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Financial Stress Indicators for Small, Open, Highly Euroised Countries – the Case of Croatia

Mirna Dumičić

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**Financial Stress Indicators
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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 placed on the choice of variables appropriate to small, open, highly euroised economies characterised by bank-centric financial systems dominantly owned by foreign banks. Apart from that, these countries are often characterized by shallow financial markets that because of the shortfall of domestic saving have to a great extent become dependent on foreign capital. Timely identification of stress disruptions on the financial markets and understanding of the specific channels by which they might spill over to the rest of the financial system and onto real economy are a precondition for effective reactions on the part of economic policy makers.

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financial stress, financial stability, financial markets, systemic risk, composite index

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1 Introduction

Numerous research papers have referred to the strong and negative connection between stress episodes on the financial markets and financial and macroeconomic stability and to their adverse impact on overall economic activity (Hubrich and Tetlow, 2012; Kliesen et al., 2012). For this reason, it is important continuously to develop and improve tools for the timely perception of stress disruptions in this segment of the financial system. In the development of an analytical framework and of indicators for monitoring financial markets developments, the objective is to encompass all the most important sources of stress that might result in the materialisation of systemic risk. For this purpose, individual indicators could be used and in order to reduce a large number of data from the financial markets into as small a number of indicators as possible, 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 greater the correlation among the different segments of the financial system. Having that in mind, the use of aggregated data which reflects developments in various segments of the financial system is the starting point for an analysis of financial stress and systemic risk (Kota and Saqe, 2013).

Since no single financial market is independent of movements in other financial markets, for calculations of a Financial Stress Index (FSI) in practice it is daily or intra-daily data from domestic and foreign markets for securities, foreign exchange and money markets and data about the banking system that are used. High frequency data can detect in real time stress events on the financial markets and promptly warn regulators of instabilities in the financial system that might result in a crisis episode. If an indicator suggests an enhanced level of financial stress, it is necessary to carry out a more detailed analysis of the individual components of the index and to identify possible channels through which it can spill over onto the remainder of the financial system and the real sector.

As against data from the financial markets, macroeconomic data and data about the operations of financial institutions that reflect the process in which systemic risk materialises are mostly low-frequency. This also means that they start later to draw attention to the need to undertake measures aimed at alleviating acute financial shocks. Belated economic policy maker reactions can finally additionally contribute to or actually produce instability and deepening of disruptions in the financial system.

The principal objective of the present paper is to construct high-frequency indicators of financial stress for Croatia, which will enable the monitoring of the level of overall financial stress in the domestic financial system and the level of stress in given segments of the financial market. Another aim is to construct an indicator that will in good time draw attention to the danger of possible appearances of stress episodes and of the materialization of systemic risk. In addition to an analysis of stress periods, particular attention will be devoted to the importance of information that indices can provide even in the tranquil periods on the financial markets.

The paper refers in particular to the characteristics of the domestic financial system and to the economic and monetary characteristics of the country. In a review work about the measurement of financial stress,

Kliesen et al. (2012) showed that most of the composite indicators used to measure financial stress are constructed for the analysis of events in highly developed financial markets, which have many various financial instruments and indicators. However, with adjustment of a set of variables included in the index, they can also be useful for the analysis of events in countries with less developed financial systems. Apart from the choice of calculation methodology, one of the biggest challenges in the construction of an index is the selection of its components. This is one of the most important contributions of this paper to existing literature that deals with the construction of financial stress indicators.

The focus of the paper is on the consideration of the variables that reflect the movement of financial stress in small, open, high-euroised economies, characterised by bank-centric financial systems dominantly owned by foreign banks with in addition shallow financial markets that because of the shortfall in domestic savings have very largely become dependent on foreign capital. Particular attention will be directed to the situation when the main transmission channel of monetary policy is the exchange rate, and when there is no classical reference interest rate. In such cases, the domestic money markets are not necessarily a relevant source of bank financing, and the interest rates in this segment of the market can have a negligible effect on the price of domestic sector borrowing. The cost in such situations depends primarily on trends in world financial markets as well as risk premiums for the country and the parent banks of domestic commercial banks.

As well as the consideration of risks specific to small and open economies, the practical contribution of the paper should be emphasised; this is manifested in the use value of the FSIs constructed for economic policy makers and participants in the financial markets. Prompt identification of stress disruptions in the financial markets and the understanding of the specific channels by which they can spill over to the rest of the financial system as well as real economy are a condition for economic policy makers to react timely and effectively. Their reactions can be aimed at preventing episodes of aggravated financial stress by influencing the identified potential sources of such disruptions. In cases in which unexpected financial shocks occur, the reactions should primarily be aimed at the stabilisation of those segments of the financial system established as being the routes through which shocks can spread to the remainder of the system.

The paper is divided into five main parts. After an introductory part there is a detailed explanation of what is understood in theory by the concept of financial stress, and the specific features of stress episodes are described, together with the channels through which they can tend to bring about financial and macroeconomic instability from the perspective of a small, open and highly euroised economy. Part three shows the problems involved in constructing FSIs, and a review of the methods of aggregating individual indicators into a composite index is given. The advantages and drawbacks of each of them are brought out.

Part four explains in detail 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 addition, in order to check the robustness of the results, the indices are calculated using three methods, and the trends in financial stress in the period from early 2001 to the end of 2013 are described. This period, in view of financial and macroeconomic developments, is divided into five sub-periods. In addition, the stress episodes identified with the use of the Markov switching model are described.

The final part of the work briefly sums up the main results of the research and its contribution to the existing literature and to the development of tools useful to those in charge of economic policy in the decision making process is underlined; also benefited are market participants and the general public, who can track trends and potential sources of risk on the financial markets, and thus attain a better understanding of the moves of economic policy makers.

2 Financial stress and the channels through which it affects financial and macroeconomic stability

There is no universally accepted definition of the idea of financial stress or of financial stability, and this to an extent makes it difficult to measure them. Dufrénot et al. (2011) describe financial stress as a situation in which there is an enhanced probability of turbulences in the financial markets accompanied with a currency or balance of payments crisis, a sudden halt in inflows of capital, or outflows, stock market collapses, the inability of a government to meet its liabilities and the like. Holló (2012) believes that financial stress consists of disturbances in the financial system that unexpectedly affect the price of and trade in financial instruments. He also emphasises that this can be accompanied by the collapse of systemically important financial institutions and the inability of the financial system to carry out its main role, i.e., to distribute and allocate financial resources. It can ultimately result in a considerable reduction in economic activity. On the basis of such broad definitions it can be concluded that the concept of financial stress in general implies disturbances in the normal functioning of financial markets and in the process of financial mediation that can spill over onto the real sector (Hakkio and Keeton, 2009; Balakrishnan et al., 2009).

Although every stress episode has its own particular features, Sinenko et al. (2012) accentuate certain features they have in common, such as increased uncertainty related to the value of financial assets and expectations of future economic developments, high expected financial losses and increased investor risk aversion, in other words, a rise in the propensity to keep less risky and more liquid financial assets. All of this is together reflected in an increase in the instability and volatility of prices on financial markets and in a rise in various kinds of risk premium. Volatility of financial assets prices at a time of crisis in financial markets can affect the economic fundamentals of a country, including interest rates, inflation, fiscal balance and business and consumer confidence, as well as confidence in the stability of financial institutions.

Another measure of financial stress often used, apart from the level, is the volatility of given variables. It expresses uncertainty related to the real value of a given category of asset and with respect to investor behaviour. But although the volatility of variables in financial markets is often associated with financial stress, this does not always have to be the case and it should be borne in mind during an analysis of the components of an FSI. Grimaldi (2010) gives examples of increased financial market volatility brought about by unexpected news that does not necessarily have to be linked with an increased degree of stress. By contrast, an essential reduction in the liquidity of financial markets, which can be practically frozen in stress situations, can result in reduced volatility, despite the fact that the stress level is at its peak.

A certain level of financial stress is a feature of the financial system at any given time. However, even when it is not high, this kind of information from the market cannot be neglected. Sinenko and others (2012) emphasize that it is periods in which the level has been low for a long period of time as compared with the long-term average that have often been accompanied with exaggerated optimism on the part of market participants. This is manifested with excessive rises in lending or a rise in the prices of various kinds of assets, the accumulation of macroeconomic imbalances in the form of soaring deficits in the balance of payments current account and of external debt, with increased risk to financial stability. The less developed financial systems that are characteristic of most emerging countries are in general apt to direct inflows of money from abroad to sectors of non-tradable investments, such as real properties, which contributes to a rise in asset prices and the creation of price bubbles. A similar effect can be produced by investments in shallow securities markets; all of this is often accompanied by a sudden appreciation of the domestic currency (Prasad and Rajan, 2008).

A good example of such pattern are developments which have marked the period before the recent financial crisis in most Central and Eastern European countries with emerging markets. These countries were characterised by low gross domestic savings that were insufficient to meet the financing needs of domestic sectors. This and generally low credit saturation levels in the private sector, in conjunction with the prolonged period of fairly mild conditions on world financial markets that were manifested in a low global risk premium, low and

stable interest rates on global markets and relatively high yields on investments in emerging market countries, resulted in strong inflows of relatively cheap capital into these countries.

Taken together, these factors strongly increased the vulnerability of their financial systems and costs of a potential crisis episode. With reference to this, Holló (2012) emphasises that in cases of increased vulnerabilities and high accumulated systemic risk even a small stress in financial markets may result in a system-wide crisis episode. If disturbances indicated by high-frequency indicators endure, there is a great probability that they will with a time lag and through various channels, such as financial or trade channels, affect low-frequency indicators as well. This puts financial stress in direct correlation with the financial and macroeconomic stability and, due to its effect on consumption and investment, with total real developments.

The growth of instability on financial markets usually results in increased investor risk aversion, causing risk premiums and financing costs of domestic sectors to rise. In combination with reduced liquidity or even a total freezing of financial markets it may result in the strong slowdown of capital flows. The research has shown that situations like these affect more strongly countries with emerging markets than developed countries. The reason for this lies in strong foreign capital inflows which have made them highly vulnerable to potential and sudden changes in their flow (Catao, 2006). In such cases, a sudden halting of capital inflows may imply country's inability to refinance its due liabilities, sturdy capital outflows or a depreciation of the domestic currency. The servicing of debt denominated in or indexed to a foreign currency additionally weakens the exchange rate which may ultimately result in the failure of the banking system and the spillover of the crisis onto the real sector (Prasad and Rajan, 2008).

Links that exist between financial institutions are an important source of financial stress. In most European countries, it is the banks that are the most important financial mediators, and their exposure to financial stress can result in high macroeconomic costs (Schou-Zibell et al., 2012). Because of the role of the bank as mediator, problems that financial stresses causes in its operations can very rapidly spill over to other segments of the financial system, like the interbank money market or the payments system, and will have a negative effect on the functioning of other financial mediators. Changes in the way that banks are financed, the degree of liquidity in money and other financial markets and the risk of shock spillover, or risk contagion, are an increasingly great threat to the liquidity and stability of the financial system, which was until recently on the whole connected with a run on the banks (Mörttinen et al., 2005).

The interbank money market is one of the very important possible channels for contagion. The links among financial institutions in this market segment constitute channels for the rapid spread of risks and difficulties from one to several financial institutions in a short period. The celerity of the spread is proportional to the level of uncertainty and information asymmetry. For example, if some institution is faced with liquidity problems and is unable to repay money it has borrowed, this can result in considerable losses in all the institutions linked with it via the market (Mörttinen et al., 2005). And if financial institutions are constrained to sell off financial assets because of shortfalls in liquidity, this can result in the plummet of asset prices and the loss of connections with economic fundamentals. Such situations are usually accompanied by a significant rise in mistrust among market participants as well as by uncertainty, which greatly hampers and increases the cost of the process of financial intermediation.

On the interbank money market, the importance of maturity transformation that is at the heart of banking operations comes particularly to the fore (BIS, 2012). In normal periods, banks are financed from short-term sources, and invest these resources in loans, which as a rule are marked by longer maturities and very low liquidity. A crisis episode that hits the money market and via it the banks can thus very easily result in considerable difficulties in the allocation of financial resources.

The recent financial crisis also drew attention to the great importance of the liquidity channel in determining both the ability and the readiness of banks to extend loans and in this manner affect the real sector. It turned out that a high degree of the use of financial leveraging, that is, a powerful reliance on exogenous sources of financing and not one's own, large maturity mismatches in the balance sheets of banks and inadequate accounting policies are crucial factors in the transmissions of liquidity shocks to the real sector (BIS, 2012).

Simultaneously, an enhanced level of uncertainty brought about by financial stress can reduce the

willingness of banks to make loans and encourage them to make lending standards more stringent, and also discourage potential debtors from borrowing; they thus postpone or give up on investments and in this way, the demand for loans is reduced (Hubrich and Tetlow, 2011). In less developed financial systems the role of bank loans in financing is as a rule much greater than in well-developed systems, in which a considerable part of funding takes place via the securities market. Hence, the influence of financial stress on loan conditions and the supply of loans via this channel are for them much more important. Similarly, if a banking crisis should prompt the foreign owner of a domestic bank to withdraw its capital from a country in which it has a major exposure, and most European countries with emerging markets are exposed to this risk, the consequence may be a long-lasting period of reduced inflows or outflows of capital in and out of the country.

From the perspective of a system in which the banks are mainly foreign-owned, parent banks of domestic banks are one of very important transmission channels of financial stress. The influence of foreign banks on inflows of capital into these countries is visible from their powerful lending to domestic banks, as well as from loans made to the non-financial sector in the countries of CEE. According to BIS data, the annual average inflow of loans from parent banks in the period between 2002 and 2007 was on average equivalent to 9% of their GDP, and at the end of the period under observation, these cumulative inflows per country reached a level as high as 38% of GDP (CNB, 2012).

Balakrishnan et al. (2009) showed that financial stress spreads powerfully and rapidly from developed to emerging market countries and that on average 70% of the financial stress from the developed countries spills over to countries with emerging markets. Since this stress spread primarily through financial channels, emerging markets with relatively high liabilities to developed countries were more strongly hit by financial stress from such countries than markets in which this kind of connection is not so highly expressed. During the recent crisis the most pronounced channel for the transmission of financial stress to European emerging market countries was actually through the western European banks. The problems of parent banks that can be measured by the increase in their risk premiums do not only affect the borrowing costs of subsidiary banks, but also the strategic orientation and overall policy towards subsidiaries. This can have a powerful influence on the flows of capital and on lending activity, and in this manner on developments in the real economy and the speed of the economic recovery of countries in which they are exposed.

In highly euroised countries, one of the most important channels for possible spillovers of financial stress onto financial and macroeconomic indicators is the movement of the exchange rate of domestic currency. In such countries a significant part of the economy is exposed to enhanced currency-induced credit risk (CICR) deriving from the fact that currency mismatches in debtors' assets and liabilities. This means that in case of a strong depreciation of the domestic currency there will be an increased likelihood of a considerable deterioration of the quality of bank loans because of the inability of the domestic sectors to service their debts.

The degree of euroisation will also affect the monetary policy of a central bank. Research has shown that countries that have the problem of euroisation and in which inflationary expectations are related to the exchange rate have much less freedom in running their monetary policy (Ivanov, 2012). In these countries, the main monetary policy transmission channel is as a rule the exchange rate, not the interest rate. Hence it should be borne in mind that information contained in the movement of domestic interest rates on such markets differs from those on developed markets, in which the interest rate transmission channel is functioning.

Attention should also be paid to the possibility that in some banking systems that are dominantly foreign owned and that are financed via their parent banks, interest rates on the domestic money market can have an almost negligible impact on the cost of domestic sector borrowing. In such cases, this cost primarily depends on the perception of the risk of the country and of the parent banks of domestic commercial banks, as well as on the liquidity of international financial markets.

3 The construction of a composite index

These specific features of small open economies with shallow financial markets, together with the fact that numerous indicators for these financial markets of the kind that are used for the calculations of FSIs for developed countries do not exist, imply a great challenge in the choice of variables that will reflect in a suitable manner the development of financial stress in these countries. Accordingly, it can be concluded that the construction of an FSI capable of successfully describing events on the financial markets of a given country is an extremely complex assignment.

Apart from the problem mentioned of there being no single definition of financial stress, there are also reasons inherent in the structural differences in the financial systems of different countries and in the degree of their development and data availability. In addition to that, financial markets are in continuous development and the importance of the individual segments of the market also varies, while new financial services are developing every day (Holló, 2012).

In other words, even when indicators that at a given moment are estimated to cover all the most important potential sources of financial stress are created, 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. Here it is necessary to point out that because of these reasons, FSIs calculated for given different countries are not always directly comparable, but they can provide useful information about the dynamics of financial stress trends in given financial markets.

In the selection of variables for the construction of an FSI, the objective is to encompass all segments of financial markets that could possibly be a source of financial stress. Available literature indicates that the most important potential sources of stress disruptions are the loan market, the foreign exchange market, the interbank money market and the capital market (Oet et al., 2011). In addition to data from domestic markets, because of the ever-greater degree of liberalisation of financial flows and the fact that in most countries movements on the domestic financial market are heavily dependent on international events, data from foreign financial markets are also used. Thus a broad set of indicators is used to attempt to cover the complex connections among the individual segments of financial markets. In the construction of an index, it is important to pay attention to shocks possibly being, with respect to their scope, either idiosyncratic or systemic, and, with respect to their origin, either endogenous or exogenous. A detailed review of indicators and methods used for the construction of FSIs can be found in the review paper of Kliesen et al. (2012).

In the literature about early warning systems, binary methods are often used. In these, calm periods are labelled with a zero, and a crisis period with a one. But in the construction of financial stress indicators, the objective is to create a continuous measure that will express the level of and the trend in financial stress in the system (Balakrishnan et al., 2011). For in financial markets, the 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).

Illing and Liu (2006) observe financial stress through a continuous variable that can take on various values, with extreme values marking a crisis episode. In such an approach, the dynamics of the index is emphasised, not the precise ascertainment of the beginning and ending of a crisis episode. Such a viewpoint is cogent particularly when the shortcoming of the Markov switching method used in the literature for this purpose is taken into consideration, for its results greatly depend on the length of the period for which the index is being calculated and the intensity of the disruption within the period (Annex 1). Simpson et al. (2001) point out that financial series are often very volatile where atypical values occur quite often, which also makes it difficult to evaluate the probability of a transition from one regime to another. If a period is marked by a very powerful crisis episode that in its intensity outdoes all those before it, there is a chance that less strong episodes will not be registered as crisis episodes, although perhaps in the period when they unfolded they did have systemic effects.

Often used methods for the aggregation of individual indicators into a composite index include

aggregation via variance-equal weights, principal component analysis, aggregation with the use of variance-equal or chained weightings 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 weightings (Illing and Liu, 2003; Sinenko et al., 2012; Puddu, 2008; Holló, 2012).

Although in the sequel similar results will be obtained irrespective of the method used for the aggregation of the index, it has to be said that each one of them has certain drawbacks.

The shortcoming of variance-equal weights aggregation is the initial assumption that all the variables incorporated into the index are equally important for the analysis of financial stress. In this manner, greater importance is given to those market segments that are represented in the index with a higher number of variables (Oet et al., 2011; Puddu, 2008).

On the other hand, factor analysis is not well-chosen if the variables do not move together and if the same shock does not affect them (Puddu, 2008). Apart from that, weighting based on just a single component will result in a fixed set of weights for the whole of the period for which the analysis is made (Oet et al., 2011).

A drawback to both of these methods described is said to be that standardised data are used for aggregation, which means that the arithmetical mean and the standard deviation of the sample are very sensitive to extreme values. This problem can be obviated by the transformation of variables with the use of a cumulative distribution function (Sinenko et al., 2012). But with this method, potential problems derive from the assumption that the gap between variables that have a neighbouring rank is equal, which is most often not the case in practice, because during long stable periods the relatively small volatility of the original variables can seem greater after transformation than it actually is (OeNB, 2013).

In addition, all the methods mentioned are characterised by the fact that the weights set by them do not have economic importance, unlike the method in which the shares of individual markets in total loans in the economy obtained by aggregating bank loans, corporate and government bonds and shares are used as weights (Illing and Liu, 2003)

The weaknesses of the individual methodological approaches mentioned indicate that in a selection of variables for the construction of an index one has to pay attention to potential constraints deriving from the method by which it is aggregated. The possibility of using weights defined by the share of credits of individual financial markets in total credits is relatively limited in countries with poorly developed financial markets. Hence for the calculation of a FSI for Croatia the method of aggregation on the basis of weightings derived from variance-equal weights will be employed, the aggregation of variables transformed via the cumulative distribution function and the principal component analysis method. Calculation of an index with the use of various methods is at the same time the first test of the robustness of the results.

Weighting based on variance-equal weights (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 standardised variables into a single index, in which every variable is ascribed an equal weight:

$$FSI_t = \sum_{i=1}^k \frac{X_{it} - \bar{X}_i}{\sigma_i} \cdot \frac{1}{k}, \quad (1)$$

in which k is the number of variables included in the index, \bar{X}_i is the sample arithmetical mean for the variable X_i and σ_i is the sample standard deviation for the variable X_i .

Aggregation of variables transformed by the cumulative distribution function (cdf)

Within this methodological approach, every variable included into the index is initially transformed with the use of the cumulative distribution function. The transformation is done by the greatest calculated value of a given variable having at the same time the highest rank and indicating the greatest degree of financial stress, while rank one refers to the lowest recorded daily 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:

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

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

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

and the total index is obtained as:

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

Principal component analysis (pca)

Principle component analysis is used to transform a large number of correlated variables into a smaller number of uncorrelated variables, that is, principal components, the highest degree of variation being retained, which makes it easier to use the data (Anh and Mägi, 2009). In other words, this is a technique used to determine a small number of factors responsible for the correlation of a large number of variables, reducing the amount of data, while retaining the maximum amount of information from them. The correlations of the variables in the groups identified are greater within the groups than among the groups. FSIs calculated with the PCA method are determined as the first principal component that explains the greatest part of the combined movement of the variables used for the construction of the index:

$$FSI_t = \mathbf{x}_t \alpha , \quad (5)$$

in which α is the weight vector (of the dimension *number of individual variables* \times 1) and \mathbf{x}_t is the vector of the values of the indicator (of the dimension *number of individual variables* \times 1) on the basis of which the indices are evaluated. The loadings determine the variables that make the greatest contribution to the explanation of the joint movement of all the components of the aggregated index.

4 Financial stress index for Croatia

In the choice of indicators used for the construction of the FSI the objective was to cover as many as possible of the relevant segments of the domestic and foreign financial systems that might affect level of financial stress in Croatia. Special focus has been put on the specific features of the domestic financial markets, the availability of high frequency data and the economic and monetary characteristics of the country, as well as the developments in foreign financial markets evaluated as possibly having a considerable influence on the stability of the domestic financial system. For the calculation of the index, daily figures from 30 January 2001 to 18 December 2013 were used. Apart from an overall FSI, sub-indices for individual segments of the financial market were also calculated. Index components are divided according to whether stress disruption on the financial market comes from domestic or foreign sources and also according to market segments (Table 1).

Because of the high degree of euroisation and the fact that in Croatia the main transmission mechanism of monetary policy is the exchange rate, for the calculation of the index, several variables that reflect developments on the domestic foreign exchange market were used. The first two are the bid-ask spread on EUR/HRK

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	Exchange rate, kuna for euro, bid-ask spread	Market liquidity, uncertainty, information asymmetry	Bloomberg, author's calculation	
		Volatility of EUR/HRK exchange rate	Uncertainty, information asymmetry, pressures on exchange rate stability	CNB, author's calculation	
		Forward exchange rate	Market expectations, appreciation or depreciation of domestic currency	CNB	
		Exchange rate weighted according to assets structure of commercial banks	Depreciation or appreciation of domestic currency	CNB, author's calculation	
	Money market	Level of overnight interbank interest rates	Liquidity of banking system	CNB	
		Volatility of overnight interbank interest rates	Uncertainty, information asymmetry	CNB, author's calculation	
		Volatility of transactions on overnight market	Uncertainty, information asymmetry, increased need for liquidity	CNB, author's calculation	
		Three month MoF T-bills/three-month ZIBOR spread	Market liquidity, credit risk	Bloomberg, MoF, 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	
		Banking system beta	Volatility and risk of banking sector compared to total stock market, risk of banking sector	Bloomberg, 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	
	International markets	Money market	LIBOR and 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
Securities market		EMBI risk premium for Croatia	Investor perception about risk of investing in Croatian government bonds, macroeconomic outlook of country		
		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 of a given issuer	Bloomberg, author's calculation	
		VDAX	Measure of expected short-term volatility on the capital market	Bloomberg	

exchange rate and the volatility of this exchange rate. The rise of these variables, regardless of the direction in which the exchange rate moves, indicates the growth of instability and uncertainty related to the behaviour of market participants and signals there is an increased level of stress in the domestic foreign exchange market. The forward exchange rate is also included as an indicator of market expectations concerning future developments in the EUR/HRK exchange rate. Forward contracts involve the sale or purchase of foreign currency according to an exchange rate set in advance on an exactly determined date in the future. Since this figure is not available for every day, particularly in the initial part of the period under observation, the five-day moving average of this variable is used instead.

Because of the high proportion of loans made in or indexed to a foreign currency, the index also includes the level of the weighted exchange rate of the kuna to the euro, the Swiss franc and the US dollar. The weights are set according to the share of the individual currency in total loans denominated in them or indexed to them in the assets of the commercial banks. Although the EUR/HRK exchange rate is the most important for the Croatian economy because of the external debt that is primarily denominated in euros and the fact that most of the loans of domestic banks are in euros or indexed to the euro, in this way there is an attempt to cover the impact of the trends in the CHF/HRK exchange rate. Swiss franc movements became an important potential source of stress because of the strong loan activity in this currency in the 2005 to 2008 period and the fact that loans expressed in Swiss francs at the end of 2008 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 that in practice on the domestic money market there is no classical reference interest rate and that this market is not a primary source for the financing of domestic commercial banks, developments and volatilities in interest rates, particularly of overnight rates, can nevertheless indicate the (in)stability of the overall financial market. The dynamics and level of domestic short-term interest rates in the observed period were on the whole determined by the developments in surpluses or deficits of kuna liquidity in commercial banks. The liquidity of the system depended not only on the operations of the banks but also on the activities of the central bank, which influenced it through its measures, and which at certain moments defended the EUR/HRK exchange rate by restricting kuna liquidity.

On the domestic money market, there are several overnight interest rates that are eligible for inclusion in the FSI: the overnight interest rate in interbank trading, the interest rate on the Zagreb Money Market (ZMM) and ZIBOR. In this case we shall use the interbank interest rates that have been available since September 2002, while for the period before this the ZMM interest rate will be used. Since these two series in the whole period are highly correlated, for the coefficient of correlation in the period during which they exist side by side exceeds 0.9, this should represent a relevant time series for the price of overnight borrowing on the domestic money market.

The advantage of this variable over ZIBOR is that transactions really do take place at this rate, while ZIBOR is calculated according to the quotations of the banks that take part in its calculation. But the banks do not take on any obligations to clients on the basis of this quotation and it is not necessarily the rate at which transactions are ultimately agreed on and executed. Although ZIBOR does largely track the movement of the interbank interest rates, it has not managed to become the reference interest rate in practice. This has been confirmed by the results of fifth bank survey carried out by the CNB, according to which the most important money market interest rate is the interbank interest rate (Ivičić et al., 2008).

In the literature, the spread between interest rates for short-term and long-term maturities, which reflects the liquidity risk premium, is used as an indicator of developments on the money market. But since trading in maturities longer than a week in the domestic money market is almost negligible and there are many days when such transactions are not executed at all, this indicator cannot be a reliable indicator of developments in this segment of the market.

And yet, in spite of this and the mentioned limitations of ZIBOR, the index will include the spread between the interest rate on the three-month treasury bills of the Ministry of Finance and the three-month ZIBOR. There is for ZIBOR a daily series of quotations, while the interest rates for a maturity of three months in interbank trading are available only on the days when such transactions are executed, which essentially reduces the number of observations. This spread is the most commonly used variable to be included in FSIs, and it measures the short-term credit risk and the premium that banks charge as against government treasury bills that are risk-free and it serves as a measure of system liquidity (Kliesen et al., 2012; Illing and Lieu, 2006). In a situation of reduced liquidity on the money market an increase in this spread can be expected, as also in the case of increased risk of the banks being unable to return money they have borrowed (Cardarelli et al., 2009).

Another indicator of liquidity on the domestic money market is the use of Lombard loans. These are overnight collateralised loans that the banks can use every day up to the amount of the nominal value of MoF treasury bills, at an interest rate set by the CNB. They are given at the request of the bank at the end of the working day, with an unpaid intraday loan being automatically considered a request for a Lombard loan. The

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

It is not very likely that developments in the domestic stock market will have a significant influence on the overall financial stability, because this market is still relatively poorly developed, and presents no significant source of domestic corporate financing which has been dominated by bank loans. But enhanced volatility in the price of shares influenced by instability in other segments of the market and macroeconomic developments can nevertheless indicate an increased degree of risk and instability in the financial system. Hence the calculation of the composite index includes return on the CROBEX share index and its volatility since a fall in the prices of shares and their increased volatility can indicate stress in this section of the financial market. 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 expresses an increased level of financial stress (Balakrishnan et al., 2009).

Since on the domestic market during the observed periods the shares of the two biggest domestic banks – Zagrebačka banka and Privredna banka – are listed, the index also includes a financial beta that reflects the volatility of shares in the banking sector in comparison to the volatility of the overall stock market (Oet, 2011). Since the Zagreb Stock Exchange does not calculate the index of prices for banking sector shares, it is separately calculated by using the index prices of these shares with the same base. Their weighted average is calculated by using individual shares in their joint assets as weights. On the basis of this index, the banking system beta is calculated as:

$$\text{banking sector } \beta = \frac{\text{cov}(r_t |_{t-1}, m_t |_{t-1})}{\text{var}(m_t |_{t-1})}, \quad (6)$$

where r indicates returns on shares of the banking sector, and m is the return on CROBEX. According to the CAPM model, a beta greater than one means that the shares of the banking sector move more than proportionally in relation to the whole market and indicate a relatively higher risk in the banking sector (Balakrishnan et al., 2009). Following the method of Cardarelli and others (2009) the beta for the needs of creating the index takes on a value different from zero only in periods when returns are negative, so as to bring out negative shocks, and in periods of enhanced stress the rise in this indicator indicates some considerable fall in banking sector shares as compared with the overall market.

The domestic debt securities market is characterised by low liquidity. Government bonds dominate the market and account for more than 90% of bond market capitalization in the reference period. The index therefore includes the volatility of the domestic bond index CROBIS. This is a price index weighed on the basis of market capitalisation that is calculated at the end of each trading day as average daily price weighted by the quantity for all bonds that are in the index. Apart from this, the FSI includes the bid-ask spread for the kuna-denominated government bond that matures in 2019 and which represents the usual measure of liquidity risk. The low level of this difference characterises liquid markets and low transaction costs, while an enhanced level suggests an increased liquidity risk (Holló, 2012).

As for the variables that reflect developments on foreign financial markets, the index includes data about trends in the euro and global money market, share prices, and various forms of risk premium calculated on the basis of data from the bond market, which affects the costs of borrowing by domestic sectors. Particularly important for the domestic financial system is the liquidity of the euro segment of the money market. One reason for this is that it affects the costs of parent banks. Another is that movements in this segment of the market and through this channel, as well as directly, can have a powerful impact on the availability and price of borrowing for domestic sectors and capital flows. In the extreme case of non-liquidity in the interbank money market, when there is a considerable fall in transactions, in which prices collapse and lose their connections with fundamentals, there is a large probability that the access to capital of domestic sectors will be made considerably more difficult or even impossible.

EONIA is the average daily euro interest rate on overnight unsecured loans, which reflects the liquidity of the euro interbank market, and to an extent it reflects movements on world financial markets. Its increased volatility suggests an enhanced level of instability in this market sector as well as information asymmetry among participants in the market.

The six-month EURIBOR is among the most used interest rates, for it represents the basis of the determination of many other rates of interest. An increase in the spread between the six-month EURIBOR and EONIA suggests an enhanced level of uncertainty on the euro interbank market and an increase in liquidity risk premium. Levels of these rates are not included in the analysis for although they do affect the borrowing costs of domestic sectors, an increase in them does not necessarily have to be linked to increased stress. In general, they follow the movement in the ECB reference interest rate, which depends on economic activity, inflationary expectations and the state in the financial system, with which the central bank via the interest rate on the interbank market affects all other interest rates.

The spread between LIBOR and the overnight index swap (OIS) is used as a measure of stress on the global money market. OIS is an interest contract swap that in practice represents the expected level of the reference interest rate of the Fed, and reflects risk and liquidity on the money market. Because of the importance of the money market for the banks' financing it also indirectly measures the health of the banking system. An increased spread between these two rates would mean that banks by borrowing from the Fed can earn by lending money to other commercial banks. Since there is no economic logic for this – except in cases of more pronounced increase in credit risk – the spread is considered a measure of risk present in interbank lending.

Because of the importance of the German capital market, and the fact that in the pre-crisis period the DAX and the CROBEX were highly correlated, as well as because the Germany economy is one of the most important trading partners of Croatia, the VDAX index is used as a variable reflecting movements on the European stock market. This indicator measures expected volatility of prices on the German stock market, and together with the VIX index, which measures the implicit volatility of prices of options on the S&P 500, in the literature it is often used as an indicator of investor risk aversion.

As measure for a country's risk premium, the spread in yields on the basis of the EMBI index is used; this reflects the risk on investment in Croatian securities, and depends not only on global risk appetite but also on the specific features of the domestic economy. It can also be seen as a synthetic macroeconomic indicator for it reflects investor perception of the macroeconomic perspective of a given country. A rise in it 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 as long as possible a time series, the ten-year bond maturing in 2014 was used for this indicator. In order to rule out the influence of general liquidity risk movements on global markets, this spread was reduced by the bid-ask spread for the German government bond with comparable maturity.

In addition to the country risk premium, the risk premium paid by the parent banks of the largest domestic banks also has a considerable impact on the financing costs in the country. According to the results of Balakrishnan et al. (2009), which show that they were one of the most important channels for the spillover of financial stress from developed to emerging markets, for the construction of an FSI, a weighted premium against credit risk of the parent banks of domestic commercial banks was employed. A common premium is calculated by the aggregation of CDS premiums for bonds of five parent banks of the biggest domestic commercial 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 the five banks observed.

This premium directly affects the price at which the parent banks borrow money, which in the next step will spill over onto the price of sources of financing for the subsidiary banks, and in the third step will affect the cost of borrowing of other domestic sectors by affecting the lending interest rates. In addition, parent bank problems can result in a reduction of available reserves for the needs of financing domestic banks.

The Markov switching model

Although this research is primarily focused on the dynamics of FSI movements, in order to calculate the contribution of individual segments of the financial market to a given stress episode and thus provide for

a better analysis of the period under observation and monetary policy reactions, their dates are calculated with the use of the Markov switching model. It needs to be mentioned that crisis episodes could also be defined exogenously, for example, by a crisis episode being defined 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 for the description of data the dynamics of which change during 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, or regimes of enhanced and reduced stress and determines the likelihood of a transition from one regime to another (Dufrénot et al., 2011).

In this case, one assumes the existence of two regimes in which there is a different dynamics of financial stress. In the standard Markov model with two states in which y_t is the index of financial stress at moment t and the arithmetical mean and variance are described by an unobserved state variable $s_t \in \{1, 2\}$ runs:

$$y_t = \mu(s_t) + \sigma(s_t)\varepsilon_t \quad \text{where is } \varepsilon_t \stackrel{\text{iid}}{\sim} N(0, 1), \quad (7)$$

from which it follows that

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

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_t represents the 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 FSIs obtained by the variance-equal weights method as it enables a more intuitive interpretation of the contributions of the individual components to the movement of the overall FSI (Sinenko et al., 2012).

Results of the model

The remainder of the paper presents indices obtained by different aggregation methods and describes the movements of FSIs during the observed period, as well as the stress episodes and reactions of the central bank related to developments in financial markets.

FSIs based on the variance-equal method are presented in the text itself (Figures 1, 2, 3 and 4), while indices based on the cumulative distribution function and principal component analysis are presented in Annexes 1 and 2, as well as in Figures 9 and 11.

Independently of the aggregation method, the indices calculated offer very similar information about the movement of the level of financial stress and stress periods and are strongly positively correlated (Table 2). The coefficient of correlation between the indices obtained by the methods of aggregation via equal weighted variances and the aggregation of variables transformed by the cumulative distribution function amounts to as much as 0.94, indicating a very strong positive link between the two indices. The coefficients of correlation between the index obtained with the principal component analysis method and the other two indices are somewhat lower, and amount to 0.75 and 0.70, which also points out a relatively strong positive correlation. Here it

is necessary to take into account that due to the smaller number of variables included in the index calculated by the PCA it is not entirely comparable with the other two indices, which partially explains the lower correlation among them.

The list of variables included in the calculation of the indices obtained by the aggregation of equal-weight variances and the aggregation of variables transformed by the cumulative distribution function is shown in Table 1, while indicators included in the index obtained by the PCA method are shown in Table 5 in Annex 2.

Table 2 Coefficients of correlation between indices calculated by various methods

Coefficients of correlation			
	FSI 1_vew	FSI 2_pca	FSI 3_cdf
FSI 1_vew	1.00	0.75	0.94
FSI 2_pca		1.00	0.70
FSI 3_cdf			1.00

Source: Author's calculation.

In order additionally to check the robustness of the results, the indices obtained by the aggregation of weights based on equal-weight variances and variables transformed by the cumulative distribution function are also calculated with the use of only those indicators that are included in the FSI_pca (Table 3). The coefficients of correlation between the indices calculated on the basis of the same variables show a still greater degree of positive correlation among the indices, for they range from 0.78 to 0.94, which also confirms the robustness of the results.

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

Coefficients of correlation			
	FSI 1_vew	FSI 2_pca	FSI 3_cdf
FSI 1_vew	1.00	0.94	0.88
FSI 2_pca		1.00	0.78
FSI 3_cdf			1.00

Source: Author's calculation.

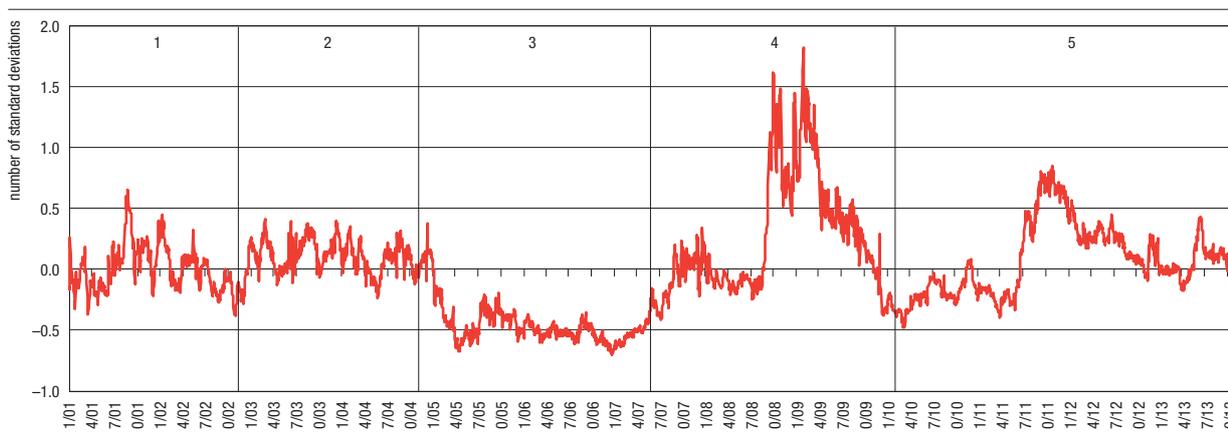
Particularly useful data about the movement of financial stress were obtained by a calculation of sub-indices. In the first step the total FSI was divided into components related to the origin of the shocks that lead to financial stress in the country (Figure 2, Table 1). The sub-index of financial stress FSI-D, which describes trends in the domestic components of overall financial stress, includes a number of variables from the foreign exchange market, the money market and the securities market. The financial stress sub-index FSI-E, which reflects movements on foreign financial markets, includes indicators from the international money market and securities markets that are considered by various channels to have an effect on financial stress in the country.

In order to obtain still more detailed information from individual market segments, in the second step sub-indices have been additionally divided into several components. The domestic FSI-D component was divided into indices that describe the domestic foreign exchange and money markets (FSI-D-FXM and FSI-D-MM), and the domestic securities market (FSI-D-SM) (Figure 3). For the sake of a better description of movements on the international financial markets that have an effect on the movement of financial stress in Croatia, the FSI-F was divided into sub-indices for international money market (FSI-F-MM) and the international securities market (FSI-F-SM) (Figure 4).

All indices are presented in such a way that the period under observation is divided into five sub-periods in order to more easily follow the financial and macroeconomic developments that determined their movements:

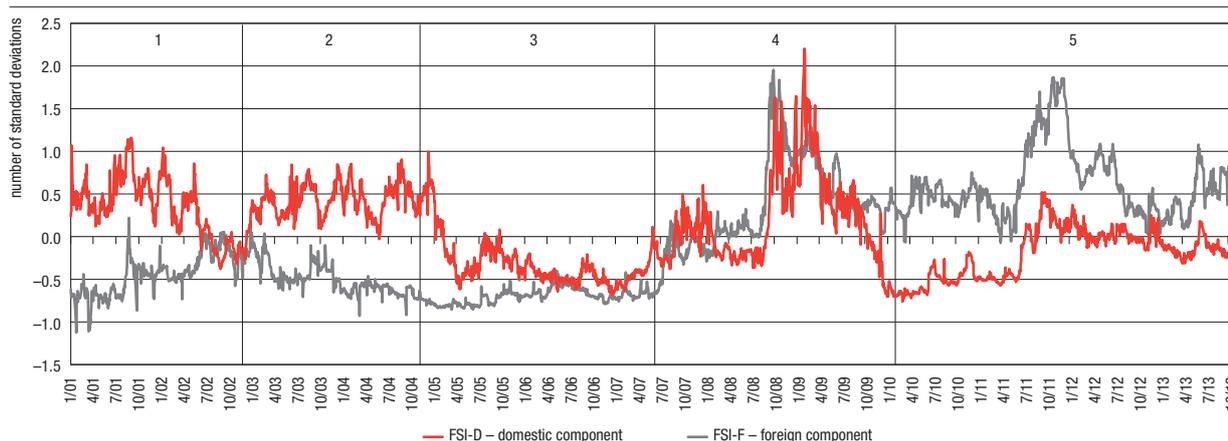
- 1) first period – from 2001 to the end of 2002,

Figure 1 Total FSI calculated with the use of weightings based on equal-weight variances



Source: Author's calculation.

Figure 2 Domestic and foreign components of overall FSI calculated with the use of weightings based on equal-weight variances



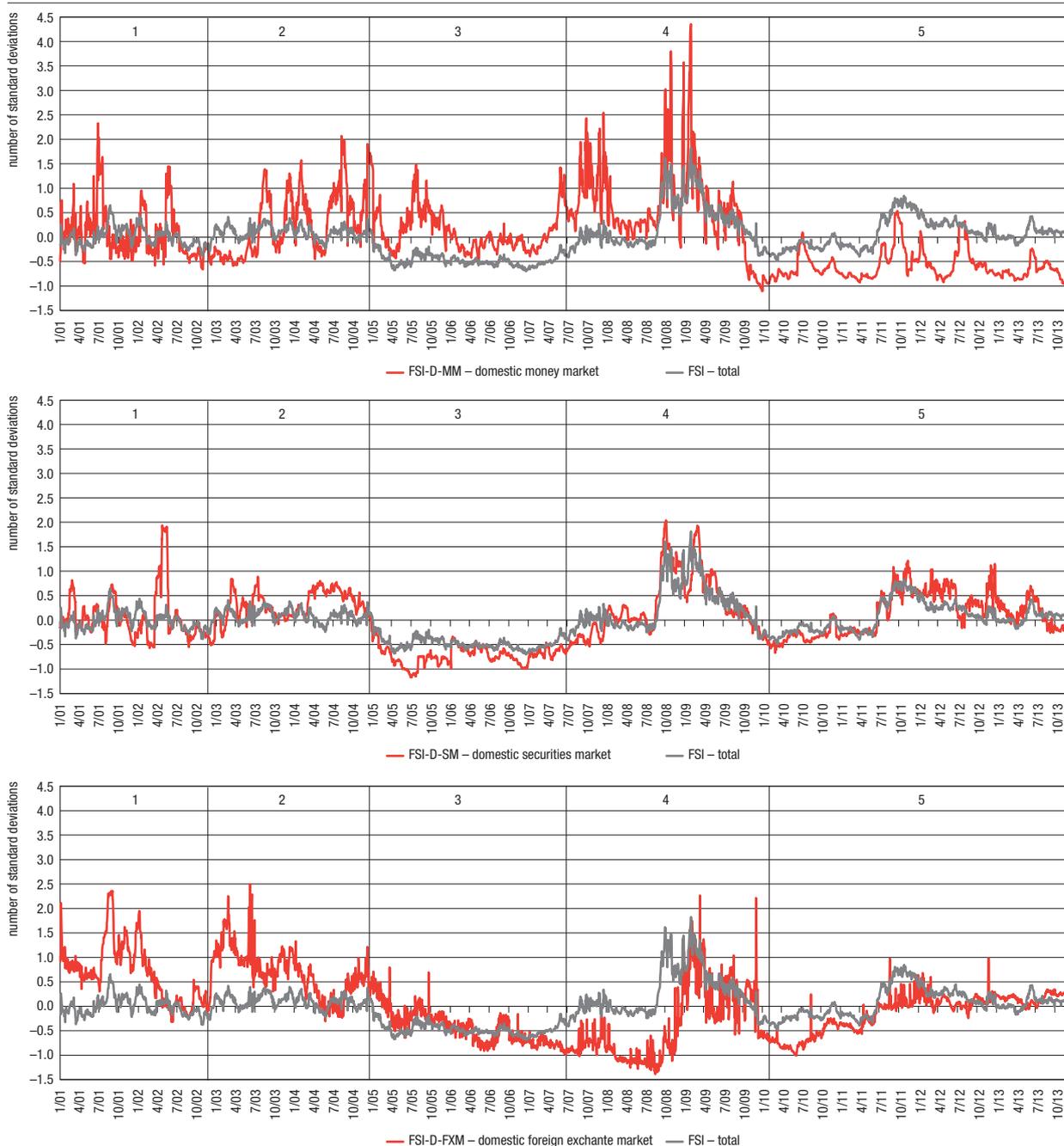
Source: Author's calculation.

- 2) second period – from 2003 to end-2004,
- 3) third period – from 2005 to mid-2007,
- 4) fourth period – from mid-2007 to the beginning of 2010, and
- 5) fifth period – from 2010 to end-2013.

These sub-periods together with the movements of total FSI and its components are described in detail in the rest of the chapter, as well as the causes of stress episodes. 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 5 shows the periods that according to the results of the Markov switching model are determined as episodes of increased turbulence on the financial markets for an FSI_vew. In order to verify the robustness and to confirm if the right stress episodes have been identified via the same model, they were determined with the use of an FSI_cdf, as shown in the Annex in Figure 10. The periods determined as stress periods are not identical, but on the whole they are correlated, which suggests that the calculated indices can correctly determine stress episodes and confirms the robustness of the results. But still it needs to be pointed out that the main objective of the identifications of stress episodes is the analysis of developments that led to them and the reaction of market participants, and not necessarily the determination of their precise dates. Also needing to be taken

Figure 3 Financial stress indices divided according to market segments – domestic money market, domestic securities market and domestic foreign exchange market



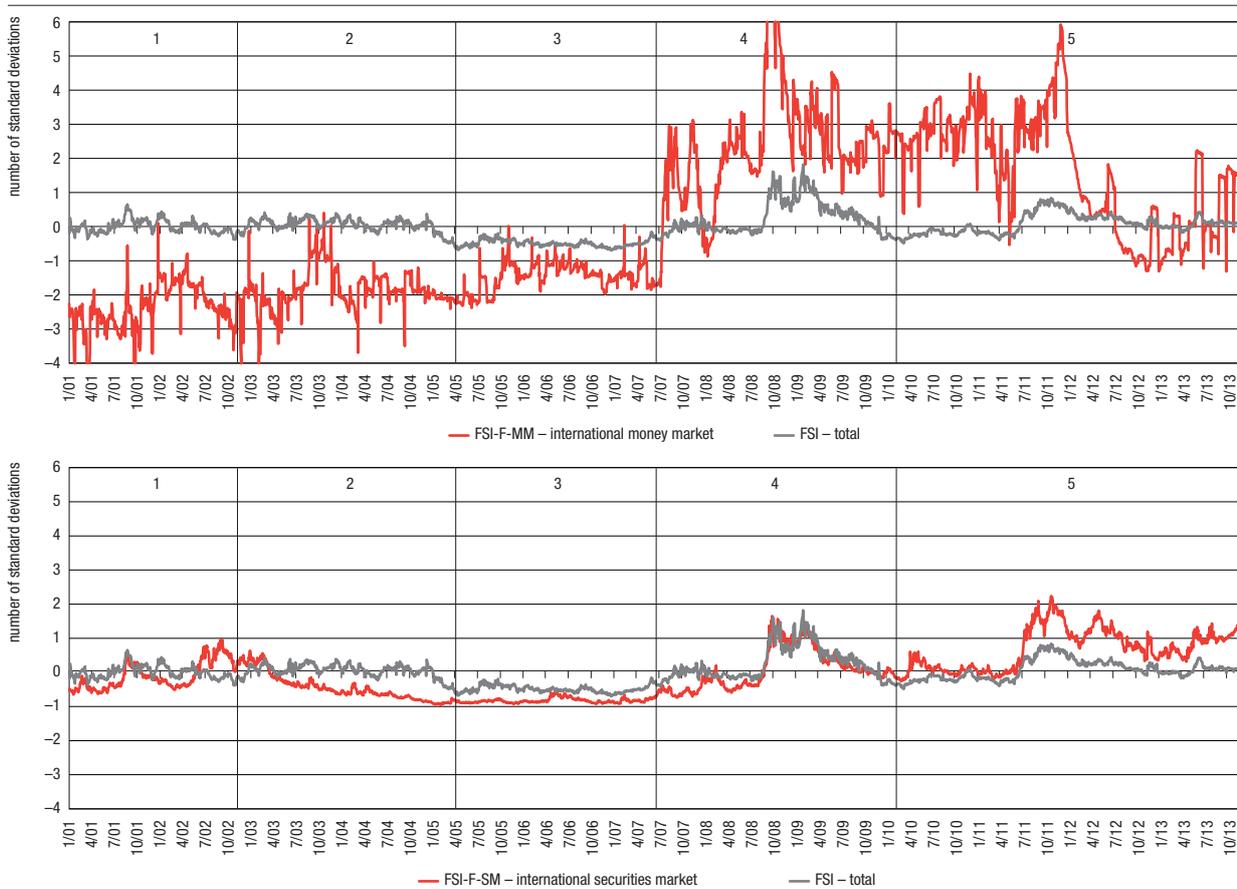
Source: Author's calculation.

into consideration are the restrictions of the Markov switching model mentioned in chapter 3 The construction of a composite index.

By using the dates determined by the Markov switching model, the contributions of individual market segments and of individual sources of risks to the stress episodes were calculated (Figures 6 and 7) for all eight stress periods identified:

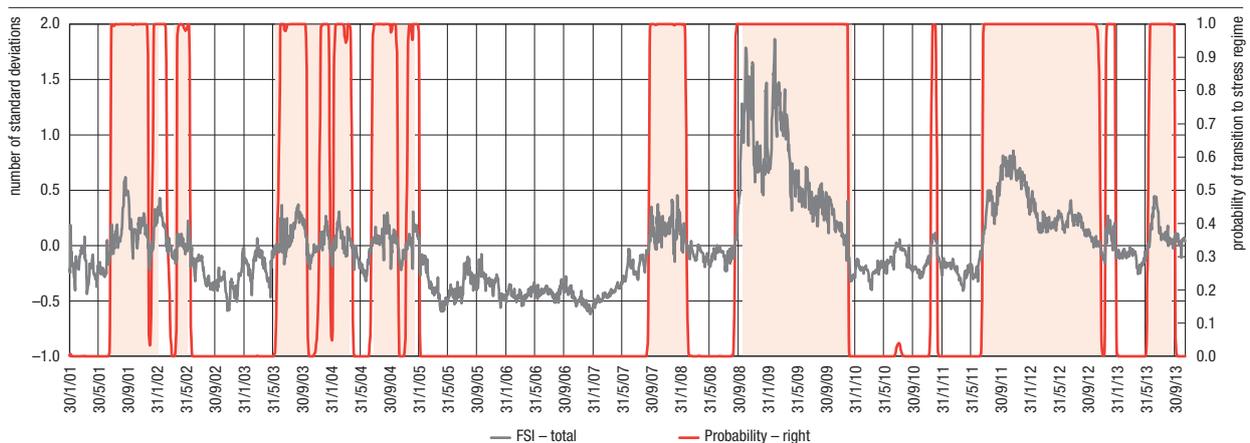
- 1) from July 2001 to December 2001,
- 2) from March to May 2002,
- 3) from June 2003 to April 2004,
- 4) from July 2004 to February 2005,

Figure 4 Financial stress indices divided according to market segments – international money market and international securities market



Source: Author's calculation.

Figure 5 Episodes of increased turbulence on the financial markets determined by the Markov switching model

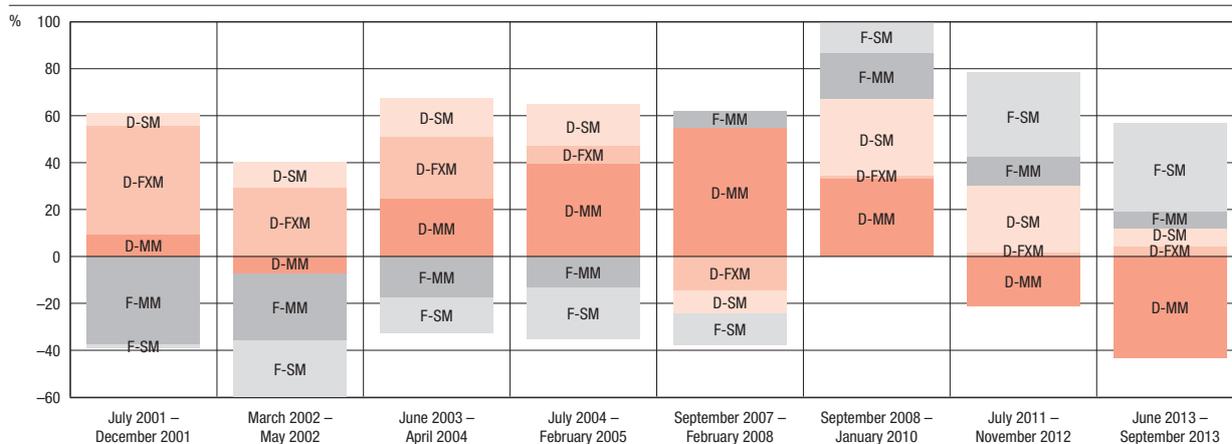


Note: The shaded regions show the described episodes of stress.

Source: Author's calculation.

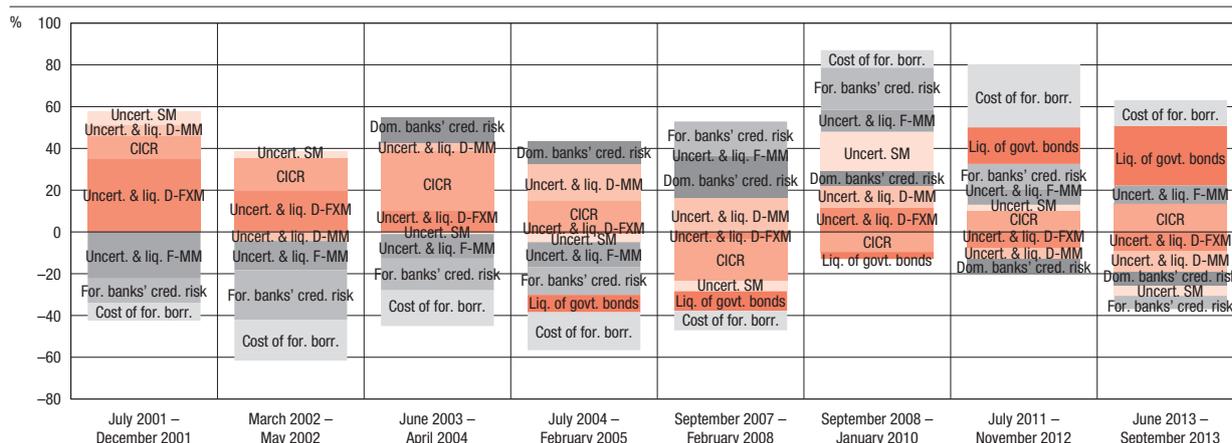
- 5) from September 2007 to February 2008,
- 6) from September 2008 to January 2010,
- 7) from July 2011 to November 2012, and
- 8) from June to September 2013.

Figure 6 Contributions of individual FSI components to episodes of increased turbulence on the financial markets – according to market segments



Source: Author's calculation.

Figure 7 Contributions of individual FSI components divided into episodes of increased turbulence on the financial markets – according to sources and kinds of risk



Source: Author's calculation.

For simplifying this analysis, episodes that were shorter-lasting but frequent in a short period of time are observed as a single stress episode.

In the analysis of the results obtained in the pre-crisis period up to the middle of the second half of 2008, four episodes of increased turbulence on the financial market can be seen. They were most affected by movements of variables on the domestic financial market that did not have very important systemic consequences. Two extremely powerful stress episodes were recorded in the period after mid-2008, which stand out not only for their intensity but also for their length, and for having had a powerful impact on real economy. They were primarily initiated by shocks from the international financial markets, although domestic indicators also had a powerful influence on them.

First period: from 2001 to 2003

The total FSI in the 2001–2003 period was relatively volatile, but there were only two, fairly mild, stress episodes. The most important event to mark this period on world markets was 9/11, which resulted in a rise in uncertainty and volatility on world financial markets and increased risk premiums. An analysis of the foreign component of the FSI reveals that a smaller part of this turbulence was transmitted to the domestic financial market via the money market channel (Figures 1, 2 and 4, column 1).

But in spite of turbulence on the world financial markets, the movement of the overall FSI in the first period was mostly marked by a speculative attack on domestic currency that occurred in August 2001 (Figures 1 and 2, column 1). In the middle of the month, depreciation pressures on the kuna against the euro were recorded, arising much earlier than usually considering the seasonal inflow of foreign capital from tourism. The reason for this lay in the speculative activities of some of the banks that in expectation of a considerable depreciation of the domestic currency started vigorously buying euros. In the shallow domestic market this rapidly caused increased nervousness and resulted in additional pressure for the kuna to depreciate (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, thus sending a clear message that the stability of the exchange rate was the priority, and so depreciation pressures were halted.

In this period, a powerful rise in interest rates on the money market was recorded (Figure 2, column 1). This encouraged some banks to use Lombard loans that they considered, in spite of their high rate of interest, favourable within the market expectations concerning trends in the exchange rate, and the central bank then made them more expensive by increasing the interest rate at which they were made from 9.5% to 10.5%. For these reasons, in October 2001 began the process of unifying foreign currency reserve requirements which sterilized part of kuna liquidity from the market, and at the same time part of the foreign currency liquidity was liberated leading to an increase of kuna interest rates. Banks reacted by issuing treasury bills, the interest rate of which fell to the lowest level to date, and the central bank intervened several times, which meant that kuna interest rates started falling again. At the end of the year 25% of the foreign currency reserve requirement was being held in kuna.

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

In 2002 monetary policy operated in conditions of a structural liquidity surplus and the kuna liquidity of the banking system was high throughout the year. The year was marked by powerful appreciation pressures because of the large inflows of foreign exchange from tourism, enhanced foreign borrowing by the government and the commercial banks and the privatisation of domestic enterprises, which encouraged the central bank to a number of foreign exchange interventions in which, in that year, a net HRK4.8bn were created. Some of these funds were sterilised by increasing the base for the kuna reserve requirement, while another part was withdrawn by increased issue of central bank treasury bills.

This ensured stability on the money and foreign exchange markets, which had been disrupted only for a short period marked by problems in Riječka banka (Figure 3, column 2) and an enhanced level of stress in these market segments. Thanks to the rapid reaction of the CNB, which ensured the necessary kuna and foreign currency liquidity for the normal operations of Riječka banka in the period until the new owner took it over, this turbulence was only of a temporary character and the crisis did not spill over to other financial institutions. This was also a period in which another stress period was identified, lasting from March to May 2002.

Apart from the relatively stable situation on the financial markets, with the exception of turbulence connected with the Riječka banka case, 2002 was marked by the continuation of powerful lending activities by the commercial banks. Although they grew rapidly, domestic sources have not been adequate to finance such strong credit activity, and the banks turned to foreign financing sources resulting in the growth of the external debt and the deterioration of the current account balance.

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. Any volatility was primarily caused by movements in the domestic component of the FSI, since no particularly strong turbulence in this period was recorded on the world financial markets. This period 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).

Movements on the domestic financial market in 2003 were influenced by the activities of the central

bank; in the beginning of the year, it tightened its policy, the aim being to slow down the credit expansion and foreign borrowings of the banks. Measures introduced were initially called monetary, but were in fact of a macroprudential nature. To be precise, sanctions were introduced on the growth of domestic loans greater than 16% a year or 4% quarterly; a decision was made on the minimum required amount of foreign currency claims of 35%, attempting to ensure appropriate foreign currency liquidity in the banks. The latter measure resulted in depreciation pressures on the kuna because of the augmented demand of commercial banks for foreign exchange and a reduction in primary liquidity in the banking system as well as a surge in the level and volatility of interest rates in the money market in the second half-year, which was reflected in financial stress indicators included in the calculation of the FSI for the domestic money and domestic foreign exchange market (Figures 2 and 3, column 2).

In September 2003, the central bank increased the percentage of the reserve requirement on foreign currency obligations that must be held in kuna from 25% to 35% and additionally in November to 42% in order to sterilise the kuna liquidity created by a greater than planned purchase of foreign exchange from the government. These changes resulted in temporary pressures on the appreciation of the domestic currency against the euro, and increased volatility of interest rates on the money market, which also affected the volatility of FSIs that describe the domestic foreign exchange and the domestic money market (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; and the beginning of the year was marked by the purchase of foreign currency from the commercial banks by foreign exchange interventions. This increased the liquidity of the banking system and reduced the interest rates on the money market, although this was of a merely temporary nature.

An analysis of the components of financial stress in the third episode of increased turbulence on the financial market identified, which lasted from June 2003 to April 2004, will show that the most important sources of stress were movements on the domestic foreign exchange and domestic money market, that is, uncertainty in these segments of the financial market (Figures 6 and 7, column 3).

In July 2004, interest rates surged again, and the central bank sought to limit capital inflows by imposing 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).

The movements described resulted in considerable changes in the level of commercial bank liquidity and in oscillations of interest rates on the money market where enhanced volatility was retained until early 2005. This had a powerful effect on the movement of the FSI that describes the domestic market, particularly on the money market component FSI-D-MM (Figures 2 and 3, column 2). Thus overnight interest rates went up to as high as 10%, but after several foreign exchange interventions in which the central bank bought euros, they dropped to the relatively low level of 2%.

The period from July 2004 to February 2005 was identified as the fourth episode of increased financial stress, mostly brought about by the described movements on the domestic money market (Figure 3, column 2, Figures 6 and 7, column 4).

Third period: from 2005 to mid-2007

During the third period, in world financial markets there was a continuation of a peaceful period. It was marked by a high level of global liquidity and low investor 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. Stable conditions on the international markets were reflected in the low and stable level of the foreign component of the FSI (Figures 2 and 4, column 3).

A similar pattern was observed with the domestic component of the FSI. This was also the longest period of low-level financial stress in which there were no major turbulences in a single segment of the financial markets and there was not a single stress episode (Figures 1, 2, 3 and 4, column 3; Figure 5).

Nevertheless, precisely in this period of apparently benign conditions on the financial markets a considerable deterioration in internal and external imbalances was recorded because of strong foreign borrowings, excessive loan activities and overheating of the domestic economy. Such trends prompted the central bank to carry on making its monetary, or rather macroprudential, policy much more stringent.

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 through which the banks endeavoured to avoid the other restrictions on foreign borrowing, 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 rise in lending was restricted to 12% a year, and in 2008 capital requirements for banks whose growth in lending exceeded the permitted rate were increased.

These measures increased the overall level of financial system resilience by creating buffers against possible shocks. But in spite of central bank efforts aimed at slowing down the process in which systemic risks were accumulating, it was precisely in this period of calm and stable conditions on the financial markets that systemic risks were being piled up in the system, to materialise when stress disruptions appeared in the fourth and fifth periods.

Fourth period: from mid-2007 to end-2009

The beginning of the fourth period was also the beginning of the world financial crisis. In the second half of 2007 the first indications of difficulties associated with sub-prime mortgages in the USA appeared. At the moment when issuers of securities based on these loans were faced with the impossibility of their re-financing, problems from the mortgage market spilled over onto the interbank money market, and from being a local turned into a global problem. This can be seen by observation of the foreign component of the FSI (Figure 2, column 4), that is, the component that describes the international money market FSI-F-MM (Figure 4, column 4).

Developments in the world financial markets were at first to no great extent reflected in indicators of financial stress in Croatia (Figures 1 and 2, column 4). Although even then a rise in the foreign component of FSI was recorded, the level it achieved was approximately the same as that recorded before the beginning of the long-lasting peaceful period, and the situation had almost completely stabilised at the beginning of 2008, when the level began to be reduced.

A much greater effect on the trends in the overall FSI was then played by increased volatility in the domestic money market (Figures 1, 2 and 3, column 4). These trends were mainly connected with the IPO of the domestic telecom company T-HT during October. Because of this process, an uncommon imbalance between supply and demand arose as a small group of banks generated a considerable part of the demand for kuna, while participants with surplus resources required interest rates higher than had hitherto been common. Although liquidity was at the usual level, the fact that this was a shallow money market that adjusted with great difficulty to large inflows or outflows of money greatly contributed to the maintenance of interest rates at elevated levels and their increased volatility until the end of the year (Figure 3, FSI-D-MM, column 4).

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

Temporary stabilisation on the international financial markets lasted until March 2008, when because of excessive reliance on financing via leveraging and short-term sources of financing, the Bear Stearns investment bank collapsed. Although this crisis situation was settled quite fast and had no great consequences, for the failed bank was taken over by the J. P. Morgan investment bank with the help and guarantee of the government, the reduction of confidence resulted in a renewed surge in volatility and nervousness on the international money market (Figure 4, column 4). In spite of that, the influence of the foreign component of FSI and FSI-F-MM on overall FSI was not very large (Figures 1 and 2, column 4).

After the initial enlargement, the foreign component of the FSI did not change very much until the escalation of the crisis after the collapse of American investment bank Lehman Brothers in September 2008 (Figures 2 and 4, column 4). This event resulted in a previously unparalleled surge in global risk aversion and an increase in price volatility on international financial markets with a simultaneous plunge in liquidity and a rise in distrust among market participants. This was manifested in the increase of both components of the foreign FSI that describe developments in the money market and the securities market (Figures 2 and 4, column 4). A

sudden leap in the risk premium for Croatia and a frozen money market greatly hindered the access of domestic sectors to foreign capital, which was reflected in all segments of the domestic component of FSI (Figure 3, FSI-D-FXM, FSI-D-MM, and FSI-D-SM, column 4).

In the fourth quarter of 2008 the domestic market recorded a strong rise in the level and volatility of overnight interest rates, and the FSI component describing the domestic money market reached in November 2011 what was then a record level (Figure 3, FSI-D-MM, column 4). The prime reason for such developments was transactions on the capital market connected with the takeover of INA d.d. by Hungary's MOL. This led to a marked division of banks into those with considerable surpluses and those with notable deficits of liquidity, and resulted in a surge in interest rates on the money market. The second reason is related to the instability on world financial markets that brought about a partial withdrawal of deposits from commercial banks in October. This encouraged banks to retain more liquid assets, and at the same time resulted in an enhanced demand for foreign currency liquidity (Figure 3, FSI-D-FXM, column 4).

Then, for the sake of maintaining overall financial stability because of marked depreciation pressures on the domestic currency, the central bank was forced to act by restricting kuna liquidity (Figure 3, FSI-D-MM, column 4). Apart from that, in order to improve foreign currency liquidity in the banks and to ensure the payment of international liabilities, the CNB started to release reserves accumulated during the pre-crisis period. The first step was the abolition of the marginal reserve requirement in October 2008.

These moves resulted in the preservation of a stable exchange rate and high levels of international reserves, as well as in the highest recorded levels of very short-term interest rates on the money market. In this manner pressures that in fact reflected movements on the foreign exchange market were manifested because of the reduction of kuna liquidity on the money market (Figure 3, column 4). This was also the reason why in the initial phase of the escalation of the crisis it was only slightly reflected in the developments of the FSI that describes the domestic foreign exchange market (Figure 3, FSI-D-FXM, column 4).

Instability on the money market at the end of the year and endeavours to make it easier to finance the government on the domestic market led in December 2008 to the lowering of the reserve requirement rate from 17% to 14%, resulting in a marked improvement in system liquidity, while interest rates went back to lower levels. This was at once reflected in a considerable reduction of FSI-D-MM (Figure 3, column 4), although it was of a short-term nature.

As well as by reverse repo auctions, the banks obtained kuna liquidity by the use of Lombard loans much more than in previous years, even though the interest rate on them had increased from the previous 7.5% to 9.0%, and in spite of the increased stringency of the regulations concerning the amount of securities needed as collateral.

Movements in the first half of 2009 were influenced by global turbulence that led to the complete freezing of world financial markets and essentially changed the previous pattern of the movements of capital flows, which were practically halted. Because of 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 held at the end of February, buying euros. In this period a marked increase in the FSI describing the domestic foreign exchange market was recorded (Figure 3, FSI-D-FXM, column 4). In order to stabilise the exchange rate, in January the CNB increased the percentage of the foreign currency reserve requirement that is set aside in kuna from 50% to 75%, which meant that the kuna reserve requirement rose by about HRK 5.8bn. Also, so that the system should be supplied with a sufficient amount of liquidity in foreign exchange, in February the rate of minimum foreign currency claims was reduced from 28.5% to 25% and in February additionally reduced to 20%.

The described developments on the foreign exchange market resulted in the first quarter of 2009 in a temporary but very powerful rise in the level and volatility of overnight interest rates and a great number of transactions in the money market because of the sparser kuna liquidity (Figure 3, FSI-D-MM, column 4). The situation was stabilised at the end of February after the weakening of depreciation pressures, and both interest rates and volatility on the money market were considerably reduced (Figure 3, FSI-D-MM, FSI-D-FXM, column 4). In the second half of the half-year a satisfactory level of liquidity was maintained in the banking system, and the interest rates on the money market remained relatively stable, as did the exchange rate (Figures 1, 2 and 3, column 4).

The end of 2008 and most of 2009 were marked by a major decline in the CROBEX share index, while fluctuations in returns on the index and in the CROBIS bond index were increased. These developments were strongly reflected in the domestic component of FSI that describes the securities market (Figure 3, column 4).

Unlike previous episodes of turbulence in which there were always some segments of the financial market capable of alleviating stress disruptions, in the sixth identified episode, which lasted from September 2008 to January 2010, all the segments of the financial markets contributed to the deterioration of conditions on those markets (Figures 6 and 7, column 6). And as earlier mentioned, the greatest part was played by events on the international and domestic money markets. Here it should be said that the trends in interest rates on the domestic money market at that moment was collateral damage caused by pressures on the foreign exchange market, since the stabilisation of the EUR/HRK exchange rate was a key precondition for the preservation of overall financial stability in the country.

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

The fifth period was marked by the deepening of the crisis in the government debt markets in peripheral eurozone states in mid-2011. As well as threatening the stability of the banking system, this crisis had an adverse effect on the expectations of market participants, consumers and enterprises connected with the only just started economic recovery. The renewed decline in investor risk appetite was reflected in increased risk premiums, which was the most important channel by which stress spilled over onto the domestic financial system through a rise in the FSI foreign component (Figures 1, 2 and 4, column 5). The risk premium for Croatia rose, absolutely and relatively, much more than the premiums for European countries with emerging markets, and exceeded the previously highest level, achieved in early 2009. These developments were reflected in the considerable enlargement of the FSI foreign component, which had an impact on international securities markets (Figure 4, column 5).

The increased reliance of domestic subsidiaries on their parent banks during the fifth stress episode reflected on the one hand support of the owners to domestic banks, but also considerably increased exposure to their liquidity, needs for capital, financing strategies and operations and to developments in the countries from which they came, as well as in those to which they were most exposed.

The exacerbation of conditions on the international debt market in the second half of 2011 led to a marked rise in the CDS premiums on the bonds of the parent banks of the five biggest domestic banks. Their average level at the end of 2011 ranged about 500 basis points and that was almost twice as much as in the period after the escalation of the world financial crisis at the end of 2008. The reason for here being such a powerful rise in these risk premiums is connected with the exposures of banks to peripheral eurozone countries that gave grounds for concern about the sustainability of their fiscal positions. One of these countries was Italy, and adverse developments in CDS premiums for Italy additionally increased the risk perception of Italian parent banks, which were worse than those of banks from Austria and France. Adverse trends in the European financial markets resulted in the partial withdrawal of the resources of parent banks from domestic banks, which slightly increased pressures on the foreign currency liquidity of the financial system (Figures 3 and 4, column 5).

During the seventh stress period, which lasted from July 2011 to November 2012, the major contribution to movement of total FSI and the increased level of stress was made by movements on the international securities market and the money market in which extremely great volatilities were recorded, as well as a powerful growth of uncertainty and risk aversion. These trends were manifested 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 in the period was quite stable, the liquidity of the system was high thanks to CNB measures, and the interest rates on the money market were both low and stable. This can be seen in the quite low levels of the domestic FSI component, which actually reduced during the major part of the year (Figures 2 and 3, column 5).

The last, eighth, identified episode of increased turbulence lasted from mid-June to September 2013. The calculated contributions of given risks and market segments to this episode of crisis confirm the dominant

impact of the cost of foreign borrowing, that is, trends in the international securities markets that assessed Croatia as being a high-risk case.

The period was characterised by a reduction of Croatian credit rating to below investment level by all three of the leading agencies (Standard and Poor, 13 December 2012; Moody's, 1 February 2013; and Fitch, 20 September 2013). A relatively strong reaction of the FSI to the first downgrading at the beginning of February can be seen, while the negative reactions to the two further credit downgrades were somewhat milder (Figure 1, column 50).

Notwithstanding this and the lack of any domestic economic recovery, the financial markets did not close for Croatia. The relatively mild reactions to the credit downgrade were helped by the stabilisation on the international financial markets, and the government made use of this complex of relatively favourable circumstances; it twice managed to take on new debts on the American market – in April, of USD 1.5bn USD, with an issue yield of 5.62%, and in November of USD 1.75bn, with a yield at issue of 6.20%. One of the reasons for the high level of the last issue of bonds was to provide the funding needed for the following year in relatively relaxed conditions in the financial markets at the end of 2013.

For if the end of the analysed period is observed, it is possible to see that it was marked by an improvement of conditions on world financial markets and a fall in general risk aversion (Figure 4, column 5). In spite of this, the Croatian risk premium stood at a high level, and the foreign component of the FSI still made a negative contribution to the movement of the overall FSI (Figure 2, column 5). The reason for this was investor concern at the lack of any economic recovery, which is not expected even in 2014, the snail's pace progress made in fiscal consolidation and in general the great deterioration in fiscal indicators, as well as the absence of changes to create the conditions for sustainable economic growth.

It can be concluded that Croatia, because of its endogenous weaknesses, did not use the period of stable and to an extent unexpectedly favourable conditions in the domestic and international financial markets so as to ensure cheaper funding for the private sector in the more favourable conditions, which would have been one of the more important steps towards economic recovery. It can also be concluded that Croatia is extremely vulnerable to any possible tightening of conditions on the international financial markets, for if there were any marked rise in risk aversion, it could well face a prohibitively high price for foreign capital.

Comparison of FSIs and indices of financial conditions

At the end, following Kliesen (2012) on the basis of the total FSIs calculated, one more check was made on the robustness and usefulness of the results obtained, which were for this purpose compared with the FCI (financial conditions index) for Croatia. This index is calculated with the use of the PCA method, on the basis of 28 macroeconomic and financial variables that reflect financing conditions in Croatia (for details see Dumičić and Krznar, 2013). Because these data about the trends in the FCI are available at a quarterly level, the FSIs were harmonised by their quarterly average values being used.

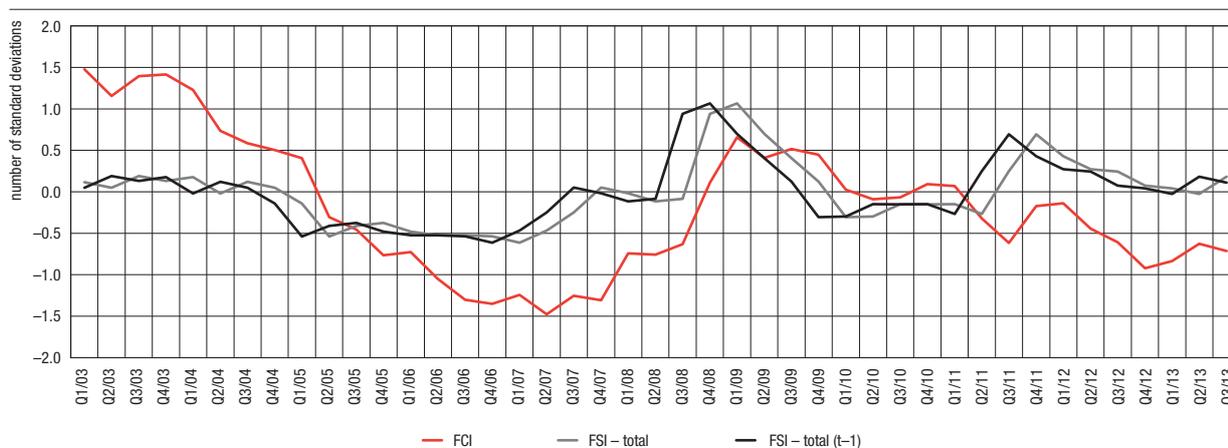
The coefficients of correlation show a relatively strong positive link between FCIs and FSIs calculated by various methods, and this correlation is still stronger if the level of the FSI of the previous quarter is used, which suggests a great influence of financial stress developments on overall financial conditions and the possible use of the FSI for predicting trends in financing conditions for domestic sectors in the forthcoming period.

Table 4 Coefficients of correlation between FCIs and FSIs

Coefficients of correlation		
	FCI	FCI (t+1)
FSI_vew	0.57	0.70
FSI_pca	0.58	0.69
FSI_cdf	0.61	0.76

Source: Author's calculation.

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).

Conclusion

Because of the adverse effect of financial market stress episodes on financial and macroeconomic stability and bearing in mind the fact that a financial system develops and changes with great rapidity, it is necessary continuously to update and develop the analytical framework for the monitoring of trends in the financial markets. The main objective of this paper has been to construct high-frequency financial stress indicators that will inform economic policy makers in due time of possible disruptions in the financial markets and be a useful tool for the analysis of risks that might jeopardise the financial and macroeconomic stability of the system.

Apart from that, the objective was to use the Croatian example to create an index that, in spite of the relatively limited accessibility of daily indicators, would still cover the most important specific features of a small, open, highly-euroised country with shallow financial markets and majority foreign-owned banks. Most of the indicators of financial stress were created for developed countries that are at a different level of economic and financial development and are characterised by different institutional and regulatory arrangements from those in countries with 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.

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 method. The indices constructed are highly correlated, which means that the aggregation method does not essentially affect the information contained in the index; this confirms the robustness of the results.

The point of the indicators of financial stress constructed is that they can practically and in real time detect movements in and the level of financial stress on the financial markets. What has to be highlighted is that in the initial period of its growth it is not possible to determine if increased turbulence will result in a stress episode or not. Although this is a matter of ex-post analysis, it is useful for the analysis of periods of increased turbulence on a longer time series of financial stress indicators. It has turned out that the calculated FSIs describe well the events on the financial markets as well as the monetary and macroeconomic trends in the period from early 2001 to end-2013, also suggesting that they are robust. The identification of sources of financial

stress and the factors that most contribute to them, the understanding of the channels through which disruptions spill over to the remainder of the financial system and real developments, as well as the analysis of the moves of the makers of economic policy in these periods can offer useful understandings and enable more effective preventive action and better reactions in stress episodes.

Through an analysis of the FSIs and the reactions of the central bank to episodes of turbulence that appeared in some of the segments of the financial market in the period and if the specifics of the domestic financial system are taken into consideration, it can be concluded that in its domain the CNB was successful in the stabilisation of the financial markets and the preservation of overall financial stability. Although in this period there were no financial stress indicators calculated in this way, they would surely have been useful in the process of identifying sources of stress disruptions. They could also have been employed so as to acquaint the public and market participants with the known risks that might threaten financial stability and with the moves of the central bank aimed at the palliation of these risks. It became apparent that market participants and the public were often unaware of the possible threats capable of threatening financial stability, particularly in stable periods on the financial markets.

In the future, it can be expected that these indicators will continue to be developed and that their components will be adjusted to developments on the financial markets. Also, in the next step the indices might be used as an early warning tool for those in charge of economic policies, for with the help of different techniques of dynamic simulation future values of FSIs can be forecast, and can be used for predicting trends in the financing conditions for domestic sectors. 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, like financial conditions indices, indices of the accumulation and materialisation of systemic risks and resilience of the system to systemic shocks, this indicator should enable a better monitoring of financial stability risks and ensure a prompt reaction on the part of economic policy makers to possible episodes of financial stress.

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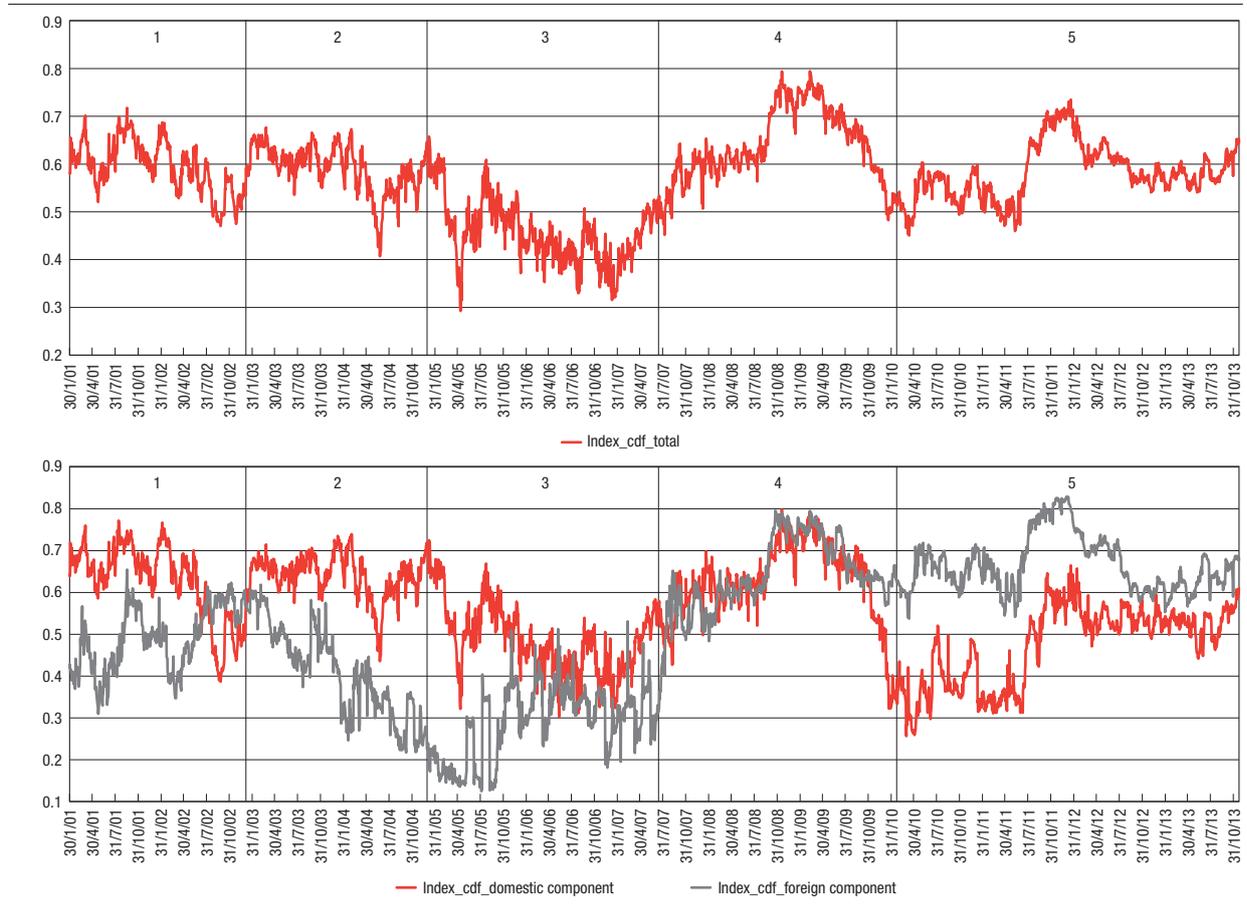
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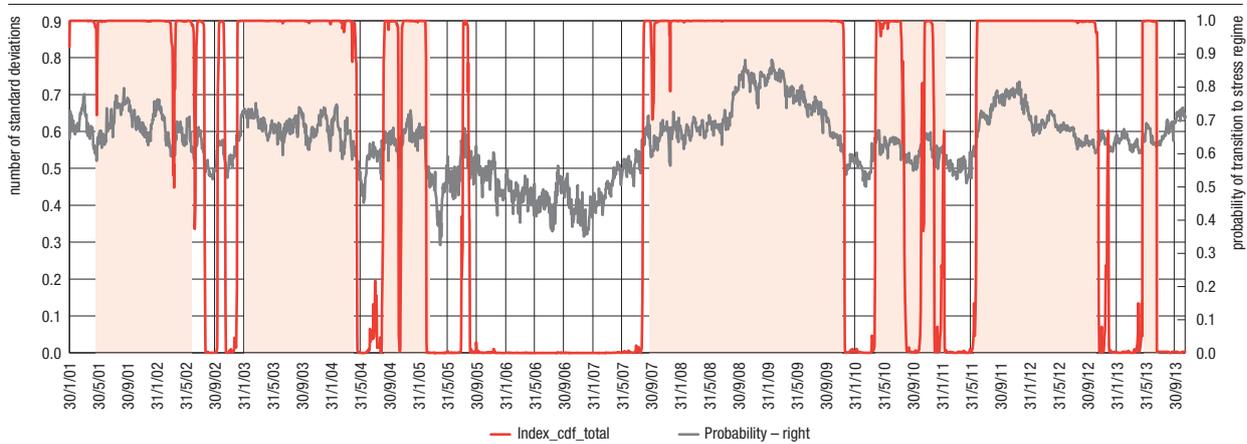
Annex 1 Indices of financial stress calculated with the use of variables transformed with the cumulative distribution function

Figure 9 Financial stress indices calculated with the use of the cumulative distribution function



Source: Author's calculation.

Figure 10 Episodes of increased turbulence on the financial markets determined by the Markov switching model

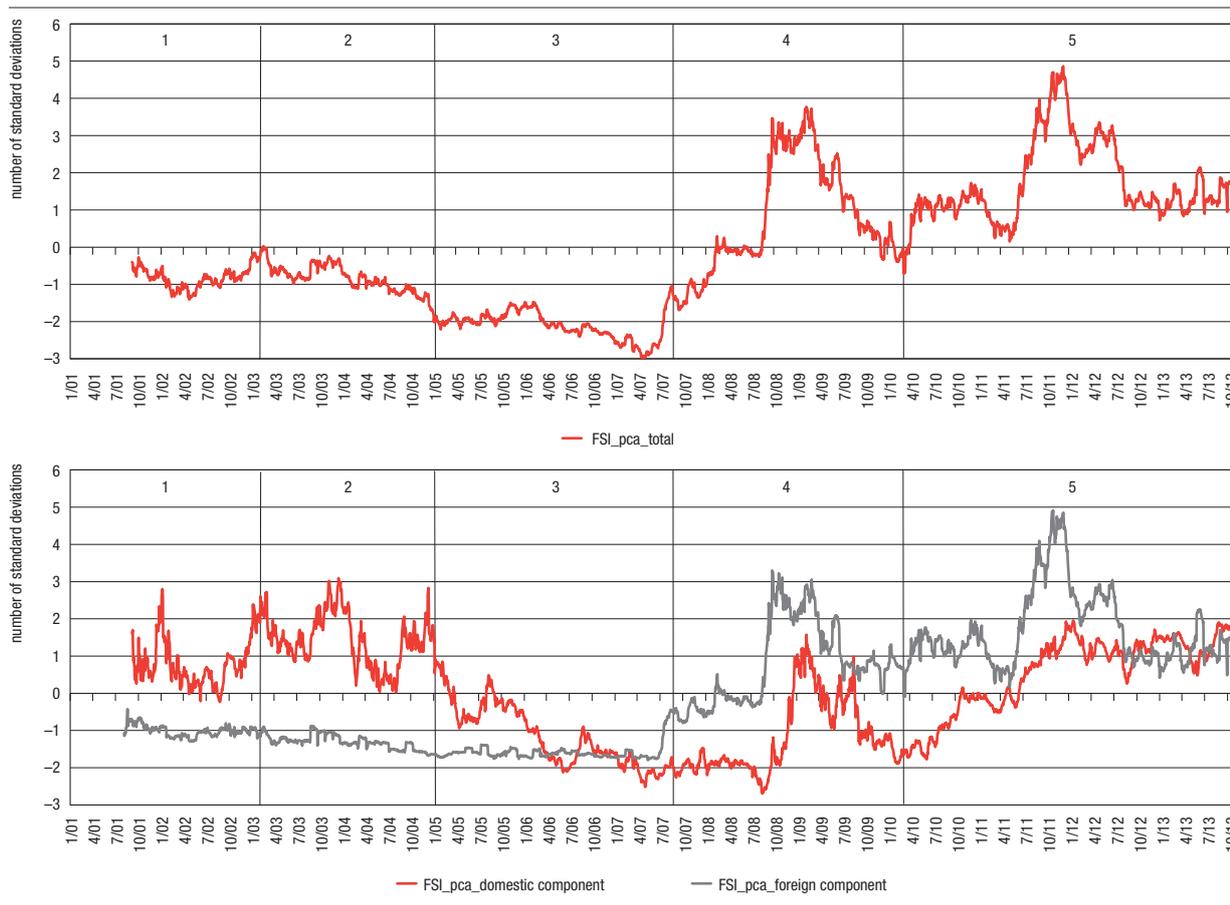


Note: The shaded regions show the major episodes of stress.

Source: Author's calculation.

Annex 2 Financial stress indices calculated with the principal component analysis method

Figure 11 Financial stress indices calculated with the principal component analysis method



Note: Fewer variables are included in the FSI obtained by the PCA method than in other indices calculated by other methods so as to obtain the maximally long time series, for not all data are available since January 2001, and variables that are not stationary are excluded. Since daily figures are involved, the usual methods of transforming variables to avoid this problem result in very volatile series.

Source: Author's calculation.

Table 5 Loadings of parameters for variables included in the FSI calculated by the principal component analysis method

Variable/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 assets structure of commercial banks	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 and OIS spread	0.36		0.42

Source: Author's calculation.

The following Working Papers have been published:

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