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A Multi-criteria Approach to Credit Risk Assessment

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Abstract: - Credit risk assessment is a significant area of financial management which demands of credit/financial analysts to investigate a large number of financial indicators of firms and make crucial decisions regarding the financing of firms. The complexity of credit risk assessment process has necessitated the construction of credit risk assessment models based on multi-criteria decision analysis. This paper deals with the ranking of firms according to the credit risk assessment using the PROMETHEE method and Analytic Hierarchy Process (AHP). The PROMETHEE method is used for final ranking of great number of Croatian firms and AHP to determine the importance of the eleven criteria from the three main criteria groups: profitability, liquidity and solvency of the firms.

Key-Words: - credit risk assessment, financial ratios, profitability, solvency, liquidity, AHP, PROMETHEE

1 Introduction

In banking industry portfolios of financial assets generate risks regarding future returns. In order to reduce the possibility of loss to an acceptable level, the risk has to be recognised, measured and of course minimised. Credit risk has been recognised as the biggest cause of bank failure. Although the credit risk is a broader term than the risk referring to credits only, in this paper we define the credit risk as a probability that the debtor, against the agreed conditions, will not pay the interest and/or pay off the principal when it is due for payment. Banks face the problem of the credit rating assessment of the credit applicant. A precise credit rating assessment of the credit applicant is certainly one of the most significant and most difficult tasks and it actually includes minimising the credit risk.

Decisions regarding credit risk assessment concern the evaluation of the firms' financial and non-financial characteristics in order to make "optimal" decisions which incorporate a tradeoff between the potential risk of loss and the probability of profits from granting credit (Srinivasan and Kim, 1987; Srinivasan and Ruparel, 1990).

The credit analysts have to identify the most relevant factors for credit risk evaluation using the financial reports, the basic ones being: balance sheet, profit and loss account, report on the money flow, as well as data on assets, source of capital, financial stability indicators, indebtedness, liquidity and business performance etc.

In this paper, on the basis of the available financial data of the firms[1], 11 financial ratios (Table 1) are used as adequate measures of corporate credit risk. The selection of these ratios has been performed according to the financial literature (Doumpos at al. 2002; Belak 1995) and in agreement of expert credit risk analysts (the expert group consists of bankers, auditors, financial managers and professors). The selected ratios cover all aspects of the corporate financial performance, including profitability, solvency and liquidity.

Further on, we show how, by using the methods of multi-criteria decision making (AHP and PROMETHEE), to use the above stated financial ratios in estimating the credit

[1] Source: www.crosec.hr, Croatian Securities Commission - Republic of Croatia, Public Reference Room, Financial Reports 2001.

Profitability	1. EBIT/TA (Earnings before interest and taxes/total assets) 2. NI/NW (Net income/net worth) 3. SALES/TA (Sales/total assets) 4. GP/TA (Gross profit/total assets) 5. NI/WC (Net income/working capital)
Solvency	6. TD/TA (Total debt/total assets) 7. LTD/(LTD+NW) (Long-term debt/(long-term debt + net worth)) 8. TD/WC (Total debt/working capital)
Liquidity	9. QA/CL ((Current assets – inventories)/current liabilities) 10. CASH/CL (Accounts receivable/current liabilities) 11. CL/NW (Current liabilities/net worth)

Table 1. List of financial ratios

risk on the example of the Croatian firms. A total of 500 Croatian firms from different business sectors have been considered. A part of these firms has not been taken into consideration because of the lack of data and some of them because the credit officers of the bank indicated them as firms of high credit risk. Out of the rest of the firms we have chosen 39 of them as a training sample, which we compare according to the 11 observed criteria.

2 AHP and PROMETHEE

The Analytic Hierarchy Process (AHP) is one of the most outstanding multicriteria decision-making approaches. It employs a method of multiple paired comparison of attributes (criteria) to rank-order alternatives.

The multiple paired comparisons are based on a standardized evaluation scheme (1=equally important; 3=slightly more important; 5=much more important; 7=very much more important; absolutely more important)[2]. The result of the pairwise comparisons on n elements can be summarized in a $(m \times n)$ evaluation matrix A in which every element a_{ij} is the ratio of weights of the criteria, e.g. $a_{ij} = w_i / w_j$, whereby small inconsistency of judgments are acceptable.

In a further step the largest eigenvalue of the evaluation matrix has to be determined. If no inconsistency in judgment exist, the relation $Aw = nw$, or $(A - nI) \cdot w = 0$, holds, where w is the vector of n evaluation weights w_j. This is a system of homogenous linear equations which has a nontrivial solution if the determinant $(A - nI)$ vanishes, thus indicating that n is eigenvalue of A. Furthermore, A has rank equal one, and all the eigenvalues of A except one are zero. Small inconsistency in judgment leads to small perturbations of the coefficients of the matrix A and its eigenvalues as well. The basic relation for the eigenvalue problem now becomes $A'w' = \lambda_{\max} w'$, where $\lambda_{\max}$ is the largest eigenvalue of the matrix A'. It can be seen that $\lambda_{\max} \geq n$ (see [8, p.13]). The difference $\lambda_{\max} - n$ can, therefore, be used as a consistency index, where consistency is defined by the relation between the entries of A: $a_{ij} \cdot a_{jk} = a_{ik}$. If the average deviation $(\lambda_{\max} - n)/(n-1)$ exceeds a predetermined value (e.g. 0.1) the evaluation procedure has to be repeated to improve consistency.

In this paper, we use AHP for ranking the criteria, e.g. for determination of the weights of criteria which we need for PROMETHE procedure.

The PROMETHEE method is appropriate to treat the multicriteria problem of the following type:

$$Max\{f_1(a),...,f_n(a) | a \in K\}, \qquad (1)$$

where K is a finite set of possible actions (here firms), and f_j are n criteria to be maximized. For each action $f_j(a)$ is an evaluation of this action. When we compare two actions, $a, b \in K$, we must be able to express the result of this comparison in terms of preference. We, therefore, consider a preference function P:

$$P : K \times K \rightarrow [0,1] \qquad (2)$$

Representing the intensity of action a with regard to action b. In practice, this preference function will be a function of the difference

[2] For details see [8, p.15].

between the two evaluations $d = f(a) - f(b)$, and it is monotonically increasing. Six possible types (1 - usual, 2 - U shape, 3 - V shape, 4 - level, 5 - linear and 6 - Gaussian; for details see Brans and Vincke, 1985; Brans and Mareschal, 1989) of this preference function are proposed to the decision maker. The effective choice is made interactively by the decision maker and the analyst according to their feeling of the intensities of preference. In each case zero, one or two parameters have to be fixed:

- q is a threshold defining an indifference area;
- p is a threshold defining a strict preference area;
- s is a parameter the value of which lies between p and q.

Now, we can define a preference index

$$\Pi(a,b) = \frac{\sum_{j=1}^{n} w_j P_j(a,b)}{\sum_{j=1}^{n} w_j}, \qquad (3)$$

where w_j are weights associated with each criteria.

Finally, for every $a \in K$, let us consider the two following outranking flows:

- leaving flow:

$$\phi^+(a) = \sum_{b \in K} \Pi(a,b), \qquad (4)$$

- entering flow:

$$\phi^-(a) = \sum_{b \in K} \Pi(b,a). \qquad (5)$$

The leaving flow ϕ^+ is the measure of the outranking character of *a* (how *a* dominates all the other actions of *K*). Symmetrically, the entering flow ϕ^- gives the outranked character of *a* (how *a* is dominated by all the other actions). The action is better if the leaving flow is higher, and the entering flow lower. The PROMETHEE I gives a partial preorder of the set of actions in which some actions are comparable, some others are not. When the decision maker is requesting a complete ranking, the net outranking flow may be considered:

$$\phi(a) = \phi^+(a) - \phi^-(a) \qquad (6)$$

And the higher the net flow the better is the action. All the actions of *K* are now completely ranked (PROMETHEE II).

3 Problem presented by Multi-criteria Methods

Looking for the credit risk assessment this paper uses multi-criteria analysis models, Analytic Hierarchy Process (AHP) and the PROMETHEE methods.

Application of AHP requires creation of hierarchically structured model in which basic groups of the criteria and single criteria are stated at different levels. In this case, all criteria are divided into three basic groups: profitability, solvency and liquidity measures. Each of the mentioned groups at the third hierarchic level is decomposed into single grading criteria.

At this moment it is necessary to form the matrix of the ratios of importance of pairs of the criteria groups concerning the main goal: minimising the credit risk. The three main criteria groups were estimated by the standard AHP scale by mutual pairwise comparisons consulting a group of credit risk experts. In the same way we got the mutual importance of criteria within each individual group. The final weight value of all criteria, got by system of equations $(A - nI) \cdot w = 0$, i.e. by application of expert choice program are given in Figure 1, including the hierarchical structure of AHP model.

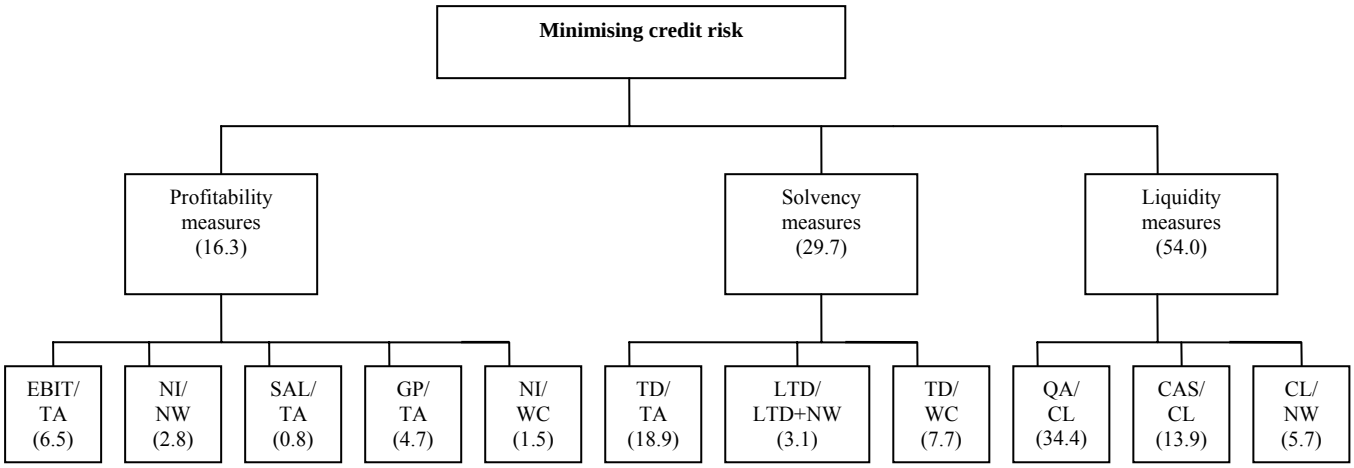

Figure 1. Hierarchical Structure of AHP-model with criteria weight values

The resulting priorities show that the liquidity and solvency criteria have the advantage over the profitability criteria which is understandable considering the most important demand made by the bank which refers to the possibility to pay off the principal and the interest at their time to maturity.

After the weight values of the criteria have been determined the analysis continues with the PROMETHEE method.

For each criterion, one of the six offered preference function types and its thresholds has been chosen, and in this way the problem was completely prepared for implementation of the PROMETHEE, one of the best methods for such multi-criteria, relatively weakly structured, problem. Its advantages are seen in the possibilities to define indifference and preference thresholds which have the real economic importance.

The choice of the function types and its thresholds was carried out in cooperation with the same group of experts who analysed in detail the values of each criterion for all the observed firms. In addition to that, the final ranking is got by the cumulation of mutual comparisons of alternative pairs, according to all the criteria, into final leaving and entering flows, i.e. the final rank of alternatives.

The group of alternatives consists of 39 Croatian enterprises which are compared according to the 11 previously observed criteria.

Values of all indicators for each enterprise have been calculated and shown in table 2, as well as the weight values of all criteria. For each criterion a specific preference function must be defined from the group of six possible types of preference functions. This function is used to compute the degree of preference associated to the best action in case of pairwise comparisons. In this case the types 3 (V-shape), 4 (level) and 5 (linear) have been respectively associated to the eleven criteria. Some criteria have to be minimized; the others have to be maximized.

4 Results

After the analysis has been done, using PROMETHEE II, the final rank of alternatives according to the credit risk assessment has been obtained and given in table 3.

PROMETHEE II provides a complete ranking. It is based on the balance of the two preference flows as it is defined in relation (6). The higher the net flow (PHI) the better is the action (enterprise).

It is obvious that the enterprises at the top of the table are "healthy" enterprises with the lower credit risk than the enterprises at the end of the ranking list, which particularly helps decision makers to analyse the "suitability" of the enterprise while granting the credit.

Among the eleven chosen criteria, solvency and liquidity have the most significant weight, which is understandable considering the most important interest of the bank - the possibility of collection of their receivables at a given moment. Even though especially important, the criterion QA/CL will not be the overall dominant one in the final ranking of enterprises, because when they are ranked only according to that criterion the obtained ranking is different.

CRITERIA	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
Name	EBIT/TA	NI/NW	SALES /TA	GP/TA	NI/WC	TD/TA	LTD/ (LTD+NW)	TD/WC	QA/CL	CASH/ CL	CL/NW
Min/Max	max	max	max	max	max	min	min	min	max	max	min
Type	3	4	5	3	4	5	3	5	5	4	4
Weight	6.5	2.8	0.8	4.7	1.5	18.9	3.1	7.7	34.4	13.9	5.7
ACTIONS (ENTERPRISES)											
E1	3.99	4.22	58.07	2.35	5.96	44.19	10.09	111.88	76.96	48.98	67.97
E2	6.73	9.87	83.77	2.74	5.10	72.19	5.80	134.25	40.61	29.63	253.43
E3	0.98	0.03	12.52	0.02	0.12	60.24	53.65	635.26	52.65	8.19	35.73
E4	9.38	10.86	180.35	8.87	16.85	25.77	0.00	53.8	131.54	84.75	34.72
E5	5.56	5.66	63.69	5.10	21.50	8.86	3.06	36.94	234.74	108.39	6.56
E6	2.38	0.50	110.47	0.28	0.71	51.14	19.32	148.97	54.00	51.05	80.73
E7	4.74	9.19	186.51	3.82	3.42	68.63	0.00	81.48	90.90	87.61	218.82
E8	25.68	23.26	33.11	13.22	46.93	43.14	0.20	153.12	42.61	32.37	75.68
E9	14.32	12.70	98.61	13.73	20.97	14.91	0.00	28.92	238.86	83.12	17.52
E10	8.72	8.59	106.52	7.78	16.32	26.27	4.18	67.72	162.98	112.29	31.27
E11	28.30	23.20	120.95	24.36	34.57	40.20	25.87	100.16	177.43	54.69	32.32
E12	10.91	6.57	65.48	10.78	11.89	6.90	1.39	13.42	679.20	179.67	6.00
E13	2.47	1.03	171.79	0.17	0.37	83.74	51.55	186.32	48.68	25.31	408.58
E14	5.70	3.53	26.74	0.79	6.96	77.59	0.00	683.85	11.59	6.75	346.27
E15	6.92	5.42	79.14	5.56	10.72	27.71	12.10	75.75	135.11	93.32	24.56
E16	11.16	13.76	72.5	8.26	18.36	44.62	31.48	107.54	163.18	54.93	34.63
E17	4.24	3.87	51.90	2.60	8.57	32.86	16.69	108.50	74.54	56.70	28.91
E18	13.11	16.40	150.64	11.40	25.63	46.23	27.04	134.41	88.01	70.10	48.93
E19	12.72	39.94	156.33	7.10	14.53	82.22	57.14	168.22	39.06	29.67	329.24
E20	8.17	13.14	174.70	5.15	5.39	69.95	8.36	95.51	83.01	78.00	223.66
E21	16.90	23.99	48.99	11.43	21.19	52.65	19.63	98.22	117.71	95.49	86.78
E22	12.62	11.38	78.78	11.74	24.38	16.15	1.64	41.27	154.53	74.87	17.59
E23	4.93	3.96	151.60	3.45	7.18	40.77	24.16	124.76	128.52	79.23	36.99
E24	12.04	11.38	84.39	8.69	20.27	38.06	15.86	109.47	113.64	60.48	42.61
E25	2.92	2.39	111.81	1.60	4.04	33.59	15.84	85.46	107.50	79.20	31.76
E26	5.23	16.81	115.16	3.61	4.44	84.17	63.72	140.44	74.69	33.02	356.07
E27	7.84	12.20	103.97	2.95	13.18	75.83	52.30	338.86	34.52	32.62	204.03
E28	23.79	22.86	78.94	22.56	45.32	21.71	6.22	54.97	143.56	33.77	21.09
E29	7.70	8.08	38.89	7.70	10.38	8.72	0.00	12.27	719.61	448.30	9.55
E30	15.29	12.06	150.10	13.81	14.43	8.81	0.00	11.56	604.95	273.02	9.66
E31	1.92	0.65	63.18	0.36	0.76	45.38	22.85	96.88	85.61	71.32	53.47
E32	4.32	1.68	131.11	0.62	1.56	69.06	47.58	207.00	74.94	3134	132.40
E33	4.68	5.53	219.11	2.87	4.81	58.49	25.63	122.54	86.08	81.62	106.41
E34	4.85	5.07	93.81	3.15	4.13	46.90	11.06	71.95	69.00	55.63	75.89
E35	2.04	2.32	70.80	0.65	1.21	72.13	52.78	134.58	122.81	66.10	147.06
E36	41.79	39.49	106.06	38.89	50.36	22.29	0.00	36.56	255.27	49.76	28.68
E37	12.35	6.35	14.74	3.13	19.74	49.79	36.07	308.39	74.49	68.31	42.75
E38	4.46	3.08	103.61	3.10	6.98	22.33	6.02	65.21	140.54	70.04	22.34
E39	2.44	2.41	60.12	2.24	7.86	7.23	0.88	25.40	349.86	286.61	6.91

Table 2. Decision matrix

RANK	**ACTION**	**PHI**	**RANK**	**ACTION**	**PHI**	**RANK**	**ACTION**	**PHI**
1.	E30	0.78	14.	E38	0.22	27.	E34	-0.24
2.	E29	0.74	15.	E16	0.16	28.	E35	-0.24
3.	E12	0.74	16.	E21	0.11	29.	E1	-0.24
4.	E39	0.60	17.	E24	0.07	30.	E37	-0.25
5.	E9	0.59	18.	E23	0.05	31.	E32	-0.29
6.	E5	0.55	19.	E25	0.02	32.	E6	-0.41
7.	E36	0.55	20.	E18	-0.05	33.	E26	-0.50
8.	E22	0.43	21.	E17	-0.15	34.	E19	-0.54
9.	E10	0.40	22.	E7	-0.19	35.	E2	-0.54
10.	E28	0.35	23.	E31	-0.20	36.	E3	-0.60
11.	E4	0.32	24.	E8	-0.23	37.	E27	-0.63
12.	E11	0.30	25.	E33	-0.23	38.	E13	-0.69
13.	E15	0.26	26.	E20	-0.24	39.	E14	-0.75

Table 3. PROMETHEE II complete ranking

5 Conclusion

Credit risk assessment is a complex financial problem which is of major interest to practitioners, financial and credit analysts.

This approach to credit risk assessment has important advantages over some well-known standard methods. For instance, the Altman model gives five criteria determined in advance and the weights of constant value obtained on the basis of studies of the American market at a given period. This approach, however, offers 11 criteria obtained in the consultation with experts and literature, and it allows various decision-makers to alternate (add) criteria and ponder them in accordance with their preferences.

The purpose of this paper is to provide the possibility of the new approach to this problem i.e. to analyse the problem of the credit risk assessment as a problem of the multi-criteria decision making since it is necessary to include more indicators at the same time. Such approach contributes to the better analysis of the problem of the credit risk assessment and can significantly help decision makers while granting the credits.

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