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Assessing the risk of banking crises[1]

Over the last two decades, banking crises have become more frequent and severe in both emerging market and industrial countries.[2] Their cost in terms of output lost has been high, typically double digit percentages of GDP. For this reason, considerable efforts have been made recently to develop "early warning indicators" of crises that could allow policymakers to take remedial action in a more timely fashion.

This special feature proposes a set of forward-looking indicators of banking distress. As in Borio and Lowe (2002) we argue that it may be possible recognise the build-up of one set of vulnerabilities that foreshadows banking distress with a reasonable degree of confidence, although the exact timing of the crises remains unpredictable. The corresponding indicators draw exclusively on ex ante information, are based on the interaction among a small set of variables, focus on the cumulative processes giving rise to distress and allow for variable horizons. Here we extend our previous work, which had mainly considered credit aggregate and asset prices, by examining the information contained in real exchange rate appreciations and the relative performance of indicators in industrial and emerging market countries.

In the first section of this article we briefly discuss the origins of banking crises. In the second we motivate the choice of indicators and assess their performance. In the concluding section we note some caveats to the analysis and suggest areas for future work.

The origin of banking crises[3]

Typical features of banking crises:

Views about the origin of banking crises influence the strategy to be followed in developing forward-looking indicators of distress and judgments about their usefulness. The view that underlies the specific indicators formulated here draws on four observations.

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[1] The views expressed in this article are those of the authors and do not necessarily reflect those of the BIS. We would like to thank Philippe Hainaut for excellent research assistance.

[2] See Bordo et al (2001) and, for focus on the cost of crises, Hoggarth and Saporta (2001), among others.

[3] For a further elaboration on some of the arguments presented in this section, see Borio (2002).

First, banking crises tend to arise primarily from deteriorating economic fundamentals, notably declines in asset quality. This view plays down the role of arbitrary changes in investor or depositor sentiment, domestic or foreign, stressed by some observers.[4] It thereby also provides a rationale for expecting that crises can be, at least to some extent, predictable, based on forward-looking proxies for deteriorating fundamentals.

deteriorating economic fundamentals ...

Second, a banking crisis with significant economic costs in terms of overall output often arises from exposure of several institutions to common risks ("common risk factors").[5] Typical examples include exposures to broad asset classes such as real estate or equity, to the fortunes of large economic sectors and to the sustainability of an economic boom. For this reason, severe banking crises tend to reflect, and in turn exacerbate, overall fluctuations in GDP.

... similar exposures across financial institutions ...

Third, vulnerabilities tend to build up over time, reflecting the mutually reinforcing interaction between the financial sector and the real economy. A highly stylised description of the process could be the following. As the economy expands, asset prices increase, risk is perceived to decline and external financing becomes cheaper and more plentiful. These developments fuel the expansion and, if they go too far, allow financial imbalances to be masked by benign economic conditions. The imbalances sustain distortions in the real economy, often in the form of excessive investment in the sectors most affected by the favourable conditions. The unbalanced boom sows the seeds of the subsequent contraction. At some point, the process goes into reverse. Unless the financial system has built up sufficient defences during the boom, the subsequent contraction can lead to widespread instability. Ex post, a financial cycle is evident.[6]

... vulnerabilities that build up over time linked to a financial cycle ...

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[4] By contrast, a common alternative perspective stresses multiple equilibria and self-fulfilling runs, made possible by the inevitable mismatch between the liquidity of assets and liabilities, be it in domestic or, in an international context, foreign currency. This view goes back to the seminal paper by Diamond and Dybvig (1983) and has been extended to the open economy context by Chang and Velasco (1998). An account of the East Asian crises sympathetic to this view can be found in Radelet and Sachs (1998).

[5] To be sure, the risk of more generalised systemic problems can originate in the failure of an individual institution caused mainly by idiosyncratic factors, such as mismanagement. In this case, the failure would spread through the system via various domino or contagion mechanisms arising from cross-exposures and, possibly, the indiscriminate reaction of market participants. However, while well known examples such as the failure of Bankhaus Herstatt and the near collapse of LTCM had some ripple effects, their economic costs pale in comparison with those of episodes that reflect widespread overextension in the financial system.

[6] The importance of lending booms has been emphasised by many observers; recent examples include Gavin and Hausmann (1996), Gourinchas et al (1999) and Eichengreen and Arteta (2000). Views differ, however, on the factors that may lie behind such boom-bust episodes. Some commentators (eg Corsetti et al (1999)) stress learning difficulties following liberalisation and moral hazard. While not denying the relevance of these factors, we tend to see these phenomena as reflecting (a) more general difficulties in assessing how risk, especially system-wide risk, evolves over time and (b) incentives that result in reasonable actions at the level of individual agents but can have undesirable aggregate outcomes. These mechanisms can lead to excessive "procyclicality" in the financial system, sowing the seeds of financial instability. For an elaboration of this view, see eg Borio et al (2001), Lowe (2002) and BIS (2001).

... and unpredictable timing

Finally, while the timing of the crisis may be unpredictable, it should be possible to detect the symptoms of the build-up of financial imbalances. The previous stylised description suggests that unusually sustained and rapid growth in credit and in asset prices would figure prominently in any set of indicators. For some small open economies, the cumulative appreciation of the real exchange rate might also be helpful. It could capture the pressure associated with capital inflows as well as the potential build-up of concomitant foreign exchange mismatches. And, if available, real-side measures of any excess build-up in the capital stock, either at a sectoral or aggregate level, might also contain useful information.

On the face of it, several banking crises since the 1980s bear a more than passing resemblance to the stylised characterisation of financial distress just outlined. Among industrial countries, the most notable instances include the crises in the Nordic countries and Japan. Likewise, while far less disruptive, the serious financial strains experienced in a number of English-speaking countries at the beginning of the 1990s, including the United States, the United Kingdom and Australia, also exhibit similar features. Among emerging market countries, cases in point include the experience of several Latin American economies in the late 1970s–early 1980s, especially in the Southern Cone, Mexico in the mid-1990s and, more recently, the crises in East Asia. These banking crises have been especially disruptive when occurring alongside currency crises.

Looking further back in history, crises of this type were not uncommon in the pre-World War II environment, the previous historical phase in which financial markets were largely liberalised, both within and across national borders.[7] More generally, the literature on financial crises brims with references to rapid credit expansion and major medium-term swings in asset prices.[8]

Empirical evidence

The above analysis is highly suggestive of the kind of processes that might underlie financial instability. But while these processes may be identifiable with the benefit of hindsight, detecting them on the basis of ex ante information alone, as policymakers need to, is bound to be harder. In other words, can the build-up of vulnerabilities be spotted in time to take preventive action?

The approach

Properties of indicators:

To begin to answer this question, we construct a set of indicators and assess statistically their predictive performance for banking crises.[9] The stylised view

[7] See, for example, Goodhart and de Largy (1999) and, for a detailed account of the Australian experience, Kent and D'Arcy (2001).

[8] Kindleberger (1996) is the classic reference here.

[9] For reviews of this literature, see IMF (2002), Bell and Pain (2000), Eichengreen and Arteta (2000) and Hawkins and Klau (2000).

of financial instability just outlined provides useful clues as to how leading indicators of banking crises may be constructed.

a small set of variables ...

To start with, a combination of a small set of variables should be sufficient to capture the build-up of vulnerabilities. Moreover, focusing on only a few variables should improve the reliability of the corresponding indicators. As discussed, the behaviour of credit, asset prices and, possibly, the exchange rate should contain useful information about the development of financial imbalances. We thus consider three core variables: the ratio of (private sector) credit to GDP; equity prices (deflated by the price level); and the real effective exchange rate. Unfortunately, owing to data limitations, we cannot examine the performance of property prices, despite the fact that they have arguably played a significantly larger role in banking crises than equity prices. Up to a point, the behaviour of equity prices and the exchange rate could act as a proxy, since experience indicates that they tend to move in tandem with property prices, although with certain leads and lags.

... measured as cumulative deviations from trend ("gaps") ...

Next, we need somehow to capture the cumulative processes that in the boom phase sow the seeds of the subsequent distress. We do so by employing deviations of the core variables, measured in levels, from a trend ("gaps").[10] The expectation is that if the credit/GDP ratio, real equity prices and/or the real effective exchange rate move "sufficiently above" their trend (ie exceed some critical threshold), then financial imbalances are emerging, signalling the risk of subsequent financial distress.[11] Moreover, we have to ensure that the trend is measured only on the basis of information that is available at the time policy decisions are made. Thus, for the assessment of vulnerabilities made at time *t*, the gaps are calculated using data only up to time *t*, and not data that would become available in subsequent periods.[12]

... and treated jointly ...

Since we are interested in a combination of variables, we consider composite indicators, where a signal of pending distress is said to be "on" if, and only if, the thresholds for the corresponding variables are simultaneously exceeded. Based on the stylised description of the origin of banking crises, we explore four combinations: (a) credit and asset prices; (b) credit and the exchange rate; (c) credit and either asset prices or the exchange rate; and (d) credit and asset prices and the exchange rate. In case (c), a signal is turned on if either the credit and asset price gaps or the credit and exchange rate gaps are simultaneously exceeded. The reason is that either of the two

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[10] The trend is estimated through a Hodrick-Prescott filter. The value of lambda is set at 1,600. The gaps are defined in percentage points for credit and as a percentage of the trend level for real equity prices and the real exchange rate.

[11] We also examined the extent to which the output gap could substitute for some of the information contained in financial variables. This variable, however, turned out not to have additional information content and to be inferior to the measures of financial imbalances. While, owing to space limitations, this evidence is not presented here, the interested reader can find it in Borio et al (2002).

[12] In practice, some information lags exist with respect to the credit/GDP ratio. These are not taken into account in what follows. Strictly speaking, given the lags, the predicted value for GDP based on available information would need to be used instead. Since, however, our analysis is performed at annual frequency, this issue is unlikely to be significant.

combinations, on its own, might be sufficient to foreshadow a crisis. By contrast, in case (d), a signal is turned on only if all three gaps are exceeded simultaneously, a more selective criterion.

... allowing for variable forecasting horizons

Finally, recognising the difficulty of predicting the exact timing of the crises, we examine the performance of the indicators over multiple horizons. The basic idea is that, as long as the vulnerabilities can be identified, then at some point in the (not too distant) future a crisis might emerge. If so, as the horizon is lengthened, the performance of the indicators might be expected to improve. If a signal is turned on, it is said to be correct if a crisis occurs in any one of the years included in the horizon.[13]

On the basis of what criterion are the critical thresholds of the indicators chosen and their performance assessed? A good indicator would have two properties. First, it would predict a high fraction of the crises that do occur. Second, it would not turn on too often, ie signal crises that, in fact, do not materialise. In technical terms, such an indicator would have a low "noise-to signal" ratio.[14] Rather than minimising this ratio per se, however, we judgmentally give somewhat more weight to the percentage of crises correctly predicted. This reflects the view that the cost of failing to predict a crisis is larger than that of predicting one that does not materialise.[15] Based on this criterion, the calibration of the thresholds is done jointly.[16] In other words, for each indicator we search through various combinations of thresholds for the one that yields the best results.[17]

Our sample includes 34 countries (21 industrial and 13 emerging market economies), selected to be relatively homogeneous in terms of economic development.[18] The data are yearly and cover the period 1960–99. We take a

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[13] If the signal is issued in the same year as the crisis occurs, we also consider it correct, given the difficulties in assigning specific dates to financial distress and the coarseness of the observation intervals (a whole year). In the tables, these cases are combined under year 1, which thus includes the current and following year.

[14] More precisely, the numerator of the noise-to-signal ratio is the ratio of crises incorrectly predicted to all non-crisis episodes (the maximum number of such mistakes). Its denominator is the ratio of the number of crises correctly predicted to all crisis episodes (the maximum number of correct crisis calls). Thus, the statistic is the ratio of type II error to one minus type I error.

[15] Moreover, in a number of cases the noise-to-signal ratio could be made arbitrarily small by tightening the selectivity of the threshold. This underscores the risk of basing conclusions exclusively on minimisation of this ratio. Of course, the choice of threshold could be carried out more formally by assigning specific weights to the costs of type I and type II errors. For a much more detailed presentation of individual threshold results for some of the indicators discussed here, see Borio and Lowe (2002).

[16] Considering composite indicators and calibrating signals jointly is equivalent to "interacting" variables in regression analysis. For instance, this means that the relevance of credit expansion differs depending on whether or not it is accompanied by rapid asset price increases. The importance of interacting variables had already been noted by McFadden et al (1985), but has since then strangely fallen into disuse.

[17] Thus, methodologically, our approach differs from that of Kaminsky and Reinhart (1999) in several respects: it uses ex ante information only; it focuses on a small set of variables; it develops composite indicators, based on joint calibration of signals; it emphasises cumulative processes; and it pays particular attention to multiple horizons.

[18] See Borio and Lowe (2002) for details on the sample.

standard definition of banking crisis employed in previous research.[19] On this basis, the sample includes 40 crises spread over 27 of the 34 countries, with 16 such episodes occurring in industrial countries and 24 in emerging market economies.

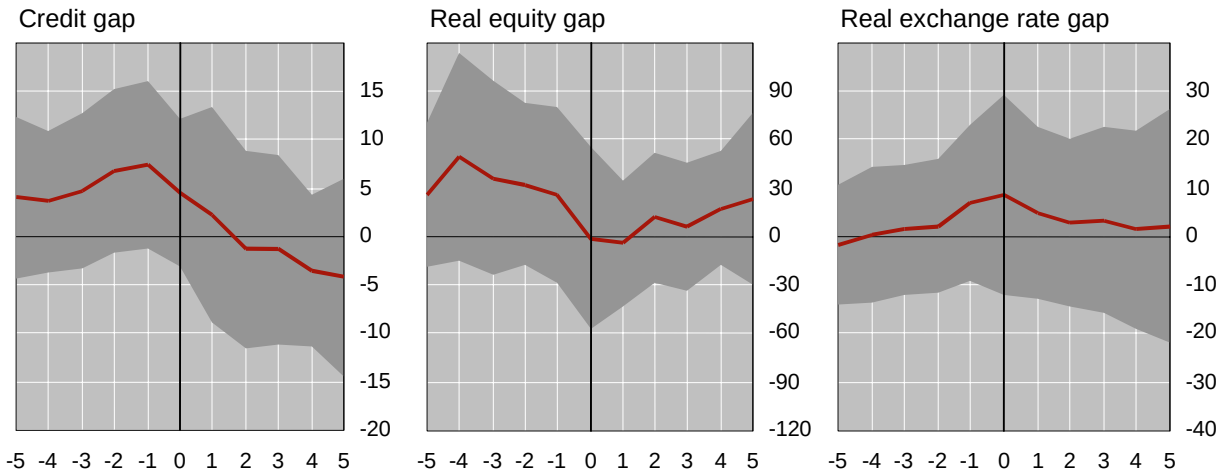
We examine the behaviour of the indicators, pooling all countries together as well as separately for industrial and emerging market economies. This could help to shed light on the extent to which the indicators need to be calibrated differently in order to take into account country-specific characteristics. One might expect the significance of the variables to differ between the two groups of countries. For instance, the exchange rate gap might play a bigger role in emerging market economies. These tend to rely more on external finance and to be more sensitive to exchange rate changes. More generally, the critical thresholds may also vary across the two groups of countries owing to factors such as the soundness of the financial infrastructure.

The results

Promising behaviour of gaps around crises

Before turning to the detailed statistical results, it may be useful to see how the various gaps behave around banking crises. Graph 1 plots the average movement in the gaps over an 11-year period centred on the crisis years. Also shown, as a shaded area, is the standard deviation across episodes, a measure of the dispersion of the behaviour of the gaps. The graph indicates that credit and exchange rate gaps tend on average to rise one period before and to peak in the crisis year, respectively. The equity price gap is consistently

Behaviour of the indicators around banking crises (all countries)



Note: The shaded area represents ±1 standard deviation around the mean. The x-axis shows a period five years either side of each crisis.

Source: Authors' calculations. Graph 1

[19] This is the one used in Bordo et al (2001), who kindly provided the underlying data. The only exception is that, in contrast to our previous work (Borio and Lowe (2002)), we add two financial stress episodes, namely one in the United States and one in the United Kingdom in the early 1990s. These are intended to capture the severe financial strains felt in these economies at the time. In fact, in the United Kingdom a number of (small) banks experienced a full-blown crisis.

Composite indicators, all countries

Horizon (years)[1]	Credit (4) and asset price (40)[2]		Credit (4) and exchange rate (7)[2]		Credit (4) and (asset price (40) or exchange rate (9))[2]		Credit (4) and asset price (40) and exchange rate (4)[2]	
	Noise/ signal	% crises predicted	Noise/ signal	% crises predicted	Noise/ signal	% crises predicted	Noise/ signal	% crises predicted
1	0.14	43	0.10	43	0.13	63	0.08	25
2	0.08	55	0.09	43	0.10	68	0.05	30
3	0.06	60	0.08	43	0.08	70	0.03	33

[1] A signal is correct if a crisis takes place in any one of the years included in the horizon ahead. Noise is identified as mistaken predictions within the same horizon. Given the data frequency and difficulties in assigning crises to a specific date, year one includes, in addition, the current year; the size of the threshold is shown in brackets. [2] All variables are measured as gaps, ie as a percentage point or percentage deviation from an ex ante, recursively calculated Hodrick-Prescott trend. The size of the threshold is shown in brackets. Credit is measured as the ratio of private sector credit to GDP; the asset price is a real equity price index; the exchange rate is a real effective exchange rate. Table 1

positive until the crisis year, but peaks well before. This is consistent with the fact that equity prices tend to fall in the years immediately preceding distress. Thus, in order to better capture the boom phase, the equity gap included in the indicator at time *t* is the one ruling two years previously. Treating equity prices this way may also help to make them better proxies for property prices, which typically peak a couple of years later (Borio and Lowe (2002)).

While this graphical evidence suggests that the variables may contain useful leading information about banking crises, their performance is assessed more formally in Tables 1 to 3. For each combination of variables and critical threshold, the tables indicate the percentage of crises correctly predicted at different horizons and the associated noise-to-signal ratio. Only the preferred threshold is shown, based on our judgment of a sensible trade-off between a low noise-to-signal ratio and a high percentage of crises correctly predicted.

Looking first at the performance of each composite indicator pooling all countries together, the following results stand out (Table 1):

Composite indicators do well

The *composite indicators tend to yield comparatively low noise-to-signal ratios* by the standards of existing work in this field. As shown in Borio and Lowe (2002), this gain in efficiency results primarily from the focus on cumulative processes and on the combination of variables. In essence, this approach reduces the frequency with which the indicators predict crises that, in the event, do not materialise.

Lengthening the horizon helps

Lengthening the horizon tends to improve the results. It often increases the percentage of crises predicted and, as would be expected, improves the noise-to-signal ratio. The improvement in performance varies across composite indicators. For instance, in the case of the credit/asset price composite indicator, moving from a one- to a three-year horizon increases the percentage of crises predicted by close to 50% and more than halves the noise-to-signal ratio. At the other end of the spectrum, in the case of the credit/exchange rate combination, there is only an improvement in the noise-to-signal ratio.

Among two-variable composite indicators, *the credit/asset price combination is superior to the credit/exchange rate alternative*, especially as the horizon is lengthened. It predicts a higher percentage of crises and exhibits a lower noise-to-signal ratio. In particular, at a three-year horizon, when the

credit gap is at least 4 percentage points and the asset gap 40%, as many as 60% of the crises are predicted, with a noise-to-signal ratio equal to just 0.06. This indicates that only roughly one in 20 observations is incorrectly classified as a crisis or non-crisis.

Credit, equity price and exchange rate gaps contain useful joint information

The assessment of the *three-variable composite indicators* depends in part on trade-offs between the types of errors made and on horizons. In particular, by comparison with the credit/asset price indicator, the indicator that combines credit with either asset prices or the exchange rate is superior at the one-year horizon. However, over a three-year horizon it predicts more crises (70%) at the cost of a somewhat higher noise-to-signal ratio (0.08), with about one incorrect classification in every 15.[20] The indicator that requires all three signals to be on simultaneously has by far the lowest noise-to-signal ratio (0.03), with about one observation incorrectly classified in every 26, but it predicts only one third of crises. This selective indicator would be relatively more useful when the authorities set the bar quite high before being prepared to take action.

Tables 2 and 3 highlight the main results for industrial and emerging market countries separately. Only a selection of composite indicators is shown. A number of points emerge:

The size of the critical thresholds is remarkably similar across the two groups of countries. This suggests that, despite structural differences, the cross-country experience may to some extent be used as a basis for calibration of indicators in individual countries with some degree of confidence. This piece of evidence is important since, as crises are inevitably infrequent events, relying on cross-country experience for calibration is very hard to avoid.

At the same time, as might be expected, *equity prices appear to perform relatively better for industrial countries and the exchange rate relatively better for emerging market countries*. This is consistent with the greater role that the exchange rate tends to play in the latter group. In fact, for industrial countries, once the equity price gap is included, the exchange rate does not seem to add

Composite indicators, industrial countries

Horizon (years)	Credit (4) and asset price (40)		Credit (4) and exchange rate (4)		Credit (4) and (asset price (40) or exchange rate (20)[1])	
	Noise/ signal	% crises predicted	Noise/ signal	% crises predicted	Noise/ signal	% crises predicted
1	0.09	50	0.11	44	0.09	50
2	0.06	56	0.10	44	0.06	56
3	0.04	63	0.10	44	0.04	63

[1] Or higher. Table 2

[20] The increase in crises predicted indicates that the episodes of distress captured by the indicators combining credit with only one of the two other gaps only partly overlap.

Composite indicators, emerging market countries

Horizon (years)	Credit (4) and asset price (40)		Credit (4) and exchange rate (5)		Credit (4) and (asset price (40) or exchange rate (13))	
	Noise/ signal	% crises predicted	Noise/ signal	% crises predicted	Noise/ signal	% crises predicted
1	0.23	38	0.15	58	0.16	67
2	0.12	54	0.11	58	0.12	71
3	0.08	58	0.10	58	0.09	75

Table 3

Some differences between industrial and emerging market economies

any useful information. Even so, the superiority of the exchange rate gap over the equity price gap in emerging market economies tends to disappear as the horizon is lengthened.

For industrial countries, the best composite indicator combines the credit with the equity price gap. It now predicts over 60% of crises at the three-year horizon, with a further sizeable reduction in the noise-to-signal ratio compared with the results for all countries taken together, from 0.06 to 0.04 (one observation in every 28 incorrectly classified).[21]

For emerging market countries, the best composite indicator combines the credit gap with either the asset price or the exchange rate gap. In this case, at a three-year horizon, 75% of crises are successfully predicted, with one wrong classification in every 13.

Overall, disaggregation into the two groups *does not yield gains in the number of crises predicted*, although it leads to *some improvement in the noise-to-signal ratio*. At the three-year horizon, the noise-to-signal ratio for the aggregate set of observations falls from 0.08 to 0.06. This results from dropping the exchange rate for industrial countries and increasing the threshold of the exchange rate gap for emerging market economies.

Which crises are actually predicted and which ones are missed? The indicators capture almost all the crises mentioned in the first section of this study. The only exceptions are South Korea and Taiwan, China in the late 1990s. In the case of Korea, this is because the credit and exchange rate gap indicators do not signal a crisis simultaneously, but just one year apart. Either of the two, taken in isolation, would have signalled danger. For Taiwan, China the horizon is one year too short: the crisis would have been captured at a four-year horizon. In both cases, real estate prices might have helped considerably.[22]

[21] Note that even if only one prediction in every 28 is wrong it does not follow that crying wolf too often is entirely avoided. This is because of the large number of observations when the signal is "off" correctly. For instance, in this case, the signal is "on" incorrectly (ie predicts crises that do not materialise) 60% of the time. Only some of these "false positives" could be avoided by a slight further extension of the horizon. In the case of the most conservative indicator (all gaps "on" simultaneously), this percentage drops to less than 40%.

[22] This is also clearly true for another episode that is missed, namely the so-called secondary banking crisis in the United Kingdom in the early 1970s. The crisis is picked up by credit alone, but not once the equity price gap is added. This is because equity prices were not

Conclusion

Our analysis suggests that it is possible to construct simple composite indicators of banking crises that can be useful in assessing the risk of future financial distress with a reasonable degree of confidence. Obviously, such indicators of financial imbalances should at best be used as one element in a more thorough assessment of vulnerabilities, and never as substitutes for it.

There are a number of caveats to our findings. First, while the performance of the indicators over the period examined is very good, the procedure employed does not permit us to make statements about the statistical precision with which the specific thresholds are identified. Second, crises are by their very nature rare events. Inevitably, therefore, calibration for individual countries can only be based on the assumption that the experience of other countries can be relied upon to make inferences. Finally, we have not tested the indicators out of sample. As always, the past need not be a reliable guide for the future. For example, the major efforts made in recent years to improve the infrastructure of financial systems might reduce the likelihood of distress for any given threshold level.

Despite these caveats, on balance the results are encouraging. The historiography of financial crises suggests that the core regularities on which the indicators are based have been so common in the past that they may indeed prove comparatively robust in the future. Moreover, research in this area is very much in its infancy; more work could provide the basis for more reliable judgments. Several directions spring to mind. More and better data should help to construct better indicators; real estate prices are critical here. It might be fruitful to perform "out of sample" exercises by testing these indicators back in time. In particular, one could look at the pre-World War II period, when banking crises were more common. If successful, this could instil greater confidence in the reliability of the indicators. Finally, following similar principles, further indicators could be developed, tailored to types of banking crises other than those considered here.

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