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RESEARCH ARTICLE

Financial Stress Indices and Financial Crises

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Abstract This paper develops a Financial Stress Index (FSI) for 28 OECD countries and examines its relationship to crises using a novel database for financial crises. A stress index measures the current state of stress in the financial system and summarizes it in a single statistic. Our results suggest that even though our FSI is clearly related to the occurrence of crises, there is only a weak relationship between the FSI and the onset of a crisis, notably the onset of a banking crisis. Policymakers should therefore be aware of the limited usefulness of FSIs as an early warning indicator.

Keywords Financial stress index · Financial crises · Developed countries · Early warning indicators

JEL Classification E5 · G10

1 Introduction

Financial crises have been around since the development of money and financial markets. They come in different forms: banking crises, sovereign debt crises, and currency crises. The costs of financial crises in terms of output lost and fiscal costs are very high. Laeven and Valencia (2013) estimate the output loss of banking crises in advanced countries at 32 % of trend income and the fiscal costs at 4 % of GDP. Policy

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makers therefore try to prevent financial crises using several instruments to monitor financial stability, including financial stress indices. The general aim of a financial stress index (FSI) is "to measure the current state of instability, i.e., the current level of frictions, stresses and strains (or the absence thereof) in the financial system and to summarize it in a single (usually continuous) statistic" (Holló et al. 2012: 4).

According to Balakrishnan et al. (2011: 44) "an episode of financial stress is defined as a period when the financial system is under strain and its ability to intermediate is impaired. Financial stress tends to be associated with at least four fundamental characteristics: large shifts in asset prices, an abrupt increase in risk and/or uncertainty, liquidity droughts, and concerns about the health of the banking system. The events affecting financial market conditions can be varied and have external or domestic origins, such as risk-reassessments of investors, changes in such events shape the supply or demand of funds in financial markets—and therefore asset prices—and may thereby afflict multiple segments of the financial system." Similarly, Hakkio and Keeton (2009) refer to increased uncertainty about the fundamental value of assets, increased uncertainty about behaviour of other investors, increased asymmetry of information, decreased willingness to hold risky assets, and decreased willingness to hold illiquid assets in describing financial stress.

Financial stress indices are widely used by policymakers as an instrument for monitoring financial stability. As Kliesen et al. (2012: 371) argue: "FSIs try to monitor financial instability by creating a time series of values in which increases indicate the increased likelihood of a crisis." According to Oet et al. (2012: 2), such a "monitoring instrument may specifically support the ability to intelligently observe systemic risk and to continuously assess financial system conditions. This tool would enable the public to observe drivers of stress in the financial system, and—by providing alerts—help to diffuse the information uncertainty and give the risk managers time to counteract."

Several papers have come up with a FSI, be it for one country (e.g., Illing and Liu 2006) or for several countries (e.g., Cardarelli et al. 2011). Another strand of academic research has come up with early warning models for financial crises, which aim to provide policy makers with signals about upcoming financial crises (see Babecký et al. 2013 and references cited therein). Most research on early warning models uses crises dummies as dependent variable (Kauko 2014). However, financial crises occur at low frequency in industrial countries, which makes it hard to examine regularities. Therefore, a FSI can be used as left-hand side variable in an early warning model (instead of a crisis dummy).

This paper examines the relationship between financial stress indices and financial crises for a sample of 28 OECD countries using a new FSI and a novel database of financial crises, which is constructed based on influential academic papers and cross-checked with the input of national experts (cf. Babecký et al. 2014). So far, only limited attention has been given to this issue. This is remarkable as the usage of FSIs as policy instrument to monitor financial stability or as dependent variable in early warning models presumes that FSIs are related to financial crises (Kliesen et al. 2012). As will be discussed more extensively in Section 2, only three studies (Illing and Liu 2006; Morales and Estrada 2010; Louzis and Vouldis 2013) have examined this issue. Whereas previous studies are all based on one country, we use a multi-country framework. As pointed out by Claessens (2009), single-country studies suffer from the problem that there are only a few financial crisis periods.

As pointed out above, a financial stress index measures the current state of stress in the financial system by combining several indicators of stress into a single statistic. In constructing our financial stress index for 28 OECD countries, we use four criteria: the index should cover the entire financial system and indicators included should be available for many countries for a long period at a quarterly frequency, be comparable, and be related to financial crisis in line with theoretical expectations. Our results suggest that even though our FSI is clearly related to the occurrence of crises, there is only a very weak relationship between the FSI and the onset of a crisis, notably the onset of a banking crisis.

The paper is structured as follows. Section 2 offers an overview of the by now large literature on stress indices, their usage and limitations. Section 3 describes our data. Section 4 examines the relationship between our FSI and financial crises. Section 5 offers our conclusion.

2 Financial Stress Indices

2.1 Overview of Financial Stress Indices

Financial stress indices have been constructed for one country (e.g., Illing and Liu 2006; Hakkio and Keeton 2009; Morales and Estrada 2010; Holló 2012) or for several countries (e.g., Holmfeldt et al. 2009; Cardarelli et al. 2011; Slingenberg and de Haan 2011; Holló et al. 2012; Cevik et al. 2013; Islami and Kurz-Kim 2013). In general, stress indices for a single country combine more indicators into one statistic than multi-country stress indices (see Table 6 in the Appendix for a comparison of several stress indices; for a more extensive comparison we refer to Kliesen et al. 2012). This is not surprising in view of data availability. Most studies use market data, but some (e.g., Holló et al. 2012) use both mixed market and balance sheet data, while Morales and Estrada (2010) consider only balance sheet data.

Authors employ different ways to combine indicators into an aggregate stress index. Whereas most studies take the average of standardized variables, others use principal components (cf. Illing and Liu 2006; Hakkio and Keeton 2009). More recently, Holló et al. (2012) employed portfolio theory based aggregation schemes that take into account the correlation structure of stress indicators in order to quantify the level of systemic stress.

Financial stress indices have been used for different purposes. Cardarelli et al. (2011) use their stress index for 17 advanced economies from 1980 to 2007 to examine the relationship between financial stress and economic slowdowns. Their findings suggest that episodes of financial turmoil characterized by banking distress are more likely to be associated with deeper and longer downturns than episodes of stress mainly in securities or foreign exchange markets. Furthermore, recessions associated with banking-related financial stress tend to last at least twice as long as recessions which are not preceded by financial stress. Likewise, Cevik et al. (2013) employ a financial stress index for Bulgaria, the Czech Republic, Hungary, Poland, and Russia to examine the relationship between financial stress and economic activity. Their impulse response functions based on bivariate VARs show a significant relationship between financial stress and some measures of economic activity. Islami and Kurz-Kim (2013) construct

a FSI for the euro area and examine its predictive ability for the real economy during the recent banking crisis and the euro-area sovereign debt crisis. These authors conclude that their FSI outperforms the Euro STOXX 50 volatility index. Their evidence suggests that the negative impact of financial stress on the real economy had a time lag of three months during the recent financial crisis and the euro-area sovereign debt crisis.

Oet et al. (2012) use their FSI to analyse the impact of financial deregulation. Their results suggest that the frequency of systemic stress episodes remains consistent pre- and post-U.S. financial deregulation. However, in the post-deregulation period the speed of systemic stress propagation slows, but the length of the recovery from systemic stress also slows substantially.

Balakrishnan et al. (2011) develop a financial stress index for developing countries and examine the transmission channels of financial stress between advanced and developing countries. Likewise, using an FSI for 25 emerging markets, Park and Mercado Jr (2013) report that that not only financial stress in advanced economies, but also regional and non-regional emerging market financial stress significantly increase domestic financial stress in emerging markets. Although domestic financial shocks account for most of the variation in domestic FSIs, regional shocks play an important role in emerging Asia.

Baxa et al. (2013) analyse whether and how the monetary policy of several central banks (the US Fed, the Bank of England, the Reserve Bank of Australia, the Bank of Canada, and Sveriges Riksbank) responded to episodes of financial stress over the last three decades. Using the financial stress index of Cardarelli et al. (2011), the authors find that central banks change their policy stances in the face of financial stress, but the magnitude of such responses varies substantially over time.

Some papers try to identify leading indicators of financial stress. For instance, Misina and Tkacz (2009) report that within a linear framework, domestic credit growth is the best predictor of the stress index for Canada at all horizons, resulting in marginally lower prediction errors compared to the base model, while asset prices tend to be better predictors of stress when they allow for nonlinearities. Slingenberg and de Haan (2011) extend the study by Misina and Tkacz (2009) expanding the analysis to 13 OECD countries. Their results suggest that financial stress is hard to predict. Only credit growth turns out to have some predictive power for most countries. Several other variables have predictive power for some countries, but not for others.

Finally, a few papers have examined the relationship between financial stress and financial crises for single countries. Louzis and Vouldis (2013) develop a systemic financial stress index for Greece. By comparing it with the results of an internal survey conducted within the Bank of Greece to determine the most stressful events for the Greek financial system, they evaluate their index based on its ability to match the results of the survey. They conclude that their index can timely identify the crisis periods as well as the level of systemic stress in the Greek financial system. Similar findings have been reported for Canada by Illing and Liu (2006) and for Columbia by Morales and Estrada (2010). As pointed out before, single-country FSIs usually contain more indicators than multi-country FSIs and may therefore be better able to capture stress. On the other hand, single-country studies suffer from the problem that there are only a few financial crisis periods (Claessens 2009). We therefore examine the

relationship between financial stress indices and financial crises within a multi-country framework, which, to the best of our knowledge, has not been done before.

2.2 Limitations

Financial stress indices have certain limitations. First, they generally do not capture interconnectedness. As Praet (2010) put it: "Interconnectedness implies that an adverse shock that generates sufficiently large losses at one bank may be transmitted to other banks, particularly in times of stress. Interconnections occur both directly through interbank deposits, loans, derivatives, and other securities and indirectly through common exposures to similar assets or risks. Prior to the onset of the crisis, credit risk transfer instruments, in particular credit derivatives, have further enhanced interconnectedness by increasing common exposures across institutions and linking banks' balance sheets in complex or nested ways."

The same holds for certain other characteristics of the financial system, like the systemic importance of certain financial institutions. It is not so straightforward to identify financial institutions that are systemically important. Apart from size, their interconnectedness to the rest of the system, and the degree of substitutability of the institutions or their activities matter (Praet 2010). Although systemic risk and systemic importance are related, they are distinct dimensions of financial stability. Take, for instance, a financial system that consists of small and unconnected banks with a large degree of common exposures. Even though this system does not contain (individually) systemically important banks, the level of systemic risk is high as the banks may be simultaneously hit by a systematic shock.

As financial stress indices focus on developments over time, they generally do not capture these important dimensions of financial stability, even though the recent financial crisis has illustrated their importance.[1]

Finally, Borio and Drehmann (2009) argue that that the lead with which market prices—on which most FSIs rely—point to distress is uncomfortably short from a policy perspective. For example, unusually low volatilities and narrow spreads prevailed across a broad spectrum of asset classes until the financial crisis started in the summer of 2007, after which they rose sharply. Borio and Drehmann illustrate this point by showing that the Illing and Liu (2006) FSI for the US starts going up sharply only once the turmoil in financial markets erupted in the second half of 2007. In the remainder of this paper we examine whether this is a general feature of financial stress indices.

[1] Several measures have been proposed to capture systemic risk, such as CoVaR (Conditional Value at Risk) which quantifies how the financial stress of one institution can increase the tail risk of others (Adrian and Brunnermeier 2011) or the systemic impact index (SII), which measures the expected number of bank failures in the banking system given a situation in which one particular bank fails (Zhou 2010). An alternative is to apply network analysis to identify interlinkages between financial institutions. Recent examples include Markose (2012) and in't Veld and van Lelyveld (2014). Markose (2012) models the contagion-like threats posed by the activities of large financial intermediaries in the over-the-counter (OTC) derivatives markets, while in't Veld and van Lelyveld (2014) investigate the network structure of interbank markets.

3 Data

3.1 Financial Stress Index

We started by taking stock of variables included in financial stress indices used in previous studies. To be included in a FSI that can be used for our purposes, a particular variable should meet the following criteria. First, it should be available for many countries for a long period at a sufficiently high frequency. [2] As pointed out by Kliesen et al. (2012), a potential advantage of using higher-frequency data is that they may better facilitate real-time decision-making. However, using higher-frequency data (for example, weekly observations rather than monthly observations) means shorter samples, while for some countries higher-frequency data may not be available. Moreover, very high frequency dynamics of some financial variables can be related to one-off non-systemic shocks that quickly fade off. That is why we decided to use quarterly data, which is also the highest frequency at which one can obtain historic tracking of financial crises (see section 3.2). The criterion that data should be available for many countries implies that some sectors, notably the real estate sector and securitization markets (cf. Oet et al. 2012), cannot be included.

Second, the included variables should be comparable across countries. Finally, the FSI should cover as much of the financial system as possible, i.e., money, capital markets, the banking sector, and the foreign exchange market (Holló et al. 2012). It is quite remarkable that several indices do not include the foreign exchange market (see Table 6 in the Appendix). Note that the variable with the shortest available period determines the period for which the FSI is available.

On the basis of these criteria, we considered the variables shown in Table 1. We will explain these indicators first and then explain how we have combined them into an index. A fourth criterion that we applied in constructing our FSI is that the indicators should be related to our financial crisis measures in line with theoretical expectations.

Several financial stress indices include stock price volatility assuming that large swings in stock prices indicate financial imbalances in the equity market (cf. Illing and Liu 2006; Hakkio and Keeton 2009; Cardarelli et al. 2011). Our index also takes stock price volatility into account. Following Cardarelli et al. (2011), time-varying stock return volatility has been derived from a GARCH(1,1) specification (Bollerslev et al. 1992).

The volatility of monthly changes in the nominal effective exchange rate is also included in our index (see also Illing and Liu 2006; Cardarelli et al. 2011; Islami and Kurz-Kim 2013). Like stock price volatility, this indicator is derived using a GARCH(1,1) specification for the monthly change of the real effective exchange rate. This volatility reflects investors' uncertainty about the fundamental value of the currency and about the investment behaviour of other agents (Cardarelli et al. 2011).

[2] When only a few observations are missing in an otherwise long time series we use linear interpolation to construct a continuous time series for the respective variable.

Table 1 Indicators considered and FSI

FSI1	Stock price volatility derived from a one year rolling GARCH(1,1) specification
FSI2	Volatility of monthly changes in the nominal effective exchange rate as calculated by a one year rolling GARCH(1,1) specification
FSI3	Beta of the banking sector, calculated as cov(return banking sector, total market)/variance(total market)
FSI4	Long term interest rate - US long term interest rate (measure of sovereign risk). This variable is zero for the US
FSI5	Inverse yield curve - (long term interest rate - short term interest rate), i.e., short term interest rate - long term interest rate
FSI6	TED-spread, which is the yield difference between a (3 month) unsecured interbank loan and the risk free rate (3 month)
FSI	Calculate the total financial stress index as the non-weighted sum of each financial stress index except FSI6 (FSI=FSI1+FSI2+FSI3+FSI4+FSI5).

An indicator of stress in the banking sector that is included in our index is the so-called β of the banking sector (see also Illing and Liu 2006; Cardarelli et al. 2011; Oet et al. 2012), which is calculated as follows:

$$\beta = \frac{\mathrm{cov}(b, m)}{\mathrm{var}(m)} \tag{1}$$

where β is the total change of the banking sector equity index and m is the total change of the market sector equity index. If beta exceeds 1, the returns for the banking sector are more volatile than the returns for the overall market.

We considered two indicators of stress in the bond market, namely the inverse yield curve, i.e., the short-term interest rate minus the long-term interest rate, and the domestic long-term interest rate minus the US long-term interest rate as a measure of sovereign risk. Some other studies also include an indicator of the slope of the yield curve (e.g., Cardarelli et al. 2011). According to these authors, "banks generate income by intermediating short-term liabilities (deposits) into longer-term assets (loans). Therefore, when there is a negative term spread—that is a negative sloping yield curve—bank profitability is seriously jeopardized." (p. 80). One of the few studies considering sovereign risk is Louzis and Vouldis (2013) who use the spread of Greek and German government bonds. In our index, we take the US as benchmark, which implies that this indicator is zero for the US.

Most stress indices include a measure for the money market, like the TED-spread, i.e., the yield difference between an unsecured inter-bank loan and the risk free rate (cf. Hakkio and Keeton 2009; Cardarelli et al. 2011; Oet et al. 2012). The TED-spread reflects credit risk and liquidity risk. It also captures stress in the banking sector as the premium captures counterparty risk. However, in our sample it turned out that this money market spread frequently had the 'wrong' sign (see Table 2). Based on our fourth criterion, we therefore decided against inclusion of this spread into our FSI. As most previous studies include the TED-spread (see also the references in Table 6 in the Appendix),

Table 2 Correlations of components and aggregate financial stress indices

	FSI1	FSI2	FSI3	FSI4	FSI5	FSI6	FSI	FSIA
FSI1	1							
FSI2	0.21	1						
FSI3	0.19	0.09	1					
FSI4	0.15	0.17	0.11	1				
FSI5	0.00	0.05	−0.15	0.28	1			
FSI6	0.12	0.02	0.06	−0.10	−0.32	1		
FSI	0.58	0.55	0.47	0.64	0.44	−0.08	1	
FSIA	0.48	0.39	0.45	0.54	0.31	−0.02	0.81	1

we nevertheless examine the relationship between this indicator and the occurrence and onset of financial crises. Note also that interpreting the TED-spread for euro area countries since 1999 is plagued by the presence of only a single euro area interbank and risk free rate. Therefore, for this period the TED-spread is not informative about individual euro area countries. This may explain partly why we observe the 'wrong' sign for the TED-spread in our analysis.

The FSI is calculated for 28 OECD countries, shown in Fig. 2. All variables are standardized, i.e., we subtract the mean and divide by the standard deviation. Our overall index FSI is the non-weighted sum of the standardized variables included (i.e., FSI1, FSI2, FSI3, FSI4 and FSI5). A justification for giving all the variables the same weight is that this makes the index easy to interpret. Gadanecz and Jayaram (2009) argue that using weighting factors may represent the financial system better, but Illing and Liu (2006) show that weighting does not make much of a difference.[3] The interpretation of the FSI is very straightforward. If the index is above 0, it indicates stress; if it is below 0, the financial system is stable. To examine whether our results are driven by the aggregation procedure, we also construct an alternative FSI, called FSIA, following a similar aggregation procedure as suggested by Holló et al. (2012), which will be explained below.

Table 2 shows the correlation of our financial stress index and its components (sub-indices). The correlation of the sub-indices is low, suggesting that they capture different dimensions of financial stress. FSI6 has a negative relationship with the overall FSI, which is counterintuitive. That is way we decided not to include the Ted-spread in our financial stress index.

The use of constant weights for the variables used to calculate the FSI is sometimes criticized. As an alternative to the non-weighted sum of the standardized indicators, we follow Holló et al. (2012) who suggest using time varying correlations, because this approach "puts relatively more weight on situations in which stress prevails in several market segments at the same time which, in turn, captures the idea that systemic risk/

[3] In contrast, Holló et al. (2012) argue that if their index were calculated as a simple arithmetic average - which implicitly assumes perfect correlation across all sub-indices all the times - it would not be able to differentiate between the aggregate levels of stress prevailing, for example, in the aftermath of September 11, 2001 and during the first year of the current 'subprime" crisis.

stress is high if financial instability is spread widely across the whole financial system" (Holló et al. 2012: 5). This method limits the likelihood of false stress incidents.

We calculate the alternative financial stress index FSIA as follows:

$$FSIA = y_t C_t y_t' \tag{2}$$

where $y=(w \circ s)$ and $w=(w_1,w_3,w_4,w_5,w_6)$ is the vector of (constant) sub-index weights, s is the vector of sub-indices (FSI1, FSI2, FSI3, FSI4, FSI5); $w \circ s$ is the Hadamard-product (i.e., element by element multiplication of the vector of sub-index weights and the vector of sub-index values in time t) and C_t is the matrix of time-varying cross-correlation coefficients ρ_{ijt} between the sub-indices i and j. We use equal weights, i.e., w=0.2, for each sub-index. The sub-indices are constructed by attaching the value 1/N to the lowest value of a sub-index, 2/N to the second lowest value up to N/N for the highest value. This maps all values of each sub-index in the (0;1] domain. We attach these values considering the full sample, since the current analysis is not about real-time forecasting. The correlation weights C_t are time-varying with persistence parameter lambda equal to 0.75 at the monthly frequency. This is close to 0.93 which Holló et al. (2012) use at a weekly frequency. The results are not very sensitive to the exact value of this parameter. As shown in Table 2, the correlation between FSI and FSIA is 0.81.

3.2 Financial Crises

Existing annual databases on financial crises differ widely (Chaudron and de Haan 2014). We use the crises database of Babecký et al. (2014).[4] These authors provide a quarterly database of the occurrence of banking, debt, and currency crises for a panel of 40 industrial countries over 1970–2010; for a number of countries—e.g., those which experienced economic transition from a planned to a market economy—the data only start at the beginning of the 1990s. The database has been constructed using several sources, including existing databases from the academic literature. This dating is often at the annual frequency. Subsequently, input from country experts, mostly from national central banks, has been used to crosscheck the crisis dates, to ensure that the quarterly dating is appropriate, and to balance the dataset for developed countries as much as possible.

Figure 1 shows the number of countries in our sample in crisis at each point in time; this number peaked in the early 1990s and during the recent crisis. Breakdown by crisis type suggests that in our sample of industrial countries banking crises occur most frequently, followed by currency crises and debt crises (see details below).

Figure 2 shows the financial stress index FSI for the countries in our sample. The figure also shows the crises according to Babecký et al. (2014). The figure suggests that our overall FSI and the occurrence of financial crises are somehow related. However, the relationship is not very strong. Frequently, the FSI is high while according to the crises data base there is no crisis, or vice versa. In the next section we examine the relationship between FSI and the occurrence and onset of financial crises in more detail.

[4] For details, see: http://ies.fsv.cuni.cz/en/node/372.

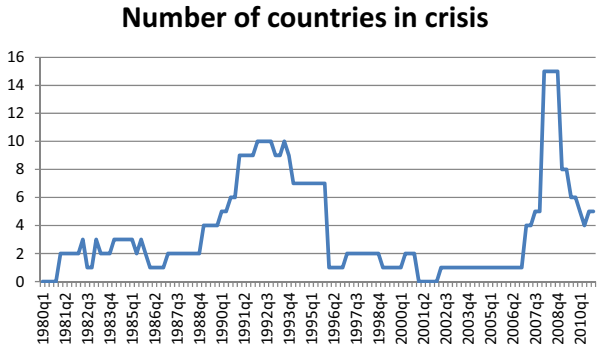


Fig. 1 Number of countries in crisis, 1980–2010

4 Financial Crises and Financial Stress

4.1 Correlations

We use six sub-indices of financial stress (FSI1-FSI6) and two aggregate indices (FSI and FSIA) in our investigation of the relationship between financial crises and stress indices. As a first step, Fig. 3 shows the correlation between the indices and the occurrence and the onset of a crisis at up to two lags and leads of the indicators. For the crisis onset, we only keep the first quarter of the crisis in the dataset and delete the other observations for as long as the crisis lasts.

A first observation following from the graphs is that correlations between the stress (sub-) indices and the occurrence of crises are low; the correlations between the stress (sub-)indices and the onset of a crisis are even lower. The FSI4 sub-index (measuring the interest rate differential with the US) has the highest correlation with the occurrence of a crisis, across all lags and leads, but the aggregate stress indices FSI and FSIA come close. FSI5 (measuring the inverse slope of the yield curve) has the highest correlation with the onset of a financial crisis when considering one or two leads. However, the correlation is still quite modest at 0.1. The lags of FSI4 and FSIA have a slightly higher contemporaneous correlation with the onset of a financial crisis.

An obvious explanation for the low correlation between the FSI and financial crises is that authorities successfully intervened and avoided crises. In order to investigate this possibility we analyse the 25 country-quarter pairs with the highest values for our stress indicator. Of these 25 highest values 15 observations are present during crisis episodes and three observations immediately after a crisis, which rules out the option that pre-emptive policy intervention avoided the onset of a full-blown crisis.

The remaining seven observations take place in five countries and may potentially indicate a successful policy action by authorities. We will briefly describe these seven FSI spikes. Australia faced a high FSI in 1986q3 due to a highly volatile exchange rate. The FSI in Mexico peaked during both 1998q4 and 1999q1 when Mexican interest

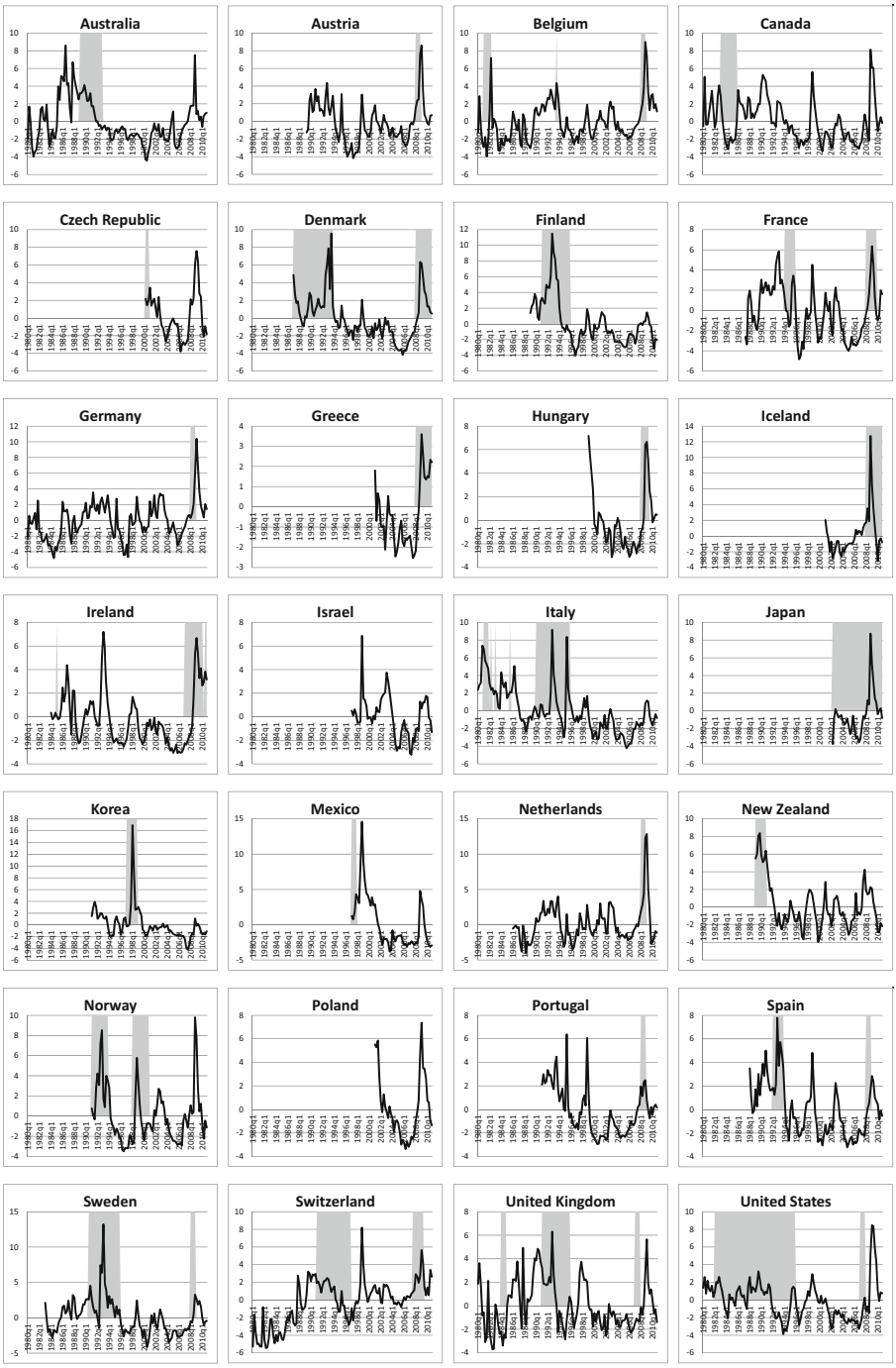


Fig. 2 FSI and crisis periods (*shaded areas*), 1980Q1-2010Q4

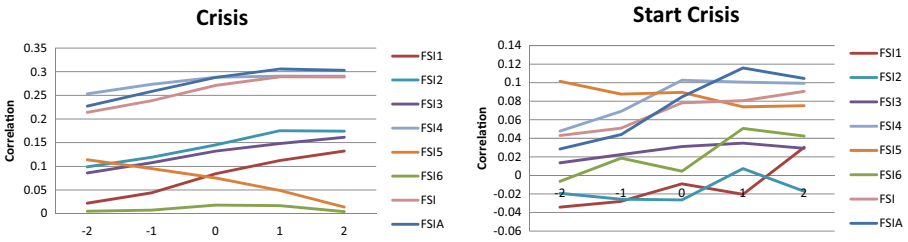


Fig. 3 Correlation between (components of) FSI and financial crises

rates surged in response to Russia's August debt moratorium. The FSI peak in Norway 2008q4 reflected that there was high volatility in stock markets and exchange rates, in part due to volatile oil prices. During the autumn of 2008 credit markets ceased to work, and credit institutions had to be rescued by central bank and government measures and guarantees. In Switzerland the FSI spiked in 1998q4, because of high stock market volatility. The US FSI peaked in 2008q4-2009q1 due to high stock market volatility and high volatility of the real effective exchange rate following the collapse of Lehman Brothers.

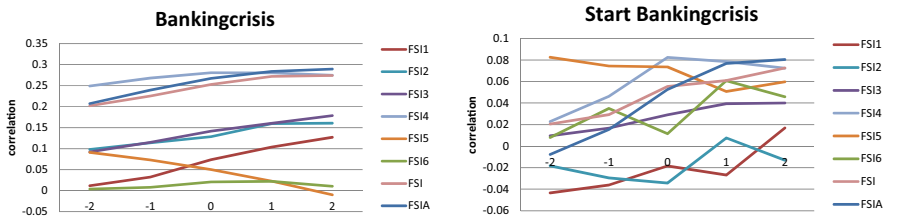
It is unlikely that (only) policy actions have led to a decrease in the FSI and authorities averted the onset of a (new) crisis in these cases. For example, the FSI in Norway spiked in 2008q4 and even though authorities intervened it is likely that global factors (e.g., a stabilizing oil price) may have been important as well. For the US the FSI spiked in 2008q4-2009q1 in part because of choices by authorities, i.e., allowing Lehman to enter bankruptcy, and the consecutive full-blown crisis was also likely affected by these policy choices.

Therefore, while making strong claims on the effectiveness of policy actions is beyond the scope of this study, the analysis of the 25 most extreme FSI observations during non-crisis periods does not suggest a strong case for the view that the authorities successfully averted a crisis when the FSI spiked. In fact, for the vast majority of FSI peaks the country is already in a crisis and for those few cases where a reverse pattern is found it is very difficult to find reliable counterfactuals confirming such hypothesis.

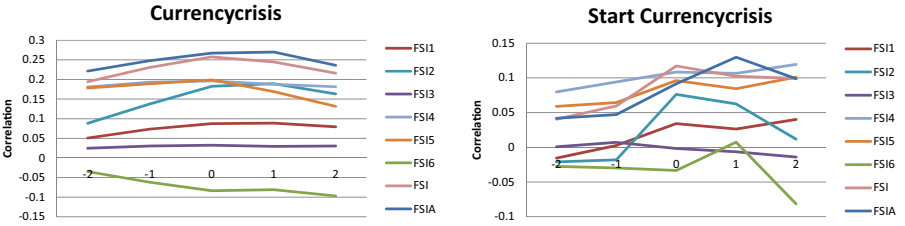
To further refine our analysis, we look at the three crisis types separately. For banking crises—the most frequent type of crises (408 quarters, 29 starts) in our sample—the picture is very similar to that for all crises (panel A in Fig. 4). FSI4 has the highest correlation with the occurrence of crises, while FSI5 has the highest correlation with the onset of a crisis. This finding is not that surprising for FSI5 that tracks the slope of the yield curve, which in turn can be related to the profitability of the banking sector. On the contrary, the lead of FSI4, which mainly measures sovereign risk, over FSI3, i.e., the β of the banking sector, comes as surprise but it might reflect spill-over effects between sovereign and banking risk.

The frequency of currency crises in our sample is lower than that of banking crises (67 quarters, 17 starts). The aggregate stress indices FSI and FSIA have the highest correlation with the occurrence of a currency crises, while sub-index FSI4 has the

Panel A: Banking crises



Panel B: Currency crises



Panel C: Debt crises

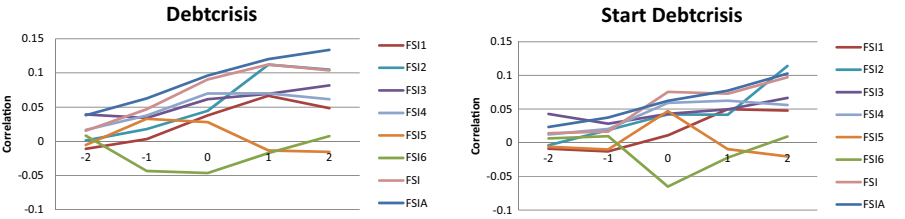


Fig. 4 Correlation between (components of) FSI and types of financial crises

highest correlation with the onset of a currency crisis one or two quarters ahead (panel B in Fig. 4). Therefore, it is a bit surprising that sovereign-risk related stress component FSI4 dominates over FSI2, i.e., the volatility of the exchange rate, which is arguably more related to currency stress. However, currency crises are associated with rising interest rates, because currency deprecations raise inflation expectations. Assuming the US is not subject to the currency crisis, we can expect (long-term) interest rates vis-à-vis the US to increase. Furthermore, if a country defends a peg it often raises interest rates before abandoning the peg. Therefore, it can be argued that the long-term interest rate has stronger predictive power of currency crises than exchange rate volatility.

Debt-crises are very rare in our sample (only 7 quarters and 4 starts). Nonetheless, we compute the correlations and find that FSI3 (i.e., the β of the banking sector) has the highest correlation with both the total crisis episode and with the onset of a debt crisis for two quarters ahead. For one quarter ahead, the total index FSIA performs best (see panel C in Fig. 4). All in all, it seems that disaggregation by crisis type does not lead to a significant increase of the correlation between stress indices and crisis occurrence (onset).

Table 3 Logit panel regressions with one stress (sub-)index as explanatory variable for the occurrence of crises

	All crises	Banking crises	Currency crises	Debt crises
FSI(−1)	0.29	0.28	0.41	0.31
	(12.2) [0.09]	(11.7) [0.09]	(8.6) [0.21]	(2.7) [0.11]
FSIA(−1)	1.92	1.81	2.58	2.02
	(12.4) [0.09]	(11.6) [0.08]	(9.2) [0.21]	(2.8) [0.13]
FSI1(−1)	0.16	0.13	0.37	0.16
	(2.8) 0.00]	(2.2) [0.00]	(3.7) [0.03]	(0.4) [0.00]
FSI2(−1)	0.34	0.34	0.46	0.30
	(5.9) [0.02]	(5.8) [0.02]	(5.2) [0.06]	(1.0) [0.01]
FSI3(−1)	0.35	0.39	0.16	0.69
	(5.8) [0.02]	(6.3) [0.02]	(1.3) [0.00]	(2.1) [0.07]
FSI4(−1)	1.02	1.08	1.06	1.37
	(14.1) [0.13]	(13.9) [0.14]	(8.1) [0.17]	(2.8) [0.16]
FSI5(−1)	0.35	0.30	1.19	0.48
	(5.7) [0.02]	(4.6) [0.01]	(7.7) [0.18]	(1.7) [0.03]
N	2300	2300	950	304

This table shows selected results for univariate logit regressions. The dependent variables are dummies indicating the occurrence of a crisis. Country fixed effects are included. T-values are shown in parentheses, and Pseudo R2 is shown in square brackets

4.2 Univariate (Panel) Logit-Regressions

Next, we estimate univariate panel logit-models that explain the occurrence of a crisis (dummy variable is 1 if there is a crisis and 0 if not) by the one-period lag of the financial stress (sub-)indices and a country-fixed effect (see also Louzis and Vouldis 2013).[5] The results of the panel logit regressions as shown in Table 3 generally confirm results of the correlation analysis. Crises in general and banking crises (the most frequent type of crisis) in particular are best explained by FSI4 (sovereign bond yield spread vis-à-vis the US) and by the aggregate indices FSI and FSIA. Currency crises are best explained by FSI and FSIA and debt crises by FSI, FSIA, and FSI3 (beta of banking sector).

Table 4 shows the results if we estimate similar models for the onset of a crisis (dummy variable is 1 if there is an onset of new crisis and 0 if not). For crisis onsets, FSI5 (inverse yield curve) has the highest t-value for crises in general and banking crises. For the onset of currency crises, FSI4 does best and for the onset of debt crises FSI3 and FSIA.

[5] As pointed out before, it is not our objective to explain the occurrence of financial crises by macroeconomic and/or financial variables. That is why we do not include macroeconomic and/or financial variables, as these may be related to our financial stress index. There is an extensive literature on the drivers of financial crises. See, for instance, Klomp (2010) and Karimi and Voia (2011) and references cited therein.

Table 4 Logit panel regressions with one stress (sub-)index as explanatory variable for the onset of crises

	All crises	Banking crises	Currency crises	Debt crises
FSI(−1)	0.17	0.12	0.25	0.17
	(2.6) [0.02]	(1.7) [0.01]	(3.1) [0.06]	(1.1) [0.03]
FSIA(−1)	0.97	0.51	1.57	1.63
	(2.1) [0.01]	(0.9) [0.00]	(2.7) [0.05]	(1.7) [0.07]
FSI1(−1)	−0.28	−0.55	0.09	−0.37
	(−1.1) [0.01]	(−1.6) [0.01]	(0.4) [0.00]	(−0.5) [0.01]
FSI2(−1)	−0.35	−0.48	−0.78	0.35
	(−1.0) [0.00]	(−1.2) [0.01]	(−0.9) [0.01]	(1.0) [0.02]
FSI3(−1)	0.19	0.20	0.10	0.64
	(1.1) [0.00]	(1.0) [0.00]	(0.4) [0.00]	(1.7) [0.07]
FSI4(−1)	0.59	0.49	1.04	0.87
	(3.4) [0.04]	(2.4) [0.02]	(4.1) [0.13]	(1.6) [0.07]
FSI5(−1)	0.64	0.59	0.75	−1.19
	(3.8) [0.04]	(3.3) [0.04]	(3.1) [0.07]	(−1.1) [0.04]
N	1757	1715	891	301

This table shows selected results from univariate logit regressions. The dependent variables are dummies indicating the onset of a crisis. Country fixed effects are included. T-values are shown in parentheses, and Pseudo R2 is shown in square brackets

We have also performed a simple logit-regression, by pooling the data without using the panel structure. This gives more observations for currency and debt crises, since the countries where these types of crises never occurred do not drop out. The results (available on request) are very similar to the panel-logit regressions.

4.3 Multinomial Logit Models

Finally, we run multinomial logit regressions that reveal which stress indices contribute to increasing the probability of a specific type of crisis. Debt crises are not considered here since they are very rare in our sample. These regressions do not use the panel structure but simply pool all the observations. Sometimes a country faces multiple crises at the same time (i.e., twin crises). In those cases, the crisis is coded according to the type with the lowest frequency. So, a country facing a banking and currency crisis at the same time is recorded as having a currency crisis as in our sample they occur less frequently. Table 5 reports the marginal effects based on the regressions. The regressions shown at the left-hand side of the table refer to the occurrence of a banking or currency crisis, whereas the regressions shown at the right-hand side of the table use the onset of either one as dependent variable. The top panels represent regressions with either FSI one quarter lagged or FSIA one quarter lagged as explanatory variable. The bottom panels use two of the most influential sub-indices identified so far, namely FSI4 (interest rate difference with the US) and FSI5 (inverse slope of the yield curve), as explanatory variables.

Table 5 Estimated probabilities of crisis from multinomial logit model

	Crisis				Start crisis			
	FSI(−1)=0	FSI(−1)=4.96	FSIA(−1)=0	FSIA(−1)=0.71	FSI(−1)=0	FSI(−1)=4.96	FSIA(−1)=0	FSIA(−1)=0.71
No crisis	83.3 %	62.0 %	89.1 %	74.0 %	97.9 %	98.7 %	98.3 %	97.2 %
Banking	14.6 %	27.3 %	10.0 %	21.2 %	1.3 %	1.9 %	1.2 %	1.5 %
Currency	2.1 %	10.7 %	1.0 %	4.9 %	0.7 %	2.3 %	0.5 %	1.3 %
	FSI5(−1)=0		FSI5(−1)=2		FSI5(−1)=0		FSI5(−1)=2	
	FSI4(−1)=0	FSI4(−1)=2	FSI4(−1)=0	FSI4(−1)=2	FSI4(−1)=0	FSI4(−1)=2	FSI4(−1)=0	FSI4(−1)=2
No crisis	83.8 %	54.8 %	83.9 %	51.9 %	98.3 %	94.7 %	95.9 %	89.7 %
Banking	14.3 %	37.3 %	11.2 %	27.5 %	1.2 %	1.5 %	3.1 %	4.0 %
Currency	1.8 %	8.0 %	4.9 %	20.6 %	0.5 %	3.7 %	0.9 %	6.3 %

Starting in the top left panel, if FSI increases from 0 to 4.96 (i.e., two standard deviations), the expected probability of being in a crisis increases from 16.7 to 38.0 %, while the probability of being in a banking crisis almost doubles from 14.6 to 27.3 %. The probability of being in a currency crisis increases from 2.1 % to 10.7 %. For our other aggregate financial stress index, FSIA, an increase by two standard deviations (from 0 to 0.71) gives similar increases in the probabilities of being in a banking crisis or a currency crisis, but at lower levels.

The top right panel in Table 5 shows that an increase by two standard deviations in FSI doubles the likelihood of a crisis starting in the next period from 2.1 to 4.3 %. The probability of a banking crisis starting rises from 1.3 to 1.9 %, while this probability for a currency crisis increases from 0.7 to 2.3 %. For the FSIA index a similar pattern emerges.

For the sub-indices, we analyse the impact of two of the most influential factors: the interest differential with the US (FSI4) and the inverse slope of the yield curve (FSI5). We also discuss the conditional effects of an increase in one sub-index given a certain value of the other. Turning to the sub-indices in the bottom left panel, if FSI5=0, an increase in FSI4 by 2 standard deviations increases the probability of being in a crisis from 16.2 to 45.2 % (most likely, a banking crisis (37.3 %)). If FSI5=2 and FSI4 increases by 2 standard deviations, the probability of being in a crisis increases from 16.1 to 48.1 %. Interestingly, if FSI5=2 the increase in FSI4 has a relatively large impact on the probability of being in a currency crisis (from 4.9 to 20.6 %). So, if a country has a high interest differential with the US (i.e., FSI4 is large), it has a high risk of being in a currency crisis. If the yield curve is normal, this will most likely be a banking crisis (37 % vs. 8 % for a currency crisis). However, in case of an inverse yield curve a currency crisis is almost as likely (20.6 % vs. 27.5 % for a banking crisis). This pattern is consistent with a situation in which a country is defending its currency through higher short-term interest rates.

For the onset of a crisis (bottom right panel in Table 5), an increase in FSI4 by 2 standard deviations increases the probability of a currency crisis starting by a factor 7. The probability of the onset of a banking crisis is hardly affected. The effect of an increase of FSI5 is more similar across types of crises.

We have also performed all analyses (correlation graphs, univariate logit and multinomial logit) with a stricter crisis definition. This stricter definition registers a crisis only when two independent sources confirm that a country experienced a crisis episode (as opposed to the baseline setting by Babecký et al. 2014 which uses the criterion of at least one source). The results from the univariate regressions are reported in Appendix 2 and are qualitatively similar to the results we presented. All other results are available from the authors upon request.

5 Conclusion

According to Borio and Drehmann (2009, p. 2) most ex ante measures of financial instability "provide thermometers rather than barometers of financial distress, i.e., do not permit its identification with a sufficient lead and confidence." The aim of this paper is to examine whether this also holds for financial stress indices that recently have become popular measures of financial instability and have even been suggested as

triggers for policy actions. For that purpose, we analyse the relationship between financial stress indices and the occurrence and onset of financial crises. We first constructed a financial stress index (FSI) for 28 OECD countries. We have used four criteria for indicators to be used in constructing our FSI (the index should cover the entire financial system, indicators used should be available at a sufficiently high frequency for many countries for a long period, they should be comparable, and indicators should be related to financial crisis in line with theoretical expectations) to come up with our FSI. Consequently, we crossed our FSI with a novel crisis dataset by Babecký et al. (2014) using simple correlations and logistic regressions. We did the same for our alternative FSI, which is based on a different weighting scheme of the indicators included.

Rather than aiming to provide some definite answer regarding the relationship between financial stress and financial crises we provide evidence on the nexus between these two concepts that are by their nature very close but that have never been satisfactory linked in the empirical literature in a multiple country setting. The results found in this study are somewhat bleak. It turns out that our stress indices as well as the sub-indices are related to the occurrence of a crisis, although to a varying degree. In other words, the stress index is indeed a good thermometer. However, the relationship between our stress indices and the onset of a crisis is rather weak. Specifically, we were unable to find any robust temporal pattern between realized stress in financial system and crisis onset disregarding also the hypothesis that this failure is related to crisis prevention by pre-emptive policy interventions. In other words, the stress index is of limited use as a barometer. Our results therefore suggest that policymakers should not strongly rely on these stress indices in assessing future threats to financial stability. Likewise, researchers should be aware that using crisis dummies and stress indices in early warning models may yield very different results in view of the weakness of the relationship between crisis dummies and financial stress indices.

An obvious limitation of our FSI is that we could not include several indicators that might be related to financial crisis, as they were not available for all countries. That is perhaps also why the results of previous studies examining the link between national FSIs and financial turmoil came to more optimistic conclusions than we did. An interesting topic for future research is therefore to examine whether FSIs as used by national authorities responsible for financial stability are related to the onset of financial crises in a multiple country setting. So instead of using the same FSI for all countries, country-specific FSIs could be used. At the moment, only some central banks publish their own FSI, but according to Smaga (2013) several other central banks are developing such an index, which should enable the suggested research at some point in time. Another suggestion for future research is the use of duration models (see, for instance, Karimi and Voia 2011). Duration models would be an alternative methodology to analyse the probability of transition from tranquil periods to a crisis, which can be linked to the financial stress indices.

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Appendices

Appendix 1

Table 6 Financial stress indices: a (selective) comparison

Variable:	Illing and Liu (2006)	Hakkio and Keeton (2009)	Cardarelli et al. (2011)	Slingenberg and de Haan (2011)	Oet et al. (2012)	Louzis and Vouldis (2013)	Islami and Kurtz-Kim (2013)
Countries:	Canada	US	17 advanced countries	13 advanced countries	US	Greece	Euro area
TED-spread		√	√	√	√		
3 month LIBOR - FRR					√		
2 year swap spread		√					
Euribor German T-bill spread						√	
Euribor - Eonia							√
Covered interest spread					√		
Liquidity spread					√		
Off-the-run/on-the-run Treasury spread		√					
CP – Treasury Bill rate					√		
AAA/10 year Treasury spread		√			√		
Treasury yield curve spread					√		
Baa/AAA spread		√					
High yield bond/Baa spread		√					
Consumer ABS/5 year Treasury spread		√					
Slope of the yield curve	√		√				
Corporate bond spread	√		√	√			
Commercial paper/T-bill spread	√						

Table 6 (continued)

Variable:	Illing and Liu (2006)	Hakkio and Keeton (2009)	Cardarelli et al. (2011)	Slingenberg and de Haan (2011)	Oet et al. (2012)	Louzis and Vouldis (2013)	Islami and Kurtz-Kim (2013)
Countries:	Canada	US	17 advanced countries	13 advanced countries	US	Greece	Euro area
Bid-ask spread on 90-day Government of Canada Treasury bills	√						
Covered interest differential with US	√						
Stock market returns			√			√	
Volatility stock prices/return	√	√	√	√	√	√	
Stock prices						√	
Correlation between stock and Treasury returns		√					
Earnings-price ratio minus 10 year bond rate							√
Volatility of bank stock prices		√				√	
Dispersion bank stock returns		√					
(Rolling) beta banking sector	√		√	√	√		
Idiosyncratic risk of bank stock prices						√	
Bank bond spread					√		
(Banks) CDS spreads						√	√
Deposit gap						√	
Loan gap						√	
Interest margin						√	
Exchange rate volatility	√		√	√	√		√
						√	

Table 6 (continued)

Variable:	Illing and Liu (2006)	Hakkio and Keeton (2009)	Cardarelli et al. (2011)	Slingenberg and de Haan (2011)	Oet et al. (2012)	Louzis and Vouldis (2013)	Islami and Kurtz-Kim (2013)
Countries:	Canada	US	17 advanced countries	13 advanced countries	US	Greece	Euro area
Government bond spread vis-à-vis Germany (US)							
Volatility bond yields						√	
Correlation German bond yield and stock returns						√	
Volatility of future oil price							√
Commercial real estate spread					√		
Residential real estate spread					√		
Asset-backed security spread					√		
Commercial mortgage-backed security spread					√		
Residential mortgage-backed security spread					√		

Appendix 2. Logit Panel Regressions Using an Alternative Crisis Definition

Table 7 Logit panel regressions with one stress (sub-)index as explanatory variable for the occurrence of crises

	All crises	Banking crises	Currency crises
FSI(−1)	0.24	0.20	0.59
	(8.8) [0.07]	(7.3) [0.05]	(7.8) [0.40]
FSIA(−1)	1.56	1.34	3.00
	(8.9) [0.07]	(7.5) [0.05]	(7.7) [0.29]
FSI1(−1)	0.02	−0.01	0.41
	(0.2) 0.00]	(−0.2) [0.00]	(3.2) [0.03]
FSI2(−1)	0.29	0.24	0.56
	(4.5) [0.02]	(3.5) [0.01]	(5.2) [0.10]
FSI3(−1)	0.20	0.18	0.30
	(2.6) [0.01]	(2.3) [0.00]	(1.9) [0.01]
FSI4(−1)	0.88	0.81	1.62
	(10.0) [0.10]	(9.2) [0.08]	(7.2) [0.33]
FSI5(−1)	0.55	0.42	1.93
	(7.1) [0.04]	(5.5) [0.03]	(7.0) [0.39]
N	2003	1912	665

This table shows selected results from univariate logit regressions. The dependent variables are dummies indicating the occurrence of a crisis. Country fixed effects are included. T-values are shown in parentheses, and Pseudo R^2 is shown in square brackets

Table 8 Logit panel regressions with one stress (sub-)index as explanatory variable for the onset of crises

	All crises	Banking crises	Currency crises
FSI(−1)	0.15	0.07	0.42
	(2.6) [0.02]	(0.9) [0.00]	(4.1) [0.22]
FSIA(−1)	1.06	0.45	2.41
	(2.3) [0.02]	(0.8) [0.00]	(3.7) [0.17]
FSI1(−1)	−0.07	−0.64	0.55
	(−0.3) [0.00]	(−1.6) [0.02]	(2.5) [0.06]
FSI2(−1)	−0.41	−0.40	−0.38
	(−1.1) [0.01]	(−1.0) [0.01]	(−0.4) [0.00]
FSI3(−1)	0.20	0.08	0.41
	(1.1) [0.00]	(0.4) [0.00]	(1.3) [0.02]

Table 8 (continued)

	All crises	Banking crises	Currency crises
FSI4(−1)	0.50	0.42	1.33
	(2.5) [0.03]	(2.0) [0.02]	(3.6) [0.21]
FSI5(−1)	0.61	0.50	1.22
	(3.1) [0.04]	(2.6) [0.03]	(3.4) [0.20]
N	1661	1581	635

This table shows selected results from univariate logit regressions. The dependent variables are dummies indicating the start of a crisis. Country fixed effects are included. T-values are shown in parentheses and Pseudo R2 is shown in square brackets

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