EARLY WARNING INDICATORS OF ECONOMIC CRISES[1]

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Monitoring a suitable set of early warning indicators is crucial for the optimal timing of macroprudential measures aimed at reducing the risk of financial crises or at least mitigating their impact on the economy. This article sets out to identify the indicators that should be monitored and to show how to overcome some problems in identifying them. As it is important to focus on robust indicators that are independent of the choice of model, the article combines two mutually complementary crisis measures: the timing of crisis occurrence and the intensity of the impact of crises on the economy. The article goes on to demonstrate that it is appropriate to rely on a system of several complementary models. For a set of 40 advanced EU and OECD countries, our two-model system identifies rising house prices and external debt as the best performing early warning indicators. Global variables, such as the volume of credit, global GDP and crude oil prices, form another useful set of indicators.

1. INTRODUCTION

The 2008–2009 financial crisis stimulated the development of a new generation of early warning systems. Whereas the creators of the first-generation systems focused mainly on developing countries and exchange rate crises (Kaminsky, 1999), the new generation of early warning systems accounts for different causes as well as the fact that advanced countries were the hardest hit by the crisis (Rose and Spiegel, 2009).

The new-generation systems have to address a series of methodological problems. This article sets out to demonstrate how certain problems associated with the definition of crisis and with the choice of sufficiently effective early warning indicators can be overcome. The article is structured as follows. Section 2 presents a discrete early warning model explaining the occurrence of crises. Section 3 is devoted to a continuous model describing the impacts of crises on the real economy. Section 4 assesses the practical applicability of early warning indicators.

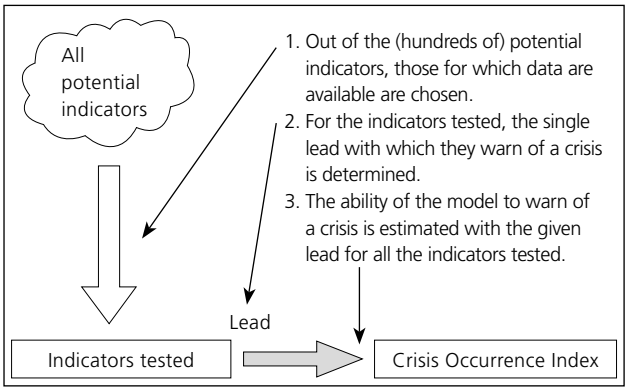
2. DISCRETE MODEL – CRISIS OCCURRENCE MODEL

The discrete model looks for early warning indicators through the lens of crisis occurrence. It does so using an index that takes a value of one if a crisis occurs and zero otherwise. Such an index is not easy to compile, as the literature does not provide a complete database of crises in advanced countries. The first step of the analysis, therefore, was to build a database of crises in individual EU and OECD countries over the period 1970–2010 at quarterly frequency. The following three main types of crises were identified: currency crises (balance of payments crises), financial (banking) crises and debt crises (inability to repay government debt, debt restructuring).

In the literature used,[2] these crises were defined either on the basis of the authors' calculations (for example if a particular indicator exceeds a critical value – see, for example, Kaminsky and Reinhart, 1999, and Kaminsky, 2006) or on the basis of the authors' expert judgement (Caprio and Klingebiel, 2003; Laeven and Valencia, 2008). By aggregating the available studies and supplementing them in collaboration with other central banks of EU and OECD countries[3] we put together a complete database of crises allowing more reliable identification of early warning indicators. The subsequently calculated Crisis Occurrence

Chart 1

SCHEME OF THE DISCRETE EARLY WARNING MODEL



1 This article is based on CNB research project C3/2011, the results of which are described in detail in Babecký et al. (2011).
2 See Caprio and Klingebiel (2003), Reinhart and Rogoff (2008), Laeven and Valencia (2008, 2010), Kaminsky and Reinhart (1999) and Kaminsky (2006).
3 Within the ESCB's Macroprudential Research Network (MaRs) – see http://www.ecb.europa.eu/home/html/researcher_mars.en.html.

Index is the subject of research of the discrete econometric model shown schematically in Chart 1.

The creation of the discrete model illustrated in Chart 1 starts with the choice of the early warning indicators to be tested. Several different approaches are used in the literature to identify these indicators. The first option is to use indicators derived from a single specific theoretical model (Kaminsky and Reinhart, 1999). The second option is to select the indicators on the basis of a systematic review of the literature (Rose and Spiegel, 2009; Frankel and Saravelos, 2010). Finally, one can use all the indicators (and their transformations) available in a selected database and test whether at least some of them will be useful for explaining crises (Alessi and Detken, 2009).

Each of these indicator selection techniques has its strengths and weaknesses. For example, a set of indicators based on a single specific model generally makes up only a small subset of all the potentially important indicators. In this article, the early warning indicators tested were chosen on the basis of systematic literature reviews (e.g. Alessi and Detken, 2009; Rose and Spiegel, 2009; Frankel and Saravelos, 2010) and were supplemented with several other important indicators based on the authors' judgement. Over 100 potential macroeconomic and financial indicators were identified using databases published by the IMF, the OECD, the World Bank and the Bank for International Settlements. Taking into account the availability of data for individual countries, a total of 50 indicators were left in the sample.

In the second step of creation of the discrete model, we need to determine the lead with which the chosen tested indicators are able to warn of a crisis. The lead is usually chosen on the basis of the authors' expert, but subjective, judgement. Most early warning models use the same lead (generally 1–2 years) for all indicators. This assumption stems from the observed facts about the evolution of important macroeconomic indicators before, during and after crises (Kaminsky et al., 1998; Grammatikos and Vermeulen, 2010). On the basis of the literature, the lead with which the indicators warn of a crisis in our discrete model was set at two years and, alternatively, at three years (to analyse the sensitivity of the results).

The third step is to estimate the econometric model and build an early warning index describing the probability of future crisis occurrence. The model presented in this article was estimated using the dynamic panel logit technique. Although the data sample ends in 2010, data were available only up to the end of 2009 for some individual countries, so the forecast horizon stretches only to the end of 2012 at the most. It is worth noting that setting an identical lead length for all the indicators is a very restrictive assumption. In reality, different indicators can provide information about an approaching crisis with different leads. The ability of the model to warn of a crisis was then tested. The discrete model sends out a crisis warning by calculating the probability of a crisis occurring in the next one or two years on the basis of the observed values of all the indicators tested.

The ability of this model, which contains approximately 50 indicators, to warn of a crisis while not issuing false alarms is shown in Table 1. Type I errors (missed crises) and type II errors (false alarms) are used for illustration. The probability of a type I error is defined by C/(A+C) and that of a type II error by B/(B+D). The discrete model therefore missed 17.3% of crises and issued false alarms in 9.5% of cases. Also interesting from the monetary policy-makers' perspective is A/(A+B), which describes the probability that the model issued a warning signal and a crisis actually occurred (64.0%). The complementary indicator is B/(A+B), namely the probability that the model issued a warning signal but no crisis occurred (36.0%).

Table 1

ABILITY OF THE DISCRETE MODEL TO WARN OF A CRISIS

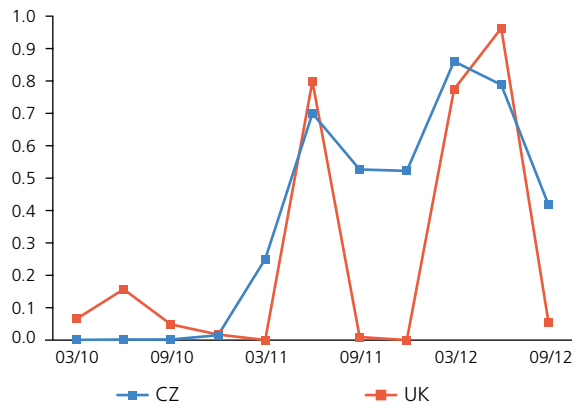
	Crisis occurred	No crisis occurred
Warning signal issued	A (477)	B (268)
No warning signal issued	C (100)	D (2566)

Note: "Warning signal issued" refers to the predicted probability of a crisis occurring in the following two years.

To illustrate the crisis occurrence probability for 2010 and for two years beyond the period for which data are available, we present here predictions for the Czech Republic and the United Kingdom (see Chart 2).[4] In 2010 the crisis probability seems relatively low, while from 2011 onwards it rises in both countries in the shape of a capital "M". Two waves of crisis are visible – in the second half of 2011 and in the middle of 2012. This may be a result of a deterioration in the global outlook combined with the effects of restrictive fiscal policy. The certain similarity in the crisis predictions for the Czech Republic and the UK underlines the importance of common (global) factors. In the case of the UK, however, national factors evidently play an important role, causing the crisis probability to leap from 0% to almost 100% in two quarters (as the global variables change very little from one quarter to the next).

Chart 2

ECONOMIC CRISIS PREDICTIONS: CZECH REPUBLIC AND UNITED KINGDOM



Note: Model predictions for 2010 Q1–2012 Q3. The actual data end in 2010. The y-axis shows the crisis occurrence probability.

The model also shows that the most useful early warning indicators – besides global factors, which play a major role – include growth in housing prices, low domestic interest rates on loans and growth in loans provided to the corporate sector. Growth in long-term government bond yields is also associated with a higher crisis probability. Conversely, a low debt ratio contributes to stability of the economy.

3. CONTINUOUS MODEL – IMPACTS OF CRISES ON THE ECONOMY

An alternative to the discrete model is the continuous model, which looks for early warning indicators that can predict crises that are very costly to the real economy. There are various different ways of describing such costs. One important indicator is the impact on gross domestic product (GDP), or, more precisely, on real GDP growth. Other indicators of real costs include the state budget balance and the unemployment rate. A decline in GDP growth and growth in unemployment and the fiscal deficit represent an increase in real costs to the economy. On the basis of these three variables one can create a continuous index of the impacts of crises on the real economy. In this article, higher index values mean higher real costs.

First of all, we need to establish whether rising real economic costs are a consequence or a cause of crises. For instance, the fiscal deficit may rise as a result of the adoption of anticrisis measures (such as spending cuts, employment support and government assistance for manufacturers and major financial institutions). On the other hand, an increase in the debt ratio may induce a crisis. Costs to the real economy will not necessarily be accompanied by a crisis if they arise as part of the normal cycle (for example, seasonal changes in production and unemployment). This means that not every decline in economic growth, rise in unemployment or increase in deficit is a consequence of a financial or other crisis. The index of the impact of crises on the real economy is derived from the observation that for "large" crises the causality runs from the occurrence of the crisis to a sharp deterioration in the real economy. Examples include the Great Depression of the 1930s and the economic slump of 2008–2009, which came in the wake of financial crises. In order to distinguish between normal cyclical movements in the economy and real economic downturns caused by crises, we used a panel data structure and a long data sample. A systemic crisis involves a deterioration in real economic growth occurring in several countries at the same time, as happened, for example, in 2008–2009.[5]

Chart 3 illustrates how the continuous early warning model was put together. This model is estimated for the same sample of 40 EU and OECD countries for which

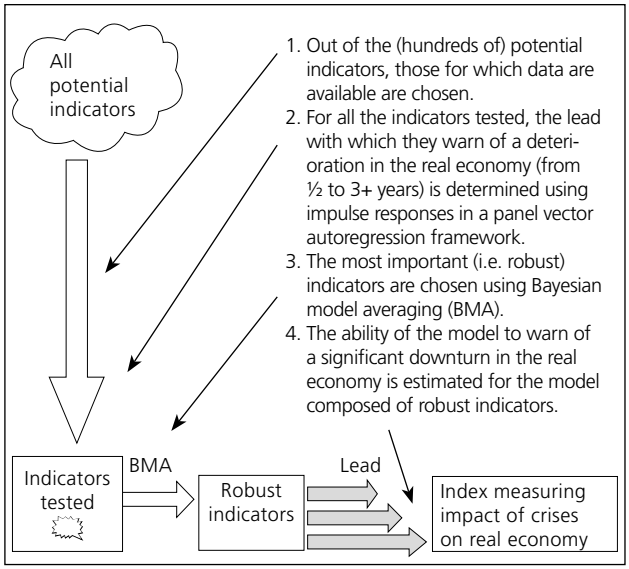
4 The results for the other countries are available in an online appendix to Babecký et al. (2011). The UK was chosen as an economy with a significant financial sector and with a similar monetary policy regime as the Czech Republic (inflation targeting, its own currency). Both the UK and the Czech Republic were affected by the 2008/2009 crisis, although neither was among the hardest hit economies.

5 Clearly this is not the only way of differentiating cyclicality from crisis effects. We are currently working on another version of the model in which we try to combine information on the occurrence of crises with downturns in economic activity. An alternative approach is to cyclically adjust economic activity for each country separately using filtration methods.

the discrete model described in the previous section was created. All the potential indicators that were identified for the purposes of the discrete model can be used for the continuous model as well.

Chart 3

SCHEME OF THE CONTINUOUS EARLY WARNING MODEL



The use of a continuous index describing the condition of the real economy on an ongoing basis opens the way to a series of methodological refinements of the early warning model. The first is the choice of the lead (see step 2 in Chart 3) with which the indicators warn of the impact of a crisis on the real economy, or of a massive increase in real costs in the countries of interest. Instead of the arbitrary assumption of an identical fixed lead for all indicators, the setting of the optimal lead length individually for each indicator was proposed. The optimal lead with which an indicator explains the intensity of the impact of a crisis on the economy was determined at between 4 and 16 quarters using impulse responses in a panel vector autoregression framework where each of the variable pairs formed by the index of the impact of crises on the real economy and each of the 50 indicators tested was analysed in turn.[6] The minimum lead length was set so that the chosen indicators were true early warning indicators, i.e. they issued a signal at least a year before the crisis erupted. (The resulting lead lengths for all the indicators tested are shown in Table A1 in Annex IV.2 in Babecký et al., 2011.)

We then identified the most useful indicators for predicting the costs of a crisis (see step 3 in Chart 3). Although the number of potential indicators had already been reduced on the basis of availability, it was still important to find the most appropriate ones. It is common practice in the literature to use all the available indicators based on theory or the authors' judgement. However, including indicators that have only a weak (or no) relationship to the explained event reduces the power of the early warning model to a similar extent as excluding important indicators.[7] So how should the important indicators be chosen? We used Bayesian model averaging (BMA[8]) for this purpose. The BMA method allows us to select the best performing combinations from all the possible combinations of explanatory indicators. To the best of our knowledge, this is the first time this modern method for selecting variables has been applied in the early warning literature. Finally, we obtained a regression model whose explanatory variables consisted solely of robust indicators (approximately half of the total of 50).

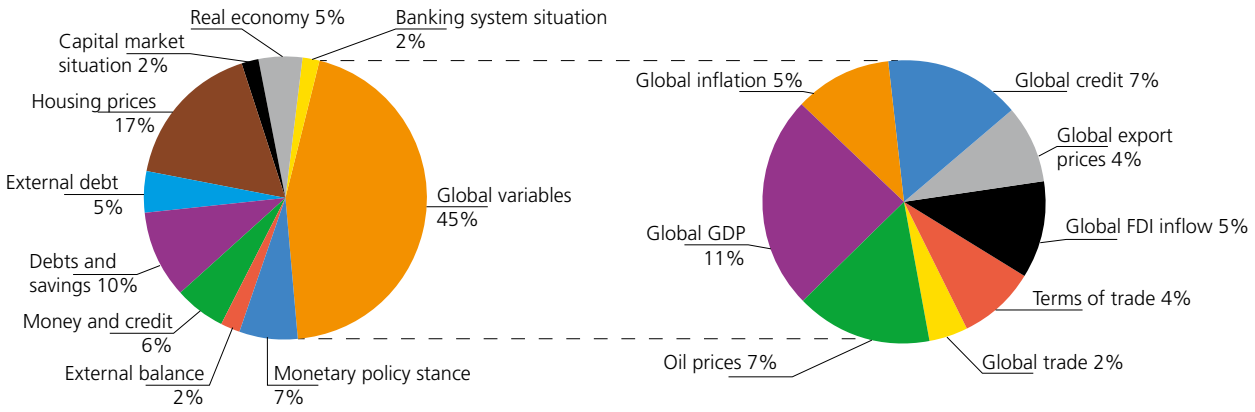
The resulting specification (i.e. the explanation of the crisis impact intensity by robust indicators) was estimated using the generalised method of moments (GMM), which is robust to the possible endogeneity of the estimate, i.e. bidirectional causality between the dependent and explanatory variables. The results of the continuous model allow us to discuss the sources of risk to the stability of the real economy and to compare the importance of different sets of variables, such as national and global indicators.

To identify the main sources of risks to macroeconomic and financial stability we need to look at the ability of the individual indicators to explain the variation in the dependent variable, i.e. the impact of crises on the real economy. The continuous model in this study is able to explain 37% of the variation in the impact of crises on the real economy over the past 40 years in the panel of 40 countries; the left-hand diagram in Chart 4 presents the percentage shares of the individual sets of indicators in the explanatory power of the overall model. As is clear from the chart, global variables are the most important set of early warning indicators. The right-hand diagram illustrates the performance of the individual global variables.

6 Analysis of the combined effects of indicators is a possible topic for future research.
7 Excluding an important indicator is generally the worst option statistically; including insignificant indicators "only" increases the volatility.
8 See Koop (2003) for a general description of the BMA method and Feldkircher and Zeugner (2009) for technical details on how it can be applied in practice.

Chart 4

THE MOST IMPORTANT EARLY WARNING INDICATORS



Note: Shares of individual indicators in explaining the variation in the impact of crises on the real economy

These results imply that macroprudential policy should monitor both global indicators (such as global GDP, global credit and global inflation) and selected domestic indicators in order to identify risk sources. Among the domestic factors, house prices represent the most significant source of risk to macroeconomic stability. The important indicators also include the price of crude oil and internal and external debt.

4. CONCLUSION

The existing literature does not offer a consensus on how to define crisis for the purposes of early warning systems. It is therefore appropriate to work with a discrete index and a continuous index in parallel so that the choice of useful early warning indicators is as robust as possible. The literature also does not offer a complete list of all crises for the advanced countries, so it was necessary to update and extend the list for the purposes of the discrete model.

Despite the differences in defining crises, it was possible to identify which potential indicators are the most useful. In practice, it is important to track rising house prices, sovereign debt and global variables. However, in the case of the discrete model, which estimates the crisis occurrence probability, national variables (such as loan interest rates, the volume of loans provided to the corporate sector and government bond yields) play a rather more prominent role; for the continuous model, which describes the impacts of crises on the real economy, global variables (such as the volume of global credit, global production and crude oil prices) are the most important category of early warning indicators owing to the interconnectedness of economies.

The results of the continuous model also reveal that early warning signals of the impacts of future crises emanate from different indicators with different leads. One set of indicators indicates the risk of crisis four or more years before a crisis breaks out, whereas another set triggers the alarm only shortly before the crisis, when it is probably too late to stop it. It is therefore important to account for differences in the predictive power of the individual indicators when building an early warning system.

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