

Testing the usefulness and predictive power of the adapted Altman Z-score model for Bulgarian public companies

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Abstract. The applicability and predictive power of the models for predicting future corporate bankruptcy depend on both the selection of the individual indicators that are chosen to construct them and the coefficients (weights) with which they are included in the model. The latter are heavily dependent on the conditions in which the companies operate and require the adaptation of the models to the economic environment in different countries and/or to different types of companies. The purpose of the paper is to test the adapted Altman Z-score model for Bulgarian public manufacturing companies (D), derived by Georgiev and Petrova (2015) in order to verify its applicability and predictive power 5 years after its release. The empirical study is designed in three parts to meet the following objectives: (1) to verify the predictive power of the adapted model (D) using the original sample of companies; (2) to test the continued applicability of the model (D), using a new sample of companies that became insolvent five years after the adapted model was derived; and (3) to compare the accuracy of the adapted model (D) to the original Altman Z-score and Z'-score models for Bulgarian public manufacturing companies. The empirical data about the status (bankrupt/non-bankrupt) of the companies in the original sample confirms that the adapted model D (Georgiev and Petrova 2015) correctly predicted their future likelihood of bankruptcy with an even higher success rate than the one achieved in the initial study (85% for 2 years and 70 % - for 5 years into the future). The results from testing the model with new data prove that it is still effective in predicting bankruptcy and can be used in practice 5 years after its release, though its success rate shows a slight (about 5%) decrease. The results also show that the adapted model D performs better than the original Altman's Z-score and Z'-score for Bulgarian public companies.

Key words: Altman Z-score, bankruptcy prediction, financial analysis.

1. Introduction

Traditional financial analysis methods that use multiple individual indicators to characterize particular aspects of a company's operations are very useful for management purposes. For capital market investors, however, the use of many separate indicators is not as effective, because they need to make their investment choices by comparing a large number of companies. In this case, it would be more appropriate and cost effective to use some type of integral indicator, like Altman's Z-score. It combines different aspects of the business (its profitability, liquidity, solvency, asset turnover, etc.) into a single value. This would provide a relatively quick overview of the company's financial situation and prospects (including the likelihood of bankruptcy) and is an appropriate basis for carrying out a more in-depth analysis of the selected companies. A disadvantage of the model is the fact that the coefficients (the weights) of the individual indicators in the overall index (calculated using multiple discriminant analysis) depend on both the type of company and the economic environment in which it operates. That is the reason why the original Z-Score model (Altman 1968), developed for public manufacturing companies, was later updated by Altman (2000) to apply to privately held firms (Z'-Score) and non-manufacturers (Z''-Score). Other authors also explore the applicability of the model and the possibilities for its adaptation to the conditions in individual countries. In 2015 we adapted Altman's Z-score model to be used for Bulgarian public companies using empirical data and multiple discriminant analysis (Georgiev and Petrova 2015).

The purpose of this paper is to test the adapted Altman Z-score model for Bulgarian public companies (D) (Georgiev and Petrova 2015) in order to verify its applicability and predictive power 5 years after its release. To achieve this goal, the following objectives can be set:

1. To analyze and verify the predictive power of the Altman model, adapted for Bulgarian public companies (D) using the original sample of companies by examining whether it correctly identified those that are most likely to go bankrupt.

2. To test the continued applicability of the model (D), using a new sample of companies that became insolvent or went into liquidation during the 2013-2017 period (i.e. five years after the adapted model was derived).

3. To compare the accuracy of the adapted model (D) to the Altman Z-score and Z'-score models for Bulgarian public manufacturing companies.

The expected contribution of this paper to the existing literature is the verification of the usefulness of the adapted version (D) of the Altman's Z-score for Bulgarian public companies. The model might be further tested or adapted for other countries in the Balkan region (individually or as a whole).

The remainder of the paper is organized as follows. Section 2 discusses the background of the study. Section 3 introduces the methodology of the research. Section 4 describes the data used for the analysis and presents the main results and the discussion. Section 5 concludes the paper.

2. Background of the study

Altman's Z-Score model (1968) is an integral indicator designed to predict the likelihood of a company becoming insolvent. Similar models are created by Beaver (1966), Springate (1978) and Ohlson (1980), who use analogous individual indicators to construct the integrated model. One of the advantages of these models is the fact that they can be easily calculated using only publicly available information – from the company's financial statements and for the market value of its equity. They also combine different aspects of its business activity - its liquidity, profitability, solvency and asset turnover in one single value and help examine them as a whole, not just as a set of individual indicators. To a certain extent, this integrated indicator approach allows for taking into account the interrelations between these important ratios. According to Küting and Weber (2012, p. 359-360) and Coenenberg, Haller and Schultze (2009, p. 1042) however, this type of analysis has some disadvantages:

1. Only individual aspects of the information from the annual financial statements may be presented through the individually selected indicators. Crises usually arise from the interplay of more reasons and each of them can be signaled by a specific indicator.

2. A crisis in a company stems from the interaction of various factors that are not necessarily reflected in the annual financial statements. Strategic, not just financial, factors play a role here, making it difficult to investigate the causes of insolvency through discriminant analysis.

3. The links between the indicators are neglected. This means that many variables that are insignificant individually, can magnify the results when interacting with each other and vice versa. Such effects cannot be encompassed by statistical analysis.

4. In the case of differences in the results from the use of individual indicators and statistical analysis methods, there is the dilemma of how to summarize them and to make the right decisions on that basis.

5. Establishing a discriminative value of an integrated indicator for an emerging crisis in a company is not economically and theoretically grounded. The empirical data for businesses' financial distress cases that are already in the past are taken as a universal measure. They describe only the symptoms of the crisis in companies, but not the specific probability of its manifestation.

In regards to the last point, it can be argued that the choice of variables is usually based on the grounds of what is theoretically considered an indicator of a company's financial health/distress – usually a larger number of separate indicators. Since different authors have different views on what can be construed as a company's financial stability (its liquidity, solvency, capital structure and so on) (Kasarova 2010), a few separate indicators reflecting these aspects of the company's business are usually used to build this type of models. Then they are tested empirically to find which of the initial variables are statistically significant (together) for assessing the probability of bankruptcy (Ohlson 1980, Altman 1968) and actually help distinguish between financially sound and bankrupt companies. For instance, the variable profile finally established by Altman (1968, p. 594) does not contain the most significant variables, amongst the twenty-two original ones, measured independently. The final model includes the variables that work best together. This way the subjectivity in choosing the variables decreases significantly, because they are determined by the actual data and not only by the researcher. It can also be argued that one single model may not be suitable for companies with different business models or operating under different economic conditions. Given the pros and cons, integral indicators

based on statistical discriminant analysis are best suited to provide a quick overview of the financial position of the company without using the full set of financial analysis tools.

Using multiple discriminant analysis, Altman (1968) derived a formula, in which each of the individual indicators is included with a certain weight, calculated on the basis of empirical data for two groups of public manufacturing companies (a total of 66 firms) – half of them bankrupt (legally filed for bankruptcy or placed into receivership) and half – a paired sample of non-bankrupt manufacturing firms, chosen on a stratified random basis (Altman 1968, p. 593). The final discriminant function (Z-score) is as follows:

$$Z = 0.012X1 + 0.014X2 + 0.033X3 + 0.006X4 + 0.999X5, \text{ where}$$

X1 = Working capital /Total assets

X2 = Retained earnings /Total assets

X3 = Earnings before interest and taxes /Total assets

X4 = Market value of equity /Book value of total debt

X5 = Sales /Total assets

Z=Overall index

The firms having a Z-score greater than 2.99 fall into the "non-bankrupt" sector, while those firms having a Z below 1.81 are in the "bankrupt" group. The area between 1.81 and 2.99 is defined as the "zone of ignorance" or "gray area" because of the susceptibility to error classification (Altman 1968, p. 606).

Altman's Z-score formula was derived using data for American companies. It may be argued that its value ranges will differ for companies operating under different economic conditions and influenced by various technological, political and historical factors. This would mean that they will not be the same for different countries and time periods. For this reason, the original Z-Score model (1968), developed for public manufacturing companies, was later updated by Altman (2000) to apply to privately held firms (Z'-Score) and non-manufacturers (Z''-Score). In the formula for privately held firms (Z'-Score), the book value of equity is substituted for the market value of equity in the X4 variable. This leads to a change in all the coefficients (weights), the classification criterion and the related cutoff scores. The model is further revised by Altman (2000) to be adapted for non-manufacturing firms and emerging markets. The new modification (Z''-score) excludes the X5 variable - Sales/Total assets to minimize potential industry effect.

To reflect the differences in the conditions under which the companies operate, the coefficients (the weights) of the variables forming the integral indicator should be adapted to the respective economic environment. The financial ratios that make up the model can also be changed if adapting the weights is not enough to improve the predictive power of the modified formula. Several other studies have explored the applicability of the original Altman's model using newer data, different sets of companies or companies operating in other countries. Some of them, like Begley, Min and Watts (1996) and Grice and Ingram (2001) test the original Altman (1968) model and show that it is not as effective when used with company data from the 1980s. Samarakoon and Hasan (2003) test the Z, Z' and Z''-score models to predict the corporate distress in the emerging market of Sri Lanka. The results show that these models have a very high success rate, but the Z''-model, which is created by Altman for non-manufacturers and emerging markets, performs best with 81% accuracy rate for Sri Lankan firms. Hayes, Hodge and Hughes (2010) also found that the new Z''-model accurately predicts bankruptcy filing for US public retail companies. These results show that the adaptation of the model is the effective strategy to improve the performance of the classic indicator. There is also a considerable amount of studies (like Primasari (2017) in Indonesia, Omelka, Beranova and Tabas (2013) for the Czech Republic, Freifalts, Pettere and Voronova (2018) for Latvia and Berzkalne and Zelgalve (2013) for the Baltic listed companies) that compare different financial distress models and test their performance for the respective country/region which show varying results. Zeytinoglu and Akarim (2013) go even further and develop three different models for the 3 consecutive years 2009, 2010 and 2011 in order to reach the highest financial failure prediction ratios for public companies in Turkey. In a similar study (Georgiev and Petrova 2015) we proposed a modified (adapted) version of the Altman model for Bulgarian public companies using multiple discriminant analysis.

The adapted version of the model (D) (Georgiev and Petrova 2015) is derived using empirical data for Bulgarian public manufacturing companies. The study is based on 40 companies, 20 of them went bankrupt (placed into receivership or went into liquidation) during 2007-2013 and the other 20 are a control group of working firms paired to the ones from the bankrupt group. The period studied is 7 years because a longer period helps to accumulate a larger sample of bankrupt companies and also aids to eliminate the influence of short-term economic changes, which would make the model more useful long-term. The Z-score model adaptation is achieved by changing the coefficients of the individual ratios using discriminant analysis without altering the classical structure of the index proposed by Altman. The only change is made in the X4 variable, where the book value of equity is substituted for the market value of equity which is more relevant for Bulgarian companies due to the lack of a highly developed stock market. The function of the adapted model (D) is as follows:

$D = -0,237 - 1,117X_1 + 1,471X_2 + 3,688X_3 + 0,04X_4 + 0,728X_5$, where

X_1 = Working capital / Total assets

X_2 = Retained earnings/ Total Assets

X_3 = Earnings before interest and taxes / Total assets

X_4 = Book value of equity / Total liabilities

X_5 = Sales / Total Assets

D=Overall index

The Wilks lambda test (calculated using SPSS, Georgiev and Petrova 2015, p. 136-137) shows that the ratios in the model that are most statistically significant in discriminating between the two groups are X_2 , X_3 and X_5 (with a significance level of 0.000, 0.003 and 0.007, respectively). An additional model built only on these three variables showed not to be as successful as the full model, which means that X_1 and X_4 also contribute to the overall performance. The mean value of the discriminant function D for the bankrupt group is -0.595 with standard deviation 1.092, while for the non-bankrupt group it is 0.595 with standard deviation 0.899.

The calculations suggest that the firms with values of the overall index D below 0 are expected to go bankrupt and those that have a D greater than 0 will continue to be operating. The range of values between -0.103 and +0.17 can be defined as a "gray area" - the cases falling within this zone cannot be reliably classified. The adapted model D correctly identified 25 of the 40 companies in the original sample to the relevant groups for both years (i.e. 62.5%), 29 for the last year (72.5%) and 27 (67.5%) for the previous year. If each of the two reporting periods for every company is considered as a separate observation, the overall success rate is 70%. These results are shown to be better compared to the Z-score and Z'-scores for the same sample of companies. The Z-score¹³ correctly identified 54.55% for both years and 57.58% for the last year before the bankruptcy (or before the survey – for the non-bankrupt firms), with noticeably better performance for the bankrupt group. The Z'-score is also calculated (even though it is meant for non-public companies), because the Bulgarian stock market is considered not active enough to provide reliable market values for companies' equity. The Z'-score correctly categorized 48.71% of the companies for both years (again with better accuracy (57.89%) for the bankrupt group) and 53.85% for the last year before the bankruptcy/survey.

3. Research methodology

In order to analyze and verify the predictive power of the adapted model D (Georgiev and Petrova 2015), the current status (bankrupt or non-bankrupt) of the 20 companies comprising the original sample of actively operating firms will be examined 2 years, respectively 5 years later. This will confirm how many of them were correctly identified by the model as operating. The period of 2 years is chosen for the test because the original Altman's Z-score is reported to give 72% accuracy 2 years prior to bankruptcy (Altman 1968, p. 600). Furthermore, a longer period of 5 years is also tested because it provides the opportunity to track the company's financial position for a few reporting periods (is it improving/worsening/non-changing) and check if the model can only predict bankruptcy (as the formal end of a company's existence) or any (temporary) financial distress that might lead to bankruptcy. The original study (Georgiev and Petrova 2015) shows an overall success rate of 70% (if every year is considered separately) and 72.5% for last year prior to the study. Any similar results can be considered as successful in predicting future bankruptcy or the lack thereof.

To verify the usefulness of the model with newer data, the adapted index (D), Altman's Z-score¹⁴ and Z'-score will be calculated for the original sample of non-bankrupt companies using data from their annual financial statements for 2016 and 2017. Success rate, close to that in the original study (about 70%) would mean that the index still continues to perform just as well. With that said, it would not be unexpected if there is a decline in effectiveness, due to the changing economic conditions (the new period studied is up to 12 years later and is after the global economic crisis in 2008-2009, which occurred during the original period).

To investigate the continued applicability of the adapted model D, it will be tested on a new group of companies. The new sample comprises of all 12 Bulgarian public companies that went bankrupt (placed into receivership or in liquidation) during 2013-2017, i.e. five years after the development the modified model D. These companies are no longer public because, by a decision of the Bulgarian Financial Supervision Commission (FSC) dated 30.10.2017, 26 companies in liquidation or receivership have been delisted from the Public companies and other issuers of securities list kept by the FSC. According to later FSC decisions, another 8 companies in liquidation were delisted from the Bulgarian Stock Exchange (BSE) in 2018¹⁵.

¹³ Data from <http://www.infostock.bg>

¹⁴ It would be calculated using the book value of equity instead the market value, because there is no reliable information about the market value of equity for all the entities studied, even though they are public.

¹⁵ Two of the reasons for delisting a company from the BSE are:

- if the company is declared insolvent (pursuant to Article 119 (1) (6) of the Public Offering of Securities Act).

On the basis of the proposed objectives of this study, the following hypotheses will be tested:

H1: The adapted model (D) correctly predicted the likelihood of bankruptcy for the companies comprising the original sample.

H2: The adapted model (D) is still effective in predicting bankruptcy 5 years after it has been developed.

H3: The adapted model (D) has a higher accuracy rate for Bulgarian public manufacturing companies than the Altman Z-score and Z'-score models.

4. Data, results and discussion

Table 1 presents the values of the adapted model D for the companies, which in the original study (Georgiev and Petrova 2015) were included in the “non-bankrupt” (operating) group for the period 2005-2012. For each of them the value of the adapted index D is calculated for a 2-year period corresponding to the same reporting periods as for the ones in the bankruptcy/liquidation group¹⁶. Table 1 shows also the status (bankrupt/non-bankrupt)¹⁷ of every company 2 years and 5 years after the original study, outlining the correctly, respectively incorrectly identified cases.

Table 1.

Values of the adapted D model for companies comprising the initial non-bankrupt sample and company status 2 and 5 years afterwards

Company N	Values of the adapted model D*/Company status												
	Reporting period												
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1						1.289	1.734	non-bankrupt	non-bankrupt				
2						-0.090	-0.012	non-bankrupt	non-bankrupt				
3							-0.491	-0.328	financial distress, generates losses	non-bankrupt			
4							0.622	0.537	non-bankrupt	non-bankrupt			
5					1.949	1.868	financial distress, generates losses	financial distress, generates losses					
6							0.570	0.313	non-bankrupt	bankrupt			
7						0.440	0.451	non-bankrupt	financial distress, generates losses	non-bankrupt			
8						0.359	1.770	non-bankrupt	non-bankrupt				
9						0.351	-0.081	financial distress, generates losses	financial distress, generates losses	non-bankrupt			
10						0.900	1.050	non-bankrupt	non-bankrupt				
11					0.521	0.812	non-bankrupt	non-bankrupt					
12				0.663	0.331	non-bankrupt		non-bankrupt	bankrupt				
13				3.052	0.683	non-bankrupt		non-bankrupt					
14		-0.223	-0.274	financial distress, generates losses	considered bankrupt (ceased operations)								
15			1.533	1.126	non-bankrupt		non-bankrupt						
16			-1.482	-0.823	financial distress, generates losses	considered bankrupt (ceased operations)							
17	0.411	0.381	non-bankrupt		non-bankrupt								
18	1.855	2.208	non-bankrupt		non-bankrupt								

• if the company is in liquidation proceedings, which has not been completed more than three years since the entry of the liquidation proceedings in the commercial register (pursuant to Article 212 (1) (10) (e) of the Public Offering Law of securities).

¹⁶ All calculations are from Georgiev and Petrova 2015.

¹⁷ Based on information from the Bulgarian Commercial Register, kept by the Registry Agency, <http://www.brra.bg/Default.ra> and information from the annual financial reports.

19	-0.082	0.064	financial distress, generates losses		financial distress, generates losses	considered bankrupt (ceased operations)					
20	-0.069	-0.104	non-bankrupt	financial distress, generates losses	considered bankrupt (ceased operations)						

Source: Calculations from Georgiev and Petrova, 2015. The values of the adapted model D are for the two years studied during the 2005 – 2012 period

*D>0 means the model predicts the company's status to be non-bankrupt; D<0 means the model identifies a high probability of the company going bankrupt.

For some of the companies, the actual financial position cannot be clearly defined as bankrupt/non-bankrupt, because they are not placed in receivership or liquidation and their financial statements are prepared on a going-concern basis, but their main operating activity is ceased and/or they have been generating losses for a few reporting periods and the auditor expresses doubts that they can continue to operate as a going-concern. In these cases, some judgement was exercised to determine their current status as bankrupt/non-bankrupt. Companies N 14, 16 and 20 are considered bankrupt for the purposes of this study. A few other companies experience temporary financial distress (generate losses for a few consecutive periods), but they improve their financial position or go bankrupt afterwards. Since Altman's Z-score (and its adapted version D) is actually designed to predict company's financial distress (which leads to bankruptcy), companies generating losses for a few reporting periods will be considered as bankrupt (even though they haven't formally been placed in receivership or in liquidation).

As can be seen from Table 1, in some cases (N6 and N12 for instance) the model was correct in predicting the company's financial health for the first 2 years, but does not predict the financial distress (leading to bankruptcy) afterwards. In 3 other cases (N 14, 16 and 20), the negative values of the adapted indicator D are indicative of future financial distress, even though the companies are continuing to operate in the next 2 years and aren't formally placed into receivership or liquidation in the next 5 years.

Table 2 summarizes the number of successes/failures in prediction for the next 2, respectively 5 years. According to the data in Table 1 and Table 2, the adapted model D (calculated for both years or taking into account only the last period, if they differ) has successfully predicted the status of 85% of companies (17 out of 20) for a period of 2 years in the future. The success rate is 70% in the long run (5 years into the future, considering the end of the period).

Table 2.

Prediction success/failure of the adapted model D for companies comprising the initial non-bankrupt sample for the period 2005 – 2012

Actual group	Prediction			
	2 years prediction		5 years prediction	
	Correct	Incorrect	Correct	Incorrect
	<i>Number of companies</i>			
Bankrupt or in financial distress	5	2	4	4
Non-bankrupt	12	1	10	3
Total, number	17	3	14	7
Total, percentage	85	15	70	30

Source: Own calculations

The adapted indicator D is also calculated for the same sample of companies but for new reporting periods (2016 and 2017) in order to assess its performance when used with newer data. The purpose of this is to check whether the model is influenced by any changes in economic conditions. The values of the Z-score and Z'-score are also calculated for comparison purposes. Three of the companies are removed from the original sample of 20 companies due to the fact that they are bankrupt as at December 31, 2017 and haven't published any recent financial reports. One company is considered bankrupt for the purposes of the study even though the financial reports at December 31, 2017 are said to be prepared on a going concern basis. The reasons for this are that it has been generating losses, is decapitalized and went into liquidation a year afterwards. Another one is considered in financial distress and also included in the bankrupt group, because it has been generating losses for a few consecutive years, has published only unaudited financial report for 2017 and the auditor expressed doubts about its ability to continue as a going concern in his opinion concerning the 2016 financial report.

Table 3 shows that the adapted model D has correctly categorized 70.58% of the companies (12 out of 17) for both years (2016 and 2017), 76.47% (13 companies) for the last year - 2017, and 76.47% overall (each reporting period considered separately). It can also be observed, that the adapted model D detects even what can be considered temporary financial distress situations in companies – for instance a company that generates losses for a few reporting periods has a negative value of D for both years studied which is indicative of financial distress and may lead to bankruptcy.

Table 3.

Classification success/failure rates of the adapted model D, Z-score and Z'-score for companies comprising the initial non-bankrupt sample for the new period studied (2016 - 2017)

Actual Group	Group membership identification by respective bankruptcy prediction model									
	Adapted model D			Altman Z-score			Altman Z'-score			
	Correctly identified	Incorrect classification	Gray area*	Correctly identified	Incorrect classification	Gray area*	Correctly identified	Incorrect classification	Gray area*	
<i>Number of companies</i>										
on company basis (for both years)										
Bankrupt	4	3	1	0	3	1	0	3	1	0
Non-Bankrupt	13	9	1	3	6	3	4	6	3	4
Total, number	17	12	2	3	9	4	4	9	4	4
Total, percent	100	70.58	11.76	17.65	52.94	23.53	23.53	52.94	23.53	23.53
on company basis (for last year before study)										
Bankrupt	4	3	1	0	3	1	0	3	1	0
Non-Bankrupt	13	10	1	2	7	3	3	6	3	4
Total, number	17	13	2	2	10	4	3	9	4	4
Total, percent	100	76.47	11.76	11.76	58.82	23.53	17.65	52.94	23.53	23.53
on observation basis (each company/year is considered separately)										
Bankrupt	8	6	2	0	6	2	0	6	2	0
Non-Bankrupt	26	20	4	2	14	7	5	12	7	7
Total, number	34	26	6	2	20	9	5	18	9	7
Total, percent	100	76.47	17.65	5.88	58.82	26.47	14.71	52.94	26.47	20.59

Source: Own calculations based on companies' annual financial reports

*Gray area or different classifications for both years

In comparison to the adapted model D, Altman's Z-score correctly identifies 52.94% of the companies (9 of them) for the two years surveyed and 58.82% (10 companies) for the last year and overall on an observation basis. The Z'-score indicator has correctly categorized 52.94% of the companies (9) for both years, for the last year and overall.

In order to investigate the continued applicability of the Altman model adapted for Bulgarian public companies (D), it is also tested on a new sample of companies. It includes all 12 companies that went bankrupt (in receivership or liquidation) during the 2013-2017 period (i.e. five years after the adapted integral indicator D was derived). Table 4 shows the success and failure in classification of the adapted integral indicator D, Z-score and Z'-score for the new sample of companies – those declared in bankruptcy (placed in receivership or liquidation during 2013-2017), calculated using data from their annual financial statements. The results show that the adapted model D correctly identified 7 out of 12 companies (58.33%) for both years surveyed, while another 3 are correctly identified as bankrupt only for one of the two periods under review. If the reporting

periods for each company are considered separately, the overall success rate is 70.83%. A total of 8 out of 12 companies (66.67%) have been correctly identified during the last period, and another 1 falls in the gray area.

Table 4.

Classification success/failure rates of the adapted model D, Z-score and Z'-score for the new sample of bankrupt companies (2013 - 2017)

Actual Group		Group membership identification by respective bankruptcy prediction model								
		Adapted model D			Altman Z-score			Altman Z'-score		
		Correctly identified	Incorrect classification	Gray area*	Correctly identified	Incorrect classification	Gray area*	Correctly identified	Incorrect classification	Gray area*
<i>Number of companies</i>										
on company basis (for both years)										
Bankrupt	12	7	2	3	5	2	5	5	1	6
Total, percent	100	58.33	16.67	25	41.67	16.67	41.67	41.67	8.33	50
on company basis (for last year before study)										
Bankrupt	12	8	3	1	7	4	1	7	3	2
Total, percent	100	66.67	25	8.33	58.33	33.33	8.33	58.33	25	16.67
on observation basis (each company/year is considered separately)										
Bankrupt	24	17	6	1	14	7	3	14	6	4
Total, percent	100	70.83	25.0	4.16	58.33	29.16	12.50	58.33	25.0	16.67

Source: Own calculations based on companies' annual financial reports

*Gray area or difference in classification for both years

The results from Table 4 also show that the Z-score and Z'-score models successfully identified only 5 out of 12 companies (41.67%) for the two years surveyed, and 7 out of 12 (58.33%) for the last year and overall.

In order to visually present the results for the adapted model D on an overall observation basis with the new sample of companies, a radar chart can be used, where the cut-off line between the bankrupt/non-bankrupt groups is 0. Since all the companies are actually bankrupt, the ones that fall within the 'circle' created by the cut-off line (zero) are the ones that are correctly classified. As it can be seen from Figure 1, 17 observations out of 24 are categorized accurately.

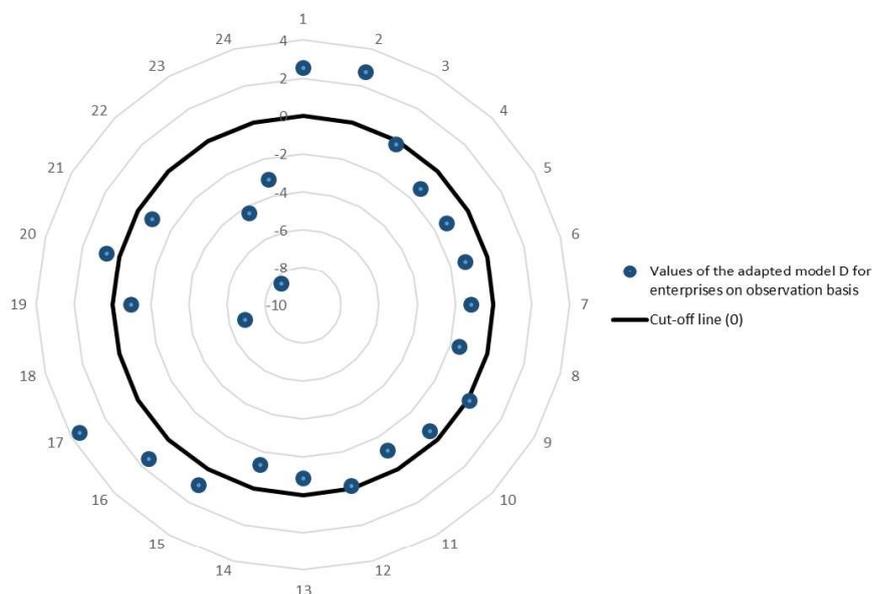


Figure 1. Classification success/failure of the adapted model D for the new sample of bankrupt companies (2013 - 2017) on an observation basis
Source: Own calculations based on companies' annual financial reports

As the results show, the adapted model D has successfully predicted the status of 85% of the companies for a period of 2 years after the initial study which is even higher than Altman's Z-Score (which is reported to have 72% accuracy 2 years prior to bankruptcy, Altman 1968, p. 600). The model also correctly predicted the status of the entities 5 years later with 70% accuracy. As indicated above, according to the data from our original study (Georgiev and Petrova 2015), the indicator had correctly classified originally 62.5% of the companies for the two years, 72.5% for the last year before the study and 70% overall. The higher success rate can be attributed to the fact that the model detects financial distress situations in companies and because of this the companies that have been generating losses for a few reporting periods and have ceased operations are considered bankrupt for the purposes of this study even though they haven't formally filed for bankruptcy. This confirms the first hypothesis (H1), that the adapted model D derived in 2015, correctly predicted the likelihood of bankruptcy of the companies in the original sample (with 85% accuracy for a period of 2 years, respectively 70% for 5 years ahead) and shows that the model has predictive power even in the long run (2 to 5 years into the future).

As seen from the empirical results, the adapted model (D) calculated for the same sample of companies, but for new reporting periods (2016 and 2017) maintains its accuracy and predictive power. The success rate is 70.58 for both years (2016 and 2017), 76.47% for the last year surveyed and 76.47% overall. When tested on a new sample of companies (that went bankrupt during the 2013-2017 period), the adapted model D correctly identified 58.33% of them for both years surveyed, 66.67% during the last period and the overall success rate is 70.83% (when each reporting period for each company is viewed as a separate observation). This means that with the new sample of companies the decrease in the success rate is about 5% when the last or both periods are considered and none in the overall performance. These results confirm the second hypothesis (H2) that the adapted model (D) is still effective in predicting bankruptcy 5 years after it has been developed. Its predictive power decreases slightly over time though, which proves the authors' initial assumption that the effectiveness of Altman's model (and other integral indicators for predicting insolvency and bankruptcy) depends on whether it is adapted to the specific economic conditions in which the business operates, which are changing over time. This view is shared by other authors, such as Zeytinoglu and Akarim (2013), who derive new discriminant functions for each year studied (2009, 2010, 2011).

As shown from the data above, the original Altman's Z-score model correctly predicted the likelihood of bankruptcy for only 52.94% of the companies in the original sample for the two years surveyed (using the data from the 2016 and 2017 reporting periods) and 58.82% of them for the last year and overall. In turn, the Z'-score model has correctly categorized 52.94% of the companies for the two reporting periods, for the last year studied and overall. With the new sample, the success rates are even lower – both the Z-score and Z'-score indicators correctly identified 41.67% of companies for the two years surveyed and 58.33% for the last year surveyed and overall. These results are not particularly useful for predicting potential insolvency and bankruptcy, because they are around 50% and are very close to statistical randomness. This shows the better performance of the adapted model D, compared to Altman's indicators, for Bulgarian public companies and confirms the third hypothesis that the adapted model (D) has a higher accuracy rate for Bulgarian public manufacturing companies than the Altman Z-score and Z'-score models. This proves the usefulness of adapting the original indicators to better match the economic environments in which the companies operate.

5. Conclusion

The search for simple, yet reliable methods and techniques for predicting future bankruptcy continues today, along with the changes in the economic environment and the development of new business models. Their applicability and predictive power depends on both the selection of the individual indicators that are chosen to construct them and the coefficients (weights) with which they are included in the model. The latter are heavily dependent on the conditions in which the companies operate and require the adaptation of the models to the economic environment in different countries and/or to different types of business.

By examining the status (bankrupt/non-bankrupt) of the companies in the original sample, it was confirmed that the adapted model D we derived in 2015 (Georgiev and Petrova 2015) correctly predicted their future likelihood of bankruptcy with an even higher success rate than the one achieved in the initial study (85% for 2 years and 70% - for 5 years into the future). The results from testing the model with new data prove that it is still effective in predicting bankruptcy and can be used in practice 5 years after its release, though its success rate shows a slight (about 5%) decrease. The results also show that the adapted model D performs better than the original Altman's Z-score and Z'-score for Bulgarian public companies. This was observed in the initial study

(Georgiev and Petrova 2015) and was expected considering the fact that these indices are derived using data for American companies.

Due to the slight decline in the success rate of the adapted indicator D, it may be suggested that a periodical update of the model using newer empirical data might be necessary in order to maintain and/or improve its accuracy in identifying the likelihood of bankruptcy according to the changes in economic conditions and business models over time. It can also be modified to be applicable for different types of companies – for instance non-public, which comprise a considerable amount of the firms in Bulgaria.

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