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Hybridizing logistic regression with product unit and RBF networks for accurate detection and prediction of banking crises

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ABSTRACT

As the current crisis has painfully proved, the financial system plays a crucial role in economic development. Although the current crisis is being of an exceptional magnitude, financial crises are recurrent phenomena in modern financial systems. The literature offers several definitions of financial instability, but for our purposes we identity financial crisis with banking crisis as the most common example of financial instability. In this paper we introduce a novel model for detection and prediction of crises, based on the hybridization of a standard logistic regression with product unit (PU) neural networks and radial basis function (RBF) networks. These hybrid approaches are fully described in the paper, and applied to the detection and prediction of banking crises by using a large database of countries in the period 1981–1999. The proposed techniques are shown to perform better than other existing statistical and artificial intelligence methods in this problem.

1. Introduction

The recent financial collapse has stressed the crucial role of the financial system to guarantee the economic development. The financial system is responsible for the allocation of resources over time and among different alternatives of investment, by pricing the postposition of consumption (free risk rate) and pricing the risk (risk premium). A correct functioning of the financial system allows economies to reach higher levels of real growth, as well as more stable macroeconomic conditions. On the other hand, good macroeconomic policies are a prerequisite for financial stability. Therefore sound macroeconomic policies together with a developed financial system reinforce each other guaranteeing financial stability and sustainable growth.

Apart from the current financial crisis, in the last 20 years at least 10 countries have experienced the simultaneous onset of banking and currency crisis, with contractions in gross domestic product of between 5% and 12% in the first year of the crisis, and negative or only slightly positive growth for several years thereafter [1,2]. This emphasizes the fact that preserving financial stability is one of the main goals for policy-makers from the beginning of the monetary systems. It is the special role that banks play in the financial system and their specificities as money issuers that explain why a great number of financial crises have had the banking sector as protagonist. In the 1980s and 1990s, several countries including developed economies, developing countries, and economies in transition, have experienced severe banking crises. Such a proliferation of large scale banking sector problems has raised widespread concern, as banking crises disrupt the flow of credit to households and enterprisers, reducing investment and consumption, and possibly forcing viable firms into bankruptcy. Banking crises may also jeopardize the functioning of the payments system and, by undermining confidence in domestic financial institutions, they may cause a decline in domestic savings and/or a large scale capital outflow. Finally, a systemic crisis may force even solid banks to go bankrupt.

In most countries, policy-makers have attempted to diminish the consequences of banking crises through various types of interventions, ranging from the pursuit of a loose monetary policy to the bail out of insolvent financial institutions with public funds. However, even when they are carefully designed, rescue operations have several drawbacks: they are often very costly for the budget; they may allow inefficient banks to remain in business; they are likely to create the expectation of future bail outs, reducing incentives for adequate risk management by banks and other markets participants (moral hazard); managerial incentives are also weakened when, as it is often the case, rescue operations force healthy banks to bear the losses of ailing institutions.

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Finally, loose monetary policy to shore up banking sector losses can be inflationary and, in countries with an exchange rate commitment, it may trigger a speculative attack against the currency. This way, preventing the occurrence of systemic banking problems is undoubtedly a major objective for policy-makers, and understanding the mechanisms that are behind banking crises in the last 15 years is a first step in this direction.

A number of previous studies have analysed different aspects of banking systems [3–5] and episodes of banking sector distress occurred. Most of these works consist of case studies, many of them applying econometric analysis of different situations. For example in [6] an econometric model is used to predict bank failures using Mexican data for the period 1991–1995. In a more recent work [7], the behaviour of a number of macroeconomic variables of the months before and after a banking crisis is analysed. Thus, the authors try to identify variables that act as "early warning signals" for crises. Other studies apply classical statistical techniques such as discriminant, logit or probit analysis [8–11], etc. However, although the obtained results have been satisfactory, all these techniques present the drawback that they make some assumptions about the model or the data distribution that are not usually satisfied. So in order to avoid these inconveniences of statistical methods, it has been recently suggested in the economic field the use of soft-computing techniques, mainly neural networks or evolutionary computation algorithms [12,13].

In recent years, artificial neural networks (ANNs) have been successfully used for modelling financial time series [14–16], for controlling complex manufacturing processes [17] and bankruptcy prediction [18,19]. The most popular neural network model is maybe the back propagation (BP) neural network [20] due to its simple architecture yet powerful problem-solving ability. In ANNs, the hidden neurons are the functional units and can be considered as generators of function spaces. Most existing neuron models are based on the summing operation of the inputs, and, more particularly, on sigmoidal unit functions, resulting in what is known as the multilayer perceptron (MLP). However, alternatives to MLP have arisen in the last few years: product unit neural network (PUNN) models are an alternative to MLPs and are based on multiplicative neurons instead of additive ones. They correspond to a special class of feed-forward neural network introduced by Durbin and Rumelhart [21]. While MLP network models have been very successful, networks that make use of product units (PUs) have the added advantage of increased information capacity [21]. That is, smaller PUNNs architectures can be used than those used with MLPs [22]. They aim to overcome the non-linear effects of variables by means of non-linear basis functions, constructed with the product of the inputs raised to arbitrary powers. These basis functions express the possible strong interactions between the variables, where the exponents may even take on real values and are suitable for automatic adjustment. Another interesting alternative to MLPs are radial basis function neural networks (RBFNNs). RBFNNs can be considered a local approximation procedure, and the improvement in both its approximation ability as well as in the construction of its architecture has been noteworthy [23]. RBFNNs have been used in the most varied domains, from function approximation to pattern classification, time series prediction, data mining, signals processing, and non-linear system modelling and control [24]. RBFNNs use, in general, hyper-ellipsoids to split the pattern space. In many cases, PU and RBF networks are trained by using evolutionary algorithms (EAs), obtaining with this method advantages respect to traditional training approaches [25–27].

In this paper we consider the hybridization of these novel networks (PUs and RBFs) with a standard logistic regression to improve the performance of the classifiers in the problem of bank crises prediction. Logistic regression (LR) has become a widely used and accepted method of analysis of binary or multi-class outcome variables as it is more flexible and it can predict the probability of the state of a dichotomous variable (in our case, the probability of crisis) based on the predictor variables (in our case, macroeconomic variables). The hybridization of LR and PUNNs or RBFNNs is done by considering a recent work in classifier construction [28], where the hybridization of the LR model and evolutionary PUNNs (EPUNNs) to obtain binary classifiers is proposed. In a first step, an evolutionary algorithm [25] is used to determine the basic structure of the product unit model. That step can be seen as a global search in the space of the model coefficients. Once the basis functions have been determined by the EA, a transformation of the input space is considered. This transformation is performed by adding the non-linear transformations of the input variables given by the PU functions obtained by the EA. The final model is linear in these new variables together with the initial covariates. On the other hand, the hybridization of the LR and evolutionary RBFNNs is also tested in this paper, in such a way that we combine a linear model with a radial basis function neural network (RBFNN) non-linear model and then we estimate the coefficients using logistic regression. In this paper we show that the hybrid models involving LR, PUNNs and RBFNNs outperforms several other existing classification techniques in the problem of banking crises prediction, and they are therefore a very interesting tool to take into account in this field.

The structure of the rest of the paper is as follows: next section briefly describes the main variables that are considered as key in banking crises detection. Section 3 describes in detail the hybrid models LR-PUNNs and LR-RBFNNs proposed in this paper. A brief description of the evolutionary algorithm used in the first training of the networks is also included. Section 4 presents the experimental section of the paper, in which we test the good performance of the proposed approaches in a Financial Crisis Database, formed by a sample of data of 79 countries in the period 1981–1999. Finally, the paper is closed with some remarks and conclusions in Section 5.

2. Data and variables involved in banking crises detection

This section defines the independent and the dependent variables involved in the present study. As for the dependent variables, the literature offers several definitions of financial instability. In [29] financial stability is defined in terms of its ability to help the economic system allocate resources, manage risks, and absorb shocks. Another strand of the literature focuses on extreme realizations of financial instability. According to [30] a financial crisis is a disruption to financial markets in which adverse selection and moral hazard become much worse, so that financial markets are unable to efficiently channel funds to those who have the most productive investment opportunities. However, in this paper we identity financial instability with banking crisis, because it is the most common example of financial instability given the especial role banks play in the financial system. Once more, academics, central banks and officials offer several definitions of banking crisis [11,31]. Many of these definitions completely solve the problem of how to summarize such description in one single quantitative indicator, or a set of them. On the other hand, these indicators are not readably available for a large number of countries, or there are not enough comparable cross-country data to construct some of the indicators. The empirical literature identifies banking crises as events, expressed through a binary variable, constructed with the help of cross-country surveys [32]. This is the approach that we follow in this work as well. The dependent variable is defined as: systemic