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ANALYSIS OF THE RELIABILITY OF MODELING THE RISK OF NON-FULFILLMENT BY BONDS

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Abstract

The analysis of the reliability of modeling the risk of default by Russian companies on bonds using boolean variables is carried out. There were analyzed 80 financial ratios, 80 average values of financial ratios for 2 years of companies' operation, as well as 28 indicators of the dynamics of the financial condition of companies. The developed mathematical models take into account the financial ratios that characterize the company's activities in the reporting year; relative deviations of financial indicators of the company's performance in comparison with the year preceding the reporting year; as well as the average values of the investigated financial ratios for 2 years of the company's operation. The developed logit model makes it possible to reliably assess the risk of default in 86% of the companies studied; the developed probit model allows to reliably assess the risk of default in 84% of the companies studied. The applicability of Boolean variables to the assessment of the risk of default by Russian companies on securities is investigated (Fisher's criterion is used). The ranking of Boolean variables according to the effectiveness of modeling the risk of default by Russian companies on bonds was carried out (the method of one-factor regression was used). A comparative analysis of the results of ranking Boolean variables and the previously obtained results of ranking other financial indicators in terms of the effectiveness of modeling the risk of default by Russian companies on bonds is also carried out.

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1. Introduction

The issue of bonds is one of the main ways large companies can attract borrowed funds. When making a decision to purchase the company's securities, the investor assesses the risk of default on financial obligations under the bonds. In Duplyakin and Boldyrev (2019), models are proposed for assessing the risk of default of Russian companies on bonds, developed using a three-step method. A sample of 96 Russian companies that have issued bonds on the Moscow Stock Exchange has been studied (Moscow Exchange, 2020). Of these, 48 companies fully fulfilled their financial obligations under securities. The other half of the companies defaulted on financial obligations within a year after the date on which the financial statements are analyzed. The data of the financial statements of companies for 2006 - 2015 were studied.

2. Problem Statement

To get a real picture of the fulfillment of their obligations on securities by Russian companies, it is necessary to conduct a comprehensive analysis of the financial risks associated with the issue of bonds. The core of the data in the study is information from the official website of PJSC Moscow Exchange. It is necessary to improve various ways and methods of assessing such risk situations. It is necessary to analyze a representative number of companies issuing securities. Algorithms for constructing the corresponding statistical models are required. We need an effective toolkit to check the reliability of the constructed risk models of default by Russian companies on bonds. Consideration should be given to the use of boolean variables in this study.

3. Research Questions

The research questions for this article were: What model for assessing the risk of default of Russian companies on bonds should be chosen? Can logit models and probit models be used to describe the processes under study? What statistics on stock statistics to choose for analysis (Moscow Exchange, 2020)? How to evaluate the quality of the constructed models. What factors should be chosen as arguments? How to analyze the reliability of modeling the risk of default? Can boolean variables be used for this purpose? What criteria should be used to rank Boolean variables?

4. Purpose of the Study

The purpose of this work is to analyze the reliability of modeling the default risk of Russian companies on bonds. Conduct this research using boolean variables. Develop mathematical models that take into account financial ratios characterizing the company's activities in the reporting year. Calculate the relative deviations of financial indicators of the company's performance in comparison with the year preceding the reporting one. Studied the average values of the investigated financial ratios for 2 years of the company (the reporting year and the year preceding the reporting year). Investigate the applicability of the analyzed Boolean variables to the assessment of the risk of default by Russian companies on bonds. To rank Boolean variables according to the effectiveness of their application in risk modeling.

5. Research Methods

The data obtained were investigated by methods of multivariate statistical analysis. Regression models of the studied processes are constructed. Logit-models and probit-models have been created that allow to reliably assess the risk of default of the companies under study (Duplyakin & Boldyrev, 2019). Basic concepts of Boolean algebra are used. The boolean variables were ranked according to the effectiveness of modeling the risk of default by Russian companies on bonds (the method of one-factor regression was used). A comparative analysis of the results of ranking Boolean variables is made. The result of ranking other financial indicators according to the effectiveness of modeling the risk of default by Russian companies on bonds.

6. Findings

According to the data obtained, the developed logit-model allows to reliably assess the risk of default in 86% of the companies studied; the developed probit model allows to reliably assess the risk of default in 84% of the companies studied (Duplyakin & Boldyrev, 2017).

At the same time, the five-factor model of Altman, the two-factor model of Altman, the model of Lego, Olson's (1980) model, Chesser's (1974) model, M's model Zmijewski (1984), Altman's model, adapted for Russian enterprises by Zaitseva (1998), two-factor and four-factor models of Kolyshkin (2003), applied to the assessment of the risk of default of Russian companies in securities, are characterized by the values of the efficiency index Ie, not exceeding 74%, according to the data obtained. The factors taken into account in the financial condition of companies in this study are shown in (Table 1).

Table 1. Factors taken into account in the financial condition of companies

№	Financial condition characteristics	Designation	Estimated formulas
I Factors of the financial condition of companies that characterize the assets of companies			
1	The size of the organization's assets	SOA	-
2	Fixed assets	FA	-
3	Unfinished production	UP	-
4	Fixed assets	FA	-
5	Current assets	CA	-
6	Stocks	S	-
7	Short-term receivables	SR	-
8	Short-term financial investments	SFI	-
9	The amount of the organization's funds	AOF	-
10	Receivables	R	-
11	Finished products	FP	-
12	Material assets	MA	$FA+S+FP+UP$
13	Own working capital	OWC	$OF+LD-FA$
II Factors of the financial condition of companies that characterize the liabilities of companies			
14	Own funds	OF	-
15	Retained earnings	RE	-
16	Borrowed capital	BC	-
17	Long term duties	LD	-
18	Short-term obligations	SO	-
19	Short-term payables	SP	-

20	Short-term loans and borrowings	*SLB*	-
21	Long-term loans and borrowings	*LLB*	-
	III Income, expenses and financial results of companies		
22	Revenue from the sale of products	*RSP*	-
23	Cost of goods and services sold	*CGS*	-
24	Total costs of production and sale of products	*TCPS*	-
25	Percentage to be paid	*PP*	-
26	Interest receivable	*IR*	-
27	Other income	*OI*	-
28	Gross profit	*GP*	-
29	Revenue from sales	*RS*	-
30	Profit before tax	*PBT*	-
31	The amount of the company's loss for the period under review	*ALP*	-
32	Net profit of the company for the period under review	*NPP*	-

Source: authors.

According to previous studies, Russian companies that have not fulfilled their obligations on bonds are characterized by an increased level of short-term and long-term debt, accounts receivable, as well as a decrease in sales proceeds, current assets, and profit (Duplyakin & Boldyrev, 2017). Boolean variables that take into account these patterns and are investigated in this work are shown in (Table 2).

Table 2. Investigated Boolean Variables

Boolean variable name	Designation	Checked condition
Variables characterizing the financial results of the company in the reporting year t		
Gross Profit Indicator	k_{GP}	$GP_t > 0$
Sales profit indicator	k_{RS}	$RS_t > 0$
Profit before tax indicator	k_{PBT}	$PBT_t > 0$
Net profit indicator	k_{NPP}	$NPP_t > 0$
Variables characterizing the financial condition of the company in the reporting year t		
Equity indicator	k_{OF}	$OF_t > BC_t$
Own working capital indicator	k_{OWC}	$OWC_t > 0$
Retained earnings indicator	k_{RE}	$RE_t > 0$
Indicator of short-term receivables	k_{SR}	$SR_t > SLB_t$
Long-term commitment indicator	k_{LD}	$LD_t > SO_t$
Variables characterizing the financial condition of the company in the reporting year t and the year preceding the reporting year, t-1		
Gross Profit Indicator	k_{GP2}	$GP_t > 0 \cap GP_{t-1} > 0$
Sales profit indicator	k_{RS2}	$RS_t > 0 \cap RS_{t-1} > 0$
Profit before tax indicator	k_{PBT2}	$PBT_t > 0 \cap PBT_{t-1} > 0$
Net profit indicator	k_{NPP2}	$NPP_t > 0 \cap NPP_{t-1} > 0$
Variables characterizing the financial condition of the company in the reporting year t and the year preceding the reporting year, t-1		
Equity indicator	k_{OF2}	$OF_t > BC_t \cap OF_{t-1} > BC_{t-1}$
Own working capital indicator	k_{OWC2}	$OWC_t > 0 \cap OWC_{t-1} > 0$
Retained earnings indicator	k_{RE2}	$RE_t > 0 \cap RE_{t-1} > 0$
Indicator of short-term receivables	k_{SR2}	$SR_t > SLB_t \cap SR_{t-1} > SLB_{t-1}$
Long-term debt indicator	k_{LD2}	$LD_t > SO_t \cap LD_{t-1} > SO_{t-1}$
Variables characterizing the dynamics of financial results and financial condition of the company		
Revenue dynamics indicator	$k_{\Delta RSP}$	$RSP_t < RSP_{t-1}$
Indicator of the dynamics of interest payable	$k_{\Delta PP}$	$PP_t < PP_{t-1}$

Indicator of the dynamics of the cost of goods and services sold	$k_{\Delta CGS}$	$CGS_t < CGS_{t-1}$
Indicator of the dynamics of the total costs of production and sales of products	$k_{\Delta TCPS}$	$TCPS_t < TCPS_{t-1}$
Net profit dynamics indicator	$k_{\Delta NPP}$	$NPP_t < NPP_{t-1}$
Indicator of the dynamics of short-term obligations	$k_{\Delta SO}$	$SO_t < SO_{t-1}$

Source: authors.

The analysis of the applicability of the boolean variables shown in Table 2 to the assessment of the default risk of Russian companies on bonds is carried out. We study a sample of 104 Russian companies that issued bonds on the Moscow Stock Exchange (Moscow Exchange, 2020), of which 52 companies fully fulfilled their financial obligations on securities ("stable" companies), the other 52 companies defaulted on financial obligations within a year after the date on which the financial reporting ("unstable" companies). The data of the financial statements of companies for 2006 - 2018 were studied.

The values of the Boolean variables shown in Table 2, which characterize the financial condition of enterprises in the study sample, have been calculated. The values of each variable are grouped according to the matrix shown in Table 3.

Table 3. Variable grouping matrix

Company group	Boolean value	
	"1"	"0"
"Stable"	A	B
"Unstable "	C	D

Source: authors.

For each boolean variable, hypothesis H1 is formulated: the samples for "stable" and "unstable" enterprises of the values of the boolean variable belong to different populations, that is, the studied variable can be used to assess the risk of default on bonds. When assessing the probability of fulfilling hypothesis H1, Fisher's test is used. This criterion is most often used in frequency analysis (Kryshtanovsky, 2007). Quantitative estimates of the probability of applicability of hypothesis H1 using the F-test are given in Table 4.

Table 4. Analysis of the applicability of boolean variables to assessing the risk of default by Russian companies on bonds

Boolean variable name	Designation	Probability of hypothesis applicability H1%
Variables characterizing the financial results of the company in the reporting year t		
Gross Profit Indicator	k_{GP}	96,0
Sales profit indicator	k_{RS}	>99,9
Profit before tax indicator	k_{PBT}	>99,9
Net profit indicator	k_{NPP}	>99,9
Variables characterizing the financial condition of the company in the reporting year t		
Equity indicator	k_{OF}	99,8
Own working capital indicator	k_{OWC}	32,6
Retained earnings indicator	k_{RE}	>99,9

Indicator of short-term receivables	k_{SR}	<0,01
Long-term commitment indicator	k_{LD}	85,3
Variables characterizing the financial condition of the company in the reporting year t and the year preceding the reporting year, t-1		
Gross Profit Indicator	k_{GP2}	91,0
Sales profit indicator	k_{RS2}	99,8
Profit before tax indicator	k_{PBT2}	>99,9
Net profit indicator	k_{NPP2}	>99,9
Variables characterizing the financial condition of the company in the reporting year t and the year preceding the reporting year, t-1		
Equity indicator	k_{OF2}	98,7
Own working capital indicator	k_{OWC2}	46,4
Retained earnings indicator	k_{RE2}	>99,9
Indicator of short-term receivables	k_{SR2}	31,5
Long-term debt indicator	k_{LD2}	<0,01
Variables characterizing the dynamics of financial results and financial condition of the company		
Indicator of the dynamics of short-term obligations	$k_{\Delta SO}$	88,7
Revenue dynamics indicator	$k_{\Delta RSP}$	98,5
Indicator of the dynamics of interest payable	$k_{\Delta PP}$	99,5
Indicator of the dynamics of the cost of goods and services sold	$k_{\Delta CGS}$	86,4
Indicator of the dynamics of the total costs of production and sales of products	$k_{\Delta TCPS}$	71,2
Net profit dynamics indicator	$k_{\Delta NPP}$	>99,9

Source: authors.

As the range of confident application of the hypothesis H1, the range of values p ∈ [85; 100]. The ranking is carried out (Eliseeva et al., 2007) of Boolean variables for which this condition is met, according to the effectiveness of modeling the risk of default by Russian companies on bonds (Makarov, 2020). For each Boolean variable, a linear regression equation is constructed using the standardized values of the variables:

$$y = b_0 + b_1 x,$$

where x is the Boolean variable under study, y is a boolean explainable variable. If the company has not fulfilled its financial obligations within a year after the date on which the reporting data are analyzed, then the variable takes on the value 1, if the company has fulfilled its financial obligations on securities, then the variable takes on the value 0.

The problems of the practical application of regression analysis in economic forecasting are also analyzed in (Boldyrev, 2018). Boolean variables are ranked modulo the values of the coefficients b1 of the regression equation. The results of ranking the studied Boolean variables modulo the coefficients b_1 of the regression equation are shown in Table 5.

Table 5. Ranking of Boolean variables according to the effectiveness of modeling the risk of default by Russian companies on bonds

Boolean variable name	Designation	Coefficient $\lvert b_1 \rvert$
Variables characterizing the financial results of the company in the reporting year t		
Gross Profit Indicator	k_{GP}	0,04
Sales profit indicator	k_{RS}	0,06
Profit before tax indicator	k_{PBT}	0,90

Net profit indicator	k_{NPP}	0,06
Variables characterizing the financial condition of the company in the reporting year t		
Equity indicator	k_{OF}	0,81
Retained earnings indicator	k_{RE}	0,04
Long-term commitment indicator	k_{LD}	0,05
Variables characterizing the financial condition of the company in the reporting year t and the year preceding the reporting year, t-1		
Gross Profit Indicator	k_{GP2}	0,05
Sales profit indicator	k_{RS2}	0,59
Profit before tax indicator	k_{PBT2}	0,03
Net profit indicator	k_{NPP2}	0,03
Variables characterizing the financial condition of the company in the reporting year t and the year preceding the reporting year, t-1		
Equity indicator	k_{OF2}	0,03
Own working capital indicator	k_{OWC2}	0,06
Retained earnings indicator	k_{RE2}	0,06
Variables characterizing the dynamics of financial results and financial condition of the company		
Indicator of the dynamics of short-term obligations	$k_{\Delta SO}$	0,04
Revenue dynamics indicator	$k_{\Delta RSP}$	0,06
Indicator of the dynamics of interest payable	$k_{\Delta PP}$	0,10
Indicator of the dynamics of the cost of goods and services sold	$k_{\Delta CGS}$	0,15
Net profit dynamics indicator	$k_{\Delta NPP}$	0,17

Source: authors.

The largest values of the coefficient $|b_1|$ the indicator of profit before taxation k_{PBT} and the indicator of equity capital k_{OF}, taking into account the factors of the financial condition of the company in the reporting year t, as well as the indicator of profit from sales k_{RS2}, characterizing the financial condition of the company in the reporting year t and the year preceding the reporting year t-1.

Thus, a positive amount of pre-tax profit *PBT* is characteristic of "stable" companies, a negative amount of profit before tax *PBT* (loss) is characteristic of "unstable" companies. Also for "stable" companies, according to the data obtained, the excess of the equity capital of the *OF* over the value of the borrowed capital of the *BC* is characteristic. The excess of the equity capital of the *BC* over the equity capital of the *OF* is typical for "unstable" companies.

You can also note the value of the coefficient $|b_1| = 0.59$, which characterizes the effectiveness of modeling the default risk of Russian companies using the profit from sales indicator, which characterizes the financial condition of the company in the reporting year and the year preceding the reporting year, k_{RS2}. Thus, "unstable" companies are characterized by a loss from sales - negative values of the profit from sales of *RS*, according to the data obtained.

A comparative analysis of the results of ranking Boolean variables by the effectiveness of modeling the risk of default by Russian companies on bonds and the results of ranking financial indicators obtained earlier in the construction of a logit model and a probit model of the risk of default by Russian companies on bonds (Boldyrev, 2018).

In work, 80 financial ratios, 80 average values of financial ratios for 2 years of the company's operation and 28 indicators of the dynamics of the financial condition of companies are analyzed (Duplyakin, & Boldyrev, 2019). Let *a, b* be the factors of financial condition. Then the average value of

the financial coefficient $k = a / b$ for 2 years of operation of the organization (the reporting year and the year preceding the reporting year) is calculated by the formula:

$$\bar{k} = \frac{\frac{a_t + a_{t-1}}{2}}{\frac{b_t + b_{t-1}}{2}} = \frac{a_t + a_{t-1}}{b_t + b_{t-1}}.$$

Let a_t be a financial condition factor characterizing the work of the organization in the year t. Then the indicator of the dynamics of the value of the financial condition factor a in comparison with the year preceding the reporting year (the relative deviation of the indicator value) $\Delta_\% a$ is calculated by the formula:

$$\Delta_\% a = \frac{a_t - a_{t-1}}{a_{t-1}}.$$

Financial indicators characterized by the highest values of the coefficient $|b_1|$, according to the data obtained (Boldyrev, 2018), are shown in Table 6.

Table 6. Ranking of financial indicators by the effectiveness of modeling the risk of default by Russian companies on bonds

Characteristics of the financial condition of the company	Designation	Formula	Coefficient $\lvert\mathbf{b_1}\rvert$
I Indicators of the dynamics of the company's financial condition			
Revenue from the sale of products	$\Delta_\% RSP$	$\dfrac{RSP_t - RSP_{t-1}}{RSP_{t-1}}$	0,229
Retained earnings	$\Delta_\% RE$	$\dfrac{RE_t - RE_{t-1}}{RE_{t-1}}$	0,187
II Financial ratios			
Return on assets on profit before tax	R_{PBT}^{SOA}	$\dfrac{PBT}{SOA}$	0,478
Return on assets by net profit	R_{NPP}^{SOA}	$\dfrac{NPP}{SOA}$	0,454
Coefficient security of short-term liabilities with profit from sales	k_{RS}	$\dfrac{RS}{SO}$	0,368
III Average values of financial ratios for 2 years of the organization			
Coefficient accumulated profit	$\overline{k_{RE}}$	$\dfrac{RE_t + RE_{t-1}}{SOA_t + SOA_{t+1}}$	0,496
Return on current assets by net profit	$\overline{R_{RS}^{CA}}$	$\dfrac{RS_t + RS_{t-1}}{CA_t + CA_{t+1}}$	0,420
Return on assets by profit from sales	$\overline{R_{RS}^{SOA}}$	$\dfrac{RS_t + RS_{t-1}}{SOA_t + SOA_{t+1}}$	0,411

Source: authors.

Analysis of Table 5 and Table 6 allows us to conclude that the values of the coefficient $|b_1|$ characterizing the effectiveness of modeling the default risk of Russian companies using the profit before tax indicator k_{PBT}, the indicator of equity capital k_{OF} and the indicator profit from sales k_{RS2}, exceed the values of the coefficient $|b_1|$ previously studied financial indicators.

7. Conclusion

The key findings of the evaluation:

- the analysis of the effectiveness of modeling the risk of default by Russian companies on bonds using boolean variables;

- the applicability of the analyzed boolean variables to the assessment of the risk of default by Russian companies on bonds has been studied;

- the ranking of the analyzed logical variables was carried out according to the effectiveness of modeling.

- according to the data obtained, the value of the coefficient | b1 |, which characterizes the efficiency of modeling the default risk of Russian companies using the indicator of profit before tax, the indicator of equity capital and the indicator of profit from sales, exceeds the value of the coefficient | b1 | previously studied 188 financial indicators.

We studied a sample of 104 Russian companies that issued bonds on the Moscow Exchange, of which 52 companies fully fulfilled their financial obligations on securities ("stable" companies), the other 52 companies defaulted on financial obligations within a year after the date on which the financial reporting ("unstable" companies). The data of the financial statements of companies for 2006 - 2018 were studied. These data are representative of the corresponding models. One of the ways to further increase the reliability of the developed models for assessing the risk of default by Russian companies in securities is the use of Boolean variables in the models, i.e. variables that take the value "1" or "0" depending on the values of indicators of financial and economic activity. The explained variable in the developed models is also Boolean, which determines the relevance of the study of the reliability of modeling the risk of default by Russian companies in securities using such variables. According to the study, when modeling the risk of default of Russian companies on bonds, the use of Boolean variables is advisable.

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