THE TRAJECTORIES OF THE FINANCIAL CRISIS OF COMPANIES AT RISK OF BANKRUPTCY

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Abstract- This article concerns the assessment of the trajectory of the collapse of enterprises in Central Europe. The author has developed a model of a Kohonen artificial neural network. This model was used to determine 6 different classes of risk and was allowed to graphically determine the 5- to 10-year trajectory of going bankrupt. The study used data on 140 companies listed on the Warsaw Stock Exchange. This population was divided into learning and testing samples. For each company analyzed, the author has calculated a set of 15 financial ratios for the period of 15 years before the bankruptcy. In the literature, this is one of the first studies on bankruptcy over a long period of time.

Index Terms- bankruptcy, the trajectories of the crisis, forecasting.

I. INTRODUCTION

A financial crisis in a company does not appear suddenly or unexpectedly. It is the result of cumulative signs that were ignored by managers for many reasons, while symptoms of the deteriorating economic situation were known for a longer period in the company and its environment. Literature on this topic distinguishes between three to five stages of the crisis ending with bankruptcy of the company. In each phase of the crisis, these factors may affect the company differently or even cause chain reactions. E. Mączyńska notes that the bankruptcy of enterprises does not constitute a central element of any known economic theory (Mączyńska, 2011). In the economic literature, there are many distinguished models of the growth / development of a company. However, we still lack theoretical models to describe the factors affecting the bankruptcy of enterprises and locating the firms in a dynamic environment - those that would represent the schema corresponding to the question of why the company assuming the aim of achieving growth and development fail.

Therefore, the aim of the research presented in this article is to develop a 5- to 10-year trajectory of the crisis in enterprises using a Kohonen neural network. Identification of early symptoms that can herald the threat of collapse (based on trajectory) can be a helpful tool to support managers in the decision-making process in an enterprise. The article consists of five sections. In the introduction, the author presents the justification for the topic and the objective of research. In the next section, in a synthetic manner, the author characterizes the development of methods for assessing the economic situation of enterprises and bankruptcy risk prediction models. The author then presents the research assumptions and discusses the results of these studies. In conclusion, there is a main summary of the research conducted by the author.

II. CHARACTERISTICS OF THE DEVELOPMENT OF METHODS FOR ASSESSING AND FORECASTING THE FINANCIAL SITUATION OF COMPANIES

The first use of financial indicators to evaluate the economic situation of the company dates back to the second half of the nineteenth century in the United States, where rapid industrial development has created the need to analyze corporate financial statements. Foundations of ratio analysis can be detected in the fifth book of Euclid's Elements, which, in 300 BC, systematized the contemporary mathematical knowledge (Horrigan, 1968, pp. 284-294). Analyses were used primarily for assessing the ability to repay loans - the first ever ratio was thus the current ratio. In the years 1900-1919, there was a significant development of the range of financial ratios used for evaluation of the economic situation of companies. In 1919, A. Wall published an article with the ratio analysis for 981 enterprises (Wall, 1919, pp. 229-243). This publication has become a catalyst for the development of new ratios and their areas of use. In the years 1920-1929, financial analysts recognized the need for division of financial ratios due to their aspect of the research (liquidity, profitability, efficiency, etc.). The thirties of the twentieth century were characterized by two achievements in the development of bankruptcy risk assessment methodologies:

- it began to look for the most effective measures for each class of financial ratios (Foulke 1933 and 1934);
- a first attempt of forecasting the financial position of companies.

The first published work on the use of ratio analysis in forecasting the economic condition of companies is an article by A. Winakor and R. Smith. They analyzed the ten-year trend for the mean values of 21 financial ratios of 29 US companies that had financial problems (Winakor, Smith, 1930). Conversely, P. Fitzpatrick

first examined the predictive power of 13 financial indicators on the example of the 20 companies that went bankrupt in the United States in the years 1920-1929 (Fitzpatrick, 1932).

In the next stage of development of methods of financial analysis (years 1940-1967) was the distinguished works of C. Merwin in 1940 and W. Beaver in 1967, who continued the research on the use of ratio analysis in one-dimensional models. Merwin applied profile analysis for comparison of solvent and insolvent companies using financial ratios (Rogowski, 1999, pp. 56-60). Profile analysis consists of the presentation of the averages of the financial ratios calculated for the group of companies solvent and insolvent in time (years before the onset of insolvency) using a line chart. In turn, the major contribution of Beaver in forecasting the financial situation of the companies is the introduction to the study of dichotomous classification test. He set the critical value for each indicator, which was used to separate the enterprises into two groups - solvent and insolvent (Wierzba, 2000, p. 82).

Milestones in the development of methods for assessing the financial situation of the companies were the purpose of E. Altman's multivariate discriminant analysis to predict the risk of bankruptcy. In 1968, he published in the Journal of Finance the first model of this analysis based on the use of five financial ratios (Altman, 1968, p. 589-609). Later, in the years 1970-2000, there was a dynamic development of this type of model in the financial analysis with already widely used statistical models (logit and probit models, multivariate discriminant analysis models).

It is worth noting that economists, with the development of new models, statistical models and artificial intelligence, quickly innovated ways to perform financial analysis of companies. In the short term after the publication of probit function (Bliss, 1934, pp. 409-410) and the logit function (Berkson, 1944 pp. 357-365), these models have been adapted to the needs of financial analysis of companies. Algorithm C&RT of decision trees in 1984 is another example of the successful implementation of statistical methods in the risk management of the company (Breiman et al., 1984).

There is no doubt that the changes in information technology and computing radically changed both actual and potential ways of forecasting the economic situation of enterprises. An example of technological progress is the use of artificial neural network models, genetic algorithms and fuzzy sets models in forecasting economic phenomena. The theoretical foundation of neural networks had been presented already in 1943 by W. Pitts (Warren, Pitts 1943, pp. 115-133), genetic algorithms in the sixties of the twentieth century by J. Holland (Holland, 1975), and fuzzy sets in 1965 by L. Zadeh (Zadeh, 1965, pp. 338-353). Practical application of these models was evidenced in management in the eighties and nineties of the twentieth century.

It also important to note the frequency of use of the discussed models in the literature. The study by M. Aziz and H. Dar showed (Aziz Dar, 2006, pp. 18-33) that the most popular models are multivariate discriminant analysis models (30.3% of cases among the models of all methods), then logit models (21.3% of all cases) and models of artificial neural networks (9% of all cases). Other types of models have been used to a marginal extent (less than 4-5% of cases).

I. Research Assumptions

The aim of this study was to develop a model of artificial neural networks – a Kohonen network using a set of financial ratios. The model allows the author

- to distinguish several classes of risk for bankruptcy of enterprises and
- to indicate 5-10 year trajectories of the crisis in the company.

The term artificial neural network refers to the mathematical model of complex network of computing nodes called neurons and their connections that imitate the action of biological systems that can effectively solve specific problems (Siemińska, 2012, p. 238). In contrast to the multivariate discriminant analysis, the operations of the neural network are a purely mechanical approach to the analyzed phenomenon, without detection of internal relations and the strength of existing relationships.

Kohonen networks are a specific group of neural network used in the process of classification and grouping of data. They usually consist of a layer of input neurons and a single processing layer. Each neuron in the processing layer is connected to all inputs. SOM networks are the most used type of Kohonen network.

SOM networks create the n-dimensional mapping of the input data in one- or two-dimensional space of neurons. Each input vector is classified using the usual method of "nearest neighbor." The values of all neurons - that is, its distance from their vectors by weight - are calculated. It is then assigned to a winning neuron that responds to the least (Kiang, Kumar, 2001, p. 177-194). The Kohonen algorithm, learning the SOM network, introduces the concept of neighborhood neurons. It is understood in the sense of geometric position in relation to the winner neuron. Weights of neurons located close to the winner are modified to be stronger than the more distant neurons. This effect is implemented by using the neighborhood function. As a function of the neighborhood, it may be utilized as follows (Bartkiewicz, 2000, p. 163):

$$h(c,i) = \exp\left(\frac{-r_{ic}^2}{2\sigma^2}\right)$$

where h (c, i) - the function of the neighborhood; ric - the distance of the i-th neuron from the winner; σ -

parameter specifies the width of the neighborhood.

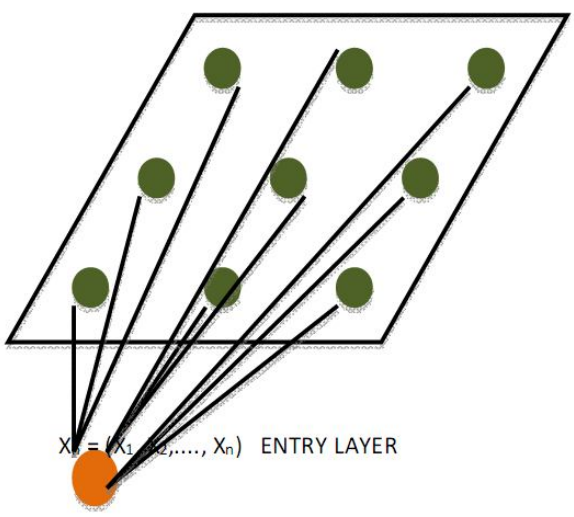


Fig. 1. An example of the structure of a self-organizing maps (SOM)

Source: own study based on Kiang, Kumar, 2001, p. 180

An example of the structure of SOM network is shown in Fig. 1. The learning process is unattended. Training data do not contain any information about the desired outputs. The network is designed to independently classify the data based only on the correlation occurring in them.

For this study, the author used data on 140 manufacturing and service companies listed on the Warsaw Stock Exchange, which published their financial statements in Notoria Service The financial results of listed companies for the period between 1998 and 2014. Within this population, two samples were distinguished:

- Learning sample - made up of 35 companies at risk of bankruptcy and assigned them 35 "healthy" companies. These companies come from different sectors, such as construction, metal industry, food, chemical, and telecommunications.
- testing sample - also composed of 35 companies at risk of bankruptcy and 35 companies in good economic condition, all from different sectors of the economy.

It should be noted that in these studies, the company was classified as at risk of bankruptcy based on three criteria:

- information from the company's authorities about the threat of collapse,
- court judgments declaring bankruptcy,
- liquidation of the company.

The author tested the effectiveness of the developed Kohonen model (SOM) on an unknown sample for the model - the testing sample. This approach ensures a high reliability of the results generated by the SOM models.

The quality classification was evaluated based on overall effectiveness of the model and Type I and Type II errors. The following formulas were used:

- Type I error - E1 = D1 / BR • 100%, where D1 - the number of bankrupted firms classified by the model as "healthy" company, BR - number of bankrupted enterprises in the testing sample;
- Type II error - E2 = D2 / NBR • 100%, where D2 - number non-bankrupt companies classified by the model as a company at risk of bankruptcy, NBR - number non-bankrupt firms in the testing sample;
- the overall effectiveness of the model - S = {1 - [(D1 + D2) / (BR + NBR)]} • 100%.

For all 140 enterprises, the author calculated the value of 15 financial ratios for the last 15 years before the moment the company was at risk of bankruptcy (in a few cases of bankrupt companies, financial ratios were calculated for the period of 5 years or 10 years back due to a lack of data). The complete list of used input variables of the model is presented in Table 1.

Symbol of input variable	Computing formula
X1	Profit on sales / total assets
X2	(current assets – current liabilities) / total assets
X3	(net income + depreciation) / total liabilities
X4	Operational costs / current liabilities
X5	Stockholders' equity / total liabilities
X6	(stockholders' equity + noncurrent liabilities) / fixed assets
X7	Total revenues / total assets
X8	Current assets / current liabilities
X9	Current liabilities / total assets
X10	Income before tax / current liabilities
X11	Total assets / total liabilities
X12	Income before tax / total assets
X13	Income before tax / total revenues
X14	Inventories / total revenues
X15	Net income / total assets

Table 1. The input variables (financial ratios) used in the study

Source: own study

III. TRAJECTORIES COLLAPSE OF ENTERPRISES

Using a learning sample consisting of 70 companies (the period of analysis - one year, two years, and three years before bankruptcy) described by 15 financial ratios, a model self-organizing maps sized 10 neurons (rows) x 10 neurons (column) was developed - Figure 2.

On the map, the author distinguished 6 risk classes:

- A - the highest level of credibility (a company with outstanding good credit reliability);
- B – very good solvency of enterprise;
- C - average solvency capabilities, visible risk;
- D - the possible repayment of liabilities, increased uncertainty, credit exposure problematic;
- E – Liabilities are at high risk, the company vulnerable to bankruptcy;
- F - the bankrupt company, unacceptable risk.

As a result, the manager can use this map not only to evaluate the risk of bankruptcy of the analyzed company but also to assess the good financial situation of the company. In addition, the black, bold line is the distinguishing area at which the company is at risk of bankruptcy and the zone of good economic situation of enterprises.

C	C	D	D	D	E	E	F	F	F
C	C	D	D	D	D	E	F	F	F
B	C	C	C	C	D	E	F	F	F
B	B	B	B	C	D	E	E	E	E
B	B	B	B	C	D	D	D	E	E
B	B	B	B	C	C	C	D	E	E
A	A	A	A	B	B	C	D	D	D
A	A	A	A	B	B	C	D	D	D
A	A	A	A	B	B	C	C	C	C
A	A	A	A	B	B	B	C	C	C

Fig. 2. Map of self-organizing network with the designated classes of risk of bankruptcy

Source: own study.

When evaluating the effectiveness of the developed SOM model (Table 2), it can be seen that a year before bankruptcy, the model is characterized by a high effectiveness of 87.14%. In extending the period of analysis to two years, the effectiveness is decreased by 4.28 percentage points and amounted to 82.86%. Extending the forecast period for another year, there was a further decline in the effectiveness to the level of 77.14%. Also important is the fact that throughout the forecast period Type I error was smaller than Type II error. It should be stressed that, from the point of view of individual stock investors, banks or investment funds, in addition to analyzing the overall effectiveness of the model, it is important to distinguish the size of these errors. Even more important than Type II error is Type I error. Buying shares of a future bankrupt firm (Type I error) will result in initial losses due to the decrease in prices of shares of said company and then its liquidation. Conversely, Type II error means the loss of "only" potential profits by deciding not to purchase the shares of "healthy" companies believing that this is a future bankrupt company.

Tab. 2. The results of the classification of enterprises for a year before, two years before and three years before bankruptcy based on testing sample of model SOM (in parentheses the number indicates the number of misclassified companies)

The results	1 year before	2 years before	3 years before
Type I error– E1	11.43% (4)	14.29% (5)	17.14% (6)
Type II error – E2	14.29% (5)	20% (7)	28.57% (10)
Overall effectiveness S	**87.14%**	**82.86%**	**77.14%**

Table 2. The results of the classification of enterprises for a year before, two years before and three years before bankruptcy based on testing sample of model SOM (in parentheses the number indicates the number of misclassified companies)

Due to the limited size of the paper, the author presents the trajectories of the crisis for only two companies - Alma SA and Bomi S.A. Figure 3 shows the following:

- in the case of Alma SA, 6 years before bankruptcy, the company was characterized as high risk. By observing its trajectory, it can be seen that the company had passed the following "path" of the collapse - 10 years before bankruptcy, class “B” (neuron 10x6); 9 years before, class "B" (neuron 9x5); 8 years before, class "B" (neuron 7x5); 7 years before, class "C" (neuron 8x7); 6 years before, class "D" (neuron 8x8); 5 years before, class "D" (neuron 6x8); 4 years before, class "E" (neuron 4x8); 3 years before, class "F" (neuron 2x8); 2 years before, class "F" (neuron 3x9); a year before, class "F" (neuron 3x10). The trajectory of this company clearly presents a systematic increase in the risk of bankruptcy for the company.
- in the case of Bomi SA (due to lack of data over a longer period, a 5-year trajectory was set), the economic situation was classified as unhealthy one year before, two years before and four years before the bankruptcy occurred. In the period of three years before bankruptcy, it can be seen that this model has rated the improvement of the economic situation of the company (the change of class from "D" to "C"). Then, there was a sudden decrease directly by two classes from "C" to "F" in a period of two years before bankruptcy. This trajectory flows as follows - 5 years before bankruptcy, class "B" (neuron 5x2); 4 years before, class "D" (neuron 3x6); 3 years before, class "C" (neuron 4x5); 2 years before, class "F" (neuron 2x8); a year before, class "F" (neuron 1x9).

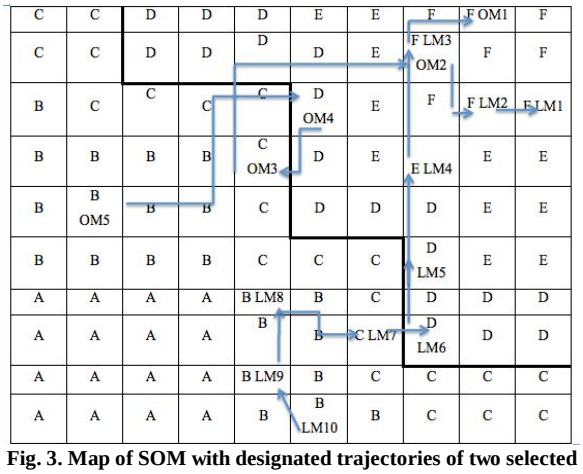


Fig. 3. Map of SOM with designated trajectories of two selected companies (the legend: LM - Alma SA, OM - Bomi SA, figure by the company identifier means the year prior to bankruptcy)

Source: own study.

CONCLUSION

This study showed that the developed SOM model can be used for the following:

- forecasting bankruptcy risk (high effectiveness of the model - from 77.14% in the long-term forecast to 87.14% in the short-term analysis);
- tracking the trajectory of growth and decline of the company - in the example of two companies listed, the author showed that this model well reproduces the economic situation of undertakings and in graphic form makes it easy to keep track of "paths" of the classification of the financial standing of the company (trajectories concern both “healthy” companies - classes "A", " B" and "C" - and “bad” companies – classes "D","E" and "F");
- making business decisions in the long term (10 years) - this model provides a good graphical tool to support managers in decision making process. A financial analyst can follow economic risks of a company on the map.

The author intends to continue the studies presented in the following directions:

- to compare the effectiveness of the SOM model to the effectiveness of the discriminant analysis models, logit model, model of decision trees and model of fuzzy sets;
- to extend the period of evaluation of the economic situation of companies to 15 years with graphic representation of their trajectories;
- to compare the course of the typical trajectory of the development of good companies with trajectories of bankrupt companies;
- to compare trajectories between companies in Central Europe and companies in Western Europe and Latin America.

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