PRACE NAUKOWE UNIWERSYTETU EKONOMICZNEGO WE WROCŁAWIU nr 98
Finanse przedsiębiorstw 2010

Anna Feruś
Politechnika Rzeszowska

THE USE OF DEA METHOD IN EVALUATING CREDIT RISKS OF COMPANIES IN ORDER TO OBTAIN THEIR PROPER CREDIT SCORE*

Summary: The aim of the article is to present a new procedure of company credit risk forecast by using the DEA method under Polish economic conditions. The suggestion is strongly supported by the fact that so far the DEA method has not been applied to estimate credit risk of companies within the framework of credit-scoring. The research described in the article has been conducted on the basis of comparison of suggested DEA method with currently used procedures, namely point method, discriminative analysis and linear regression. Considering the research, it can be concluded that DEA method facilitates forecasting financial problems, including the bankruptcy of companies in Polish economic conditions, and its effectiveness is comparable or even greater than approaches implemented so far.

Key words: credit scoring, credit risk, Data Envelopment Analysis, technical efficiency, creditworthiness.

1. Introduction

Credit risk is inextricably linked with every bank's activity. It is one of the basic types of credit risk. It is understood mainly as the risk of default by a borrower with remaining interest rates and commissions. Competent credit risk management plays the major role in the process of bank administration. All operations undertaken by a bank, especially those involving loans, are meant to reduce that risk. Using credit-scoring methods is believed to be one of the most accurate solutions, facilitating the process of credit risk management. It is worth mentioning that the procedure of credit–scoring has become more significant since Basel Committee on Banking Supervision published the guidelines of New Capital Contract, according to which credit–scoring is one of the possible tools of assessing credit risk within internal ratings [Iwanicz-Drozdowska 2005, p. 130, 150]. The procedure of using DEA method

* The article presents the results of research conducted within research project # H02B 015 30 financed with educational sources.

for credit-scoring suggested in the article may prove an effective tool in solving the problems of credit risk assessment in Polish banks.

2. Implementing DEA method in credit risk management

The methodology of credit risk assessment with the use of DEA[1] method suggested below was prepared on the basis of literature studies [Emel, Oral, Reisman, Yolalan 2003, p. 103-123; Simak 2000, p. 1-189; Gospodarowicz 2004, p. 119-129] as well

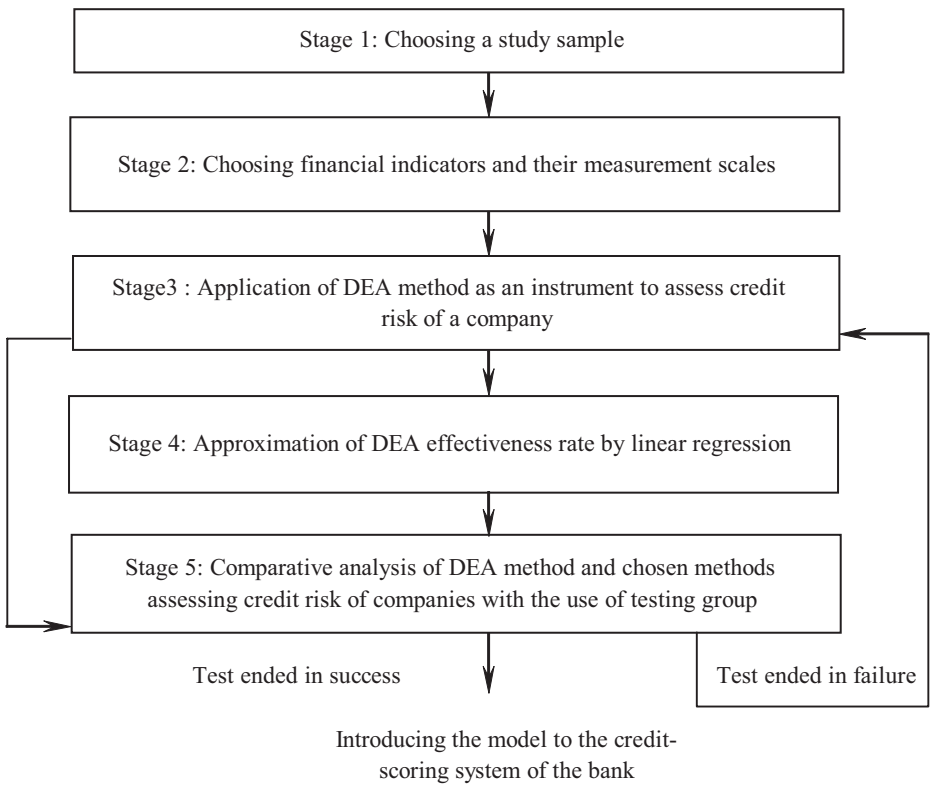

Figure 1. Suggested method of assessing credit risk of companies, using DEA method
Source: self-study.

[1] DEA method was first introduced in 1978 by American economists Charnes, Cooper and Rhodes. Relying on productivity concept, formulated by G. Debreu (1951) and M.J. Farrel (1957), which defined effectiveness measure as quotient of singular effect and singular set-up, they used it for a multidimensional situation in which there was more than one set-up as well as more than one effect. Using DEA method, the effectiveness of an object is calculated in relation to other objects from a particular group. Effective objects within particular group make so-called effectiveness curve. The effectiveness of remaining objects is calculated in relation to the curve defined through solving the issue of linear programming (using DEA method).

as the author's own research [Feruś 2006a, p. 44-59; Feruś 2006b, p. 245-253; Feruś 2006c, p. 263-269; Feruś 2007a, p. 225-233; Feruś 2007b, p.144-154; Feruś 2008a, p.196-215; Feruś 2008b, p.153-160; Feruś 2008c, p. 109-118; Feruś 2009, p. 221--231]. It consists of five stages, as presented in Fig. 1.

Stage 1

The base of a study was statistical matter containing information provided by a bank on 100 construction companies that obtained a credit loan in the years 2001--2003. This study included the status of credit repayment history[2].

Stage 2

The analysis was conducted for one year period as well as two years before considering the firms as bankrupts. The study used 22 financial indicators. Next, based on correlation assumption 6 indicators were chosen (Table 1) that did not contain any information provided by other financial indicators from this study, but at the same time were good representative indicators that were not chosen for diagnosis[3].

Table 1. Financial indicators used in the study

Indicator's symbol	Indicator's formula
X_1	Net profit indicator = (financial result × 100) / (profit from sales and equals + other operation profits + financial profits)
X_2	Asset return indicator (ROA net) = (financial result × 100)/ total of assets
X_3	Individual assets return indicator (ROE net) = (net financial result × 100 × 12/n)/ individual assets
X_4	Current liquid indicator = revolving capital / short term debts
X_5	Daily return indicator = (total of return × #of days) / (profit from sales and equals + other operation profits + financial profits)
X_6	General debt indicator = (general debts × 100) / total return

Source: self-study.

Stage 3

A crucial problem in this stage is the choice of the right set ups and effects used in firms' component. The assignment of the individual financial indicators to groups of set ups and effects depends mainly on a problem format. Often the scripts on the studied object indicate five basic ways to define set up and effect: producer concept, financial agent concept, financial asset concept, summarized value concept and user expense concept. The solution of a given problem based on DEA method depends on choosing the right DEA model. To classify DEA model two criteria must be presen-

[2] Statistical matter contained 50 solvable firms and 50 firms with delinquency risk.

[3] Chosen indicators were weakly correlated with each other and strongly correlated with fluctuating alignment.

ted at the same time: type of effect scale and orientation of the model. The first criterion defines what theories were applied to effect scale in the model (variable (VRS), constant (CRS) or not rising (NIRS)). The second factor demonstrates whether set ups are minimized or effects are maximized. Depending on the choice of the model orientation, what can be calculated is either the technical effectiveness of set up or technical effectiveness oriented on solution or so called undirected models.

Based on thorough literature study [Emel, Oral, Reisman, Yolalan 2003, p. 108--121; Simak 2000, p. 43-100; Gospodarowicz 2004, p. 123-129], credit inspectors' interview and personal experiences [Feruś 2006a, p. 44-59, Feruś 2006b, p. 245-253; Feruś 2006c, p. 263-269; Feruś 2007a, p. 225-233; Feruś 2007b, p.144-154; Feruś 2008a, p.196-215; Feruś 2008b, p.153-160; Feruś 2008c, p. 109-118; Feruś 2009, p. 221-231] in that aspect, set up and effect classifications were created[4]:

– **set ups**: X_5 and X_6,
– **effects**: X_1, X_2, X_3 and X_4.

To calculate the technical effective indicator value of studied firms CCR (constant scale effect) model was used. This was directed towards set ups with search for minimal value of effectiveness indicator that will possibly reduce the amount of set up and result in equal effect of the study object. For this calculation optimal linear program EMS[5] was used. The effectiveness indicator results for each firm in the study ranged from 0 to 1. The value of effectiveness indicator equal to 1 demonstrates the firm being effective whereas the effectiveness indicator value lower than 1 demonstrates the firm has an opportunity to improve the relations of set ups and effects – indicates effectiveness loss level.

In this part of the study research was also carried out aiming at finding the base point (cut off point) of effectiveness coefficient that would separate the solvent group of firms from the firms with the risk of delinquency.

A good concept, allowing for setting the right base point value, but also considering incorrect object classification, was a study of interdependency between the value of incorrect classification and the value of base point. In this approach, optimal base point regulates minimal entire cost of incorrect classification. Moreover, this concept permits multi variant analysis, the optimal base point change due to incorrect classification Type I or II. To show the entire cost of incorrect classification the following formula was applied [Simak 2000, p. 94-95]:

$$TC = i(p) \cdot C_1 + j(p) \cdot C_2, \tag{1}$$

where: C_1 – loss indicator Type I error,
C_2 – loss indictor Type II error,

[4] The author used numerous studies examining the model effectiveness. Present article gives the final model that proved to be the most effective in determining the firms' credit risk factor.

[5] Dortmund University website sources: http://wiso.unidortmund.de/LSFR/OR/scheel/ems.

$i(p)$ – error quantity Type I,
$j(p)$ – error quantity Type II.

For the purpose of this study, C1 and C2 is equal to 0.6 and 0.03 respectively.

For the above mentioned CCR model (constant scale effect) concentrated on set ups, effectiveness coefficient base value was verified for a year as well as two years before delinquency below 0.40. This indicates the 0.40 or lower rank implies a high risk of defaulting. Furthermore, 0.40 or higher rank implies a low risk of defaulting.

The DEA method classification effectiveness is illustrated in Table 2. In addition, the DEA method results (Table 2) were compared with point method (MP) results as well as with regressive linear (RL) results. Using the same material, the author was able to complete a credible comparative analysis using statistical data.

Based on the classification results shown in Table 2 it could be concluded that the effectiveness of I and II classification with the use of DEA method is similar to discriminating analysis and regressive linear regression.

Table 2. Evaluation of different methods effectiveness using 2001-2002 data[6]

Method	MP		AD		RL		DEA	
Base point	–		0		0.5		0.4	
2001	S_2	100%	S_2	96%	S_2	96%	S_2	90%
	S_1	58%	S_1	80%	S_1	80%	S_1	72%
	S	79%	S	88%	S	88%	S	81%
2002	S_2	100%	S_2	90%	S_2	90%	S_2	80%
	S_1	70%	S_1	86%	S_1	86%	S_1	84%
	S	85%	S	88%	S	88%	S	82%

Source: self-study.

[6] S_2 –Type II Efficiency – determines what percentage of solvable firms was correctly classified ($S_2 = \frac{P2}{P2 + NP2} \times 100\%$; where $P2$ – number of solvable firms classified as solvable group, $NP2$– number of solvable firms classified as delinquency risk group), S_1 – Type I Efficiency – determines what percentage of firms with delinquency risk was correctly classified ($S_1 = \frac{P1}{P1 + NP1} \times 100\%$; where $P1$ – number of firms with risk of delinquency classified as delinquency risk group, $NP1$– number of firms with risk of delinquency classified as solvable, S – General Classification of Efficiency – determines what percentage of all firms was correctly classified with application of the ($S = \frac{P1 + P2}{P1 + NP1 + P2 + NP2} \times 100\%$). The base point value in the discrimination analysis model and regressive linear model was calculated as average value from average of the groups.

Stage 4

The main purpose of this phase is an attempt at reducing the DEA method fallacy caused by a necessity of applying an optimal linear programme for every study of a firm applying for a credit loan [Simak 2000, p. 94-95]. The suggested solution to this problem is the application of regressive linear function that allows for finding a correlation between the coefficient DEA method value and its effectiveness with defined set ups and effects. In this case, regressive linear function could be used as linear estimation of coefficient DEA method values without the need of extensive process of DEA method verification each time a new firm is applying for a credit. In other words, regressive linear function could be used while determining the studied firm's credit risk level without going through the first three phases [Emel, Oral, Reisman, Yolalan 2003, p. 108-115]. Accordingly, the regressive linear function was defined during the process of estimating the coefficient value of DEA method effectiveness. Past coefficient DEA method of effectiveness values through regressive linear function was treated as a dependent variable Y (endogenous variable), and defined set up and effect were noted as an operand X_i (exogenous variable). The regressive linear function research was conducted through Statistica 6.0 programme. When rating the value of regressive linear function model the level of significance $\alpha = 0.05$was established.

This is the final linear regression model formula:

$$Y_{\text{DEA\_2001-2002}} = -0.0006X_5+0.0010X_6+0.0826X_1+0.0126X_2-0.0003X_3+0.2831X_4+0.0564$$

Table 3. Selected properties of regressive linear function Y_{DEA}

$R^2 = 67\%$, $F(6/93) = 31{,}46$						
Variables	X_5	X_6	X_1	X_2	X_3	X_4
$t(a_i)$	–4.82	2.32	3.64	2.62	–2.13	6.57
Empirical level of essence p	0.0000	0.0227	0.0004	0.0102	0.0354	0.0000

Source: self-study.

Summarizing the results of above study (Table 3 – test of essence: t-Student, F-Snedecora, determining coefficient R^2) one can recognize that the choice of dependent variables in the regressive linear function Y_{DEA} is accurate. Furthermore, all the regressive linear function Y_{DEA} properties were statistically significant.

The efficient classification results in Table 4 in regressive linear function Y DEA-2001-2002 do not differ considerably from the DEA method results shown in Stage 3 of this study, which means that equalization of the linear regression could be treated as linear approximation of the coefficient DEA effectiveness value.

Table 4. Comparing the classification effectiveness of DEA method with regressive linear function Y_{DEA}

	Base point = 0.40			
	DEA		Y_{DEA}	
	2002	2001	2002	2001
S_2	80%	90%	86%	86%
S_1	84%	72%	86%	76%
S	82%	81%	86%	81%

Source: self-study.

Stage 5

To check and verify the accuracy and effectiveness of prognostic qualities of above studied models, the statistic matter (100 firms) was divided equally 1:1 in respect to two separate research samples: controlled and placebo group. The effectiveness rate of both groups' classification is presented in Table 5.

Table 5. Comparing the effectiveness of various methods for the placebo sample group using 2001-2002 data

Method	AD		RL		DEA	
Base point	0		0.5		0.5	
2001	S_2	96%	S_2	96%	S_2	88%
	S_1	68%	S_1	68%	S_1	80%
	S	82%		82%		84%
2002	S_2	88%	S_2	88%	S_2	84%
	S_1	80%	S_1	80%	S_1	96%
	S	84%	S	84%	S	84%

Source: self-study.

Based on the above classification results in Table 5 it can be determined that DEA method has superior prognostic indicators. It best minimizes type I errors where classification effectiveness was higher than 12% two years before delinquency and higher than 16% one year before delinquency. However, general classification effectiveness of DEA method is similar to general classification for methods: discrimination and linear regression analysis.

3. Conclusion

Founded by the study, it can be concluded that DEA method correctly predicts possible financial difficulties including a company's bankruptcy risk in Polish economic situation. These results are comparable or even superior to other methods presently employed.

This study signifies the universal application of DEA method in analyzing large spectrum of credit risk uncertainty. It not only measures efficiency in respect of the use of financial risk indicators, but it also facilitates accurate credit risk classification for corporations in the credit application process.

Literature

Emel A.B., Oral M., Reisman A., Yolalan R., *A credit scoring approach for the commercial banking sector*, "Socio-Economic Planning Sciences" 37, 2003.

Feruś A., *Zastosowanie metody DEA do określania poziomu ryzyka kredytowego przedsiębiorstw*, „Bank i Kredyt" 2006a, nr 7.

Feruś A., *Określanie poziomu ryzyka kredytowego przedsiębiorstw z wykorzystaniem metody DEA*, [w:] *Problemy zarządzania finansami we współczesnych przedsiębiorstwach*, red. P. Szczepankowski, VIZJA PRESS, Warszawa 2006b.

Feruś A., *Szacowanie ryzyka kredytowego przedsiębiorstw z wykorzystaniem metody DEA*, [w:] *Finanse przedsiębiorstwa*, red. P. Karpuś, Wydawnictwo Uniwersytetu Marii Curie-Skłodowskiej, Lublin 2006c.

Feruś A., *Szacowanie ryzyka kredytowego przedsiębiorstw ze szczególnym uwzględnieniem metody DEA*, [w:] *Harmonizacja bankowości i ubezpieczeń w skali narodowej i europejskiej*, red. M. Marcinkowska, S. Wieteska, Difin, Warszawa 2007a.

Feruś A., *Wykorzystanie metody DEA do oceny ryzyka kredytowego przedsiębiorstw w ramach credit-scoringu*, [w:] *Zarządzanie finansami firm – teoria i praktyka*, red. W. Pluta, Prace Naukowe Akademii Ekonomicznej nr 1152, AE, Wrocław 2007b.

Feruś A., *Управління кредитними ризиками підприємств за допомогою методу DEA – Zarządzanie ryzykiem kredytowym przedsiębiorstw z zastosowaniem metody DEA*, [w:] *Актуальні проблеми управління* – A*ktualne problemy zarządzania: Монографія*, t. 2, Запоріжжя-Жешув 2008a.

Feruś A., *Zarządzanie ryzykiem kredytowym przedsiębiorstw z wykorzystaniem metody DEA w ramach credit-scoringu*, [w:] *Zarządzanie finansami firm – teoria i praktyka*, red. B. Bernaś, Prace Naukowe Akademii Ekonomicznej nr 1200, AE, Wrocław 2008b.

Feruś A., *The DEA metod in managing the credit risk of companies*, [w:] "Ekonomika", 84/2008, Vilnius University, Vilnius 2008c.

Feruś A., *Zarządzanie ryzykiem kredytowym przedsiębiorstw z wykorzystaniem metody DEA w ramach credit-scoringu*, [w:] *Zarządzanie finansami firm – teoria i praktyka*, red. B. Bernaś, Prace Naukowe Akademii Ekonomicznej nr 48, UE, Wrocław 2009.

Gospodarowicz A., *Możliwości wykorzystania metody DEA do oceny ryzyka kredytowego w kontekście Nowej Umowy Kapitałowej*, [w:] *Przestrzenno-czasowe modelowanie i prognozowanie zjawisk gospodarczych*, red. A. Zeliaś, AE, Kraków 2004.

Iwanicz-Drozdowska M., *Zarządzanie finansowe bankiem*, PWE, Warszawa 2005.

Simak P.C., *Inverse and Negative DEA and their Application to Credit Risk Evaluation*, Centre for Management of Technology and Enterpreneurship, Faculty of Applied Sciences and Engineering, University of Toronto, Toronto 2000.

ZASTOSOWANIE METODY DEA DO OCENY RYZYKA KREDYTOWEGO PRZEDSIĘBIORSTW W RAMACH CREDIT-SCORINGU

Streszczenie: Celem artykułu jest zaproponowanie nowego postępowania prognozującego ryzyko kredytowe przedsiębiorstw w polskich warunkach gospodarczych, wykorzystującego metodę *Data Envelopment Analysis* (DEA). Za podjęciem proponowanych badań przemawia fakt, że dotychczas w naszym kraju nie podejmowano prób zastosowania metody DEA do szacowania ryzyka kredytowego przedsiębiorstw w ramach *credit-scoringu*. Badania w artykule były prowadzone na zasadzie porównania proponowanej metody DEA z metodami obecnie stosowanymi (tj. metodą punktową, analizą dyskryminacyjną, regresją liniową). Na podstawie przeprowadzonych badań można wnioskować, że metoda DEA umożliwia przewidywanie trudności finansowych, łącznie z zagrożeniem bankructwem przedsiębiorstw w polskich warunkach gospodarczych na poziomie porównywalnym lub nawet przewyższającym dotychczas stosowane metody.