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Use of Binary Dependent Variables for Modelling Borrowers' Creditworthiness

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Abstract

This article provides an econometric analysis of borrowers' creditworthiness in order to create corporate organizational and economic knowledge. It stresses the need for modern methods of applied analysis of credit portfolio management. The authors seek to prove the feasibility of using binary variables to identify and measure creditworthiness drivers in cognitive supporting of a credit institution management. The paper proposes a methodological approach to modeling the creditworthiness of potential borrowers based on models with binary dependent variables. The results of empirical evaluations which were received through the application of Gretl software confirmed their feasibility in management of the loan portfolio by credit institutions.

Keywords: creditworthiness, applied analysis, models with binary dependent variables

1. Introduction

Credit operations while playing an important role in the development of banks and welfare of legal entities determine the efficiency of the economy as a whole. One of the main ways to reduce the risk of loan default is a thorough examination of potential borrowers by analyzing key informative parameters of solvency and creditworthiness (Robert, 2011; Lee, Lee, & Lee, 2009; Sekkel, 2015). Proper assessment of the borrower's creditworthiness and, in accordance with it, the fair value of the loan product is a foundation of effective lending to legal entities. Therefore, improving techniques for objective evaluation of the creditworthiness of borrowers - legal entities are particularly relevant in the instable economy of the country. In this context, the aim of the study is to construct an econometric model of borrowers creditworthiness using binary dependent variable (Y takes the value of one if the loan was issued, and a value of zero in case of rejection) (Wooldridge, 2013; Kupriyanov, Borzenkova, & Sergeevna, 2013; Hirth, 2014) and forecasting lender's loan approval. The practical significance of the study is the possibility of using the developed model by commercial banks in order to enhance the validity of credit decisions.

2. Method

In the study, with regard to industrial enterprises and wholesale trade of the Republic of Tatarstan, the methodology for the creditworthiness assessment is adapted (Baele, De Bruyckere, De Jonghe, & Vander Vennet, 2015; Fall & Viviani, 2015; Kamalova & Polovkina, 2014; Kadochnikova & Ismigilov, 2014; Grigoreva & Fesina, 2014), it is based on the examination of five major financial indicators of the company - liquidity, financial stability, business activity, debt service and profitability on the basis of the financial statements.

D_1- leverage ratio characterizes the firm's dependence on foreign loans. It is calculated as the ratio of equity to borrowed funds. The optimum value for the index is 0.5.

D_2 - profit ratio which shows the share of profit in each ruble earned. It is usually calculated as the ratio of net profit (profit after tax) for a certain period to the sales in money terms for the same period.

D_3 - financial stability index shows how much of an asset is financed by sustainable sources, and it is calculated as the ratio of equity and long-term loans to the balance sheet currency. Recommended value is not less than 0.75.

D_4 - working assets turnover shows the activity of use and the velocity of current assets circulation. It is calculated as the ratio of revenues to average annual value of current assets (receivables, cash, stocks and prepaid expenses, short-term investments).

D_5 - asset coverage ratio measures the ability of an organization to repay its debts at the expense of existing assets. Asset coverage ratio = ((Assets - Intangible assets) - (Current liabilities - Short-term loans and borrowings)) / liabilities. In industry it is considered normal when asset coverage ratio is no less than 2, in service companies - 1.5.

There are three entities - applicants for a loan with the following financial indicators:

1) $D_1 = 0{,}534$; $D_2 = 0{,}068$; $D_3 = 0{,}762$; $D_4 = 3{,}234$; $D_5 = 2{,}106$;
2) $D_1 = 0{,}670$; $D_2 = 0{,}098$; $D_3 = 0{,}773$; $D_4 = 1{,}480$; $D_5 = 1{,}890$;
3) $D_1 = 0{,}375$; $D_2 = 0{,}102$; $D_3 = 0{,}810$; $D_4 = 6{,}653$; $D_5 = 1{,}172$.

To construct a binary logit model of creditworthiness, 50 industrial enterprises and wholesalers of the Republic of Tatarstan were filtered on the basis of "Interfax" - http://www.e-disclosure.ru/, a corporate disclosure site. The analysis was carried out using the Gretl 1.9.92. software.

3. Results

The research resulted in logit model (Figure 1)

```
Model 1: Logit, using observations 1-50
Dependent variable: Y
Standard errors based on Hessian

             coefficient   std. error      z         slope
  ------------------------------------------------------------
  const      -79.6730      58.2786      -1.367
  D1         -23.2395      13.7934      -1.685    -0.00856659
  D2          27.0698      33.5149       0.8077    0.00997852
  D3          97.7615      76.6194       1.276     0.0360371
  D4           0.374203     0.260902     1.434     0.000137940
  D5           9.15724      4.44209      2.061     0.00337556

Mean dependent var   0.780000   S.D. dependent var   0.418452
McFadden R-squared   0.827581   Adjusted R-squared   0.599837
Log-likelihood      -4.542454   Akaike criterion     21.08491
Schwarz criterion    32.55705   Hannan-Quinn         25.45356

Number of cases 'correctly predicted' = 48 (96.0%)
f(beta'x) at mean of independent vars = 0.000
Likelihood ratio test: Chi-square(5) = 43.6059 [0.0000]

           Predicted
             0    1
  Actual 0  10    1
         1   1   38

Excluding the constant, p-value was highest for variable 3 (D2)
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Figure 1. Logit model with binary variable Y

In the penultimate column (z), a ratio of assessment to the average value is given which can be interpreted as a change of direction of the likelihoods for all variables. Direction parameters (z) indicate that an increase in leverage ratio (D_1) as a negative parameter, the probability of loan approval for the enterprise decreases. With an increase in indicators such as return on sales, turnover ratio of current assets, financial stability and coverage - the probability of the loan approval increases. These findings do not contradict the assumptions of economic theory and the results of previous studies (Kuo, Huang, & Jhang, 2015; Liebwein, 2006).

Despite the large number of correctly predicted cases (48 of 50), P-values indicate the significance of only two factors: the dependency ratio and coverage ratio. To improve the model, we use the sequential elimination of omit variables.

Elimination of omit variables improved the three criteria used. Along with dependence and coverage ratios, significant for the study was a turnover ratio of current assets, which is actively used in the assessment of the solvency of the organization, when tendering, for example. As for return on sales, differences in competitive strategies and product lines cause considerable variety of values of this indicator in different companies, which makes it dependent on many other factors. The financial stability index is also not included in the list of important ones.

```
Sequential elimination using two-sided alpha = 0.10

 Dropping D2               (p-value 0.419)
 Dropping D3               (p-value 0.314)

Test on Model 1:

  Null hypothesis: the regression parameters are zero for the variables
    D2, D3
  Test statistic: F(2, 44) = 0.929708, p-value 0.402283
  Omitting variables improved 3 of 3 model selection statistics.

Model 2: Logit, using observations 1-50
Dependent variable: Y
Standard errors based on Hessian

             coefficient   std. error     z         slope
  ------------------------------------------------------------
  const       -5.64789      5.18483     -1.089
  D1         -20.3614      11.5324      -1.766   -0.139965
  D4           0.458335     0.249215     1.839    0.00315061
  D5           9.83127      4.54521      2.163    0.0675805

Mean dependent var   0.780000   S.D. dependent var   0.418452
McFadden R-squared   0.756142   Adjusted R-squared   0.604313
Log-likelihood      -6.424531   Akaike criterion     20.84906
Schwarz criterion    28.49715   Hannan-Quinn         23.76150

Number of cases 'correctly predicted' = 47 (94.0%)
f(beta'x) at mean of independent vars = 0.007
Likelihood ratio test: Chi-square(3) = 39.8417 [0.0000]

           Predicted
             0    1
  Actual 0   9    2
         1   1   38
```

Figure 2. Logit model with sequential elimination of variables using two-sided p-value which is equal to 0.1

The explaining properties of the model presented by McFadden R-squared and the adjusted R-squared, made up 75.61% and 60.43%, respectively. The number of predicted cases decreased by one and reached 94.04%.

We will test for collinearity problem (Figure 3).

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Variance Inflation Factors

Minimum possible value = 1.0
Values > 10.0 may indicate a collinearity problem

         D1    1.042
         D4    1.023
         D5    1.064

VIF(j) = 1/(1 - R(j)^2), where R(j) is the multiple correlation coefficient
between variable j and the other independent variables
```

Figure 3. Test for collinearity problem of D_1, D_4, D_5 variables

The values of the test show no collinearity problem between indicators. To assess the predictive capability of the model constructed as a measure of model's correspondence to empirical data, one can use the correlation coefficient between the variable Y_i and theoretical values of the model P_i. The result is shown below (Figure 4).

```
corr(Y, YR) = 0.87317614
Under the null hypothesis of no correlation:
 t(48) = 12.4117, with two-tailed p-value 0.0000
```

Figure 4. Calculation of the correlation coefficient between the actual and predicted values of the binary dependent variable Y

The correlation coefficient was 0.873, which confirms that the model corresponds to empirical data. Student's statistics (12.41) confirms the statistical significance of the correlation coefficient.

We will write down the final model:

$$Y = -5{,}648 - 20{,}361D_1 + 0{,}458D_4 + 9{,}831D_5 + \varepsilon$$

We will use the model constructed to select among the available candidates the ones who should be given credit in the first place.

$$1)\quad \hat{P}_i = \frac{1}{1+e^{-y_t^*}} = \frac{1}{1+e^{-(\beta_0+\sum_{j=1}^{k}\beta_i x_{ij}),}} = \frac{1}{1+e^{-5,648-20,361*0,534+0,458*3,234+9,831*2,106}} = 0,99999$$

$$2)\quad \hat{P}_i = \frac{1}{1+e^{-y_t^*}} = \frac{1}{1+e^{-(\beta_0+\sum_{j=1}^{k}\beta_i x_{ij}),}} = \frac{1}{1+e^{-5,648-20,361*0,670+0,458*1,480+9,831*1,89)}} = 0,4874$$

$$3)\quad \hat{P}_i = \frac{1}{1+e^{-y_t^*}} = \frac{1}{1+e^{-(\beta_0+\sum_{j=1}^{k}\beta_i x_{ij}),}} = \frac{1}{1+e^{-5,648-20,361*0,375+0,458*6,653+9,831*1,172)}} = 0,9007$$

Therefore, it is expedient to grant the loan to the first and third applicants, and it is not to the second.

4. Conclusions

The study found a statistical dependence of creditworthiness of industrial and wholesale enterprises on leverage ratio, turnover ratio of current assets, asset coverage ratio. It should be noted that due to differences in competitive strategies and product lines there is considerable diversity in the values of return on sales in different companies. Therefore, the ratio of return on sales depends on many other factors (Filippova, Khairullin, & Usanova, 2014; Strelnik, Usanova, & Ushakova, 2014; Pignataro, 2013; Sandstrom). The financial stability index is also not included in the list of importance. We can assume that for the negative coefficients before the variables D_i - the likelihood of obtaining the loan reduces, for positive ones, on the contrary, it increases. With an increase in indicators such as return on sales, turnover ratio of current assets, financial stability and coverage, the likelihood of obtaining the loan increases. These findings do not contradict the assumptions of economic theory.

In the present method of assessing the creditworthiness we used the factors which directly characterize the liquidity and solvency of the organization, which is why the resulting model is suitable for the rapid analysis of the creditworthiness of industrial enterprises and wholesale trade. To develop an integrated methodology in future studies, the authors recommend increasing the number of factors and sample size.

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