical concept of financial stress, and the specific features of stress episodes are described, together with the channels through which they can influence financial and macroeconomic instability from the perspective of a small, open and highly euroized economy. The third section presents the problems involved in constructing FSIs, and a review of the methods of aggregating individual indicators into a composite index is given. Part four explains the variables assessed as being appropriate for the construction of the FSIs for Croatia, considering the characteristics of the financial system, and the country's economic and monetary characteristics. In order to check the robustness of the results, the indices are calculated by three methods. The main trends in financial stress in the period from early 2001 to the end of 2013 are also described, as well as the stress episodes identified by the Markov switching model. The final part briefly summarizes the main results and contributions of this paper.

2 FINANCIAL STRESS AND THE CHANNELS THROUGH WHICH IT AFFECTS FINANCIAL AND MACROECONOMIC STABILITY

There is no universally accepted definition of financial stress. Dufrénot et al. (2011) describe it as a situation in which there is an enhanced probability of turbulence in the financial markets accompanied with a currency or balance of payments crisis, a sudden stop in capital inflows or capital outflows, stock market crashes or the inability of a government to meet its liabilities. Holló (2012) considers financial stress as disturbances in the financial system that unexpectedly affect the price and turnover of financial instruments, which can be accompanied by the collapse of systemically important financial institutions and the inability of the financial system to carry out its main role and allocate financial resources, resulting in a considerable economic slowdown. It can be concluded that financial stress implies disturbances in the normal functioning of financial markets and in the process of financial intermediation that can spill over onto the real sector (Hakkio and Keeton, 2009; Balakrishnan et al., 2009).

Although all stress episodes have their own specific features, Sinenko et al. (2012) accentuate their common attributes, such as increased uncertainty related to the value of financial assets and to the expectations of future economic developments, high expected financial losses, increased risk aversion and the general tendency of investors to keep less risky and more liquid financial assets. All of this increases the instability and volatility of prices on financial markets and results in rising risk premiums. Therefore, apart from the level, as a measure of financial stress the volatility of given variables is also often used.

Financial stress is an inherent characteristic of a financial system. However, even when it is not high, such information should not be neglected. Sinenko et al. (2012) emphasize that prolonged periods of relatively low financial stress compared to the long-term average have often been accompanied by an exaggerated optimism on the part of market participants. This has resulted in excessive credit activity, a rise in the prices of different asset classes and the accumulation of macroeconomic imbalances due to increased current account deficits and external debt. All of this has increased risks to financial stability. If disturbances indicated by high-frequency indicators endure, there is a great probability that they will shortly affect low-frequency indicators through financial or trade channels.

Increased instability on financial markets usually results in higher risk aversion, causing a rise in risk premiums and in the financing costs of domestic sectors. If combined with reduced liquidity or even completely frozen financial markets, this may result in the strong slowdown of capital flows. The research has shown that emerging markets are more affected by this than developed countries because of their increased vulnerability to potential sudden changes in capital flows (Catao, 2006).

Financial institutions' interlinkages are also an important source of financial stress. In most European countries banks are the most important financial intermediaries, and their exposure to financial stress can result in high macroeconomic costs (Schou-Zibell et al., 2010). Because of their role, problems induced by the financial stresses that they have can rapidly spill over to other segments of the financial system, such as the interbank money market or the payments system. The links among financial institutions in the money market present potential channels for the rapid spillover of risks and difficulties among financial institutions in a short period. The speed of this process is proportional to the level of uncertainty and information asymmetry.

An enhanced level of uncertainty related to financial stress can reduce the banks' willingness to make loans. This motivates them to tighten their lending standards, which reduces the demand for loans as borrowers might postpone or give up on investments (Hubrich and Tetlow, 2011). In less developed financial systems the role of bank loans in the financing of the economy is usually higher than in devel-

oped countries, in which the securities market is a noteworthy source of funding. This makes the influence of financial stress on loan conditions and the loan supply via this channel much more important for developing countries.

In dominantly foreign owned banking systems, the parent banks of domestic banks represent an important transmission channel of financial stress from international to domestic financial markets. Parent banks' problems measured in their increased risk premium affect not only the funding costs for their subsidiaries, but also their strategy related to the operations of the subsidiary banks. This can strongly influence credit activity and real economic developments in the countries where they have large exposures. Balakrishnan et al. (2009) confirm that the most pronounced channel for the transmission of financial stress to European emerging markets during the recent crisis was through the western European banks.

In highly euroized countries, one of the most important channels for possible spillovers of financial stress onto financial and macroeconomic indicators is the exchange rate. In such cases a significant part of the economy is exposed to a currency-induced credit risk deriving from the currency mismatches in debtors' assets and liabilities. If a strong depreciation of the domestic currency occurs, there is an increased likelihood of a considerable deterioration of the loan quality. In these countries, the main monetary policy transmission channel usually is not the interest rate, but the exchange rate. Therefore, the information contained in movements in domestic interest rates differs from those on developed markets, in which the interest rate transmission channel is functioning. In addition to that, in some banking systems that are dominantly foreign owned and that are reliant on parent bank funding, domestic money market interest rates can have an almost negligible impact on the cost of domestic sector borrowing. This cost primarily depends on the perception of the country risk and parent banks' risks, as well as on the liquidity of international financial markets.

3 THE CONSTRUCTION OF A COMPOSITE INDEX

Specific features of small open economies with shallow financial markets and lack of indicators used for the calculations of FSIs for developed countries imply a great challenge in the choice of variables reflecting financial stress. According to the literature, the most important potential sources of stress are the credit market, foreign exchange market, inter-bank money market and capital market (Oet et al., 2011; Jakubik and Slačik, 2013). In addition to domestic data, due to the increased liberalization of financial flows and the fact that in most countries movements on the domestic financial market are heavily dependent on international developments, data from foreign financial markets are also used. But, even if the created indicators cover at a given moment all important potential sources of financial stress, it is necessary continuously to re-examine the appropriateness of the set of selected variables and to adjust it to the development of and trends in the financial system. Therefore, FSIs calculated for different countries are not always directly

comparable, but they can provide useful information about the financial stress dynamics in different markets. Kliesen et al. (2012) present a detailed review of indicators and methods used for the construction of FSIs, while Jakubik and Slačik (2013) provide a useful example of the construction of financial instability indices for CEE countries, including Croatia.

In the literature about early warning systems, use is often made of binary methods, in which tranquil periods are marked with a zero and a crisis period with a one. But in the construction of the FSIs, the objective is to create a continuous measure that will show the level and the development of financial stress (Balakrishnan et al., 2011). Financial markets' conditions are never either absolutely good or absolutely bad, as might be concluded according to binary indicators, and they should be observed relatively over a period of time (Oet et al., 2011). Therefore, Illing and Liu (2006) observe financial stress through a continuous variable, where extreme values mark a crisis episode. Such an approach emphasizes the index dynamics, rather than precise definitions of the beginning or end of a crisis episode.

Commonly used methods for aggregating individual indicators into a composite index include aggregation via variance-equal weights, principal component analysis, aggregation with the use of variance-equal or chained weights of variables transformed with the use of the empirical cumulative distribution function and aggregation in which the shares of given markets in the total financing of the economy are used as weights (Jakubik and Slačik, 2013; Illing and Liu, 2003; Sinenko et al., 2012; Puddu, 2008; Holló, 2012).

Although similar results are obtained irrespective of the method used, each one of them has certain drawbacks. The shortcoming of variance-equal weights aggregation derives from the initial assumption that all the variables included in the index are equally important. In this manner, greater importance is given to those market segments represented in the index with more variables (Puddu, 2008). On the other hand, weighting based on a single component in factor analysis results in a fixed set of weights for the whole analysed period (Oet et al., 2011). In the transformation of variables with the cumulative distribution function the assumption is that the gap between neighbouring variables is equal, which is usually not the case, because during long stable periods the relatively small volatility of the original variables can seem greater after transformation than it actually is (OeNB, 2013). At the same time, the weights determined by all of these three methods have no economic significance, unlike the method where shares of individual markets in total loans in the economy calculated by aggregating bank loans, corporate and government bonds and shares are used as weights (Illing and Liu, 2003). The potential use of the latter approach is relatively limited in less developed countries. Hence, for calculating the FSIs for Croatia the first three methods are used. Calculation of the FSIs with various methods is the first test of the robustness of the results.

3.1 WEIGHTING BASED ON VARIANCE-EQUAL WEIGHTS (FSI_VEW)

Weighting based on variance-equal weights is the most often used method for the calculation of composite indices (Kliesen et al., 2012). It implies the aggregation of standardized variables into a single index, in which every variable has an equal weight:

$$FSI\_vew_t = \sum_{i=1}^{k} \frac{X_{i,t} - \overline{X_i}}{\sigma_i} * \frac{1}{k}, \quad (1)$$

in which k is the number of variables included in the index, $\overline{X_i}$ is the sample arithmetic mean for the variable X_i and σ_i is the sample standard deviation for the variable X_i.

3.2 AGGREGATION OF VARIABLES TRANSFORMED BY THE CUMULATIVE DISTRIBUTION FUNCTION (FSI_CDF)

Every variable included in the index is initially transformed with the use of the cumulative distribution function. The greatest value of a given variable has the highest rank and indicates the greatest degree of financial stress, while rank one refers to the lowest recorded value of the indicator (Oet, 2011). Values around the median correspond to the average level of stress. After the rank of every observation within the time series has been determined, the empirical cumulative distribution function is calculated as:

$$CDF(X_{it}) = \frac{rank(X_{it})}{\text{total number of daily observations}}. \quad (2)$$

In this manner every observation is turned into the corresponding percentile of the cumulative distribution function and takes a value between 0 and 1. Following Sinenko et al. (2012), for the aggregation of transformed variables in the index, weights for every variable are determined as a share of the transformed variable in the sum of total transformed variables:

$$w_{it} = \frac{CDF(X_{it})}{\sum_j CDF(X_{jt})} \quad (3)$$

and the total index is obtained as:

$$FSI\_cdf_t = \sum_i w_{it} CDF(X_{it}). \quad (4)$$

3.3 PRINCIPAL COMPONENT ANALYSIS (FSI_PCA)

In practice, this method is used for easier interpretation of a large number of variables which are transformed into a smaller number of uncorrelated variables or principal components (Anh and Mägi, 2009). This technique reveals the main drivers behind data variation and the interlinkages between variables that are not necessarily obvious. The correlations of the variables in the groups identified are greater within the groups than among the groups. FSIs are determined as the first principal component that explains the greatest part of the joint movement of the variables used for the construction of the index:

$$FSI\_pca_t = x_t \alpha \quad (5)$$

in which α is the weight vector (of the dimension *number of individual variables* x 1) and x_t is the vector of the values of the indicator (of the dimension *number of individual variables* x 1) on the basis of which the indices are evaluated. The loadings determine the variables that have the greatest contribution to the explanation of the joint movement of all the components of the aggregated index (table A1).

4 FINANCIAL STRESS INDEX FOR CROATIA

In choosing variables for FSI construction, the objective was to take into consideration as many as possible of the relevant segments of the domestic and foreign financial systems that might affect the level of financial stress in Croatia. Focus has been put on the specific features of the domestic financial markets, the availability of high frequency data, the economic and monetary characteristics of the country and relevant developments in foreign financial markets that might affect the stability of the domestic financial system. Daily data from 30 January 2001 to 18 December 2013 were used and risks were divided according to the stress origin – domestic or foreign, and also according to market segments (table 1). Apart from such a division, the main difference compared to the financial instability indices constructed by Jakubik and Slačik (2013) is that these FSIs include more variables for each market segment, as well as additional market signals and sources of risks such as risks related to the mother banks, bid-ask spreads and country risk premiums.

Due to the high degree of euroization and the fact that in Croatia the main transmission mechanism of monetary policy is the exchange rate, several variables that reflect developments on the domestic foreign exchange market were used. Regardless of the direction in which the exchange rate moves, the increased EUR/HRK bid-ask spread and its volatility indicate higher instability and uncertainty related to the behaviour of market participants and signals an increased stress level. The forward exchange rate is an indicator of market expectations about future movements in the EUR/HRK exchange rate. Since this figure is not available for every day, particularly in the initial part of the observed period, the five-day moving average of this variable is used instead.

The index also includes the level of the weighted exchange rate of the kuna to the euro, the Swiss franc and the US dollar. Although the EUR/HRK exchange rate is the most important for the Croatian economy as the external debt and most of the loans of domestic banks are in euros or indexed to the euro, Swiss franc movements have become an important potential source of stress because of the strong credit activity in this currency from 2005 to 2008. In this way the impact of the CHF/HRK exchange rate has also been covered. At the end of 2008, Swiss franc loans accounted for 16% of total loans, or 24% of all loans denominated in or indexed to a foreign currency (CNB, 2012).

In spite of the importance of the exchange rate for financial stability and notwithstanding the fact there is no typical reference interest rate on the domestic money

market, which is also not a primary funding source for domestic banks, interest rate movements and their volatility can nevertheless indicate the (in)stability of the overall financial market. The dynamics and level of short-term interest rates in the observed period were primarily determined by the surpluses or deficits of banks' kuna liquidity. Apart from the banks' operations, the liquidity of the system depended on the CNB's activities, which, when necessary, maintained the exchange rate stability by restricting kuna liquidity.

There are several overnight interest rates on domestic money market: the overnight interest rate in interbank trading, the interest rate on the Zagreb Money Market (ZMM) and Zagreb Interbank Interest Rate (ZIBOR). For calculating the FSI, the interbank interest rates have been used for the period from September 2002, while for the previous period the ZMM interest rates are used. The coefficient of correlation for these two series in the coinciding period exceeds 0.9, confirming this is a reliable time series for the price of overnight borrowing. The advantage of this variable over ZIBOR is that it is at this rate that transactions are really executed, while ZIBOR is based on the banks' quotations which are not obligatory and do not necessarily represent the rate at which transactions are executed. Although ZIBOR largely tracks the movement of the interbank interest rates, it has not been perceived as the reference interest rate, which is confirmed by the CNB bank survey according to which the most important money market interest rate is the interbank interest rate (Ivičić et al., 2008).

The spread between interest rates for short-term and long-term maturities reflects the liquidity risk premium and is often used as an indicator of money market developments. Since trading in maturities longer than a week in the domestic money market is negligible and there are many days when such transactions are not executed at all, it is not a reliable indicator for this market segment. In spite of this and the mentioned limitations of ZIBOR, the FSI includes the spread between the interest rate on the three-month treasury bills of the Ministry of Finance (MF) and the three-month ZIBOR. For ZIBOR there is a daily series of quotations, while the interbank interest rates for a three month maturity are available only when such transactions are executed, which significantly reduces the number of observations. This spread is the most commonly used variable for FSI calculations as it indicates the liquidity of the system by measuring the short-term credit risk and the premium on risk-free government treasury bills (Kliesen et al., 2012; Illing and Lieu, 2006). When money market liquidity is reduced or there is an increased risk that banks are unable to repay their liabilities it is expected to increase (Cardarelli et al., 2009).

Another money market liquidity indicator is the use of Lombard loans. These are overnight collateralized loans available to the banks every day up to the prescribed amount of the nominal value of MoF treasury bills, at an interest rate set by the CNB. They are granted at the bank's request at the end of the working day. An unpaid intraday loan is automatically considered a request for a Lombard loan.

The use of Lombard loans can indicate liquidity problems in individual banks, and can also be used as an indicator of banking sector stability.

TABLE 1

Variables used for the calculation of the FSI divided according to market segments

Financial market segment	Variable	Measure	Source
Domestic markets			
Foreign exchange market	EUR/HRK bid ask spread	Market liquidity, uncertainty, information asymmetry	Bloomberg, author's calculation
	EUR/HRK volatility	Uncertainty, information asymmetry, pressures on exchange rate stability	CNB, author's calculation
	EUR/HRK forward exchange rate	Market expectations, appreciation or depreciation of domestic currency	CNB
	Exchange rate weighted according to commercial banks' asset structure	Depreciation or appreciation of domestic currency	CNB, author's calculation
Money market	Level of O/N interbank interest rates	Liquidity of banking system	CNB
	Volatility of O/N interbank interest rates	Uncertainty, information asymmetry	CNB, author's calculation
	Volatility of turnover on overnight market	Uncertainty, information asymmetry, increased need for liquidity	CNB, author's calculation
	Spread between 3M MoF T-bills and 3M ZIBOR	Market liquidity, credit risk	Bloomberg, MF, author's calculation
	Lombard loans used	Problems with liquidity of some participants of financial markets, indicator of stability of banks	CNB
Securities market	Returns on CROBEX * (–1) and its volatility	Uncertainty and information asymmetry on capital market	ZSE, author's calculation
	CROBIS return volatility	Uncertainty and information asymmetry on bonds market	ZSE, author's calculation
	Croatian kuna – denominated government bond maturing in 2019, bid-ask spread	Measure of market liquidity, reflects liquidity of bonds of a given issuer	Bloomberg, author's calculation
Foreign markets			
Money market	LIBOR – OIS spread	Uncertainty on global money market, risk of interbank loans on money market	Bloomberg, author's calculation
	EONIA volatility	Uncertainty on euro money market, market liquidity	Bloomberg, author's calculation
	EURIBOR 6M and EONIA spread	Liquidity premium	Bloomberg, author's calculation

Financial market segment	Variable	Measure	Source
Foreign markets			
Securities market	EMBI for Croatia	Investor perception about risk of investing in Croatian government bonds, macroeconomic outlook of country	Bloomberg
	CDS of parent banks of domestic banks weighted according to their share in banking sector assets	Stability of operations of parent banks, costs of borrowing, capital withdrawal	Bloomberg, author's calculation
	Difference between bid-ask spreads for Croatian and German government eurobonds (2014)	Liquidity measure, reflects liquidity of securities	Bloomberg, author's calculation
	VDAX	Measure of the expected short-term volatility on the capital market	Bloomberg

It is not very likely that developments in the domestic capital market will significantly influence the overall financial stability, because it is still relatively underdeveloped and is not significant funding source for domestic corporates. Nevertheless, enhanced volatility in the stock prices induced by the instability in other market segments or macroeconomic developments can indicate an increased degree of risk and instability in the financial system. Hence the FSI includes return on Zagreb Stock Exchange index CROBEX and its volatility, since a fall in the prices of shares and their increased volatility can indicate stress in this market segment. Return on CROBEX is calculated as the annual change in the index multiplied by minus one so that a fall in the price of shares indicates an increased financial stress (Balakrishnan et al., 2009).

The domestic debt securities market is characterized by low liquidity where government bonds account for more than 90% of bond market capitalization. CROBIS is a bond price index calculated on the basis of market capitalization calculated at the end of each trading day as average daily price weighted by the quantity for all bonds included in the index and its volatility is included in the FSI. The FSI also includes the bid-ask spread for the kuna-denominated government bond maturing in 2019, which measures the liquidity risk. A low level of this spread characterizes liquid markets with low transaction costs (Holló, 2012).

From the variables representing the foreign financial markets, the index includes data from global money market, share prices and various forms of risk premiums calculated on the basis of data from the bond market, which affect the borrowing costs of domestic sectors. Particularly important for the domestic financial system is the liquidity of the euro money market as it affects the funding costs of parent

FINANCIAL THEORY AND PRACTICE
39 (2) 171-203 (2015)

banks. Developments in this market segment can have both direct and indirect impacts on the availability and price of borrowing for domestic sectors and capital flows. In the extreme case of market illiquidity, when there is a considerable fall in turnover and prices collapse beyond values justified by fundamentals, there is a large probability that domestic sectors' funding will be considerably constrained or even made impossible.

The average daily interest rate on overnight unsecured loans in euros (EONIA) shows the liquidity of the euro interbank market, and partially reflects movements on world financial markets. Its increased volatility suggests an amplified level of instability as well as information asymmetry among market participants. The six-month EURIBOR is among the most often used interest rates, as it represents the basis of the determination of many other interest rates. An increase in the spread between the six-month EURIBOR and EONIA implies an enhanced uncertainty level on the euro interbank market and an increase in liquidity risk premium. Although levels of these rates do affect the borrowing costs of domestic sectors, they are not included in the FSI because their growth is not necessarily linked to an increased stress. They generally closely follow the ECB reference interest rate, which is used to influence all other interest rates and depends on economic activity, inflationary expectations and the developments in the eurozone financial system.

The spread between LIBOR and the overnight index swap (OIS) measures the stress on the international money market. OIS is an interest contract swap that reflects the expected level of the Fed's reference interest rate, as well as the risk and liquidity on the money market. Because of the importance of the money market for the banks' financing, as a measure of risk of interbank lending it also indirectly measures the health of the banking system. An increased LIBOR-OIS spread implies that banks could profit by borrowing from the Fed and lending to other banks, which makes sense only in cases of a more pronounced increase in credit risk.

Because of the importance of the German capital market and the high correlation between Deutsche Boerse AG German Stock Index (DAX) and the CROBEX in the pre-crisis period, the VDAX index is used as variable reflecting movements on the European stock market. This indicator measures expected volatility of prices on the German stock market, and together with the Chicago Board Options Exchange Volatility Index (VIX), which measures the implicit volatility of prices of options on the S&P 500, it is often used as an indicator of risk aversion.

The J. P. Morgan Emerging Market Bond Index (EMBI) reflects the risk on investment in Croatian securities and measures the country's risk premium. It is related not only to global risk appetite, but also to the specific features of the domestic economy. It can be seen as a synthetic macroeconomic indicator as it presents in-

vestor perception of the country's macroeconomic perspective. A rise in this index reflects an increased level of financial stress and leads to a rise in domestic sectors' borrowing costs.

Considering the importance of government borrowing on foreign financial markets, the index also includes the bid-ask spread for Croatian government eurobonds. In order to obtain long time series, the ten-year bond maturing in 2014 was used. The influence of general liquidity risk on global markets is excluded by reducing the bid-ask spread for the German government bond with comparable maturity from this spread for Croatian government bond.

The risk premium for the parent banks of the largest domestic banks also considerably impacts the domestic financing costs. It is calculated by aggregating the CDS premiums for bonds of five parent banks – Unicredit S.p.A., Intesa Sanpaolo S.p.A., Société Generale, Erste Group Bank and Raiffeisen Zentralbank. Weights used were the shares of each individual domestic bank in the total assets of these five banks. This premium directly affects the price of borrowing for parent banks, which in the next step spills over onto the funding price for the subsidiary banks, and in the third step affects the borrowing costs for other domestic sectors through increased lending interest rates. Difficulties in parent bank could also reduce their available sources for financing domestic banks.

4.1 THE MARKOV SWITCHING MODEL

Although this research is primarily focused on FSI dynamics, in order to calculate the contribution of individual market segments to stress episodes and enable a better analysis of monetary policy reactions, their dates are calculated with the use of the Markov switching model. Crisis episodes could have also been defined exogenously, for example, as a period in which the value of the index exceeds a certain number of standard deviations or some boundary value set on the basis of a well informed assessment.

The Markov switching model is suitable if the data dynamics changes through time (Yuan, 2011; Kuan, 2002). This model endogenously finds the boundary values for the determination of a stress episode and divides the sample into periods of enhanced and reduced stress. It also determines the likelihood of a transition from one regime to another (Dufrénot et al., 2011).

It is assumed there are two regimes with different FSI dynamics. In the standard Markov switching model with two states in which y_t is the FSI at the moment t and the arithmetical mean and variance are described by an unobserved state variable $s_t \in \{1,2\}$ runs:

$$y_t = \mu(s_t) + \sigma(s_t)\varepsilon_t \qquad where\ is\ \varepsilon \overset{iid}{\sim} N(0,1) \tag{7}$$

from which it follows that

$$y_t = \begin{cases} \mu_1 + \sigma_1 \varepsilon_t & if \ \ s_t = 1 \\ \mu_2 + \sigma_2 \varepsilon_t & if \ \ s_t = 2, \end{cases}$$

where s_t is the current state of stress on the financial markets, μ_1 and μ_2 are the expectations, and σ_1 and σ_2 are standard deviations for the two regimes, while ε_1 represents white noise.

In this case $s_t = 1$ can be seen as a steady state on the financial markets, while $s_t = 2$ designates a state of increased financial stress. It is assumed that this variable follows a Markov process with the following transition matrix:

$$P = \begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix}$$

where $p_{ij} \equiv \Pr(s_t = j | s_{t-1} = i)$ designates the likelihood of a transition from one regime to another, that is, the probability that the process is at time *t* in regime *j*, with the assumption that it was previously in regime *i*, and that $\sum_j p_{ij} = 1$ (Yuan, 2011).

Calculation of dates and contributions to the episodes of financial stress was based on FSI_vew as it enables a more intuitive interpretation of the contributions of the individual components to the movement of the total FSI (Sinenko et al., 2012).

4.2 RESULTS OF THE MODEL

The remainder of the paper presents indices obtained by different aggregation methods and describes the FSIs during the observed period, as well as the stress episodes and the CNB reactions related to financial market developments.[1]

Independently of the aggregation method, the indices are strongly positively correlated and result in similar information about the stress episodes (table 2).

TABLE 2

Coefficients of correlation between indices calculated by various methods

	IFS 1_vew	IFS 2_pca	IFS_3_cdf
IFS 1_vew	1	0.75	0.94
IFS 2_pca		1	0.70
IFS_3_cdf			1

Note: Due to the smaller number of variables included in the FSI_pca it is not entirely comparable with the other two indices, which partially explains the lower correlation among them.

Source: Author's calculation.

In order to additionally check the robustness of the results, FSI_vew and FSI_cdf are also calculated with the use of only those indicators included in the FSI_pca

[1] FSIs_vew are presented in the text itself (figures 1, 2, 3 and 4), while FSI_cdf and FSI_pca are presented in appendix, as well as in figures A1 and A3. The list of variables included in the calculation of the FSI-vew and the FSI_cdf is shown in table 1, while indicators included in the FSI_pca are shown in table A1 in appendix.

(table 3). The correlation coefficients show even greater positive correlation among the indices and confirm the robustness of the results.

Table 3
Coefficients of correlation between indices calculated with the use of the same variables

	IFS 1_vew	IFS 2_pca	IFS_3_cdf
IFS 1_vew	1	0.94	0.88
IFS 2_pca		1	0.78
IFS_3_cdf			1

Source: Author's calculation.

Useful data about financial stress were obtained by a calculation of sub-indices. In the first step the total FSI was divided into components related to the origin of the shocks that might lead to financial stress (figure 2, table 1). The sub-index FSI-D, which describes trends in the domestic components of overall financial stress, includes variables from the foreign exchange market, the money market and the securities market. The sub-index FSI-F, which reflects movements on foreign financial markets, includes indicators from the international money market and securities markets that are considered to affect the financial stress in the country through various channels.

In order to obtain more detailed information from individual market segments, sub-indices have been additionally divided into several components. The domestic component FSI-D was divided into indices that describe the domestic foreign exchange market, money markets and securities market (FSI-D-FXM; FSI-D-MM; FSI-D-SM – figure 3). In the same manner, the FSI-F was divided into sub-indices for the international money market (FSI-F-MM) and the international securities market (FSI-F-SM) (figure 4).

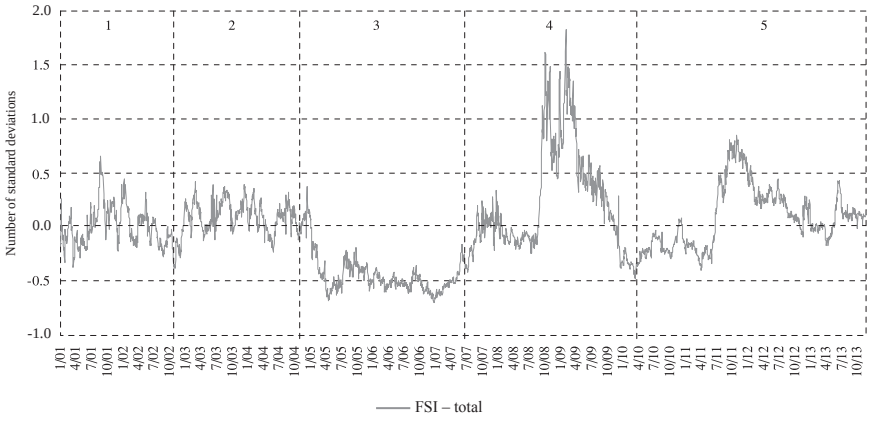
Following the financial and macroeconomic developments that tended to bring about financial stress in Croatia, the period under observation is divided into five sub-periods:

1) from 2001 to the end of 2002,
2) from 2003 to end-2004,
3) from 2005 to mid-2007,
4) from mid-2007 to the beginning of 2010, and
5) from 2010 to end-2013.

These sub-periods, movements of total FSI and its components and the causes of identified stress episodes are described in the rest of the chapter. A comparison of movements of total FSI and its components with financial, macroeconomic and

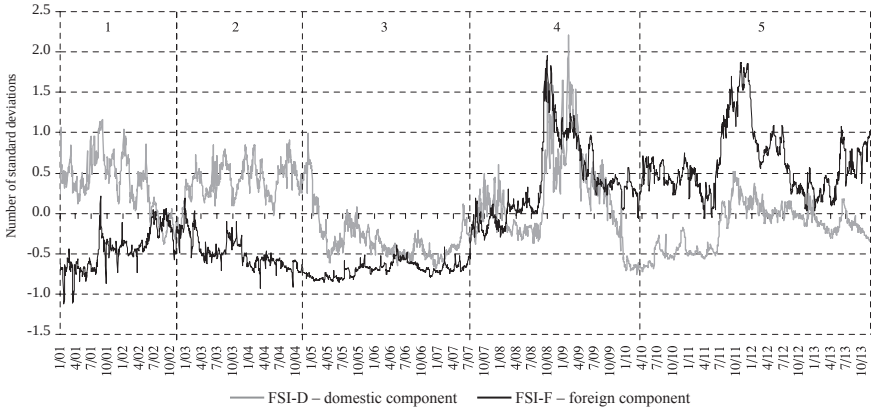
monetary developments presents another verification of the robustness of the calculated composite indicators.

FIGURE 1
Total FSI_vew



Source: Author's calculation.

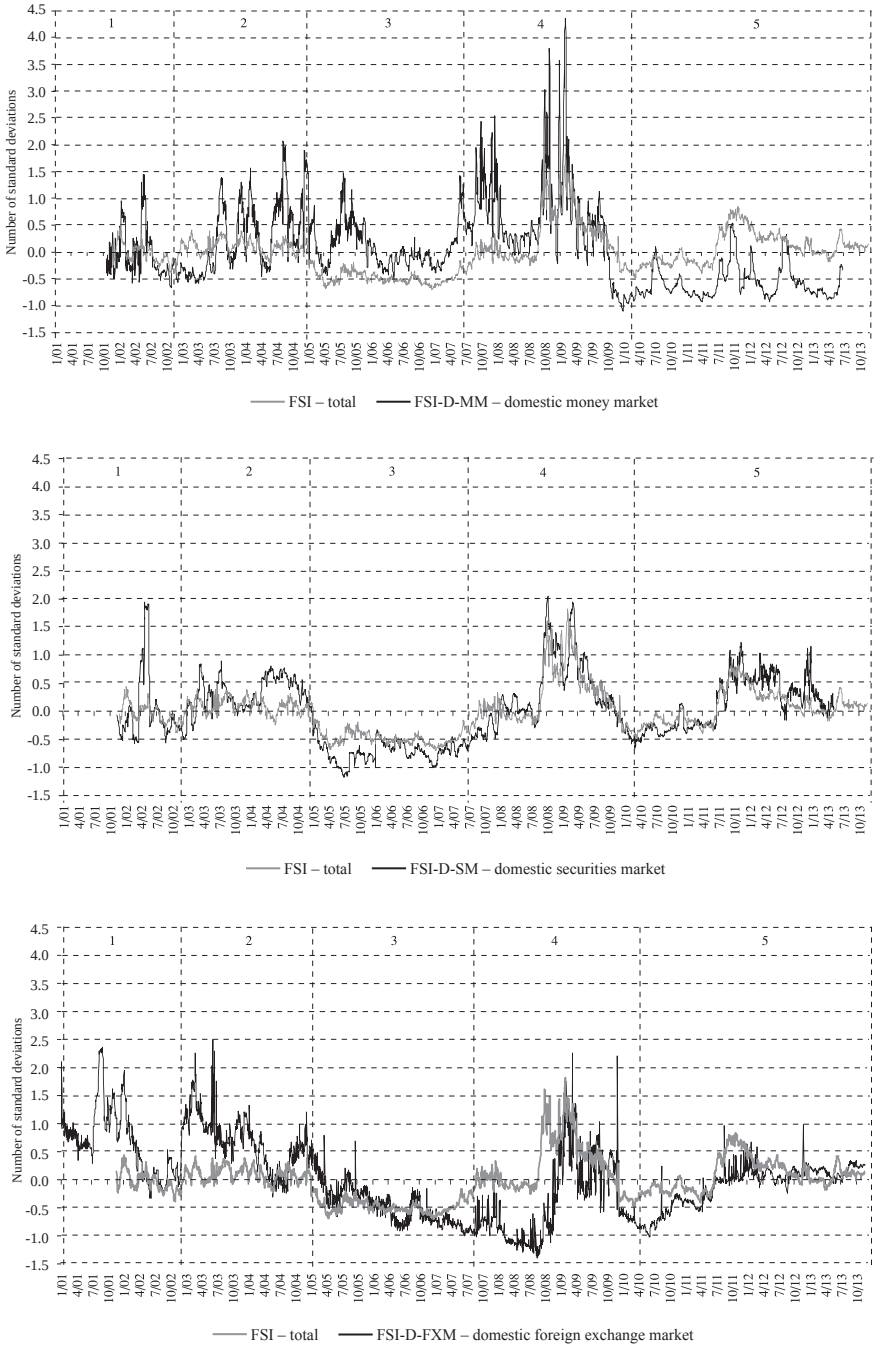
FIGURE 2
Domestic and foreign components of total FSI_vew



Source: Author's calculation.

FIGURE 3

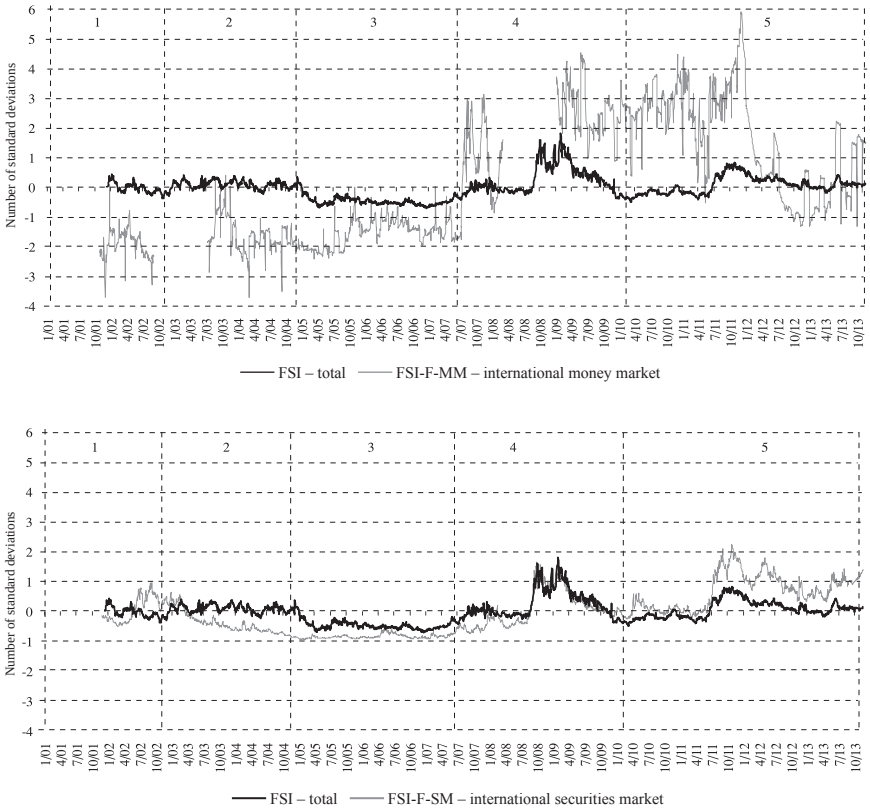
FSIs divided according to market segments: domestic money market, domestic securities market and domestic foreign exchange market



Source: Author's calculation.

FIGURE 4

FSIs divided according to market segments: international money market and international securities market



Source: Author's calculation.

Figure 5 shows the periods determined as episodes of increased turbulences on the financial markets for an FSI_vew according to the Markov switching model. In order to verify the robustness and to confirm if the stress episodes have been correctly identified, they were also determined with the use of the FSI_cdf (appendix, figure A2). The stress periods are very similar, implying the robustness of the results. Nevertheless, it needs to be pointed out that the main objective of the identification of stress episodes is the analysis of the underlying developments and the market participants' reactions, rather than determining their precise dates.

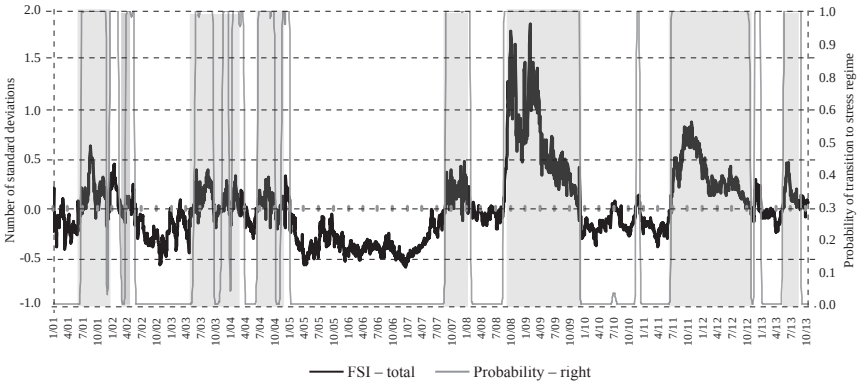
The contributions of individual market segments and of individual sources of risks to the stress episodes were calculated for all eight stress episodes (figures 6 and 7). To simplify this analysis, episodes that were shorter-lasting but frequent in time are observed as a single stress episode.

In the pre-crisis period up to the second half of 2008, there were five stress episodes. They were mostly affected by domestic financial market variables, but did

not have pronounced systemic consequences. In the subsequent period, there were three stress episodes, two of which were extremely powerful not only for their intensity but also for their length, and for their strong negative impacts on the real economy. They were primarily initiated by shocks from international financial markets, although domestic indicators also contributed to them significantly.

FIGURE 5

Episodes of increased turbulence on the financial markets determined by the Markov switching model

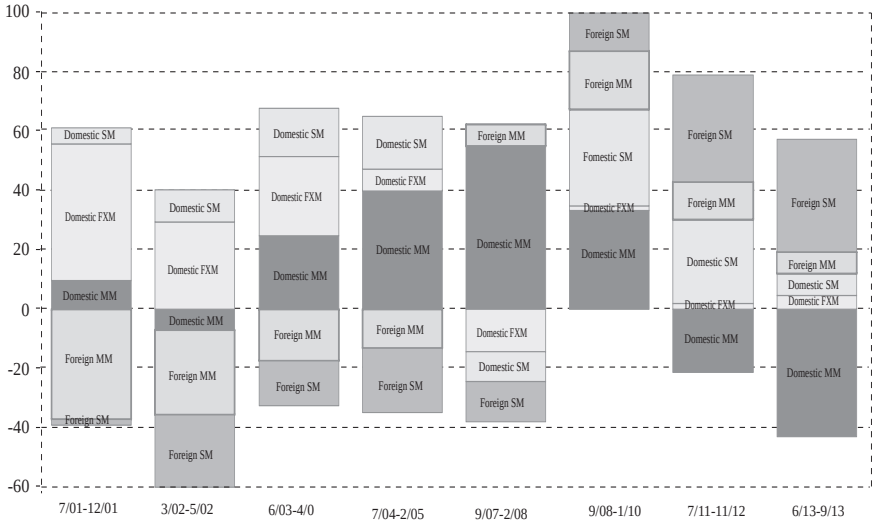


Note: The shaded areas mark the stress episodes.

Source: Author's calculation.

FIGURE 6

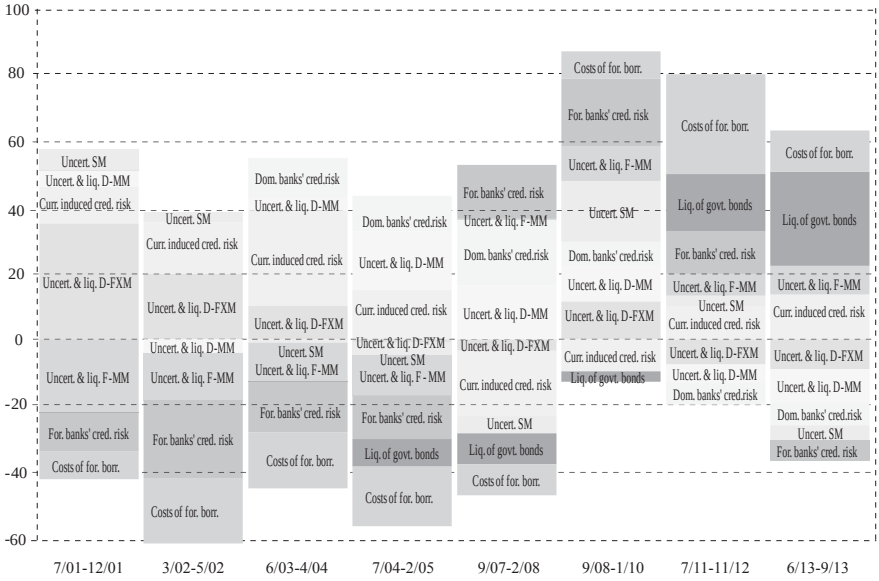
Contributions of individual FSI components to stress episodes: according to market segments (in %)



Source: Author's calculation.

FIGURE 7

Contributions of individual FSI components to stress episodes: according to sources and types of risk (in %)



Source: Author's calculation.

4.2.1 First period: from 2001 to 2003

The total FSI in the period from 2001 to 2003 was relatively volatile, but there were only two, fairly mild, stress episodes. The first one is related with the 9/11 attacks, which led to a rise in uncertainty and volatility on world financial markets and increased risk premiums. The FSI-F reveals that these turbulences were partially transmitted to the domestic financial market via the money market channel (figures 1, 2 and 4, column 1). The total FSI in this period was mostly affected by a speculative attack on domestic currency (figures 1 and 2, column 1). In the middle of August 2001, depreciation pressures on the EUR/HRK exchange rate arose, showing up much earlier than would usually have been expected, considering the seasonal inflow of foreign capital from tourism. This was encouraged by the speculative activities of some banks that in expectation of a considerable kuna depreciation started vigorously buying euros. In the shallow domestic market this additionally enhanced depreciation pressures (figure 3, column 1). The central bank intervened three times in the period between 9 August and 20 August and sold EUR 408m to the banks, which halted the depreciation pressures. In this period, a strong rise in the money market interest rates was recorded (figure 2, column 1). This encouraged some banks to use Lombard loans that they, in spite of their high rate of interest, considered as favourable within the market expectations regarding the exchange rate, so the central bank increased the interest rate for Lombard loans from 9.5% to 10.5%.

The contributions calculated for this stress episode, which lasted from July to December 2001, confirm the importance of events and uncertainties on the foreign exchange market, and to a lesser extent of movements on the domestic money market, for the development of overall financial stress in the system (figures 6 and 7, column 1).

Domestic banking system liquidity in 2002 was relatively high and the year was marked by strong appreciation pressures due to large foreign capital inflows from tourism, enhanced foreign borrowing by the government and the commercial banks and the privatization of domestic enterprises. Through several foreign exchange interventions the CNB net created HRK4.8bn, which was partially sterilized by increasing the base for the kuna reserve requirement and by increased issuance of central bank T-bills. This ensured stability on the money and foreign exchange markets, which had been disrupted only for a short period due to the internal fraud in the treasury of Riječka banka (figure 3, column 2). The rapid CNB reaction ensured the necessary domestic and foreign currency liquidity for the normal operations of Riječka banka in the period until the new owner took it over, so this turbulence was only temporary and the crisis did not spill over to other financial institutions. This stress episode lasted from March to May 2002.

4.2.2 Second period: from 2003 to 2004

The period from early 2003 to the end of 2004 was marked by a relatively low level of financial stress. This was an introduction into a quite long period of low risk premiums and low volatility of international market indicators (figures 1, 2, 3 and 4, column 2).

Developments on the domestic financial market in 2003 were influenced by the tightening of the CNB's policy aimed at slowing down the credit expansion and banks' foreign borrowing. Sanctions were introduced on the growth of domestic loans greater than 16% a year or 4% quarterly and banks were obliged to hold the minimum required amount of foreign currency claims of 35% in order to ensure appropriate foreign currency liquidity. The latter measure resulted in depreciation pressures on the kuna because of the augmented demand for foreign exchange and a reduction in primary liquidity in the banking system, as well as in a surge in the level and volatility of money market interest rates in the second half-year (figures 2 and 3, column 2).

In September 2003, the CNB increased the percentage of the reserve requirement on foreign currency obligations that must be held in kuna from 25% to 35%, and additionally to 42% in November 2003. These changes resulted in temporary appreciation pressures on the EUR/HRK exchange rate and increased volatility of money market interest rates (FSI-D-FXM; FSI-D-MM – figure 3, column 2). In February 2004, the minimum percentage of reserve requirements that were set aside in a special account at the CNB was increased from 40% to 60%; and by foreign exchange interventions the banking system liquidity was increased, which temporarily reduced the money market interest rates.

The most important sources of stress in the third stress episode from June 2003 to April 2004 were developments and uncertainty on the domestic foreign exchange and domestic money market (figures 6 and 7, column 3).

In July 2004, interest rates surged again when the CNB imposed a marginal reserve requirement on an increase in foreign liabilities of banks, which was initially set at 24%, but has additionally been raised several times (figure 3, FSI-D-MM, column 2). This resulted in considerable changes in banks' liquidity and in oscillations of money market interest rates until early 2005. This strongly affected the FSI-D, particularly the FSI-D-MM (figures 2 and 3, column 2). Overnight interest rates went up to as high as 10%, but after several foreign exchange interventions they dropped to a relatively low 2%. The fourth stress episode lasted from July 2004 to February 2005 and was marked by developments on the domestic money market (figure 3, column 2; figures 6 and 7, column 4).

4.2.3 Third period: from 2005 to mid-2007

The third period was the longest period of low-level of financial stress in which there were no major turbulences in a single segment of the financial market and not a single stress episode was recorded (figures 1, 2, 3 and 4, column 3; figure 5). It was marked by high level of global liquidity, low risk appetite and the beginning of a gradual increase in reference interest rates by the Fed and the ECB prompted by exceptionally propitious economic trends.

However, precisely in that period of benign market conditions a considerable deterioration in internal and external imbalances was recorded because of strong foreign borrowing, excessive credit activity and overheating of the domestic economy. Therefore, the CNB continued tightening its monetary, or rather macroprudential, policy. The marginal reserve requirement rate was gradually increased and reached 55% by the end of 2005. In early 2006, a special reserve requirement on newly issued bank debt securities, and increased capital requirements for currency-induced credit risk were introduced, the capital adequacy ratio was increased to 12%, at the beginning of 2007 the annual credit growth was restricted to 12%, and in 2008 capital requirements for banks with higher than permitted credit growth were increased. These measures increased the overall level of financial system resilience by creating buffers against possible shocks. But in spite of CNB efforts aimed at slowing down systemic risk accumulation, it was precisely in this period of calm and stable conditions on the financial markets that systemic risks significantly increased. These risks materialized during the following stress episodes.

4.2.4 Fourth period: from mid-2007 to end-2009

The beginning of the fourth period was also the onset of the world financial crisis. In the second half of 2007 the first difficulties associated with sub-prime mortgages in the USA appeared. When issuers of securities based on these loans faced problems with their re-financing, the crisis spilled over from the mortgage market

onto the interbank money market and spread globally (FSI-F – figure 2, column 4; FSI-F-MM – figure 4, column 4). Initially, these developments only slightly affected domestic FSIs (figures 1 and 2, column 4). The FSI-F increased, but its level was similar to the level recorded before the long-lasting tranquil period. It had stabilized at the beginning of 2008 and even started decreasing.

A much greater impact on the total FSI came from the increased volatility in the domestic money market caused by the IPO of the domestic telecom company T-HT in October 2007 (figures 1, 2 and 3, column 4). At that time, an imbalance between money supply and demand arose as a small group of banks generated a considerable part of the demand for kuna, while participants with liquidity surplus required interest rates higher than usual. Although the system liquidity was at the usual level, the shallow money market had difficulties in adjusting to the large inflows or outflows of money, which contributed to the elevated interest rates levels and their increased volatility until the end of the year (figure 3, FSI-D-MM, column 4).

The fifth identified stress episode lasted from September 2007 to February 2008 and was mostly attributable to uncertainty and volatility on the domestic and international money markets due to the increased credit risk and the fall in confidence among market participants (figures 6 and 7, column 5).

Temporary stabilization on the international financial markets lasted until March 2008 and the collapse of the investment bank Bear Stearns. Although this crisis situation was solved promptly and there were no significant negative consequences for the rest of the financial system as the failed bank was taken over by the J. P. Morgan, the reduced confidence among market participants stimulated a new surge in volatility and nervousness on the international money market (figure 4, column 4). In spite of that, the influence of the FSI-F and FSI-F-MM on total FSI was not significant (figures 1 and 2, column 4). After the initial rise, the FSI-F did not change much until the collapse of Lehman Brothers in September 2008 (figures 2 and 4, column 4). This resulted in a previously unrecorded rise in global risk aversion and an increase in price volatility with a simultaneous plunge in liquidity and a rise in distrust among market participants. Therefore, both components of the FSI-F surged (figures 2 and 4, column 4). A sudden jump in the Croatian risk premium and a frozen international money market hindered the access of domestic sectors to foreign capital, which was reflected in all segments of the FSI-D (figure 3, column 4).

In the fourth quarter of 2008, level and volatility of overnight interest rates rose considerably, and in November 2011 the FSI-D-MM reached a record level (figure 3, FSI-D-MM, column 4). This was induced by transactions on the capital market related to the takeover of INA d.d. by Hungary's MOL. This led to a division of banks into those with considerable surpluses and those with notable liquidity deficits, leading to a surge in money market interest rates. Apart from that, the insta-

bility on world financial markets resulted in a partial withdrawal of bank deposits in October 2008. Banks were encouraged to retain more liquid assets, which increased the demand for foreign currency liquidity (figure 3, FSI-D-FXM, column 4). In order to maintain overall financial stability, the CNB was forced to restrict kuna liquidity (figure 3, FSI-D-MM, column 4). The CNB started releasing previously accumulated reserves and the first step was the abolition of the marginal reserve requirement in October 2008, which improved foreign currency liquidity in the banks and ensured the payment of international liabilities. This resulted in the preservation of a stable exchange rate and high level of international reserves, as well as in the highest recorded short-term money market interest rates. Due to the restricted kuna liquidity, the pressures on the foreign exchange market were reflected on the money market (FSI-D-MM), so in the initial phase of the escalation of the crisis it was only slightly reflected in the developments of the FSI-D-FXM (figure 3, column 4).

Instability on the money market at the end of the year and efforts to make it easier for government to finance within the country led in December 2008 to the lowering of the reserve requirement rate from 17% to 14%. System liquidity was improved and interest rates decreased noticeably. This was reflected in a considerable, but temporary, reduction of FSI-D-MM (figure 3, column 4). As well as through reverse repo auctions, banks obtained kuna liquidity by the intensive use of Lombard loans, even though their interest rate had increased from 7.5% to 9.0% and the regulations concerning the amount of securities needed as collateral had been strengthened.

The first half of 2009 was influenced by global turbulences, frozen international money markets and a sudden stop in capital flows. Due to renewed depreciation pressures, in the first quarter of 2009 the CNB intervened three times in the foreign exchange market, at the first two auctions selling and, in the last auction at the end of February, buying euros. In this period a marked increase in the FSI-D-FXM was recorded (figure 3, column 4). In order to stabilize the exchange rate, in January 2009 the CNB increased the percentage of the foreign currency reserve requirement set aside in kuna from 50% to 75%, and in order to ensure adequate foreign liquidity of the system in February the rate of minimum foreign currency claims was reduced from 28.5% to 20%.

The developments on the foreign exchange market resulted in the first quarter of 2009 in a temporary, but a significant rise in the level and volatility of overnight interest rates and increased turnover in the money market because of the lower kuna liquidity (figure 3, FSI-D-MM, column 4). This stabilized at the end of February after the weakening of depreciation pressures, and both interest rates and volatility on the money market were reduced (figure 3, FSI-D-MM, FSI-D-FXM, column 4). By the end of the year, banking sector liquidity was satisfactory and the interest rates and the exchange rate remained stable (figures 1, 2 and 3, column 4).

The end of 2008 and most of 2009 were marked by a major decline in the CROBEX and increased volatility of returns on both CROBEX and CROBIS, which were strongly reflected in the FSI-D-SM (figure 3, column 4).

Unlike previous stress episodes, when some market segments alleviated stress disruptions, in the sixth episode from September 2008 to January 2010 all of them contributed to the increase of financial stress (figures 6 and 7, column 6). The greatest influence on these movements was made by the events on the international and domestic money markets. Since the stabilization of the EUR/HRK exchange rate was a key precondition for the preservation of overall financial stability in the country, interest rates on the domestic money market were, at that time, "sacrificed" in order to achieve that goal.

4.2.5 Fifth period: from the beginning of 2010 to end-2013

In the fifth period, the crisis in the government debt market in peripheral eurozone countries deepened in mid-2011. Apart from threatening banking sector stability, this crisis adversely affected the expectations of market participants, consumers and corporate sector related to the economic recovery. The renewed decline in investor risk appetite increased risk premiums, and stress spilled over onto the domestic financial system through a rise in the FSI-F (figures 1, 2 and 4, column 5). The risk premium for Croatia rose, absolutely and relatively, much more than the premiums for European emerging markets, and exceeded the record level reached in early 2009. These developments considerable enlarged the FSI-F-SM (figure 4, column 5).

The increased reliance of subsidiaries on their parent banks during the fifth stress episode reflected a support of the owners to domestic banks, but also increased exposure to parent banks' liquidity, their needs for capital, financing strategies and to developments in their home countries, as well as in those in which they had considerable exposures. The worsening of the international debt market conditions in the second half of 2011 led to a rise in the CDS premiums on the bonds of the parent banks of the five largest domestic banks. Their average level at the end of 2011 ranged about 500 basis points, almost twice as much as in the period after the escalation of the crisis, primarily because of the exposures to peripheral eurozone countries and concerns regarding the sustainability of their fiscal positions. Adverse developments in CDS premiums for Italy additionally increased the risk perception of Italian parent banks compared to those from Austria or France. This resulted in the partial withdrawal of the parent banks' funding from domestic banks and increased pressures on the foreign currency liquidity (figures 3 and 4, column 5).

During the seventh stress episode from July 2011 to November 2012 the major contribution to movement of total FSI and the increased level of stress came from the international securities and money market due to high volatility and strong

growth of uncertainty and risk aversion observed in an increase of FSI-F (figures 1, 2 and 4, column 5; figures 6 and 7, column 7).

In spite of the negative macroeconomic trends in 2013 and the fall in the country's credit rating, the EUR/HRK exchange rate remained stable, the liquidity of the system was high due to the CNB measures and the money market interest rates were low and stable. Components of FSI-D were quite low and decreased throughout the year (figures 2 and 3, column 5).

The eighth stress episode lasted from mid-June to September 2013 and was driven by the cost of foreign borrowing, particularly trends in the international securities markets which assessed Croatia as a rather risky investment. This period was characterized by the Croatian credit rating downgrade to below investment level by all three major agencies (Standard and Poor's, 13 December 2012; Moody's, 1 February 2013; and Fitch Ratings, 20 September 2013). Notwithstanding this and the lack of economic recovery, Croatia still had access to the financial markets. The total FSI reacted relatively strongly to the first downgrade, while the negative reactions to the two further credit downgrades were somewhat milder (figure 1, column 50). Such moderate reactions were partially caused by the stabilization on the international financial markets. Government took advantage of favourable circumstances and issued two new bonds in the USA (in April, USD 1.5bn, yield at issue of 5.62%; November, USD 1.75bn, yield at issue of 6.20%).

The end of the period was marked by improved world financial market conditions and a fall in general risk aversion (figure 4, column 5). Nevertheless, the Croatian risk premium remained elevated and FSI-F negatively contributed to the total FSI (figure 2, column 5). The reason for this were investors' concerns regarding the lack of economic recovery, deterioration of fiscal indicators and absence of structural reforms that would create conditions for sustainable economic growth. Due to its inherent weaknesses, Croatia did not use the period of stable and unexpectedly favourable conditions in the domestic and international financial markets to ensure cheaper funding for the private sector, which would have been an important step towards economic recovery. Croatia therefore remained extremely vulnerable to any possible tightening of financial conditions, meaning that in the event of a more pronounced increase in risk aversion it could face a prohibitively high price of foreign capital.

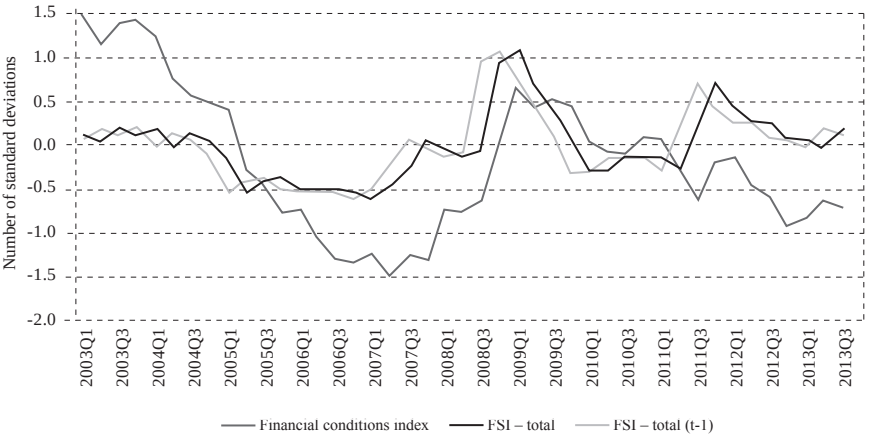
4.3 COMPARISON OF FSIs AND INDICES OF FINANCIAL CONDITIONS

Following Kliesen (2012) and in order to additionally check the robustness and usefulness of the results obtained, total FSI was compared with the financial conditions index (FCI) for Croatia. FCI is calculated by using the principal component analysis, on the basis of 28 macroeconomic and financial variables that reflect financing conditions in Croatia (for details see Dumičić and Krznar, 2013). FCI is available at a quarterly level, so the FSI was adjusted by calculating its quarterly averages.

The coefficients of correlation imply a strong positive link between FCI and FSIs calculated by various methods. This correlation is even stronger if the level of the FSI of the previous quarter is used, suggesting a great influence of financial stress on overall financial conditions and the possible use of the FSI for predicting trends in financing conditions for domestic sectors in the forthcoming period.

FIGURE 8

Comparison of total FSI with FCI



Source: Author's calculation (FCI is calculated on the basis of the data and methodology presented in Dumičić and Krznar, 2013).

TABLE 4

Coefficients of correlation between FCIs and FSIs

	FCI	FCI (t+1)
IFS_vew	0.57	0.70
IFS_pca	0.58	0.69
IFS_cdf	0.61	0.76

Source: Author's calculation.

5 CONCLUSION

Due to the adverse effects that financial market stress episodes have on financial and macroeconomic stability, the main objective of this paper has been to construct high-frequency financial stress indicators that will in good time inform economic policy makers of possible disruptions in the financial markets and be a useful tool for the analysis of risks that might jeopardize the financial and macroeconomic stability of the system. Another objective was to use the Croatian example to create an index that, in spite of the relatively limited accessibility of daily data, would still cover the most important specific features of a small, open, highly-euroized country with shallow financial markets and majority foreign-owned

banks. Namely, most of the financial stress indicators were created for developed countries that are at a different level of economic and financial development and are characterized by institutional and regulatory arrangements different from those in emerging markets. Special attention has been devoted to the particular channels through which financial stress spills over from the financial markets to other segments of the financial system and the real sector in such countries. The identification of sources of financial stress and the factors that affect them, the understanding of the channels through which disruptions spill over to the remainder of the financial system and real sector, as well as the analysis of the policy makers' activities in these periods can enable more effective preventive actions and better reactions in stress episodes.

For the aggregation of individual indicators into a composite index, three methods were used – aggregation with the use of weightings based on equal-weight variances, aggregation of variables transformed with the use of the cumulative distribution function, and the principal component analysis. The indices constructed are highly correlated, which means that the aggregation method does not essentially affect the information contained in the index, confirming the robustness of the results. The Croatian example shows that the calculated FSIs present a useful tool for describing events on the financial markets as well as monetary and macroeconomic trends, also suggesting the robustness of results.

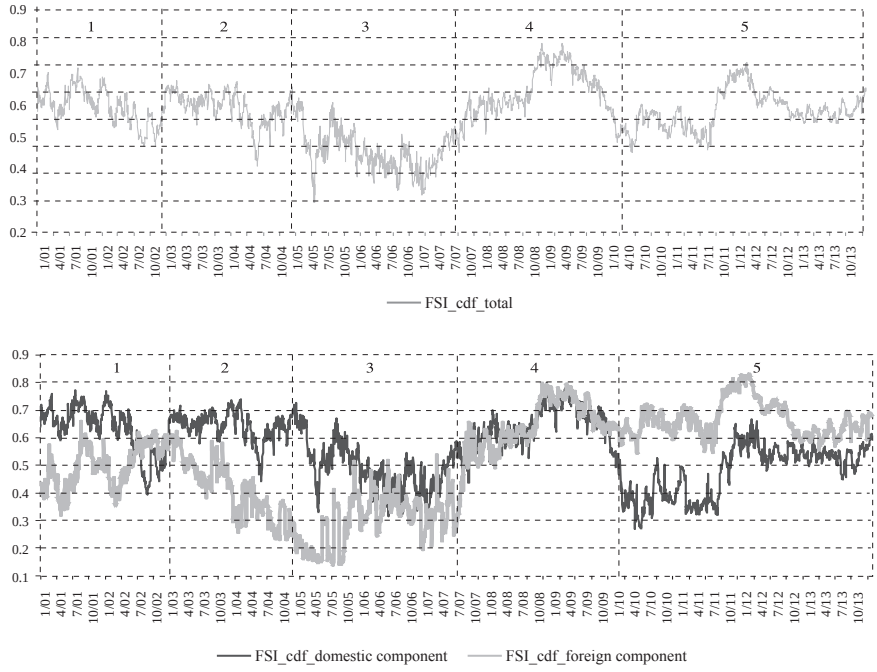
By analysing the FSIs and the CNB reactions to the observed financial stress episodes, it can be concluded that the CNB was successful in the stabilization of the financial markets and the preservation of overall financial stability. Although FSIs did not exist in the observed period, they could have been useful in the process of identifying sources of stress disruptions, particularly in communication with public and market participants when explaining the preventive measures. Market participants and the public were often unaware of the possible threats to threatening financial stability, particularly during the stable periods on the financial markets.

It can be expected that these indicators will continue to be developed and that their components will adjust to financial markets' developments. In the next step, the indices might be used as an early warning tool for predicting trends in the financing conditions for domestic sectors or forecasting real economic developments (i.e. like Jakubik and Slačik, 2013). In combination with other techniques, like stress testing, various systems of early warning, and other composite indicators created for the analysis of financial stability in Croatia, such as FCI or indices of the accumulation and materialization of systemic risks, this indicator should enable a better monitoring of risks and ensure a prompt reaction of economic policy makers to possible stress episodes.

Indices of financial stress calculated with the use of variables transformed with the cumulative distribution function

Figure A1

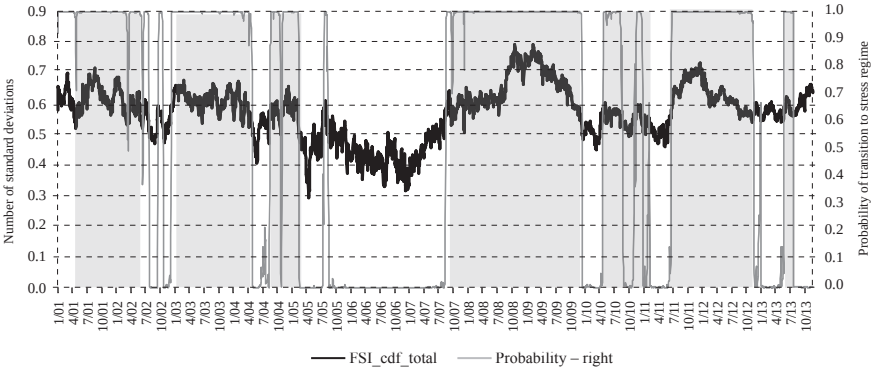
FSIs calculated with the use of the cumulative distribution function



Source: Author's calculation.

Figure A2

Episodes of increased turbulence on the financial markets determined by the Markov switching model



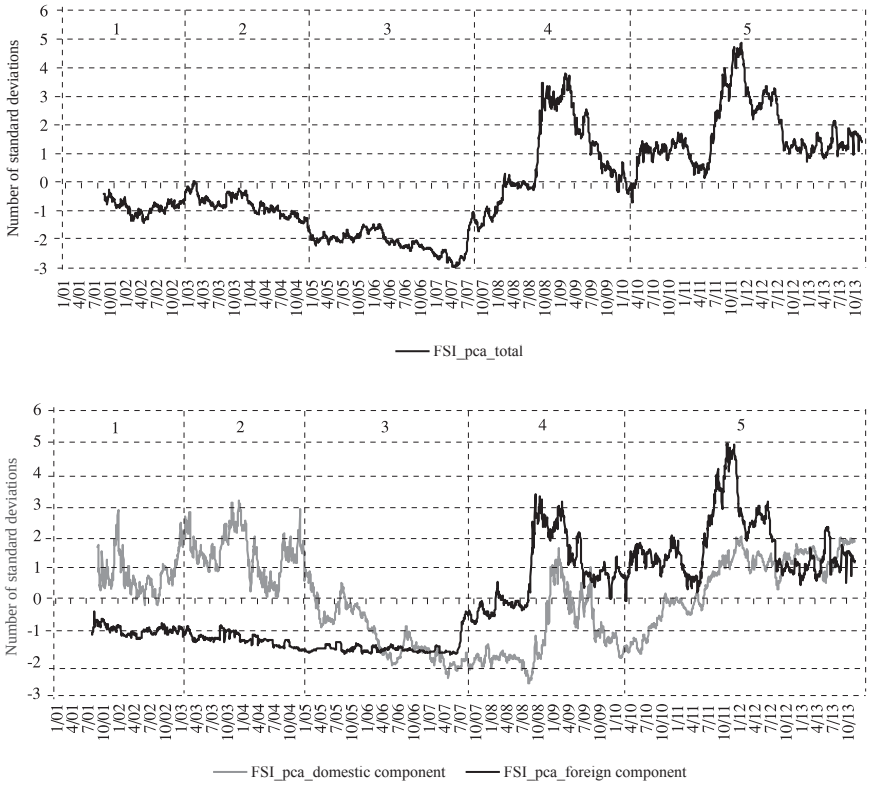
Note: The shaded areas mark the stress episodes.

Source: Author's calculation.

Financial stress indices calculated with the principal component analysis method

FIGURE A3

FSIs calculated with the principal component analysis method



Note: Number of variables included in the FSI obtained by the PCA method is smaller than in indices calculated by other methods because not all data are available since January 2001 and the exclusion of non-stationary variables. The usual methods of transforming variables with daily frequency to avoid this problem result in very volatile series.

Source: Author's calculation.

TABLE A1

Loadings of parameters for variables included in the FSI_pca

Variables/Index	FSI_pca_total	FSI_pca_domestic	FSI_pca_foreign
Returns on CROBEX	0.45	0.23	
Volatility of overnight interbank interest rates	0.01	0.13	
Exchange rate weighted according to banks' assets structure	0.09	0.68	
Forward exchange rates	0.15	0.69	
CDS of parent banks of domestic banks weighted according to their share in banking sector assets	0.50		0.57
EMBI risk premium for Croatia	0.55		0.61
EONIA volatility	0.28		0.34
LIBOR – OIS spread	0.36		0.42

Source: Author's calculation.

REFERENCES

1. Anh, T. and Mägi, S., 2009. *Principal Component Analysis – Final Paper in Financial Pricing.* National Cheng Kung University.
2. Balakrishnan, R. [et al.], 2009. "The Transmission of Financial Stress from Advanced to Emerging Economies". *IMF Working Paper*, WP/09/133.
3. Cardarelli, R., Elekdag, S. and Lall, S., 2009. "Financial Stress, Downturns, and Recoveries". *IMF Working Paper,* WP/09/100.
4. Catao, L. A. V., 2006. "Sudden Stops and Currency Drops: A Historical Look". *IMF Working Paper*, WP/01/133.
5. CNB, 2012. *Financial Stability*, No. 9. Zagreb: Croatian National Bank.
6. CNB. *Annual Reports 2000-2012.* Zagreb: Croatian National Bank.
7. Dufrénot, G., Furceri, D. and Zdzienicka, A., 2011. *Financial globalization and financial stress in Latin America: the case of Argentina, Brazil and Mexico*. Preliminary version of the paper. Available at: <http://www.defi-univ.org/img/pdf/paper_march2011pdf>.
8. Dumičić, M. and Krznar, I., 2013. "Financial Conditions and Economic Activity". *CNB Working Paper*, W-37. Zagreb: Croatian National Bank.
9. Grimaldi, B. M., 2010. "Detecting and interpreting financial stress in the euro area". *ECB Working Paper,* No. 1214.
10. Hakkio, C. S. and Keeton, W. R., 2009. "Financial stress: what is it, how can it be measured, and why does it matter?". *Economic Review, Federal Reserve Bank of Kansas City,* (q ii), pp. 5-50.
11. Hubrich, K. and Tetlow, R. J., 2012. "Financial stress and economic dynamics: the transmission of crises". *Finance and Economics Discussion Series, Federal Reserve Board*. Washington, D.C.
12. Illing, M. and Liu, Y., 2003. "An Index of Financial Stress for Canada". *Bank of Canada Working Paper,* No. 2003-14.
13. Illing, M. and Liu, Y., 2006. "Measuring financial stress in a developed country: An application to Canada". *Journal of Financial Stability*, 2 (3), pp. 243-265. doi: 10.1016/j.jfs.2006.06.002
14. Ivičić, L. [et al.], 2008. "Results of the Fifth CNB Bank Survey". *Survey*, S-15. Zagreb: Croatian National Bank.
15. Jakubik, P. and Slačik, T., 2013. "Measuring Financial (In)Stability in Emerging Europe: A New Index-Based Approach". *Oesterreichische Nationalbank, Financial Stability Report*, No. 26.
16. Kliesen, K. L., Owyang, M. T. and Vermann, E. K., 2012. "Disentangling Diverse Measures: A Survey of Financial Stress Indexes. *Federal Reserve Bank of St. Louis, Review*, 94 (5), pp. 369-397.
17. Kota, V. and Saqe, A., 2011. "A Financial Systemic Stress Index for Albania". *Bank of Albania Working Paper,* WP03/42/2013.
18. Kuan, C. M., 2002. *Lecture on the Markov Switching Model*. Academia Sinika: Institute of Economics.

19. OeNB, 2013. *Financial Stabilisty Report*, No. 26. Oesterreichische Nationalbank.
20. Oet, M. V. [et al.], 2011. "The Financial Stress Index: Identification of Systemic Risk Conditions". *Federal Reserve Bank of Cleveland Working Paper*, No. 11/30.
21. Puddu, S., 2008. *Optimal Weights and Stress Banking Indexes.* Lausanne: HEC-Université de Lausanne.
22. Schou-Zibell, L., Albert, J. R. and Song, L. L., 2010. "A Macroprudential Framework for Monitoring and Examining Financial Soundness". *ADB Working Paper Series on Regional Economic Integration*, No. 43.
23. Sinenko, N., Titarenko, D. and Arinš, M., 2012. "Latvian Financial Stress Index". *Discussion Paper*, No. 1-2012. Riga: Latvijas Banka.
24. Yuan, C., 2011. "Forecasting Exchange Rates: The Multi-State Markov-Switching Model with Smoothing". *International Review of Economics & Finance*, 20 (2), pp. 342-362. doi: 10.1016/j.iref.2010.09.002
25. Zagreb Stock Exchange. Available at: <www.zse.hr>.