Journal of Financial Stability 14 (2014) 54–65

Contents lists available at ScienceDirect

Journal of Financial Stability

journal homepage: www.elsevier.com/locate/jfstabil

# Predicting financial stress events: A signal extraction approach

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ARTICLE INFO

*Article history:*
Received 24 December 2013
Received in revised form 22 June 2014
Accepted 18 August 2014
Available online 6 September 2014

*JEL classification:*
C12
C14
G01
G17

*Keywords:*
Cut-off probability
Early warning system
Financial crisis
Financial stress event
Signal extraction approach

ABSTRACT

The objective of this paper is to propose an early warning system that can predict the likelihood of the occurrence of financial stress events within a given period of time. To achieve this goal, the signal extraction approach proposed by Kaminsky et al. (1998) is used to monitor the evolution of a number of economic indicators that tend to exhibit unusual behavior in the periods preceding a financial stress event. Based on the individual indicators from 13 OECD countries, we propose three different composite indicators, the summed composite indicator, the extreme composite indicator and the weighted composite indicator. The in-sample forecasting results for the 13 OECD countries indicate that the three composite indicators are useful tools for predicting financial stress events, while none of them outperforms the others across all the criteria considered. The out-of-sample forecasting results suggest that for most of the 13 OECD countries, including Canada, the United Kingdom and the United States, the weighted composite indicator performs better than the two others across all the criteria considered.



## 1. Introduction

There is evidence that financial stress may cause severe financial crises and recessions (Bloom, 2009; Borio and Drehmann, 2009). It is therefore of crucial importance to detect and to predict potential financial stress for the conduct of economic policy. Given the definition that financial stress is an interruption to the normal functioning of the financial system (ECB, 2009),[1] the starting point for monitoring financial stress is to develop formal measures of financial stress.

In recent years, many studies have been creating a Financial Stress Index (FSI), a measure of the state of stress in the financial system, to examine which economic variables can help in predicting financial stress for one country or for several countries. For example, the International Monetary Fund (IMF), the Organization of Economic Co-operation and Development (OECD), the Bank for International Settlements (BIS), GoldmanSachs, Bloomberg, Citigroup and the Bank of Canada have developed FSIs to monitor financial stress. Slingenberg and de Haan (2011) use a FSI for 13 OECD countries to examine whether a list of variables can help in predicting financial stress. Misina and Tkacz (2009) investigate whether credit and asset price movements can help predict financial stress in Canada. However, their work provides only point predictions of future financial stress. The point predictions can, at most, convey some notion of the central tendency of future financial stress, and provide nothing at all about the possible uncertainty of the future financial stress. However, for most decision problems, the point predictions will not be sufficient and probability forecasts will be needed to provide insights on the likelihood of the occurrence of financial stress events for a given period of time (Gneiting and Ranjan, 2011, and the references therein).

The objective of this paper is to propose an early warning system (EWS) that can predict the likelihood of the occurrence of financial stress events within a given period of time. To achieve this goal, we use the FSIs proposed by the IMF for developed economies as the measures of financial stress. We study 13 OECD countries:

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[1] It is difficult to provide a more exact definition, because episodes of financial stress are often different. However, certain key features are frequently associated with financial stress, such as increased uncertainty about the fundamental value of assets, increased uncertainty about the behavior of other investors, increased asymmetry of information, decreased willingness to hold risky and illiquid assets (Hakkio and Keeton, 2009).

http://dx.doi.org/10.1016/j.jfs.2014.08.005
1572-3089/

Belgium, Canada, Denmark, France, Finland, Germany, Italy, Japan, the Netherlands, Sweden, Switzerland, the United Kingdom and the United States. The signal extraction approach proposed by Kaminsky, Lizondo and Reinhart (KLR) (1998) is used to monitor the evolution of a number of economic indicators that tend to exhibit unusual behavior in the period preceding a financial stress event.[2] Most of the indicators used in this paper come from the indicators reported in Demirgüç-Kunt and Detragiache (1998), Kaminsky (1998), and Davis and Karim (2008), but for different countries and different time spans.[3] These indicators are chosen based on theoretical considerations and their availability on a quarterly basis. In particular, we add an indicator of financial contagion to the set of indicators to capture the possible contagion effect, because a financial stress event is more likely to spread to a country that is competing and trading with countries that have been experiencing a financial stress event. Twelve indicators are included in our model: real GDP growth rate, exchange rate, real short-term interest rate, inflation, ratio of M2 to foreign exchange reserve, return on house price index, growth rate of private credit, ratio of bank reserves to bank assets, ratio of current account to GDP, return on stock market index, indicator of financial contagion, and three-quarter moving average of the FSI.

Given these individual indicators, we propose three different composite indicators, namely, the summed composite indicator, the extreme composite indicator and the weighted composite indicator, which are used to predict the likelihood of the occurrence of financial stress events within a given period of time. We evaluate the in-sample and out-of-sample performance of the three composite indicator models. The in-sample forecasting results suggest that the three composite indicators are useful tools for predicting financial stress events, although none of them outperforms the others across all the criteria considered. The out-of-sample forecasting results suggest that for most of the 13 OECD countries, including Canada, the United Kingdom and the United States, the weighted composite indicator consistently outperforms the summed composite indicator and performs better than or equal to the extreme composite indicator across all the criteria considered.

The paper is organized as follows: Section 2 presents the definition of a financial stress event and introduces how to use the signal extraction approach proposed by KLR (1998) to predict the likelihood of the occurrence of financial stress events. Section 3 evaluates the performance of the three composite indicator models in predicting financial stress events. Section 4 concludes.

## 2. Model specification

The design of an early warning system for financial stress events requires consideration of the scope of the model (country coverage, choice of indicators and time dimensions), the definition of a financial stress event and the econometric model. In this paper, we adopt the econometric model used by KLR (1998) to predict the probability of the occurrence of financial stress events within a given period of time.

### 2.1. The definition of a financial stress event

In general, financial stress is unobservable, but some key features are frequently associated with an increased degree of perceived risk and uncertainty. To capture these features of financial stress, the IMF constructed a FSI for developed economics (Cardarelli et al., 2009). The FSI is a variance-weighted average of three subindexes associated with the banking, securities and foreign exchange markets. All components in the three subindexes are originally in monthly frequency. The FSI is constructed by taking the average of the components after adjusting for the sample mean and standardizing by the sample standard deviation. Finally, it is converted into a quarterly frequency by taking the average of the monthly data.[4] In this paper, we use the FSI proposed by the IMF as the measure of financial stress for 13 OECD countries: Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Sweden, Switzerland, the United Kingdom and the United States.

The signal extraction approach used in this paper involves monitoring the evolution of a number of economic indicators. When one of these indicators deviates from its "normal" behavior, this is taken as a warning signal about a possible financial stress event within a given period of time. To make the approach operational, we need to define what is a financial stress event.

As a first step, for country $j$, we define a financial stress event as the event when the FSI rises above $k$ ($k > 0$) standard deviations away from the average of its country FSI,

$$hfs_{j,t} = \begin{cases} 1 & \text{if } FSI_t > \mu_{FSI} + k\sigma_{FSI} \\ 0 & \text{otherwise,} \end{cases} \quad (1)$$

where $\mu_{FSI}$ and $\sigma_{FSI}$ are the sample mean and the sample standard deviation of the FSI, respectively. The threshold, $\mu_{FSI} + k\sigma_{FSI}$, is called the stress-identification threshold. The different values of the stress-identification thresholds obviously result in different dates being identified as financial stress events, and particularly a lower value of the stress-identification threshold leads to the identification of more financial stress events. The choice of the threshold level will depend on the degree of concern with the financial stress by a policy maker. A policy maker concerned with avoiding financial stress events at all costs may choose a quite lower threshold level even if this may entail unnecessary intervention. On the other hand, a policy maker with a relatively stable financial system may prefer a high threshold level by avoiding undue intervention.

To identify financial stress events, Illing and Liu (2006) use $k = 2$ in Eq. (1), while Cardarelli et al. (2009) use $k = 1$ in Eq. (1). In this paper, we use $k = 1.5$ to identify the financial stress events. Although the choice of $k = 1.5$ is somewhat arbitrary, the cataloging of financial stress events obtained by this choice tends to follow closely the chronology of financial market stress described in the literature. Another reason that we chose $k = 1.5$ standard deviation is that it yields a reasonable number of observations for estimating the probability that financial stress events occur within a given period of time.[5] In Section 3, we will report and assess the effects

[2] The definition of a financial stress event will be given in Section 2. Van Norden and Wildi (2012) use the real-time signal extraction approach to predict banking crises. The real-time signal extraction approach is based on the estimated common spectral density, which is obtained by estimating the common autocorrelogram with the constrained OLS method.

[3] Demirgüç-Kunt and Detragiache (1998), Kaminsky (1998), and Davis and Karim (2008) predict financial crises using economic and financial variables. Their procedure runs into difficulties when applied to countries where financial crises are rare or non-existent. A typical example is Canada, which has not experienced any "twin crises" (banking and currency crises) since the beginning of its sample in 1883, and has experienced only four currency crises since 1945. The absence of financial crises, however, does not imply that a country has not been subjected to financial stress in the past. To circumvent this problem, this paper focuses on predicting the likelihood of the occurrence of financial stress events.

[4] The FSI comprises seven variables: the banking-sector beta, the TED spread, term spreads, stock market returns, time-varying stock market return volatility, sovereign debt spread, and exchange market volatility. The details of the components of the index are explained in Cardarelli et al. (2009).

[5] Between 1981Q2 and 2010Q2, 270, 146, and 99 financial stress events are identified under the stress-identification thresholds with $k = 1$, 1.5 and 2, respectively.