

Binary encoding in data series and early warning signals on financial crises

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1. Financial crises have strong impacts on the economy, including labor markets, household incomes, and the profitability of companies (see, e.g., [1]-[3]). It is therefore important to understand how financial crises develop and whether it is possible to detect early warning signals on financial crises.

Financial crises lie in the area of extreme events. Compared to fluctuations in values of the indicators of a system's performance, extreme events are usually understood as qualitative shifts in the system's behavior. In this context, signals on the upcoming extreme events can be characterized in terms of tendencies rather than predictions on particular quantities. Roughly, one can group the tendencies in two categories – tendencies to a crisis and tendencies to avoiding a crises. Under that paradigm, early warning signals can be treated in a binary way – as either “minus” signals registering a tendency to a crisis, or “plus” signals registering a tendency to avoiding a crisis (see [4]).

Based on this binary approach, we develop a three-stage research pattern for identifying tendencies to crises in application to two recent financial crises – the Dot-com crisis of 2001-2002, and the latest global financial crisis of 2008-2009.

2. A first stage is *recognition*. Assessing an eight-year-long financial time series (the Dow Jones Industrial Average and the Federal Reserve Interest Rate) preceding the Dot-com crisis of 2001-2002, we identify some “minus” and “plus” signals. We understand the “minus” signals as short (four-month-long) patterns in the time series, which occur, primarily, close to the time of the crisis, and the “plus” signals as those occurring, primarily, in earlier periods. We propose a *binary encoding rule* that transforms short data patterns into “minus” and “plus” signals.

A second stage is a *statistical analysis*. We use the binary encoding rule to transform a long (1954-2001) time series preceding the crisis of 2001-2002 into a sequence of “minus” and “plus” signals, and analyze the frequencies of a “minus” and a “plus” to follow each short *binary window* in the sequence (in our analysis each binary window is formed by three subsequent overlapping signals covering six months). We treat the frequencies as transition probabilities, which define a *binary random process* operating in the space of the binary windows. In our analysis the binary random process serves as a model describing the mechanism for the “plus” and “minus” signals to occur in the operation of the financial system under consideration. Two important features of the model are the following. Firstly, as ensured by the recognition analysis, the model recognizes early warning signals on

the crisis of 2001-2002. Secondly, as ensured by the statistical analysis, the model captures the dynamics of signals occurring in a long historical time series.

A third stage is *testing the forecasting ability* of the model. We use the model to assess, retrospectively, the probability of a financial crisis to occur in October 2008 (the latest global financial crisis was registered in the period from October 2008 to mid-2009). We show that the probability grows steadily starting from October 2007 and reaches value 1 in August 2008.

We also find the probability of a crisis to occur in each month in the period November 2008 - August 2009. The behavior of the probability is similar to that found for October 2008, i.e., it starts to grow fast and reaches size 1 several months before the month, for which we calculate the probability. It is shown that the probability of a crisis to occur starting from September 2009 (in the period when the real economy showed signs of recovery) grows slightly but never reaches 1.

Thus, our binary stochastic model based on analysis of data preceding the crisis of 2001-2002, demonstrates an ability to register early warning signals on the global financial crisis of 2008-2009.

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