Early-warning of Financial Crises based on Fuzzy Logic

E. Sztojanov[1], G. Stamatescu[2], I. Sztojanov[3]

Abstract – The paper discusses the application of fuzzy logic and fuzzy inference systems (FIS) as an effective tool for alerting decision makers of impending economic crises. Following a promising literature-based approach, we build an experimental system model for validation on credit growth and housing market historical data. The system is subsequently applied using the two key economic indicators for Romania between 2005 and 2013. Results are presented and necessary conclusions are drawn as well as challenges in carefully designing the fuzzy system in order to adapt it to emerging market conditions. Also an adaptive weighting method is implemented in order to fine tune the overall behaviour of the proposed system.

Keywords – economic forecasting, fuzzy logic, modeling, adaptive weighting, crisis mitigation.

1 Introduction

Economic crises can have devastating effects. Over the last ten years a severe economic crisis took place, and the way out of this crisis was extended, continuing even today. The economic crisis of the last decade, has its origin in financial and banking system, had not a single cause and managed to quickly contaminate the global economy.

It's in the nature of the markets and the economic agents to have a pro-cyclical behavior, which leads to increased crisis effects. In the boom periods a euphoric atmosphere installs, which leads to waive regulations, constraints and caution. As a natural consequence of such an attitude this will lead, sooner or later, to the outbreak of a new crisis. It is therefore rational to lead a counter-cyclical policy which essentially consists in making savings in the boom periods that can be released during the times of crisis, in order to mitigate economic fluctuations and the effects of the crisis. (Figure 1).

One such tool, that could reduce the intensity of future financial crises is the capital reserve buffer (Countercyclical Capital Buffer - CCB), proposed by International Banking Financial Institutions.

The efficiency of anti-cyclical policy, through creating the capital buffer reserve - CCB, is strongly influenced by the existence of credible ways and means of anticipating crises. These methods should be based on existing data at that time and their processing methodology to provide a reliable prediction. The accuracy of the prediction depends on the number and the importance of variables taken into account and also on the interpretation of the results.

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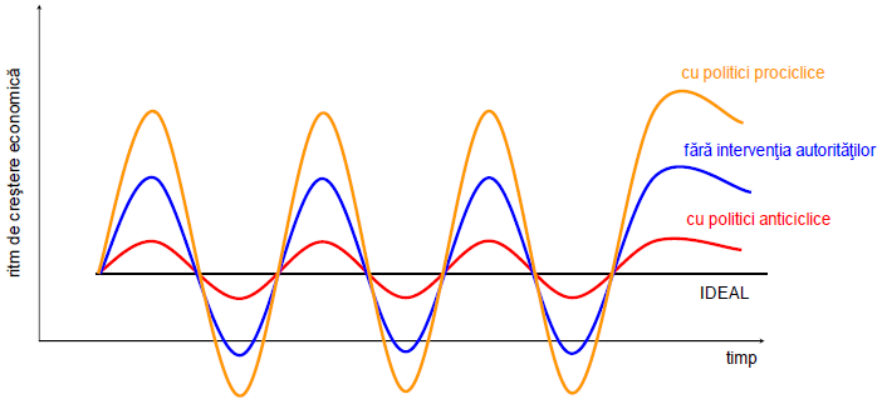

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Fig. 1. The cyclical evolution of the economy (economic growth: orange a pro–cyclical evolution, red an anti–cyclical evolution and with blue intervention free evolution)

In order to give international consistency to the creation of the capital buffer (CCB), the Basel Committee on Banking Supervision - BCBS, suggested a methodology based on „the deviation of the domestic credit to GDP ratio from its backward – looking trend, given its track record of signaling economic stress well in advance.

2 Proposal to achieve early warning mechanism based on fuzzy logic

Fuzzy logic has become today a very useful and spread tool for the development of sophisticated control systems [1-2], but it can be successfully used also in other areas.

When is Fuzzy logic recommended?

- when the input and output of a system are analogical;
- where the studied phenomenon is extremely complex and depends on many uncontrollable variables with unpredictable evolution;
- when there is no precise and adequate mathematical model of the process.

These qualities recommend Fuzzy logic for achieving an early warning system of financial crises.

For achieving and verifying the proposed model, the results of the research and study findings published in [3] will be used.

In order to verify the principle of the method, a fuzzy system with two input variables and one output will be built. From the six variables taken into consideration in the above mentioned study, only two will be chosen for the early warning system, namely: the graphs showing annual growth of credit and the annual growth of real estate prices. These two are the most conclusive in order to have easily detectable and significant changes in the pre-crisis period (Figure 2).

Thus for the first variable "Annual credit growth rate" will be chosen, generically named CREDITARE in the simulation program, and for the second variable

"Annual growth of real estate prices," generically named IMOBILIARE in the simulation program. As output value “early warning” will be defined, with the generic name WARNING.

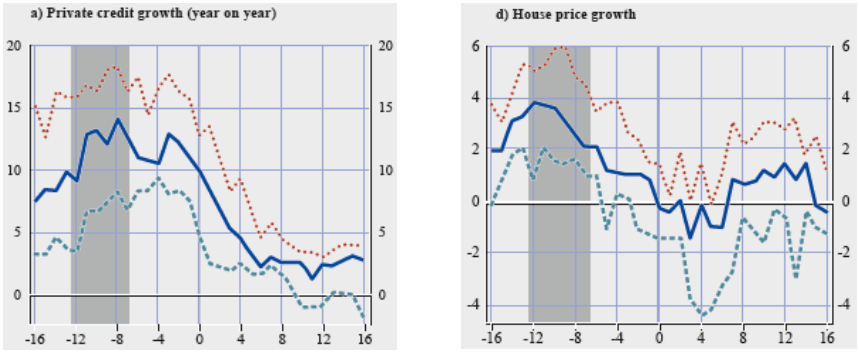

Fig. 2. The evolution of the variables considered to be representative

In [4] the author indicates the following rules for early warning, which will be used for model development:

- For the first variable (CREDITARE), an annual growth rate of credit by 15% - 20% is a signal of a possible crisis over two years;
- For the second variable (IMOBILIARE), an annual growth in real estate prices by approx. 5% - 6% may be a warning of a possible crisis in three years.

In conclusion, it can be affirmed, that a growth of the credit rate of approx. 15 to 20% along with an increase of 5-6% in real estate prices can be interpreted as a fairly clear signal observable on the outbreak of a crisis in the next two or three years!

For achieving and simulating the Fuzzy Logic system, the programming environment:"Fuzzy Logic Operating Program" was used, which is available on the diskette accompanying the book "Jörg Kahlert, Hubert Frank.”Fuzzy - Fuzzy Logik und Control: eine Einführung mit anwendungsorientierte Begleitsoftware" 2., Verbesserte und erweiterte Auflage - Braunschweig; Wiesbaden: Vieweg, 1994 [5].

For the simulation it is necessary to define the Fuzzy functions sets for the two inputs and output variables, and establish composition rules for the input variables to generate certain predictions. For the first input variable - CREDITARE - the values are between 0% and 20% (see Figure 2) which have been divided into Fuzzy functions set presented in Table 1.

Table 1 The set of functions associated with the variable CREDITARE

Function	Abbreviation	Function domain in %
Slow CREDIT	LE	0 ÷ 6
Moderate CREDIT	MO	5 ÷ 10
Medium CREDIT	ME	8 ÷ 12
Big CREDIT	MR	11 ÷15
Alarming CREDIT	AL	14 ÷ 20

For the second input variable - IMOBILIARE - the values are between - 6% and 6% (see Figure 2) which has been divided into Fuzzy functions set presented in Table 2.

Table 2 The set of functions associated to the variable IMOBILIARE

Function	Abbreviation	Function domain in %
Decrease	SC	-6 ÷ 0
Stagnation	ST	-1 ÷ 1
Moderate growth	CM	0 ÷ 2.5
Growth	CR	1.5 ÷ 4
Alarming growth	CA	3.5 ÷6

For the output variable, "Early warning" WARNING, a domain was associated for the values between one and five years, that have been divided into Fuzzy function set shown in Table 3.

Table 3 The set of functions associated to the output variable WARNING

Function	Abbreviation	Function domain in %
Imminent crisis	IM	1÷1.75
Crisis in two years	C2	1.5 ÷ 2.5
Crisis between two and three years	2P	2 ÷ 3
Crisis in three years	C3	2.5 ÷ 3.5
Evolution without crisis	FC	3 ÷5

Once the variables have been defined and their associated Fuzzy functions set have been set, it is necessary to define the application-specific calculation rules.

The following rule will be used:

IF <Fuzzy Sentence> **AND** <Fuzzy Sentence> **THEN** <Fuzzy Sentence>.

Since there are two input variables, each decomposed into five elementary functions, it results that there are 25 rules grouped in the matrix below (see Table 4).

Table 4 The set of functions associated to the output variable WARNING

	IMOBILIARE				
CREDITARE	SC	ST	CM	CR	CA
LE	**FC**	**FC**	**FC**	**C3**	**C3**
MO	**FC**	**FC**	**FC**	**C3**	**C3**
ME	**CI**	**CI**	**CI**	**C3**	**C3**
MR	**C2**	**C2**	**C2**	**C2**	**2P**
AL	**C2**	**C2**	**C2**	**C2**	**2P**

As an important remark, the prediction outcome and its accuracy depend essentially on how the set of functions associated with input and output variables is defined and also on the set Fuzzy rule. The introduction of the input and output variables in the simulation program, as well as the set of rules is shown in Figure 3.

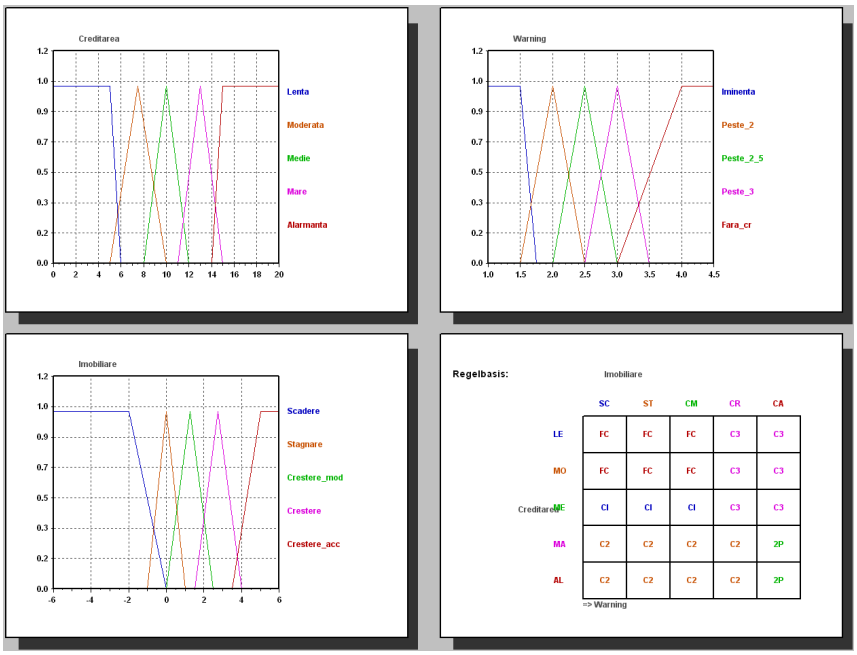

Fig. 3. The input variables, the output and the composition rules associated to the simulation

The result of the simulation for an annual rate of credit growth of 14% and an annual increase of 2.52% in real estate prices indicate a possible financial crisis after two years, as shown in Figure 4. The calibration of the proposed warning system was made based on the data presented in [3] with the data read from the variables graphs presented in Figure 2 and summarized in Table 5.

Table 5 Fuzzy prediction

The period before crisis	The rhythm of the annual credit growth	Annual growth of real estate prices	The results from Fuzzy model		
			Creditare	Imobiliare	Fuzzy prediction
- 4 semesters	11	1	11	1.08	1.34 years
- 8 semesters	14	2.5	14	2.52	2 years
- 12 semesters	9	4	9	4.08	3 years
- 16 semesters	7	2	7	2.04	3.77 years

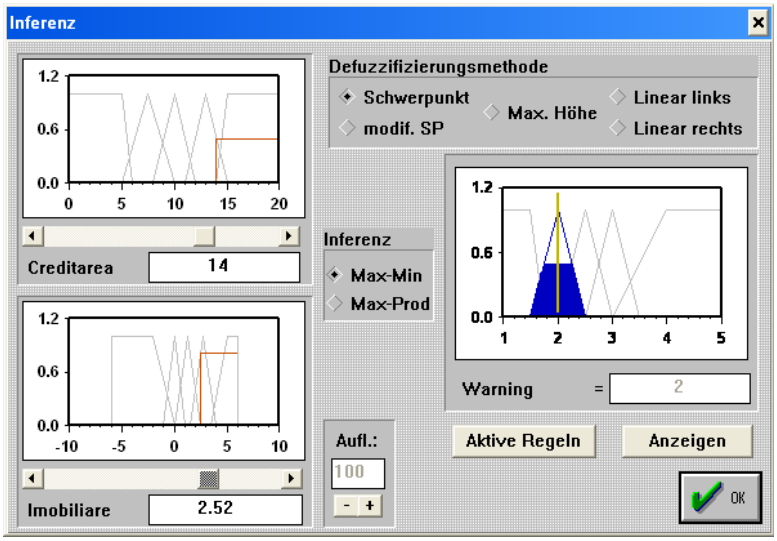

Fig. 4. The simulation result for the credit rate of 14% and an increase of 2.52% in estate prices that predict a possible crisis in the next two years.

3 Application to the Romanian economic indicators 2005-2013 and rule base weighting

The model in Section 2 is subsequently applied to the Romanian scenario between the years 2005-2013. This period included a economic boom phase between 2005 and 2008, a deep crisis starting at the end of 2008 until 2010, followed by a slow recovery stage from 2011 onwards. The relevant economic indicators are listed in Table 6.

Table 6 Economic indicators Romania 2005-2013

Year / Indicator [%]	CREDITARE	IMOBILIARE	GDP
2005	73	65.96	4.2
2006	75	12.82	7.9
2007	70	54.55	6.3
2008	33	61.76	7.3
2009	-2	-27.95	-6.6
2010	-2	-16.72	-1.1
2011	2.1	-17.62	2.3
2012	0.2	-4.37	0.6
2013	-1.3	-5.77	3.5

Here CREDITARE represents the year-on-year growth of private domestic credit as published by the Romanian National Bank. IMOBILIARE represents the year-on-year medium price growth for a one bedroom appartment in the capital city of

Bucharest, chosen as representative housing market. GDP is used as reference and corresponds to the European Central Bank published values for the analyzed interval.

The design of the fuzzy logic forecasting system has been adapted in order to accommodate higher rates of growth (and larger positive and negative variations) corresponding to the emerging market status of the country. This is reflected by the intervals of the two input variables and associated membership functions. The output of the system, WARNING, has been kept the same. Figure 5 illustrates the behaviour of the 2 input, 1 output, fuzzy system depending on the variations upon the inputs. Here all the rules are equally weighted at 1.

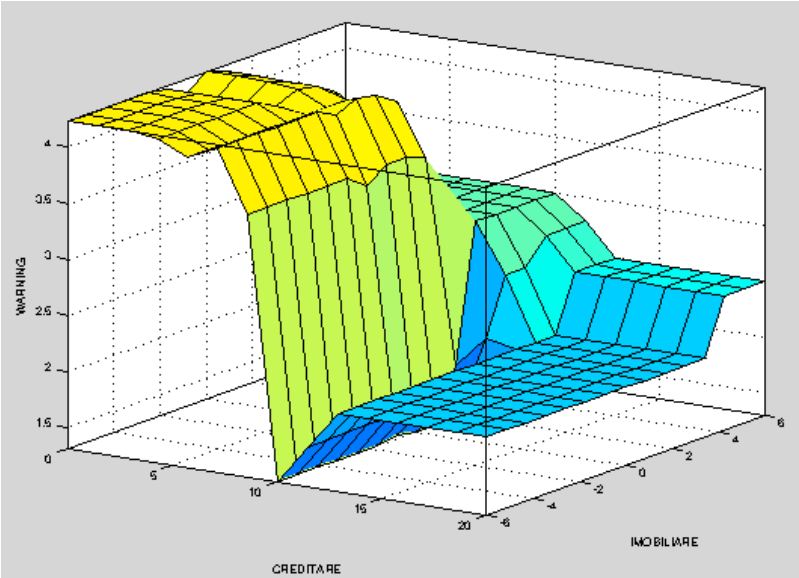

Fig. 5. Surface view of the fuzzy system for early crisis warning (constant weights=1)

In order to achieve smoother transitions of the output values at the edges of the input intervals, we decide to apply selective static weighting of the fuzzy rules. Basic idea is that all the rules in which the CREDITARE input is either „Big" (MR) or „Alarming" (AL) and the IMOBILIARE input is „Alarming growth" (CA) are weighted down to a constant 0.5 factor. This also opens up the path for future extensions towards dynamic adaptive rule weighting. The modified rules, with the chosed weight at 0.5 are listed below, along with the modified surface view in Figure 6:

If (CREDITARE is MR) and (IMOBILIARE is SC) then (WARNING is C2) (0.5)
If (CREDITARE is AL) and (IMOBILIARE is SC) then (WARNING is C2) (0.5)
If (CREDITARE is MR) and (IMOBILIARE is ST) then (WARNING is C2) (0.5)
If (CREDITARE is AL) and (IMOBILIARE is ST) then (WARNING is C2) (0.5)
If (CREDITARE is MR) and (IMOBILIARE is CM) then (WARNING is C2)(0.5)
If (CREDITARE is AL) and (IMOBILIARE is CM) then (WARNING is C2) (0.5)

If (CREDITARE is MR) and (IMOBILIARE is CR) then (WARNING is C2) (0.5)
If (CREDITARE is AL) and (IMOBILIARE is CR) then (WARNING is C2) (0.5)
If (CREDITARE is LE) and (IMOBILIARE is CA) then (WARNING is C3) (0.5)
If (CREDITARE is MO) and (IMOBILIARE is CA) then (WARNING is C3)(0.5)
If (CREDITARE is ME) and (IMOBILIARE is CA) then (WARNING is C3) (0.5)
If (CREDITARE is MR) and (IMOBILIARE is CA) then (WARNING is 2P) (0.5)
If (CREDITARE is AL) and (IMOBILIARE is CA) then (WARNING is 2P) (0.5)

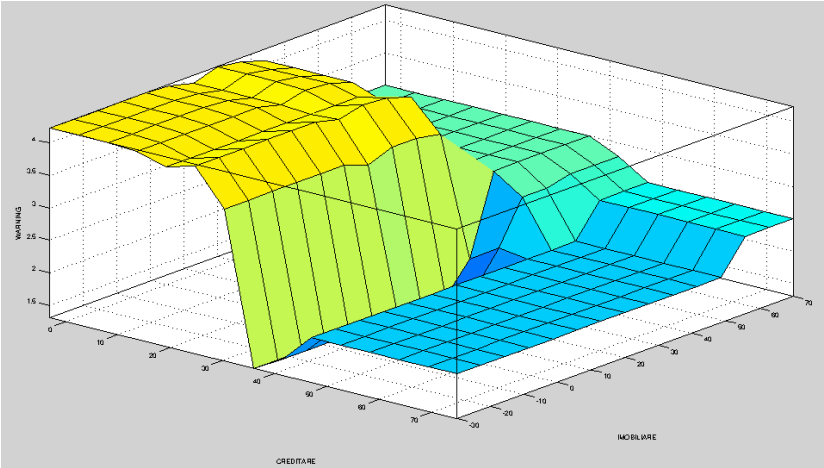

Fig. 6. Surface view of the fuzzy system for early crisis warning ("extreme" cases weighted at 0.5)

Final results of the early warning method based on the Romanian case study are shown in Table 7. As with the general model, the output corresponds to the estimated number of years before a potential economic crisis.

Table 7 Fuzzy sytem output Romania 2005-2013

Year / Indicator [yrs.]	WARNING (equal weights)	WARNING (weighted)
2005	2.5000	2.5000
2006	2.0000	2.0000
2007	2.5000	2.5000
2008	2.8561	2.8777
2009	4.2326	4.2326
2010	4.2326	4.2326
2011	4.2326	4.2326
2012	4.1149	4.1149
2013	4.1464	4.1464

4 Conclusions

The way the sets of functions associated with the variables were chosen and their composition rules established in this work allowed the calibration of the model to indicate a financial crisis prediction with a good accuracy (see Table 5). The

checkpoints chosen from the graphs of variables (Figure 2) for calibration correspond to pre-crisis periods with 4, 8, 12 or 16 semesters. The proposed Fuzzy model can be used as an additional tool for early warning of financial crises to supplement the information provided on this and other models and methods. The major advantage of the proposed Fuzzy method is the ease with which models can be achieved, which allows the initiation of comprehensive studies prior periods through various crisis scenarios and the evaluation of the results that they provide.

The system shows promising results and, as it has been already proven in an extensive study for business bankruptcy modeling [6], we plan on developing it further. Future work will be focused on using more extensive reference data sets in order to design and apply an adaptive neuro-fuzzy method for automated design of the fuzzy inference system (FIS) [7]. This leads to supervised automatic generation of membership functions using the neural network approach on training, testing and validation data. One tentative path is to use data from countries for which extensive records and crises data is readily available e.g. the United States, western Europe developed countries and build a robust system which can be adapted easily and provide trustworthy outputs in local market conditions.

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