

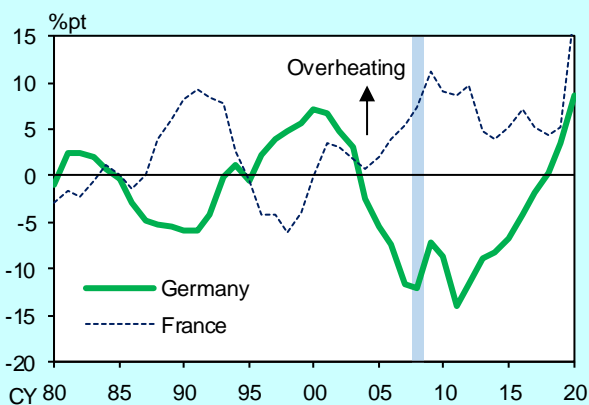
indicator is colored "red" if it signals "red" by the same criteria as the heat map, and the black box indicates periods for the duration of the banking crisis. The definition of a banking crisis follows that of Reinhart and Rogoff (2009). For example, in their definition, Japan saw a banking crisis from 1992 to 2001, and the period is circled in black.^{2,3}

Developments of FAIXs preceding a banking crisis vary across crises. Indeed, Japan's bubble period is the only episode when all indicators turned "red" ahead of a crisis. During the Lehman shock, seven indexes were "red" in France, whereas only *growth rate of M2* and *stock prices* were "red" in Germany.

These differences in developments in the FAIXs across countries before a crisis may reflect the different natures of the crisis for each country. As described above, in France before the Lehman shock, all indicators other than *stock prices*, including the *total credit to GDP ratio*, were "red," indicating that domestic financial activities were overheated, as in Japan's bubble period. By contrast, in Germany, the number of indicators that were "red" before the crisis was limited, suggesting that the nature of the banking crisis was different from that of the respective crises in France and Japan. Indeed, as shown in Chart 3, the gap between *total credit to GDP ratio* and its trend, a measure of the degree of overheating in domestic financial activities, was significantly positive in France and negative in Germany before the Lehman shock.

This observation accords well with assessments made by financial authorities and existing studies on the German banking crisis during the Lehman shock. The European Systemic Risk Board (ESRB, 2017), for example, points out that for Germany the banking crisis during the Lehman shock was caused by the adjustment

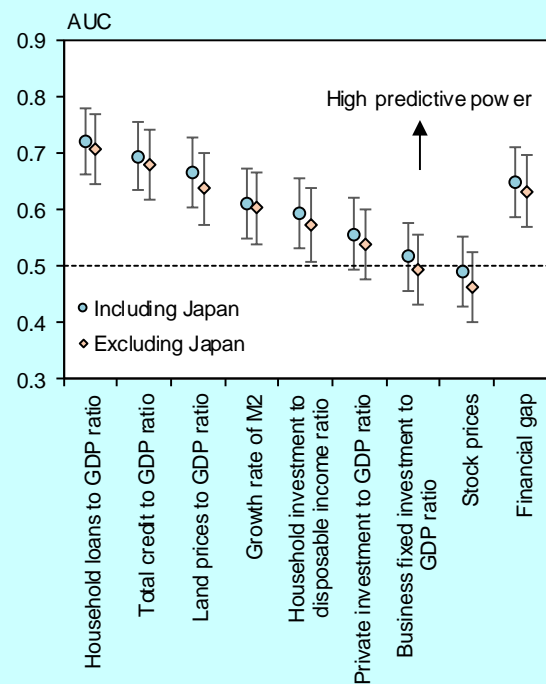
[Chart 3] Total credit to GDP ratio gap



Note: 1. Total credit to GDP ratio gap is deviation from trend.
2. The shaded area indicates the first year of the banking crises in Germany and France. The figures for 2020 are the average from January to September of 2020.

Source: BIS.

[Chart 4] Predictive power of the FAIXs



Note: 1. Bandwidth indicates 95% significance levels.
2. Financial gap indicates the average of the FAIXs.

of foreign financial markets and the resulting decline in economic activities, which had a significant impact on some banks with large amounts of credit in the real estate market outside Germany and shipping industry, and that the banking crisis may have been an "imported crisis" for the country.⁴

Chart 4 shows the predictive power of each of the eight indicators in the FAIXs, separately evaluated using the Area Under the Receiver Operating Characteristics Curve (AUC), which is widely used in the literature of early warning indicators and a criterion similar to the one used for the selection of FAIXs for Japan. The AUC measures the degree to which an indicator correctly signals "red" before a crisis and does not signal "red" when no crisis occurs. Defining the correctness of a prediction as being able to signal "red" 2-5 years before a crisis, the measure takes a value of 1 when an indicator always correctly predicts a crisis, and 0.5 when it does so half of the time.

Looking at the AUC for each indicator, with the exception of three variables including *stock prices*, all indicators exceed 0.5 at the 95% significance level. The predictive power of *household loans to GDP ratio* is the highest followed by *total credit to GDP ratio* and *land prices to GDP ratio*. The AUC for the "financial gap," which is a simple average of the eight indicators, is also significantly above 0.5, making it the second most predictive indicator. These observations are

unchanged even when Japan is dropped from the sample, which in turn suggests that many of the indicators of the FAIXs are not only relevant to Japan's bubble period, but also to the banking crises in other countries.

These results indicate that overseas banking crises have the same tendencies as those seen during Japan's bubble period, such as the overheating of domestic financial activities accompanied by rises in asset prices that preceded the onset of the crisis, and that the FAIXs could serve as a way to predict a banking crisis. However, the results also indicate that, as reflected in the example of Germany at the time of the Lehman shock, the usefulness of the heat map as an early warning indicator may be limited for crises originating overseas.

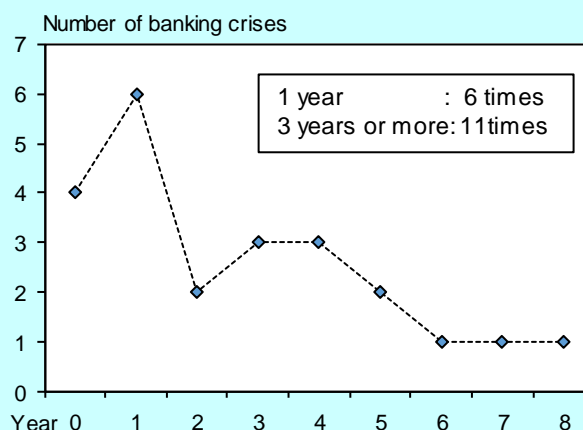
Effects of Prolonged or Simultaneous "red" Signals on Crisis Probabilities

As mentioned earlier, some indicators in Japan's FAIXs have been "red" for some time. This section studies if the length of time an indicator has been "red" or whether it has been "red" alone or with other indicators can provide additional information on the predictability of an indicator of a banking crisis, and aims to derive implications that can be used when assessing developments of Japan's FAIXs.

Chart 5 focuses on the *total credit to GDP ratio*, which shows high predictive power in the above analysis and is regarded as capable of capturing the credit activities of the private sector as a whole. It shows the distribution of the number of banking crises according to the duration of "red" signals prior to a crisis. The duration of "red" signals varies considerably across crises. As in the case of the German crisis, there were instances where the "red" signal was absent. In terms of the number of years of being "red" before a crisis, the number of occurrences is highest with a single year while the total number of cases for three years or longer is about double that.

Chart 6 shows how crisis probabilities differ depending on the duration of a "red" signal for the *total credit to GDP ratio*. Here, the distribution of the probability of a banking crisis occurring in the next one to two years from a certain point *t* is categorized according to the duration of the "red" signal up to point *t*. The longer the number of years that "red" signal remains, the higher the probability of a banking crisis occurring after that point.⁵ In particular, when the duration of the "red" signal exceeds three years, the probabilities are more than twice as high, compared to

[Chart 5] Duration of total credit to GDP ratio's "red" signaling prior to a crisis



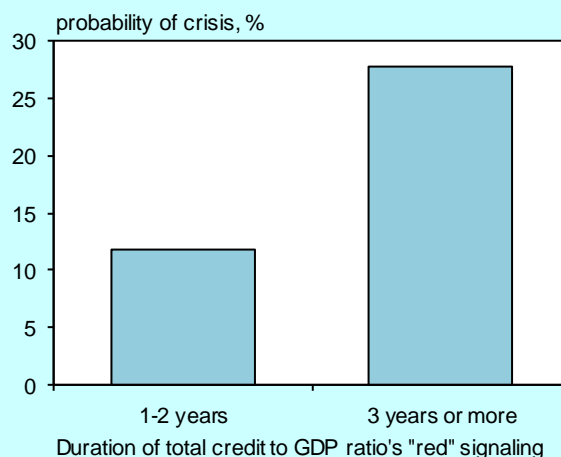
Note: The horizontal axis indicates the number of years when the credit to GDP ratio signaled "red" in the 10 years prior to a banking crisis. Banking crises which occurred less than 10 years after the previous banking crises are excluded.

cases where the duration is one or two years. This implies that even when the same "red" signals are seen, a longer lasting "red" signal is associated with greater vulnerabilities that require attention.

Lastly, implications for simultaneous "red" signals of multiple indicators are studied. Chart 7 shows the distribution of the number of banking crises according to how many indicators in the FAIXs are simultaneously "red" before a crisis. The number of cases when four indicators are "red" at the same time is the highest at nine, followed by the case with two and five indicators.

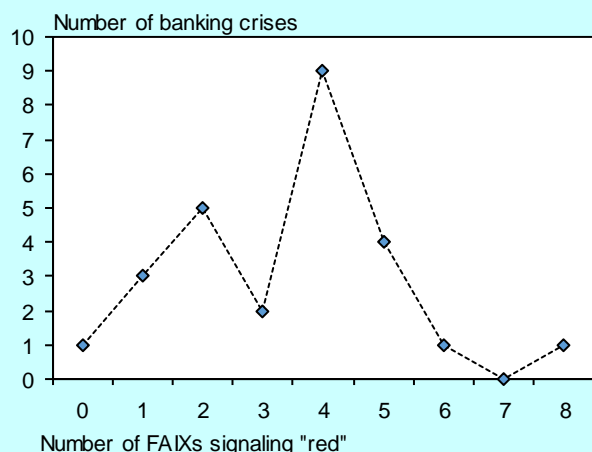
Focusing on the *total credit to GDP ratio* once again, Chart 8 compares banking crisis probabilities occurring within a two-year horizon, when the *total credit to GDP ratio* is "red" on its own and when each of other seven

[Chart 6] Duration of total credit to GDP ratio's "red" signaling and probability of crisis



Note: Chart indicates probability of crisis over the subsequent two years.

[Chart 7] Number of FAIXs signaling "red" before banking crisis



Note: The horizontal axis indicates the number of FAIXs signaling "red" 2-5 years prior to a crisis.

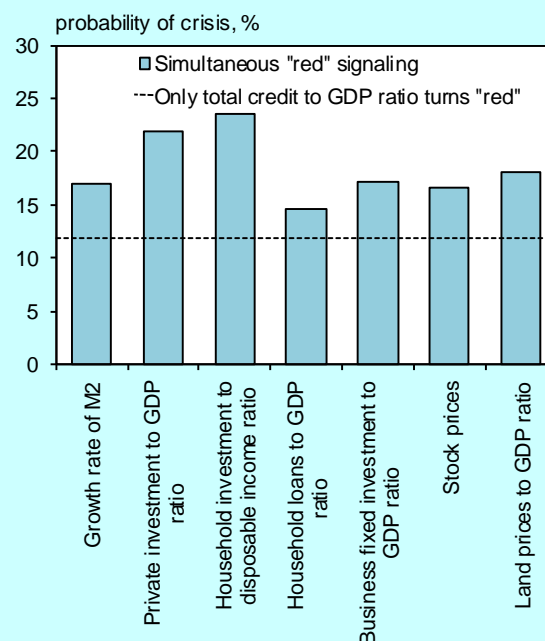
indicators besides *total credit to GDP ratio* is "red." For most of the indicators in the FAIXs, the probability of a future banking crisis increases when the indicator is "red" at the same time as the *total credit to GDP ratio*. It is also noteworthy that indicators that are not highly predictive on their own, such as *business fixed investment to GDP ratio* and *stock prices*, tend to become more predictive when they are "red" jointly with the *total credit to GDP ratio*. On the premise that the "red" signal of these indicators reflects bullish expectations of future returns from investment, this result suggests that the combination of bullish expectations and the overheating of domestic credit activity indicated by the "red" signal of the *total credit to GDP ratio* may have caused banking crises not only following the bubble period in Japan but also following crises overseas.⁶

Conclusion

Early warning indicators included in the FAIXs are selected based on their ability to detect the overheating of financial activities in Japan's bubble period. This article examines the general applicability of the FAIXs by analyzing whether they have broad predictive power for overseas banking crises.

First, the nature of banking crises varies and not all FAIXs necessarily turn "red", particularly in the case of an "imported crisis", and indicators that signal "red" are not the same across crises. However, some indicators, such as the *total credit to GDP ratio*, are found to have predictive power not only for the crisis following Japan's bubble period but also for banking crises more broadly, suggesting that the FAIXs can be used to predict a wide range of banking crises.

[Chart 8] Probability of crisis when other indexes turn "red" in addition to total credit to GDP ratio



Note: 1. Chart indicates probability of crisis over subsequent two years.
2. Results when total credit to GDP ratio is "red" for one to two years.

Furthermore, as for the *total credit to GDP ratio*, the length of duration of a "red" signal and simultaneous "red" signals with other indicators may provide information on the probability of a future banking crisis. For example, when the *total credit to GDP ratio* is "red" for an extended period of time, or when it is "red" at the same time as other indicators of the FAIXs, the probability of a banking crisis may have been elevated. The experiences of various past banking crises suggest that there is a need in such situations to be more vigilant against the risk of build-ups of financial imbalances.

There are also some reservations regarding the current analysis. The first is the sample size. The analysis restricts the sample to 26 banking crisis episodes from 1980 onward for developed economies, to ensure the homogeneity of economic and financial systems at the time and in the regions the crises occurred. This narrowing of the scope of analysis is necessary to obtain implications for Japan's financial activity indicators, but it also means that the results need to be viewed more carefully. The second is that the analysis is limited to the probability of occurrence. For measuring the economic costs associated with banking crises, the duration and depth are important as well. Related to this, existing studies have indicated that the degree of economic downturn and the period until recovery may differ depending on the type of crisis.⁷ When viewing the results of this article, it is worthwhile to keep these reservations in mind.

* Currently at the Personnel and Corporate Affairs Department.

¹ For detail, see Ito, Y., T. Kitamura, K. Nakamura, T. Nakazawa, "New Financial Activity Indexes: Early Warning System for Financial Imbalances in Japan," BOJ Working Paper Series, No.14-E-7, April 2014.

² Banking crisis periods are taken from the following: Reinhart, C. M., and K. S. Rogoff, *This Time Is Different: Eight Centuries of Financial Folly*, Princeton University Press, 2009. A banking crisis is defined as times when there are closures of banks, mergers, and nationalizations due to bank runs etc. The analysis is done on an annual basis. In case of the Lehman shock period, 12 countries experienced a banking crisis but the main conclusion of the analysis hereafter does not change with the exclusion of this event. There are multiple approaches to defining banking crises and identifying the periods of occurrence, including those that use quantitative as well as qualitative information. For a holistic survey of the literature, see Sufi, A., and A. M. Taylor, "Financial Crises: A Survey," NBER Working Paper Series, No. 29155, 2021.

³ In constructing the series for *land prices to GDP ratio*, housing prices are used as proxies in countries where land prices were not available.

⁴ The German experience during the Lehman shock is not the only example of an "imported crisis" where origins of the crisis are not from overheating of domestic financial activities. Following the ESRB, "A New Database for Financial Crises in European Countries," Occasional Paper Series No. 194, 2017, where they classify banking crises in the Euro area, Belgium 2008, Italy 1990, and Sweden 2008 crises are also classified as "imported crises." The paper also indicated that the root causes of the crises during the Lehman shock for Belgium and Sweden were turmoil in foreign financial markets, analogous to the German case, and the European currency crisis for Italy. There is another example not included in ESRB (2017). Reinhart and Rogoff (2009) points out that the 1995 banking crisis in the UK originated from losses in foreign transactions of derivatives. On this point, Chart 2 shows that there were no "red" signals in the FAIXs before the 1995 crisis in the UK.

⁵ Using the same method, the probability of a banking crisis occurring tends to rise with longer durations of a "red" signal in the following four variables; *growth rate of M2*, *household investment to disposable income ratio*, *household loans to GDP ratio*, and *land prices to GDP ratio*.

⁶ A similar point is often raised in the literature on the effects of sharp rises in asset prices, such as "bubbles," on the macro economy. For example, Mishkin, F. S., "Not All Bubbles Present a Risk to the Economy", *Financial Times*, November 9, 2009, classifies asset price "bubbles" into two types -- a "credit boom bubble" and a "pure irrational exuberance bubble" -- and points out that when the former collapses, it tends to be followed by large contractions of the economy through balance sheet impairments of financial institutions. On the other hand, if the latter collapses, it has limited effects on the financial system and hence the economy. Another example is Jordà, Ò., M. Schularick, and A. M. Taylor, "Leveraged Bubbles," NBER Working Paper Series, No. 21486, 2015, where they use 140 years of data for 17 countries and show that bubbles with credit expansion, especially housing price bubbles, tend to deepen the recession after the burst of the bubble and delay its recovery. Another leading example in this line of research is Greenwood, R., S. G. Hanson, and J. A. Sorensen, "Predictable Financial Crises," NBER Working Paper Series No. 27396, 2020. The analysis uses the data from 1950 to 2016 for 42 countries, including developing countries, and shows that the probability of a financial crisis increases dramatically when overheating of credit activity and overheating of stock prices or housing prices occur simultaneously, compared to the case where only overheating of credit activity occurs.

⁷ For example, Jordà, Ò., M. Schularick, and A. M. Taylor, "The Great Mortgaging: Housing Finance, Crises, and Business Cycles," NBER Working Paper Series, No. 20501, 2014, points out that financial crises, fueled by high growth in lending to households, has been more severe than other crises.

Bank of Japan Review is published by the Bank of Japan to explain recent economic and financial topics for a wide range of readers. This report, 2021-E-5, is a translation of the original Japanese version, 2021-J-11, published in October 2021. The views expressed in the Review are those of the authors and do not necessarily represent those of the Bank of Japan. If you have comments or questions, please contact Financial System and Bank Examination Department (E-mail: emu-fsbe51_post@boj.or.jp). Bank of Japan Review and Bank of Japan Working Paper can be obtained through the Bank of Japan's Web site (<https://www.boj.or.jp/en/index.htm>).