A Simple Early Warning System for Evaluating the Credit Portfolio's Quality

Nicolae Dardac
Academy of Economic Studies, Bucharest
Nicolae.Dardac@ase.ro
Iustina Alina Boitan
Academy of Economic Studies, Bucharest
iustinaboitan@yahoo.com

Abstract. *The last decade has witnessed the development of a vast literature devoted to the study of several phenomena like banking crises or episodes of vulnerability and distress, characterized by inadequate capitalization, impairment of the asset quality and of the credit institutions' rating. The purpose of this study is to design an early warning system in order to highlight at an earlier stage the likelihood of deterioration of the Romanian banking system credit portfolio's quality. We have applied an econometric model which constitutes a reference for this type of analysis, having as purpose the identification of a significant correlation between increasing weight of bad loans in total assets, on the one hand, and a number of macroeconomic variables and indicators of the banking system, on the other hand.*

Keywords: early warning system; logistic regression; probability of deterioration of the loans portfolio; *goodness-of-fit* tests; predictive ability.

JEL Codes: E44, G01.
REL Codes: 10B, 11C.

Introduction

The need for careful monitoring of credit portfolio quality has become a major concern of monetary policy makers, the more so as, in the context of current international financial crisis, the resources available to credit institutions must be managed with care and efficiency. This concern overlaps in both the dynamics of intrinsic factors associated with business lending in our country in recent years, as well as external factors of credit institutions. Intrinsic factors are represented, primarily, by deficiencies in the management of credit risk. External factors consist in the dynamics of demand for currency, optimistic expectations of households on revenue increase and intensifying of banking competition, which led to the existence of credit institutions with majority foreign capital, characterized by a different credit culture and corporate governance, business strategies well outlined and implemented, aggressive lending policies (especially in the case of small banks).

In order to quantify the likelihood of credit portfolio's quality deterioration, we have identified the mix of variables that will constitute our starting point in creating a monitoring model, structuring the study as follows: the first part, we presented the methodology used and we defined a series of logit models, based on financial indicators identified as relevant from a statistical viewpoint; in the second part, we applied several complementary statistical tests to assess the predictive accuracy of each model used in the analysis. Ultimately this empirical approach has been a selection, from an extensive set of specifications of the logit model, of the one that meets the requirements of a good predictive capacity.

1. Assumptions and methodology used

The purpose of the statistical forecasting model that is the subject of this study is the ex-ante reporting of episodes of deterioration of credit portfolio's quality for the whole Romanian banking system. To this end, we opted to implement an econometric technique of reference for this type of analysis, namely a limited dependent variable model. We applied a multivariate logit model because the sample of observations we have is not balanced, the frequency of events of deterioration in credit portfolio's quality being much lower than that of non-deterioration events. Dependent variable, defined as the ratio of overdue and doubtful loans to total assets, is binary, taking value 1 for periods characterized by significant increase in the share of bad loans in total assets and 0 otherwise.

From the initial set of 32 financial indicators, selected so as to capture the full characteristics of both macroeconomic as well as specific banking system variables, after performing the univariate tests, we stored in the analysis a number of 9 indicators,

which have proved to be statistically significant, namely: M2/international foreign reserve (*M2forex*); money multiplier (*M2mult*); return on assets (*ROA*); the consumer price index (*CPI*); real exchange rate; government expenditure in GDP (*gc/GDP*); degree of openness of the economy; the relationship between the interest rate charged for loans and interest rate granted for non-bank customer deposits (*lenddep*); the share of exports in GDP (*exp/GDP*).

Given the small size of the quarterly series of observations considered (small sample problem), but also to meet the requirements of creating a parsimonious warning model, with a reduced number of variables, we tested a series of simple logistic models composed by the dependent variable and at most two predictor variables.

Specifications of the logistic models developed

Table 1

Predictor variables	Predictive power (%)	-2LL	Likelihood ratio test	Observations
M2/forex	86.8	17.969		-
M2/forex ROA	94.7	14.786	3.183	-
M2/forex Cpi	89.5	17.529	0.44	-
M2/forex real exchange rate	89.5	16.514	1.455	-
M2/forex Gc/gdp	92.1	15.185	2.784	-
M2/forex Lend/dep	92.1	10.024	7.945	Lend/dep has a good predictive ability
M2/forex openness	97.4	7.787	10.182	Openness has a good predictive ability
M2 mult	89.5	24.376		-
M2 mult Cpi	92.1	16.985	7.391	Cpi has a good predictive ability
M2 mult Curs real	89.5	22.116	2.26	-
M2 mult Gc/gdp	92.1	14.632	9.744	Gc/gdp has a good predictive ability
Cpi	84.2	27.608		-
Cpi real exchange rate	92.1	22.608	5	real exchange rate has a good predictive ability
Cpi Gc/gdp	89.5	24.228	3.38	-
Cpi Exp/gdp	89.5	13.451	14.157	Exp/gdp has a good predictive ability
Cpi Openness	97.4	8.799	18.809	Openness has a good predictive ability
real exchange rate	89.5	28.981		-
real exchange rate Gc/gdp	86.8	25.218	3.763	-
real exchange rate Lend/dep	89.5	10.208	18.773	Lend/dep has a good predictive ability
real exchange rate Exp/gdp	92.1	13.828	15.153	Exp/gdp has a good predictive ability
real exchange rate openness	94.7	10.670	18.311	Openness has a good predictive ability
Openness	92.1	15.729		-
Lend/dep	92.1	10.310		-

According to Wald test, the coefficients of predictor variables included in the regression equation are statistically significant only if their corresponding probability is lower than the threshold of 5%. Variables related to models: *M2/forex* and *ROA*, *M2/forex* and *openness*, *M2/forex* and *real exchange rate*, *M2/forex* and *CPI*, *M2/forex* and *lend/dep*, *M2/forex* and *gc/GDP*, *M2mult* and *real exchange rate*, *M2mult* and *gc/GDP*, *CPI* and *gc/GDP*, *real exchange rate* and *gc/GDP*, *real exchange rate* and *lend/dep*, *openness* and *real exchange rate* achieved a level of probability that exceeds the critical value of 5%, therefore they aren't statistically significant and, as such, those models should not be examined further.

The accuracy of Wald test is, however, directly influenced by the number of observations included in the sample analyzed. For a reduced sample size it is recommended caution with the interpretation of the results of Wald test, being preferred the likelihood ratio test. Since the size of our sample is of 38 observations, relating to the period between IIIrd quarter 1997 and IVth quarter 2006, we have considered that the analysis should be continued with all the models illustrated in the table above, by applying additional goodness-of-fit tests, in order to identify those independent variables with the best predictive ability of the probability of deterioration of credit portfolio's quality.

2. Criteria for evaluating the predictive performance of logistic regressions

To perform a statistically based, but also relevant discrimination between the predictive performance of the logistic regression equations tested, it is necessary to apply several goodness-of-fit tests. We chose the most representative four statistical tests, which have a complementary nature, in order to progressively eliminate those models whose specifications do not meet the requirements of a good predictive ability, namely:

- Assessing the value of *-2 log likelihood (-2LL)*. In the third column of Table 1 one can observe that, by including other independent variables into the initial model, the model fit improves, as illustrated by the decreasing value of -2LL for each logistic regression carried out. For example, the univariate model composed by the dependent variable and the explanatory variable *M2/forex* obtained a value of 17.969 for -2LL. Regression equations constructed after the introduction of a second explanatory variable (*ROA, CPI, real exchange rate, gc/ GDP, lend/dep* and *openness*) recorded lower values of -2LL. The lower the -2LL value is, the best the tested model is, through the ability of considered variables to indicate at an earlier stage a potential state of vulnerability. According to this criterion, models consisting of independent variables: *M2/forex* and *openness* (7.787), *M2mult* and *gc/GDP* (14.632), *CPI* and *openness* (8.799), *real exchange rate* and *lend/dep* (10.208) are the most appropriate for making predictions.
- *The likelihood ratio test* calculates the chi-square statistics as a difference between -2LL for the full model and -2LL for the univariate model, comprising only one independent variable (nested model). Subsequently, the calculated statistics is

compared with its value in the table, for one degree of freedom and $\alpha = 0.05$.

In other words, the chi-square statistics quantifies the accuracy improvement of the logistic model as a result of including in the univariate model of an additional independent variable. The greater the calculated value of chi-square statistics is, the more significant will be the accuracy decrease in the case of exclusion of that additional variable from the model. A low value of the chi-square statistics indicates the absence of significant differences in the predictive ability of models compared (full model and the model from which we excluded an independent variable), therefore it is justified to keep in the further analysis the model with fewer predictor variables.

In Table 1, in the fourth column we have specified the values obtained for chi-square statistics, and on the column of remarks, we have mentioned those independent variables whose maintenance into the logistic regression equation is justified from a statistical viewpoint, since the calculated values for those models have a higher value than that in the table, which is of 3.84. Keeping in mind the results obtained by applying the two statistical tests outlined above, we considered appropriate to remove from the analysis the logistic models that do not meet the criteria of statistical relevance and accuracy. Therefore, in Table 2 we have presented the restricted set of models that will be subject to further discrimination according their predictive power.

▪ *type I error and type II error*. Type I error reflects the probability that the warning model fails in forecasting episodes of deterioration of credit portfolio's quality. Type II error implies that the model wrongly signals an event of damage, although the quality of the loans portfolio is satisfactory. Will be preferred that model whose type I error reaches the lower value (see Table 2) because the fundamental purpose of a forecasting model is the accurate ex-ante reporting of a potential deterioration of the banking activity.

Undetected errors

Table 2

Nr. crt.	Predictor variables	Type I error (%)	Type II error (%)
1	M2/forex	33%	6.89%
2	M2/forex openness	0	3.45
3	M2 mult	33	3.45
4	M2 mult Gc/gdp	33	0
5	Cpi	55.55	3.45
6	Cpi Openness	0	3.45
7	Real exchange rate	44.44	0
8	Real exchange rate Lend/dep	22.22	6.89
9	Openness	22.22	3.45
10	Lend/dep	11.11	6.89

The undetected episodes of deterioration in the quality of loans portfolio, for the consolidated banking system, varies between 0% and 55.55% of all adverse events, while the percentage of false alarms is included in the range 0% - 6.89%. From this point of view, we can distinguish four models whose power of discrimination is satisfactory: *M2/forex* and *openness*, the *CPI* and *openness*, *openness*, *lend/dep*.

If, from a statistical viewpoint, the variables retained in the analysis show a good predictive ability, from an economic perspective, the sign of the coefficients attached to explanatory variables reflect the

influence of these variables on the values that the dependent variable can get. Thus, the "+" sign associated with a variable indicates an increased likelihood of deterioration of credit portfolio quality, as its value increases, while the sign "-" shows a negative correlation between the likelihood of loan portfolio impairment and the evolution of independent variables.

One can observe that the probability of deterioration is a positive function of variables *M2forex* and *CPI* because the coefficients' sign is positive, in turn it is negatively correlated with variables *openness* and *lend/dep*. Thus, an increase of the consumer price index (*CPI* variable), and, implicitly, of the inflationary pressures, contributes to enhancing the state of vulnerability of the banking system. Due to erosion of purchasing power of population income, there is a significant risk of increasing the degree of indebtedness and debt service, with negative effects on the share of outstanding and doubtful loans in total assets.

The positive sign of the coefficient of *M2forex* variable indicates that an increase in the volume of M2 or a reduction in the level of international reserves held by central bank lead to an increased likelihood of deterioration of the loans portfolio. The growth of money in the economy attracts imports' expansion, with a favorable effect on the size of *openness* indicator (degree of openness of an economy), while there is a magnification of the current account deficit. Probability of deterioration is negatively affected by *openness* variable. Thus, increasing the share of outstanding and doubtful loans in total assets determines credit institutions to adopt a reserved attitude towards requests for funding, a more sensible assessment of the repayment capacity of borrowers, reducing the volume of loans granted. Consequently, some productive and investment activities will restrict, entailing a contraction of the volume of exports and imports, and hence a reduction in the *openness* indicator.

The ratio between the interest rate charged for loans and the interest rate granted for non-bank customer deposits (*lend/dep* variable) recorded a decline in the run of episodes of credit portfolio deterioration, being characteristic to periods of rapid expansion of lending activity, where credit institutions are less vigilant in assessing exposure to risk. In other words, a persistent decrease in the value of the indicator signals a potential deterioration, in the medium term, of the quality of loans portfolio.

To facilitate the interpretation of the alarm signals provided by logistic regression, it is necessary to define a probability threshold. If the probability estimated by the logit model it's above this critical level, we say that we have an alarm signal of a potential deterioration in loan portfolio quality. For each alarm threshold between 0 and 100%, we have plotted the percentage of unsignaled deterioration events (type I error) and, respectively, the percentage of false alarms (type II error), compared for each of the four models.

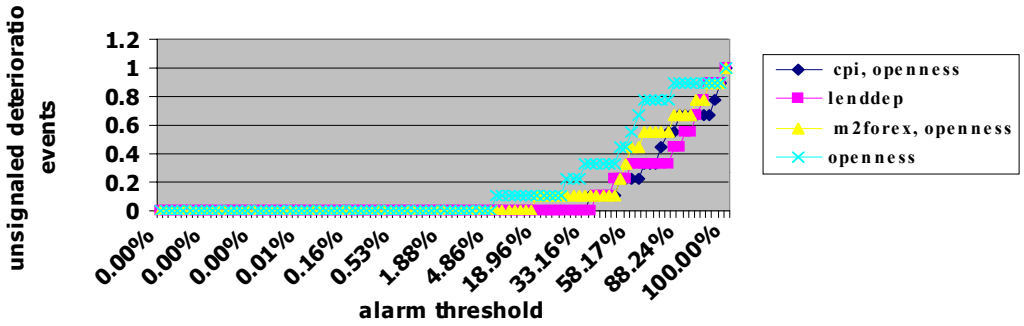

Figure 1. *The percentage of unsignaled deterioration events*

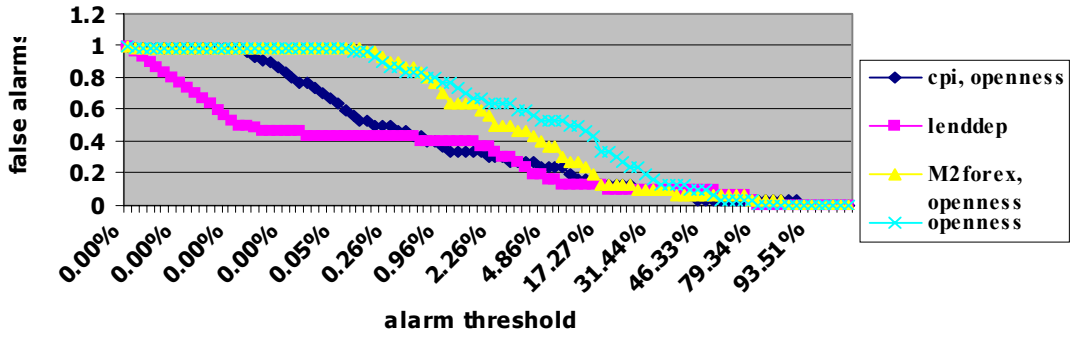

Figure 2. *The percentage of false alarms*

For a threshold equal to 0 any model identifies 100% of events of deterioration or crisis, and the number of false alarms is still 100%. An alarm threshold of 100% did not correctly identify any crisis, and, as such, there will be no false alarms. As the critical threshold value increases, the number of false alarms decreases, but also the percentage of deterioration events correctly identified decreases significantly, too. Will be preferred the model whose curve is nearest to the abscissa. One can observe that the model represented by the independent variable *lending/deposit rate* generates the lowest number of false alarms, and for certain values of the alarm threshold, it has the most correctly reported episodes of deterioration. Another model whose predictive performance is satisfactory consists of the explanatory variables *CPI* and *openness*.

For each of the two models it must be defined a probability threshold, which will be subject to a comparative analysis with the probabilities estimated through logistic regression, in order to anticipate events of credit portfolio quality deterioration. We have noticed that for an alarm threshold of 43%, both models provide a type I error of 11%. Regarding the percentage of false alarms, the univariate model *lending/deposit rate* has a type II error of 10% and the model composed by *CPI* and *openness* of 3.3%. For an alarm threshold of 50%, both models record an increase of type I error of up to 22%, but type II error for the model *lending/deposit rate* is reduced to 6.7%, while for the other model it does not change. In practice it is preferable to select a lower level of the threshold probability because the type I error (unsignaled episodes of deterioration

or crisis) is considered more costly than type II error.

In what follows, we have applied a final test to validate the conclusions drawn regarding the performance of the four logit models considered.

▪ *The AUROC* (Area under the Receiver Operating Characteristics). According to the authors Hosmer, Lemeshow (2000), an indicator value between 0.6 and 0.7 is acceptable, values between 0.7 and 0.8 indicate a good accuracy of predictions and a value close to 1 show a remarkable predictive ability. All four models recorded a value of AUROC indicator greater than 80% (see Table 3), therefore are suitable for making predictions, having a good power of discrimination.

AUROC indicator

Table 3

Logistic model	AUROC	Standard error[a]	Asymptotic Sig.[b]	Asymptotic confidence interval 95%	
				Lower bound	Upper bound
M2/forex, openness	0,956	0,033	0,000	0,000	1,000
Cpi, openness	0,976	0,022	0,000	0,000	1,000
Openness	0,841	0,070	0,002	0,705	0,978
Lend/dep	0,976	0,021	0,000	0,000	1,000

a. under the assumption of a nonparametric distribution

b. null hypothesis : true area = 0.5

In the next figure we have illustrated the ROC curve, which allows the graphic visualization of the rate of false alarms compared to the percentage of correct predictions for all the possible values of the probability threshold.

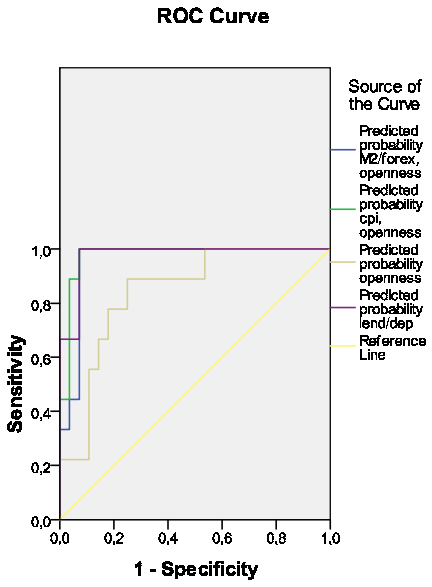

Figure 3. *The ROC curve plot*

It is noted that the logistic model represented by the *CPI* and *openness*, as well as the univariate one, represented by the variable *lend/dep* obtained a value of the AUROC indicator of 97.6%. Accordingly, it is difficult to assess which of these models is most suitable to be used as a simplified early warning system of the likelihood of deterioration of credit portfolio quality because both have notable performances.

In order to validate models' performance, we proceeded to test their predictive ability on a validation sample, and not on an out-of-sample one. Although the process of validation of the logistic models assumes the estimation for the period between first quarter 2007 and IIIrd quarter 2008, the insufficient number of quarterly observations available, and the

fact that in the period mentioned were not recorded events of severe deterioration of credit portfolio quality, led us to resort to a compromise. Thus, the set of observations for which the models were estimated ranges between IIIrd quarter 1997 – IVth quarter 1999, to ensure the existence of episodes of severe deterioration of credit portfolio quality, and first quarter of 2002 - III quarter 2008. Table 4 illustrates, in comparison, how has evolved the power of discrimination of considered models.

Discrimination power (validation sample)

Table 4

Predictor variables	Predictive power (%)	Type I error (%)	Type II error (%)
M2/forex openness	89.2	22.22	7.14
Cpi Openness	94.6	11.11	3.57
Openness	81.1	44.44	10.71
Lend/dep	91.9	11.11	7.14

The accuracy of predictions made by independent variables *M2/forex* and *openness* decreased by 8.2 percentage points from the original sample testing, Type I error registering an increase with 22.22 percentage points. The univariate logistic model composed of the independent variable *openness* had a predictive power decreased by 11 percentage points, the type I error increasing with 22.22 percentage points, while the univariate model in which the explanatory variable was *lend/dep* diminished its accuracy by only 0.2 percentage points and has maintained constant the proportion of type I errors, at 11.11%. The model represented by the *CPI* and *openness* experienced a loss of accuracy by 2.8 percentage points, the type I error increasing with 11.11 points. It is noted that the logistic univariate model composed of the independent variable *lend/dep* was the most stable, keeping its power of discrimination relatively unchanged in both the original sample and the validation one.

Conclusions

In the economic literature devoted to the creation and testing of early warning systems, some authors (Jagtiani, Kolari, Lemieux, Shin 2003, Davis, Karim, 2006) concluded that the accuracy of predictions of a simple logit model, with only two explanatory variables, outperforms the one of a complex multivariate model. The disadvantage of this type of models lies, however, in the fact that it is difficult to surprise comprehensively the roots of the distress phenomenon analyzed. In other words, will be selected those explanatory variables with a good predictive ability, maximizing the probability of correctly reporting the events of deterioration, to the detriment of the variables that contribute directly to trigger the adverse phenomenon analyzed.

Following the survey conducted, we reached the same conclusion: the best predictive performance is achieved by models with at most two independent variables. Thus, according to the statistical tests of goodness-of-fit done, the model represented by the independent variable

lending/deposit rate generates the lowest number of false alarms, and for certain values of the alarm threshold, have the most correctly reported episodes of deterioration. In addition, the estimation of the univariate model on the validation sample showed that the predictions generated were stable, the proportion of type I errors remainining constant and the predictive ability registering a decline of only 0.2 percentage points.

Another model with satisfactory performance, through the AUROC indicator value, the percentage of type I errors and predictive ability is composed of explanatory variables *CPI* and *openness*. Although the results obtained from re-estimation have proved to be less stable than the model presented above, we recommend applying both models in a complementary manner, to obtain the best predictive performance and have an overall picture on the likelihood of deterioration of the quality of loans portfolio for the Romanian banking system.

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