Evaluation of the functionality of bankruptcy models in mining companies

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Abstract
Mining companies are an important part of the national industry of the Czech Republic. Since mining companies are important for the industry, it is necessary to predict their economic development. Moreover, forecasting the economic development of an enterprise in terms of the risk of bankruptcy is an important activity for the financial management of any enterprise. One of the ways to predict economic development and assess the risk of possible bankruptcy is to use bankruptcy models. The aim of this paper is to determine the most appropriate model for predicting the bankruptcy risk of a mining company. The subject of the article is to identify the most suitable bankruptcy models applicable for bankruptcy risk prediction in Czech conditions of mining enterprises and to verify their functionality on real data of mining enterprises. On the basis of a search of expert sources and comparative analysis, it was found that the most suitable models for predicting the development of the enterprise in terms of bankruptcy risk are modified versions of traditional bankruptcy models. The analysis showed that the bankruptcy models are the IN05 Index, Altman's analysis for Czech companies and the modified Taffler's index. The authors' team conducted a thorough analysis during which they verified the functionality of the selected bankruptcy models on real data of mining companies. After a thorough analysis to test the functionality of bankruptcy models on real data from mining companies, the most appropriate model for estimating the evolution of bankruptcy probability risk was identified.

Keywords
bankruptcy model, IN05 index, modified Taffler's index, Altman's analysis, mining company.

Introduction

The main reason for selecting appropriate bankruptcy models, examining and demonstrating the functionality of the selected bankruptcy models and determining their predictive power on mining companies is the fact that it is necessary to predict the development of companies in terms of the probability of bankruptcy in the field of mineral extraction. Machek (2014) states that bankruptcy models are a suitable tool for predicting the financial distress of a company. Enterprises in the mining industry are very sensitive to the economic cycle and also to global crises. It is necessary to realise how important minerals are for everyday life.

There are a number of traditional models for determining a company's financial situation. Kim, Cho and Ryu (2021) investigated whether the prediction of corporate bankruptcy can be improved. A number of foreign authors and research teams from Europe and beyond are exploring methods for a comprehensive assessment of creditworthiness and bankruptcy risk. Many foreign authors have been engaged in validating traditional bankruptcy models on their national firms; for example, Stryukov et al. (2020) assessed the bankruptcy risk of Russian industrial firms based on the Altman analysis and Taffler index also Dakovic, Czabo and Berg (2010) validated models suitable for predicting the bankruptcy of Norwegian firms. Zadnanova and Vagner (2019) validated traditional models to predict the financial situation of Slovak firms in different industries. Matviychuk (2010) developed a methodological approach to conduct a comprehensive analysis of the financial condition of Ukrainian enterprises.

Dvořáček et al. (2012) also dealt with the issue of monitoring and forecasting the economic development of mining companies in their study. They assessed the economic development of mining companies on a sample of companies that are currently operating and companies that have ceased their business activities. Also, Vaněk et al. (2021) conducted benchmarking research on Czech mining enterprises, using traditional methods of financial analysis and applied bankruptcy models. Chlopecký et al. (2019) emphasise in their paper that conducting economic analysis is important for strategic decision-making, and it is desirable to deal with the analysis of bankruptcy models as part of the financial analysis of the company to predict the possible bankruptcy of the company. At the same time, monitoring the financial situation of the company, thus the area of risk of imminent bankruptcy is a certain competitive advantage; this statement is based on Teplická et al. (2021), which evaluated the performance indicators of mining processes and described their importance for performance management in mining companies and gaining competitiveness in the market of mining companies in the direction of sustainable development and economic growth. Also, Čulková et al. (2018) and Manová et al. (2018), in measuring the economic efficiency of the company, emphasise that maintaining optimal levels of indicators of financial stability and activity are tools for achieving competitiveness in the market. Research by Čámská (2014) shows that existing models that predict financial distress still have sufficient predictive power and accuracy, and therefore there is no need to create new ones. Thus, it is only necessary to select the models to those that are appropriate for a particular industry and business location. No author has examined in detail the investigation and determination of appropriate methods for predicting the risk of bankruptcy of a mining company and verifying the performance of these methods on a real sample of mining companies.

The paper's main objective is to demonstrate the functionality of the selected bankruptcy models and to define their predictive power on selected mining industry enterprises. In order to fulfil the main objective, the selection of the most appropriate models through comparative analysis must be managed. The main importance of identifying appropriate bankruptcy models and verifying their performance on selected mining companies is that they are a suitable tool for predicting the bankruptcy risk of the analysed company.

Material and Methods

The aim of the paper is to determine the most appropriate model for bankruptcy risk prediction for mining companies from The Branch Classification of Economic Activities CZ-NACE 10-14 - Mining of mineral resources. In order to achieve the objective of the paper, it is necessary to determine the traditional bankruptcy models, select from them the appropriate models applicable to the subject category of enterprises and verify their functionality on real data to obtain one suitable model for bankruptcy risk prediction.

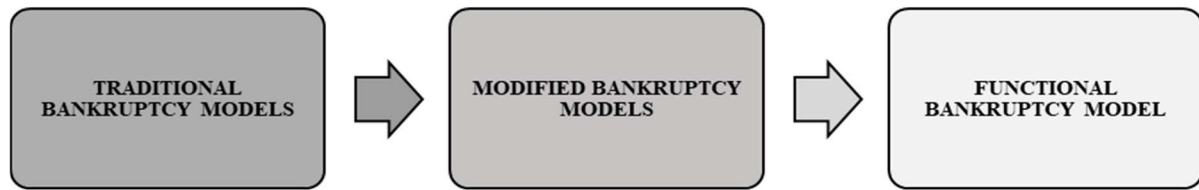The following figure shows a diagram of the methodological approach used:

Fig. 1. Procedure of applied methodological steps

Firstly, the traditional bankruptcy models were identified from which suitable bankruptcy models were selected using a comparative suitability analysis. Suitable modified bankruptcy models were selected on the basis of the parameters (ownership of the enterprise, size of the enterprise, subject of business, territory of business activity). These are modified bankruptcy models applicable to Czech companies. The following modified bankruptcy models corresponded to the given parameters:
- IN Index,
- Altman's model,
- Taffler's index.

Secondly, items from the extracted financial statements of the mining companies were inserted into the application equations of these modified bankruptcy models. One hundred and eight mining companies were the subject of the analysis; these were the forty-four mining companies that ceased operations between 2008 and 2020 and the sixty-two mining companies that continued to operate.

Forty mining enterprises were selected from the original one hundred and eight enterprises analysed for which the accounting data was comprehensive, and the enterprises were suitable for further research. These were the twenty mining enterprises that ceased operations between 2008 and 2020 and the twenty mining enterprises that continued in business after 2020.

In order to be subject to the analysis of the verifiability of the functionality of bankruptcy models, the following conditions had to be met:
- An enterprise from the category CZ-NACE 10-14 - Mining and quarrying of minerals.
- Completeness of accounting data is required for the calculation of modified bankruptcy models for three consecutive periods.
- The size of enterprises (representation of SMEs and large enterprises).
- The time of business activity.

Also, in order to be included in the analysis, enterprises that did not continue in business activity subject to the analysis of the verifiability of the functionality of bankruptcy models had to meet certain conditions:
- An enterprise in CZ-NACE 10-14 - Mining and quarrying.
- Cessation of business activity between 2008 and 2020.
- The time of business activity. (Completeness of accounting data is required for the calculation of the modified bankruptcy models for three consecutive periods prior to the year of cessation of business activity).
- The size of enterprises (representation of SMEs and large enterprises).

In order to test the functionality of bankruptcy models for bankruptcy risk prediction for Czech mining companies, three modified bankruptcy models were selected. Each bankruptcy model has an application formula into which the accounting values from the financial statements for the period under consideration are inserted. The following application formulas (1), (2) and (3) were used to calculate the modified bankruptcy models.

Furthermore, for all forty subject companies, the output values were calculated based on the application formulas of the modified bankruptcy models for the three consecutive periods studied, see Tab. 4, 6, 8, 10, 12 and 14. The output values, further, were compared with the scorecards Tab. 1, 2 and 3. The assessment was carried out for both categories of mining enterprises, both continuing and discontinued enterprises. Tab. 5, 7, 9, 11, 13 and 15 were produced for both categories of enterprises with the resulting percentage rating of their accuracy in the years under review. Based on all the analyses performed, the most appropriate bankruptcy model was selected to predict the bankruptcy risk of mining companies; see Tab. 16 for a comparison of the three modified bankruptcy models.

Altman's model

This model was developed in 1968 primarily for publicly traded companies and has been modified over time. For the Czech market conditions, Altman's model was also modified to reflect best the shape of our national

business (Altman and Hotchkiss, 2006). A modified Altman's model for Czech enterprises was used for the analysis.

Application formula of Altman's model for Czech enterprises (Vochozka, 2020):

$$Z_{cz} = 3.3 * \frac{EAT}{assets} + 0.99 * \frac{revenues}{assets} + 0.6 * \frac{equity}{total\ liabilities} + 1.4 * \frac{EBIT}{assets} + 6.56 * \frac{net\ working\ capital}{assets} - 1 * \frac{overdue\ liabilities}{revenue} \quad (1)$$

Items from balance sheets and profit and loss statements of selected mining companies for the analysed periods are inserted into the modified Altman's model formula. These items are: profit before tax (EAT), total assets, revenues from operating activities, the value of equity capital, the value of current and non-current liabilities expressed as total liabilities, retained earnings (EBIT), net working capital, which is expressed as current assets less current liabilities, as well as overdue liabilities and revenue expressed as revenue from operating activities.

The modified version of Altman's model for Czech firms has several features identical to the original Altman's model. The main change is a significant increase in the coefficient used to multiply net working capital divided by assets. In addition, the Czech modification of Altman's model adds a sixth ratio, which includes past-due liabilities divided by revenues. This sixth parameter was added to the equation to prevent corporate insolvency.

The evaluation of Altman's model for Czech companies is presented in Tab. 1.

Tab. 1. Evaluation of Altman's model for Czech companies (Vochozka, 2020)

RESULT	RATING
$Z_{CZ} \in\ <2.99; \infty)$	creditworthy enterprise
$Z_{CZ} \in (1.8; 2.99)$	grey area
$Z_{CZ} \in (-\infty; 1.8>$	bankrupt enterprise

IN05 Index

In 1995, Inka and Ivan Neumaier created the IN95 Index. It was then modified three times. The latest modification is from 2005, when the formula has five parameters with the highest weight given to the return on total assets ratio (Neumaier and Neumaier, 2002). For the purpose of the analysis, a modified IN Index was used, namely, the IN05 Index.

Application formula of the IN05 index (Vochozka, 2020):

$$IN05 = 0.13 * \frac{assets}{foreign\ capital} + 0.04 * \frac{EAT}{interest\ costs} + 3.97 * \frac{EAT}{assets} + 0.21 * \frac{revenues}{assets} + 0.09 * \frac{current\ assets}{short\ term\ foreign\ capital} \quad (2)$$

The IN05 Index application formula includes items from balance sheets and profit and loss statements of selected mining companies for the periods analysed. These items are the total assets, the sum of foreign capital, profit before tax (EAT), the value of interest costs, the value of income as revenues from operating activities, the value of current assets and the value of short-term foreign liabilities, which is expressed in terms of short-term foreign capital of the enterprise.

The modified version of the IN05 Index has the narrowest grey area compared to the previous IN indices. The model is primarily built for Czech conditions, and its indicators are applied on the basis of Czech accounting standards.

The evaluation of the IN05 Index is presented in Tab. 2.

Tab. 2. Evaluation of the IN05 Index (Vochozka, 2020)

RESULT	RATING
$IN05 \in\ <1.6; \infty)$	creditworthy enterprise
$IN05 \in (0.9; 1.6)$	grey area
$IN05 \in (-\infty; 0.9>$	bankrupt enterprise

Taffler's index

Taffler's index was created in response to Altman's analysis. It was primarily tested on a sample of UK businesses, identifying four key ratios. Over time, the index was modified, and the last ratio was adjusted.

In the original Taffler's index, the grey area as the range between creditworthiness and bankruptcy was missing. In the modified version of Taffler's index, the grey zone range is already included in the assessment. The modified Taffler's index was used for the analysis.

Application formula of the modified Taffler's index:

$$T = 0.53 * \frac{EAT}{short\ term\ liabilities} + 0.13 * \frac{current\ assets}{foreign\ capital} + 0.18 * \frac{short\ term\ liabilities}{assets} + 0.16 * \frac{revenues}{assets} \quad (3)$$

The modified Taffler's index formula includes items from balance sheets and profit and loss statements of selected mining companies for the analysed periods. These items are profit before tax (EAT), the value of short-term liabilities, current assets, foreign capital, total assets, value of current liabilities and size of revenues from core business.

The evaluation of the modified Taffler's index is presented in Tab. 3.

Tab. 3. Evaluation of the modified Taffler's index

RESULT	RATING
$T \in (0.3; \infty)$	creditworthy enterprise
$T \in< 0.2; 0.3 >$	grey area
$T \in (-\infty; 0.2)$	bankrupt enterprise

Results

Results of Altman's analysis of companies that have gone out of business

Values from the financial statements (balance sheets and profit and loss statements) of selected Czech mining companies that have ceased operations were analysed for three consecutive periods and entered into the application formula (1) of Altman's analysis for Czech companies and then calculated. The resulting values are presented in Tab. 4.

Tab. 4. Results of Altman's analysis of companies that have gone out of business

	ALTMAN'S ANALYSIS OF CZECH COMPANIES		
COMPANIES	PERIOD		
	t_1	t_2	t_3
1	2.19	1.21	0.89
2	-8.84	-9.33	-0.12
3	-4.16	-3.38	-3.79
4	5.17	6.42	5.18
5	2.35	-2.42	-0.47
6	2.38	-0.26	2.05
7	8.20	4.73	0.56
8	-20.55	-19.75	-19.75
9	6.13	5.26	3.32
10	0.82	-1.92	-17.64
11	6.21	5.10	4.50
12	0.66	-0.14	-9.64
13	1.26	-1.56	-1.65
14	8.21	10.72	10.70
15	-8.12	-17.53	-24.63
16	-2.14	-1.77	-2.86
17	5.31	-35.15	-49.42
18	1316.17	65.02	89.57
19	-12.45	-12.46	-19.68
20	-6.16	-8.24	-9.19

Based on the calculations, Tab. 4 was created, which contains the results of Altman's analysis for Czech companies. For the twenty mining companies that have ceased operations. The result of Altman's equation is to determine, based on the values obtained, whether the enterprise is creditworthy or in the grey zone or whether it is at risk of bankruptcy. Since all the enterprises analysed in this table have indeed ceased operations, it is realistic to indicate what percentage of predictive power the application of the model has in practice on enterprises in the mining sector.

Tab. 5 shows the percentage of Altman's analysis performance for mining companies that have ceased operations. The percentage of the risk level is determined for each period analysed.

Tab. 5. Expression of the functionality of Altman analysis for Czech enterprises that have gone out of business

[%]	PERIOD		
	t_1	t_2	t_3
creditworthy enterprise	35	35	30
grey area	15	0	5
bankrupt enterprise	50	65	65

Table 5 shows that according to Altman's analysis of Czech enterprises three years before the closure of operations, 50% of the firms report values indicating the firm's bankruptcy. Altman's analysis value for Czech firms two years before the closure of the firms was 65%, and one year before the closure of the firms, Altman's analysis value indicated a risk of bankruptcy for 60% of the analysed firms. In conclusion, this analysis shows that the modified Altman's analysis designed for Czech enterprises is applicable to Czech mining enterprises on a sample of twenty enterprises with an accuracy between 50 and 65%.

Results of the IN05 Index of companies that have gone out of business

The values from the data obtained from the financial statements of the Czech mining companies that have ceased operations were analysed for three consecutive periods and fed into the application formula (2) of the IN 05 Confidence Index and then calculated. The resulting values are presented in Tab. 6.

Tab. 6. Results of the IN05 Index of companies that have gone out of business

INDEX IN05			
COMPANIES	PERIOD		
	t_1	t_2	t_3
1	0.94	-0.44	-10.88
2	-1.08	-1.04	-1.77
3	-0.57	-1.14	8.90
4	-5.62	2.41	-51.12
5	-55.86	-573.54	0.21
6	-0.87	-3.62	2.07
7	-36.99	-5.29	-28.01
8	-23.89	0.06	0.06
9	420.94	-85.89	2.05
10	0.52	-1.54	-6.94
11	185.94	2.64	-7.28
12	0.30	0.12	-4.03
13	0.52	-0.78	0.38
14	8.52	-12.81	-27.51
15	-1225.10	-271.03	-167.33
16	-33.61	-2.68	-3.96
17	-87.57	-117.75	-124.41
18	-30.59	-0.15	-0.68
19	-35.79	-49.62	-45.05
20	0.05	-0.05	-0.14

It is clear from Tab. 6 that the IN05 Index results predicted a higher probability of bankruptcy compared to the results found by Altman's analysis for Czech enterprises. In addition, none of the enterprises monitored using the IN05 Index showed good creditworthiness in more than one period, whereas Altman's analysis shows good creditworthiness for five enterprises, which is not really consistent since we know that the enterprises have actually gone out of business.

Tab. 7 shows the percentage performance of the IN05 Index for the three periods under review for Czech mining companies.

Tab. 7. Expression of the functionality of Index IN05 of enterprises that have gone out of business

[%]	PERIOD		
	t_1	t_2	t_3
creditworthy enterprise	15	10	15
grey area	5	0	0
bankrupt enterprise	80	90	85

Three years prior to the closure of the IN05 Index, 80% of the companies showed values indicating that the company would go bankrupt. The IN05 index value was as high as 90% two years before the closure. Ninety per cent of the firms analysed had IN05 values indicating bankruptcy two years in advance. One year before the closure, the IN05 Index value indicated bankruptcy for 85% of the analysed companies. In conclusion, this analysis shows that the IN05 Index is applicable to Czech mining companies and has a high predictive power, where the IN05 Index predicts the bankruptcy rate of a company really reliably. The value of the index for the twenty analysed enterprises reached an accuracy of 80% to 90%.

Results of the modified Taffler's index of companies that have gone out of business

The values from the financial statements of the subject mining companies that have ceased operations were examined for three consecutive periods and entered into the application formula (3) of the modified Taffler's index and then calculated. The resulting values are presented in Tab. 8.

Tab. 8. Resulting values of the modified Taffler's index of companies that have gone out of business

COMPANIES	MODIFIED TAFFLER'S INDEX		
	PERIOD		
	t_1	t_2	t_3
1	2.18	0.66	0.43
2	0.79	0.74	-0.04
3	0.88	0.97	0.97
4	2.47	2.18	-0.11
5	0.45	0.18	0.47
6	2.22	2.26	3.08
7	2.02	2.10	0.20
8	0.78	0.90	0.90
9	1.60	0.66	0.79
10	0.49	0.36	0.47
11	2.00	1.51	1.23
12	1.09	0.97	0.09
13	1.40	2.02	1.80
14	3.95	4.17	0.78
15	0.48	1.23	1.32
16	0.39	0.48	0.43
17	-3.87	2.56	2.05
18	-28.61	1.49	0.56
19	2.48	1.62	1.80
20	0.72	0.66	0.70

Based on the calculations of the modified Taffler's index, it was found that only four firms are at risk of bankruptcy, according to the Taffler index prediction. Given that all of the companies in question have actually ceased operations, it is clear that the use of Taffler's index is completely inappropriate for Czech mining companies.

Tab. 9 shows the percentage performance of the modified Taffler's index for individual periods for selected Czech mining companies that have closed down.

Tab. 9. Expression of the functionality of the modified Taffler's index of enterprises that have gone out of business

[%]	PERIOD		
	t_1	t_2	t_3
creditworthy enterprise	90	100	85
grey area	0	0	5
bankrupt enterprise	10	0	10

It was found that the value of the modified Taffler's index three years prior to the closure of the business for 10% of the companies showed values indicating the bankruptcy of the company. The IN05 index values two years prior to the closure of the firms did not indicate bankruptcy for any of the firms analysed. One year before the closure, the modified Taffler's index value indicated bankruptcy for only 10% of the analysed firms. In conclusion, this analysis shows that the modified Taffler's index is not applicable to Czech mining companies.

The index has almost no predictive power as all the analysed enterprises have gone out of business but based on the prediction of the modified Taffler's index, only 10% of the analysed enterprises were warned of bankruptcy.

Results of Altman's analysis for Czech companies that continue their business activities

The values from the financial statements of mining companies that continue in business were examined for three consecutive periods, entered into Altman's analysis application formula for Czech companies (1) and then calculated. The resulting values of Altman's analysis for Czech enterprises are shown in Tab. 10.

Tab. 10. Results of Altman's analysis for Czech companies that continue their business activities

ALTMAN'S ANALYSIS OF CZECH COMPANIES			
COMPANIES	PERIOD		
	t_1	t_2	t_3
1	4.24	4.46	4.19
2	11.08	8.01	8.96
3	39.16	29.23	18.22
4	0.47	7.30	7.52
5	3.72	2.94	3.83
6	-5.09	-6.70	-13.85
7	7.11	0.51	3.93
8	1.17	-3.87	-3.15
9	1.98	1.65	2.86
10	1.46	1.91	3.98
11	7.29	9.78	10.26
12	5.35	6.38	5.56
13	4.97	5.16	3.66
14	1.64	1.22	1.56
15	6.07	8.79	5.13
16	7.36	4.93	7.94
17	1.74	2.06	1.99
18	0.26	0.00	0.78
19	9.70	9.51	32.70
20	-2.80	-9.39	-7.03

Based on the calculations, Tab.10 was created with the results of Altman's analysis for Czech companies. The calculations were carried out on the twenty mining companies under study that continues to operate. The indicator is intended to determine, on the basis of the values obtained, whether the enterprise is creditworthy, in the grey zone or at risk of bankruptcy. Since all the enterprises analysed in this table continue their activity, it is realistic to indicate what percentage predictive power the application of the model has in practice on real data of mining enterprises.

Tab. 11 shows the percentage of Altman's analysis functionality for Czech companies for the three periods under review for selected Czech mining companies that continue their business activities.

Tab. 11. Expression of the functionality of Altman's analysis for Czech enterprises that continue their business activities

[%]	PERIOD		
	t_1	t_2	t_3
creditworthy enterprise	55	50	65
grey area	5	20	10
bankrupt enterprise	40	30	25

Based on the results, it was found that the value of Altman's analysis for Czech enterprises for three periods back reached the following values, namely, three years back, 55% of the analysed enterprises threw out the rating that it is a creditworthy enterprise. Two years back, Altman's analysis value showed creditworthiness for only 55% of the analysed enterprises. One year back, Altman's analysis rating for the subject enterprises was 65%, i.e. 65% of the analysed enterprises are rated as creditworthy on the basis of the modified Altman's analysis for Czech enterprises. In conclusion, this analysis shows that the modified Altman's analysis had an accuracy rating between 50% and 65%. Even 25% of the analysed enterprises showed values for three consecutive periods that indicate bankruptcy values based on Altman's analysis assessment.

Results of the IN05 Index for companies that continue their business activities

In the application formula (2) of the IN05 Index, the numerical values from the financial statements of the selected mining companies were entered. Tab. 12 shows the results of the IN05 Index application formula for three consecutive periods for mining companies that continue their business activities.

Tab. 12. Results of IN05 Index values of companies that continue their business activities

COMPANIES	INDEX IN05		
	PERIOD		
	t_1	t_2	t_3
1	1.30	1.05	0.89
2	5.29	12.05	9.64
3	11.04	7.90	4.18
4	0.66	1.67	69.12
5	9.21	-1.40	1.74
6	-15.89	-1.63	-5.86
7	2.81	0.71	0.09
8	-5.11	-5.29	-3.59
9	1.59	1.91	2.30
10	0.68	0.65	2.53
11	454.15	526.51	494.54
12	2.49	-4.05	1.28
13	2.08	0.95	0.84
14	0.51	0.59	0.34
15	2.83	3.73	2.14
16	2.48	0.91	11.46
17	133.31	43.64	32.27
18	0.34	0.37	0.38
19	2.58	2.54	11.31
20	-0.39	-0.95	-2.08

Based on the calculations performed, Tab. 12 was created with the results of the IN05 Index. The calculations were performed for the twenty mining companies surveyed that continue to operate. On the basis of the values obtained, we determine whether the enterprise is creditworthy or in the grey zone or whether it is at risk of bankruptcy. Since all the enterprises analysed in this table continue their activity, it is realistic to indicate what percentage of predictive power the model has in practice.

From the calculated values of the IN05 Index for mining companies for the three periods under review, the following Tab. 13 is established with the percentage expression of the functionality of the IN05 Index on real data of Czech mining companies.

Tab. 13. Expression of the functionality of the IN05 Index for enterprises that continued their business activities

[%]	PERIOD		
	t_1	t_2	t_3
creditworthy enterprise	55	40	55
grey area	10	15	5
bankrupt enterprise	35	45	40

Based on the results, it was found that the functionality of the IN05 Index over the three look-back periods was as follows: three years back, 55% of the enterprises analysed were rated as creditworthy. Two years back, the index value showed creditworthiness for only 40% of the analysed enterprises. One year back, the index rating was 55%, i.e. 55% of the analysed enterprises are rated as creditworthy on the basis of the IN05 Index. In conclusion, this analysis shows that the IN05 Index showed an accuracy rating between 40% and 55%. Even 25% of the analysed companies showed values for three consecutive periods that indicate bankruptcy values based on the IN05 Index assessment.

Results of the modified Taffler's index for continuing enterprises

Tab. 14 presents the results of the application of formula (3) of the modified Taffler's index for three consecutive periods for mining companies that continued in business when the relevant values from the financial statements of the mining companies were entered into the application formula of the model in question.

Tab. 14. Resulting values of the modified Taffler's index of companies that continue their business activities

COMPANIES	MODIFIED TAFFLER'S INDEX		
	PERIOD		
	t_1	t_2	t_3
1	1.80	1.63	1.47
2	6.95	3.77	4.44
3	53.45	36.94	18.96
4	1.24	3.50	3.97
5	1.54	1.07	1.27
6	-2.07	0.31	0.15
7	3.73	0.67	0.75
8	1.32	1.18	1.27
9	1.47	1.41	1.71
10	1.14	1.25	1.70
11	2.65	3.49	3.53
12	2.23	2.08	1.84
13	1.95	1.69	1.40
14	0.96	1.08	1.15
15	1.97	2.86	1.80
16	2.91	1.43	3.49
17	1.08	0.74	0.66
18	1.05	1.00	1.10
19	1.93	2.33	5.55
20	0.42	0.49	0.19

Based on the calculations performed, Tab. 14 was created with the results of the modified Taffler's index for the twenty mining companies under study that continue to operate. Since all the enterprises analysed in this table are still in business, it is realistic to indicate what percentage of predictive power the application of the model has in practice.

From the calculated values of the modified Taffler's index for the periods in question, the following Tab. 15 is compiled with the percentage expression of the functionality of the model for mining companies.

Tab. 15. Expression of the functionality of the modified Taffler's index enterprises that continued their business activities

[%]	PERIOD		
	t_1	t_2	t_3
creditworthy enterprise	95	100	90
grey area	0	0	0
bankrupt enterprise	5	0	10

It was found that the value of the modified Taffler's index analysed over the three periods was as follows, namely, three years back, 95% of the analysed enterprises were rated as creditworthy enterprises. Two years back, the index value showed the creditworthiness of all 100% of the analysed enterprises. One year back, the index score for the analysed enterprises was 90%, i.e. 90% of the analysed enterprises are rated as creditworthy on the basis of the modified Taffler's index. In conclusion, this analysis shows that the modified Taffler's index showed an accuracy of a rating between 90% and 100%. For only 10% of the companies analysed, the modified Taffler's index came out at values in the third period that indicates creditworthiness problems and the companies are affected by bankruptcy.

Comparison of methods

For enterprises that have gone out of business

None of the enterprises analysed showed three consecutive values of the modified Taffler's index, while in reality, all the enterprises analysed have ceased operations due to bankruptcy. The modified Taffler's index is

completely unsuitable for assessing the creditworthiness of Czech mining companies. All enterprises assessed using Altman's analysis for Czech enterprises that had three consecutive periods of values corresponding to bankruptcy were also assessed as bankrupt using the IN05 index. For three consecutive periods, 65% of the enterprises had IN05 values corresponding to bankruptcy.

For enterprises that continue their business activities

Based on the methodology used, using a modified Altman's analysis and the IN05 Index, it was found that businesses six, eight, fourteen, eighteen and twenty had three consecutive periods of values that corresponded to poor creditworthiness, and the businesses were at risk of bankruptcy. Only for the modified Taffler's index were the values for enterprises six and twenty found to be consistent with bankruptcy according to the assessment.

The following Tab. 16 evaluates the functionality of the three selected bankruptcy models on Czech mining companies.

Tab. 16. Evaluation of the functionality of bankruptcy models in Czech mining companies

Suitability of the model	Altman's analysis of Czech companies	Index IN05	Modified Taffler's index
For businesses that have gone out of business	✓	✓	✗
For enterprises that continue their business activities	✗	✓	✓
Overall suitability for Czech mining companies	2.	1.	3.

Based on all the analyses performed, the most reliable index for predicting the risk of bankruptcy of Czech mining companies is the IN05 index, followed by Altman's analysis for Czech companies, and we consider the modified Taffler's index to be the least suitable.

Discussion

The biggest problem in determining the suitability of bankruptcy models as a tool for estimating the risk of corporate bankruptcy appears to be the unavailability of some accounting data. In conducting our research, we encountered precisely the missing data, mostly for firms that have ceased operations, which is why only twenty subject firms were ultimately included in the research. If the databases had been in place and the data had been collected and archived for a long time, we would have had more accurate analyses and better predictive estimates.

Karas and Režňáková (2013) came up with new approaches to bankruptcy risk prediction. However, the problem is that their model is applicable to large accounting units that express their data in euros in their financial statements. Therefore, this new approach is inappropriate for Czech mining companies, and it is necessary to verify the bankruptcy risk prediction rate on the original models, such as the IN05 Index. Moreover, this index is created by Czech authors, so its application to domestic companies is more than appropriate.

The three analysis models in question meet the condition that they are applicable to Central European companies, which is also proved in their contributions by a number of authors such as Čámská (2016) or Hájek et al. (2019). In addition, this idea is supported by the research of Dakovic, Czabo and Berg (2010), who state that the use of Altman's analysis is not appropriate for Norwegian firms and therefore develop a new model to predict the risk of failure of Norwegian firms using which they show that their model is more appropriate than Alman's analysis. Also, Hasprová (2002), in her paper, tested Altman's model in Czech conditions and concluded that Altman's model is not suitable for assessing the financial situation of Czech companies. Other authors, Kuběnka, Čapek and Sejkora (2021), tested Altman's model on Czech companies and concluded that the accuracy of Altman's model is lower than that declared by its author.

The issue of using bankruptcy models to determine bankruptcy risk prediction is addressed by Čámská (2014). This author examined modified Altman's models and their accuracy in predicting financial distress in Lithuania and Latvia. She concluded that the use of the modified Altman model is appropriate for the Baltic Republics. Also, the authors Mackevicius and Sneidere (2010), in their research for testing the prediction of bankruptcy of Latvian companies, Altman's model and Fulmer's H model are appropriate. Based on our analysis of the research of the modified Altman's model, we also concluded that the application of the modified Altman's model to Czech mining companies is appropriate, but the IN05 Index has better values for predicting the risk of bankruptcy. Čámská (2014), in her research, also verified the IN05 Index. In her further research, the subject was enterprises of The Branch Classification of Economic Activities CZ-NACE - 25 group; these were metallurgical enterprises where Čámská (2016) states that for the rapid prediction of the risk of bankruptcy of metallurgical enterprises, Altman's model, Grünwald's model, Kralick's test or the IN01 Index is suitable. The fact that the metallurgical and mining industries are close to each other is proved in Mikušová et al. (2014). Also, our analysis conducted on Czech

companies, however, mining companies, confirmed that Altman's model and the IN index are suitable models. However, for the IN index, we verified its modification from 2005, not 2001.

Kubíčková and Jindřichovská (2015) state that in the Czech environment, the best-known and most used bankruptcy models are Altman's model, Taffler's model, the IN05 index and Beaver's model. Based on our comparative analysis, we confirm that the modified Altman's and Taffer's models and the IN05 Index are suitable indicators for predicting the bankruptcy risk of Czech firms. On the contrary, the modified Taffler model emerged from our study as an inappropriate model for assessing the creditworthiness of Czech mining companies. The result is based on the assertion that for companies that had real creditworthiness problems and ceased operations, the model did not indicate in more than 90% that the company was at risk of bankruptcy. In addition, our result is supported by Machek (2014), who analysed the preliminary predictive ability of the Taffler model, the IN99 index, the IN05 index and Altman's model on Czech firms and found that the best results were provided by the IN05 and IN99 credibility indices and also by Altman's model score model, while the predictive ability of the Taffler model and very limited.

Validation of the functionality of creditworthiness models as a tool for estimating bankruptcy risk in Czech mining companies was carried out because other industries were tested similarly. For example, Kuběnka and Králová (2013) tested the Altman model on enterprises in the construction sector, and Hájek et al. (2019) conducted research on the applicability of the IN05 index for estimating bankruptcy risk also on Czech enterprises, but these were enterprises in the food industry. The results of their research showed that the IN05 Index is a very suitable indicator for estimating bankruptcy risk for post-socialist countries. Klepáč and Hampel (2017) tested the prediction of financial distress on more than two hundred agricultural enterprises. Also, Kuběnka, Čapek, and Sejkora (2021) tested more than two hundred and eighty Czech enterprises in terms of bankruptcy model validation and concluded that Altman's model had significantly lower accuracy for enterprises that ceased operations than those that continued to run their business. This research is refuted by our study, as Altman's model for Czech mining firms was found to have higher accuracy for firms that went out of business.

Conclusions

The aim of the paper was to demonstrate the functionality of selected bankruptcy models and to define their predictive ability on selected Czech mining companies. The selection of the most suitable models through comparative analysis and the verification of their functionality on selected mining enterprises that met the specified parameters was conducted.

In order to verify the functionality of bankruptcy models as a tool for estimating the risk of bankruptcy of mining enterprises, three modified bankruptcy models were established, namely Altman's analysis for Czech enterprises, Taffler's model and IN05 Index. These modified bankruptcy models were built for two groups of enterprises. The first group of twenty enterprises consisted of mining enterprises that continued their business activities after 2020, and the second group consisted of twenty mining enterprises that ceased their activities between 2008 and 2020.

This research was very specific as it focused only on a certain area of economic activities, namely mining enterprises from The Branch Classification of Economic Activities CZ-NACE categories 10 to 14. In addition, the analysis and validation were carried out on a large sample of enterprises; hence, it is a contribution to the whole sector and not a general characteristic. Another advantage is considered to be that it was focused on the model developed in the Czech Republic (IN05 Index) as well as foreign models of Western countries (Taffler's model and Altman's analysis).

The authors' team is aware that a major problem is the availability of data, as the data is not archived for long enough for companies that have ceased operations. In conclusion, we would like to say that it would be good to follow the enterprises for which the models showed an indication of impending bankruptcy. It would be beneficial to analyse other economic activities from CZ-NACE in order to refute or confirm the hypothesis of using the IN05 Index on Czech enterprises as a suitable and accurate model for predicting possible bankruptcy.

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