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The Capacity to Forecast Enterprise Insolvency on the Polish Market Using the Precursory Altman Z-Score Model (1968)

Keywords: bankruptcy; insolvency; discriminant analysis; Z-Score models; Altman

JEL: C53; G33; M43

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Abstract

Theoretical background: Many years have passed since the publication of the first multidimensional model (Z-score) of early bankruptcy warning by E.I. Altman in 1968. New models have since emerged in different countries. In this research stream, the share of econometric modelling based on the assumptions of discriminant analysis, i.e. MDA – Multiple Discriminant Analysis – one of the multidimensional classification methods categorised as empirical-induction methods, plays a particularly important role.
Purpose of the article: The article assesses the capacity of the Altman Z-Score to forecast (1 year ahead) insolvency of enterprises on the Polish market.

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Research methods: Due to the sample size (i.e. over 2,700 bankrupt entities in Poland), the study constitutes one of the broadest studies carried out so far on the assessment of the predictive capacity of early warning models in Polish economy.
Main findings: The authors, conducting research in this area, put forward a hypothesis that the variables that were well identified and introduced to discriminatory models in one economy work equally well in other countries. Despite the economic differences in these countries and the phases of the business cycle, the financial-analysis indicators that allow effective forecasting of enterprise bankruptcy are valid for different economies. The discriminant-function variability ranges that are characteristic of failing and healthy economic entities change but the variables themselves are good predictors.

Introduction

The pioneering research carried out by E.I. Altman in 1968 presented the results of studies on the use of discriminant analysis for forecasting enterprise bankruptcy. Today, it can be stated that these studies were based on a mere 66 enterprises (33 solvent entities and 33 insolvent entities) (Altman, 1968). Nevertheless, it was a very important step in the further evolution of the research stream pertaining to the use of multidimensional analyses to create early warning systems for enterprise bankruptcy (insolvency). Since then, many scientific articles have been written around the world on the effectiveness and applicability of the Altman model in various countries: Greece (Apergis et al., 2011; Gerantonis et al., 2009), Italy (Altman et al., 2013), Romania (Siekelova et al., 2019), Slovakia (Boďa & Úradníček, 2016), the United Kingdom (Almamy et al., 2016), Poland (Antonowicz, 2008), Serbia (Milašinović et al., 2019), Turkey (Apan et al., 2018; Cındık & Armutlulu, 2021), Ghana (Mahama, 2015), India (Anjum, 2012), (Joshi, 2019; Tyagi, 2014), Jordan (Jawabreh et al., 2017; Manaseer & Al-Oshaibat, 2018), Lebanon (El Khoury & Al Beaïno, 2014), Malaysia (Thai et al., 2014), Oman (Mohammed, 2016), Sri Lanka (Niresh & Pratheepan, 2015), Vietnam (Tung & Phung, 2019), Zimbabwe (Mavengere, 2015), cross-analysis (Claus et al., 1999). In addition, Altman summarised what had been learned within the 50 years after it was first published (Altman, 2018a, 2018b).

The main aim of the study was to assess the predictive capacity of Altman's Z-Score Model from 1968 on the contemporary Polish market. Although many years have passed since the Z_A Model was built, the variables included in this formula are constantly present in the economic and financial analysis of enterprises, while the formula itself has been repeatedly cited and used worldwide (Kitowski, 2018).

The authors of this article carried out a study on a group of over 2,700 companies in Poland that went bankrupt. The research covered 77% of the population of Polish enterprise bankruptcies in a 7-year period (from 2007) during which financial data was obtained. Further extensive research on the variability of financial analysis indicators in failing enterprises was developed by Antonowicz (2015a; Kitowski 2017). The study contains both general conclusions from the development of the predictive capabilities of Altman's model (in general), as well as the volatility of individual variables (indicators), which is reflected in the structure of the text.

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Literature review

At the outset it should be emphasised that the evolution of econometric modelling, which has its application in the forecasting of threats to enterprises (bankruptcy), had begun much earlier, in 1934, with the creation of a one-dimensional model based on the comparative method. Fitzpatrick, who, based on a group of entities, selected by the type of industry, the balance-sheet total, the volume of the turnover and the size of the registered office (19 solvent and 19 insolvent companies), carried out a comparative analysis of the indicators calculated, was a forerunner in this research (Fitzpatrick, 1932). These studies were not particularly valued, because they were based on a small sample and could not therefore be considered representative of the population. His contribution was nonetheless significant, if only due to the introduction of the "pair-matching" of solvent and insolvent enterprises (Rogowski, 1999). The research on the possibility of early warning of corporate insolvency carried out by Merwin constituted another nexus in the evolution of one-dimensional models (Merwin, 1942). This study of 939 solvent and insolvent enterprises entailed a much broader enterprise analysis than the work of Fitzpatrick in terms of companies removed from the commercial register (in the years 1926–1936). The use of arithmetic means for these groups of companies allowed identification of the indicators showing differences between the two groups as early as in the sixth year before an entity was deleted from the commercial register, while these disparities grew more pronounced each subsequent year. Studies published in 1966 by Beaver, carried out on a group of 158 entities – 79 solvent and 79 bankrupt – classified within 38 different industries in accordance with the Standard Industrial Classification, were a breakthrough in the evolution of one-dimensional models used for extrapolation of a threat to solvency (Beaver, 1966). This method was based on the assumptions that: (1) the larger the company's liquid assets, the lower the risk of defaulting on its financial obligations; (2) the larger the net cash flow (the difference between cash inflows and outflows), the lower the risk of insolvency; (3) the greater the share of debt capital in the financing of an enterprise's activities, the greater the risk of its insolvency; (4) the higher the operating costs (without depreciation of fixed assets), the greater the risk of company insolvency (Olszewski, 1992). Beaver formulated a thesis that as early as five years before the bankruptcy of a weak enterprise, a significant difference in the average values of indicators emerges, and the closer to bankruptcy, the greater the difference. Methodologically similar studies (the use of profile analysis and dichotomous classification test) were described in 1973 in the work of Weibel (1973). He examined a group of 200 insolvent enterprises that were clients of one of Swiss banks. From among the insolvent companies, he selected 36 and matched them with 36 solvent enterprises in accordance with the following criteria: industry affiliation, size of assets, age, legal form, place of business and economic situation. Weibel's proposed assessment of companies in terms of solvency met with criticism similar to what was said of Beaver's research. The basic disadvantages of the research present-

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ed include, above all, separate analysis of the indicators identified (lack of a model that would take into account the importance of a given indicator), which meant high arbitrariness of the decisions that were based on the proposed classification methods. The undoubted advantages of Weibel's research, in which he paid attention to the high prognostic properties of the financing structure, liquidity and turnover ratios, should be noted. What is more, Weibel noticed that the indicators built on the basis of a large number of successive financial statements do not lead to results significantly better than the indicators built on the basis of a single financial statement.

Discriminant functions began to be used in the 1930s in biology and psychology (Hołda, 2001). Altman was a pioneer in the adaptation of multidimensional discriminant analysis to the research on extrapolation of enterprise bankruptcy (Altman, 1968; Pitera, 2018; Mentel, 2013). To select his research sample, Altman used criteria similar to those used by Beaver, namely he selected enterprises in pairs, coupling the enterprises identified as insolvent with relevant entities operating in the same industry and having comparable balance-sheet totals. After identifying the representative sample of enterprises whose financial data was to be analysed, Altman assessed 22 indicators in terms of their discriminatory capacity, and therefore in terms of the possibility of classifying entities as solvent and insolvent. Five financial relations were arbitrarily selected, forming part of the discriminant function defined by the following formula:

$$Z_A = 1.2 \times X_1 + 1.4 \times X_2 + 3.3 \times X_3 + 0.6 \times X_4 + 1.0 \times X_5 \quad (1)$$

where subsequent variables of the Z-Score (Z_A) formula are:
X_1 = [working capital] / [total assets]
X_2 = [retained earnings] / [total assets]
X_3 = [earnings before interest and taxes] / [total assets]
X_4 = [market value equity] / [book value of total debt]
X_5 = [sales] / [total assets]

The value of the Z-Score (Z_A) postulated by Altman was determined on the basis of a random sample in the range of (2.67–2.68). The median for this range assumes the value of 2.675, therefore, the entities for which the value of the Z_A was greater than or equal to the adopted critical value were classified as solvent companies, while those for: $Z_A < 2.675$ were defined as insolvent companies. Based on a detailed analysis in order to minimise the likelihood of making a mistake in the enterprise classification, Altman defined the ranges of the Z-Score determining the three-level bankruptcy probability scale: (1) for [$Z_A < 1.81$] – high probability of insolvency; (2) for [$1.81 < Z_A < 2.99$] – the grey economy (no interpretation); (3) for [$Z_A > 2.99$] – low probability of insolvency. The above-presented form of Altman's discriminant function underwent significant modifications in later years (Altman 1980, 1983).

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Research methods

The data on enterprise bankruptcies in Poland was collected by the authors of this article over a period of 7 years (starting in 2007 and ending before the SARS-CoV global pandemic) directly from the official Court and Commercial Gazette [original title in PL: *Monitor Sądowy i Gospodarczy*]. The publication is a nationwide official journal publishing announcements as required by the Commercial Companies Code, the Code of Civil Procedure, the Act on the National Court Register, the Accounting Act and other acts. Out of the nearly 5,000 enterprise bankruptcies that took place in this period, over 2,700 enterprises were selected, whose financial statements in the form of balance sheets and profit and loss accounts were submitted to commercial courts in Poland. In order to assess the variability of the Z_A Model over a span of 4 years before the declaration of bankruptcy, the financial statements of these entities for a period of 5 years before the court declaration of bankruptcy (insolvency) were obtained. Financial data for these periods was required due to the fact that the principle of financial ratio calculation, adopted and used in theory and practice, entails adoption of the average annual balance-sheet value in the ratio relations that are based on static (balance sheet) and dynamic (profit and loss account) statements. Indicators X_1 and X_4 were calculated according to the balance-sheet values as of the end of a given financial year preceding the bankruptcy of the enterprises. In turn, in the indicators X_2, X_3 and X_5, the assets and the sources of financing (asset and liability components) were assumed on an annual basis. From a methodological perspective, it is also quite significant that the variables used in the construction of indicators X_2 (retained earnings) and X4 (the market value of equity) were modified in the calculations presented in this study. As a result, the predictive value of the model may have changed in relation to Altman's base model from 1968.The author of the present study substituted retained earnings with the value of the net financial result for a given financial year, while the market value of equity was replaced by the book value. The modification is a result of differences in accounting standards, in particular with the difficulty of estimating (depending on the adopted valuation method) the market value of equity. Conclusions from the extensive discussion on this subject are included in the study (Kitowski, 2011, p. 219) and treat the calculation methodology in the same way as the authors of the study: (Peplak, 2001, p. 77; Zelek, 2001, p. 114; Parvi, 2010, p. 234; Szyma, 2010, p. 22).

The Z_A Model results calculated for individual enterprises sometimes exceed the average ranges of variability due to the appearance of atypical values (outliers), which is obvious with such a large population (research sample). It should therefore be emphasised that in order to generalise and synthetically discuss the results obtained for each of the indicators calculated in the subsequent part of the study (as well as for the Z_A Model itself), the results were subjected to a process of elimination of outliers (Koronacki & Mielniczuk, 2006).

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The authors of the study assumed as such the results that did not fall within the following range:

$$<Q1 - 1.5 \times IRQ \; ; \; Q3 + 1.5 \times IRQ> \quad (2)$$

where:

Q1 – the first quartile, i.e. the 0.25 quantile – taking the limit value to which the level of the trait forms in 25% of observations

Q3 – the third quartile, i.e. the 0.75 quantile – taking the limit value to which the trait forms in 75% of observations

IRQ – the Interquartile Range, which is the difference between Q3 and Q1

The set of results developed in this way allowed, in the next stage, the estimation of selected basic descriptive statistics. In the next sections of the study, these results were presented in the form of box and whisker plots (also called "box plot graphs/ charts" or "box plots"). In these graphs, the vertical borders of the frame (box), corresponding to the coordinates of the *y* axis, create Q1 and Q3, respectively. In its interior, the median level is marked as well (Me = Q2).

Results

In Altman's base Z_A Model (1968), the average value of the Z-Score discriminant analysis in the examined group of solvent entities was 4.89, while the average Z_A for insolvent entities one year prior to bankruptcy was 0.26 (Altman, 1968). Table 1presents basic statistics related to the shaping of the Z_A Model in the period of 4 years before the announcement of over 2,000 enterprise bankruptcies in Poland. A year before these bankruptcies, the average value of the Z_A Model was $Z_{A(t-1)} = 0.54$, over 70% lower than in the period $t_{(-2)}$. The chain index of the Z_A dynamics from $t_{(-4)}$ to $t_{(-3)}$ was (-16%) and from $t_{(-3)}$ to $t_{(-2)}$ – (-24%). This means that the largest change in the value of the model took place 1 year before the declaration of bankruptcy. Research in this field conducted by Antonowicz in the years 2002–2007 provided similar results: the average value of the Z_A Model, calculated for the period of one year before bankruptcy, was $Z_{A(t-1)[2002–2007]} = 0.52$, while in the group of enterprises with good economic and financial standing it was $Z_{A(H)[2002–2007]} = 4.72$ (Antonowicz, 2007), which should be considered very close to the values estimated by Altman in the 1960s.

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Table 1. Basic variability statistics of Altman's Z_A Model (1968) – in the period of 4 years prior to the adjudication of bankruptcy (t_0) of enterprises in Poland

No.	Category of statistics for the variable		Years before the adjudication of bankruptcy $t_{(-4)}$	$t_{(-3)}$	$t_{(-2)}$	$t_{(-1)}$
1	N important observations		1,428	1,948	2,036	1,421
2	Missing data		1,311	791	703	1,318
3	5 percentile	(5% of observations)	-1.36	-1.86	-3.03	-7.23
4	**QI – quartile I**	**(25% of observations)**	**1.49**	**1.13**	**0.43**	**-1.16**
5	**Me – median**	**(50% of observations)**	**2.79**	**2.36**	**1.85**	**0.49**
6	**QIII – quartile III**	**(75% of observations)**	**4.47**	**3.88**	**3.12**	**2.06**
7	95 percentile	(95% of observations)	8.90	8.12	6.64	5.26
8	Interquartile range	(IRQ)	2.99	2.75	2.69	3.22
9	The lower range of typical values <Q1 – 1.5 × IRQ>		-2,99	-2.99	-3.61	-5.99
10	Upper range of typical values <Q1 + 1.5 × IRQ>		8.96	8.01	7.16	6.89
11	N important observations (without outliers values)		1,321	1,791	1,866	1,291
12	Number of outliers values removed		107	157	170	130
13	**Arithmetic average in the range without outliers values**		**2.87**	**2.40**	**1.82**	**0.54**
14	Standard deviation in the range without outliers values		2.17	2.02	1.94	2.35
15	MIN – minimum in the range without outliers values		-2.92	-2.96	-3.54	-5.92
16	MAX – maximum in the range without outliers values		8.90	8.00	7.09	6.78

Source: Authors' own study based on the analysis of financial statements of 2,036 companies.

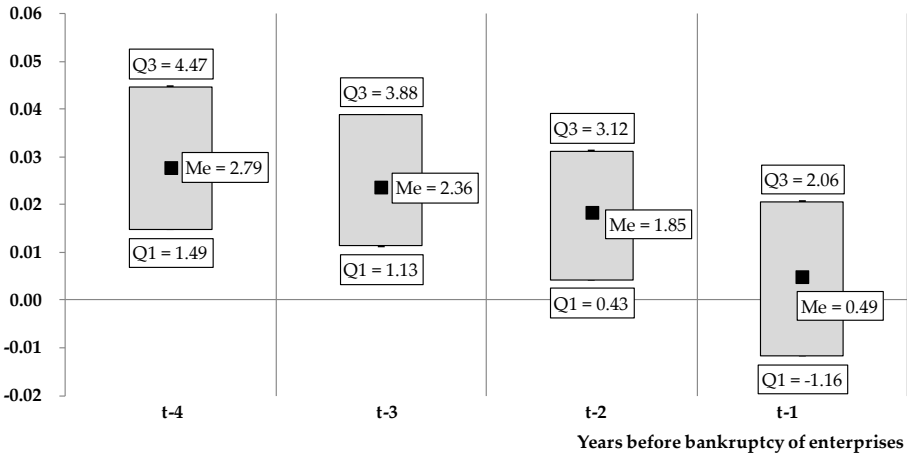

Figure 1. Variability of Altman's Z_A Model (1968) in the period of 4 years before the adjudication of bankruptcy of enterprises in Poland

Source: Authors' own study based on the analysis of financial statements of 2,036 companies.

As shown in Figure 1, a year before the declaration of bankruptcy, half of the analysed enterprises assume a value of Z_A not higher than 0.49. It is important to note the dynamics of the changes in the Z_A Model, which indicates a significant change in the value of Z_A along with the approaching bankruptcy as well as shows

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the highest value a year before insolvency. Assuming the boundary values determined by Altman at the levels of 1.81 and 2.99 (Altman 1968), it should be emphasised that the Z_A Model:

– correctly classified 70.80% of the analysed entities (1,006 out of 1,421 entities, not including data gaps) a year before bankruptcy, i.e. in the period (t-1),

– incorrectly indicated no threat of bankruptcy in relation to 29.20% of the entities analysed (i.e. 415 out of 1,421 entities, not including data gaps) in the period (t-1),

– the Z_A Model values below the cut-off point, at the level of 1.81, were adopted respectively in the periods: (t-2) – in 49% of the analysed entities; (t-3) – in 36% of the analysed entities, and in (t-4) – in 31% of the analysed entities.

Although, in general, a higher level of model matching could be expected, attention should be paid to its high usability for horizontal evaluation in particular, i.e. over successive years. The highest peak of the Z_A value takes place 1 year before bankruptcy and is significantly higher than indicated by the Z_A dynamics index in previous years. The results obtained do not disqualify this model from use in the Polish economy, although re-estimation of the structural parameters of the function itself as well as re-estimation of the cut-off levels for this system of the variables forming it would probably be worth considering. This would probably allow the indicators used by Altman in the 1960s to be better matched to the current economic requirements of the Polish market. Many analogous early warning models based on various variables have been created in Poland. The question therefore arises whether the indicators used by Altman in the Z_A Model behave as expected in the years preceding enterprise bankruptcy. This question can be answered by analysis of the interior of the Z_A Model carried out in subsequent sections.

Each of the indicators included in the Z_A discriminant function was analysed separately. This study entailed an assessment of the volatility of five indicators in the period of 4 years preceding the court declaration of bankruptcy of the examined enterprises. Analysis of the interior of the Z_A function allows more careful familiarisation with the variability of individual one-dimensional predictors of enterprise insolvency, which enables answering the question regarding the timeliness of the predictive financial-analysis indicators used by Altman in the 1960s.

The first of the indicators used in the Z_A Model involves the ratio of working capital to the balance-sheet total. This ratio was calculated by taking into account the balance-sheet components as of the date the balance-sheet books were closed (i.e. as of the end of the fiscal year). The volatility characteristics of this indicator in the four year period preceding the bankruptcy of 2,281 enterprises in Poland has been presented in Table 2 and Figure 2.

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Table 2. Basic variability statistics of the working capital to total assets ratio in the period of 4 years prior to the adjudication of bankruptcy (t_0) of enterprises in Poland

No.	Category of statistics for the variable		Years before the adjudication of bankruptcy $t_{(-4)}$	$t_{(-3)}$	$t_{(-2)}$	$t_{(-1)}$
1	N important observations		2,039	2,228	2,281	1,578
2	Missing data		700	511	458	1,161
3	5 percentile	(5% of observations)	-0.96	-1.19	-1.64	-3.96
4	**QI – quartile I**	**(25% of observations)**	**-0.13**	**-0.18**	**-0.26**	**-0.75**
5	**Me – median**	**(50% of observations)**	**0.05**	**0.03**	**-0.02**	**-0.24**
6	**QIII – quartile III**	**(75% of observations)**	**0.22**	**0.20**	**0.16**	**0.02**
7	95 percentile	(95% of observations)	0.61	0.55	0.52	0.43
8	Interquartile range	(IRQ)	0.36	0.38	0.42	0.77
9	The lower range of typical values <Q1 – 1.5 × IRQ>		-0.67	-0.75	-0.89	-1.90
10	Upper range of typical values <Q1 + 1.5 × IRQ>		0.76	0.77	0.78	1.17
11	N important observations (without outliers values)		1,843	1,977	2,021	1,399
12	Number of outliers values removed		196	251	260	179
13	**Arithmetic average in the range without outliers values**		**0.06**	**0.04**	**-0.00**	**-0.26**
14	Standard deviation in the range without outliers values		0.26	0.27	0.29	0.52
15	MIN – minimum in the range without outliers values		-0.66	-0.75	-0.88	-1.90
16	MAX – maximum in the range without outliers values		0.76	0.77	0.77	1.00

Source: Authors' own study based on the analysis of financial statements of 2,281 companies.

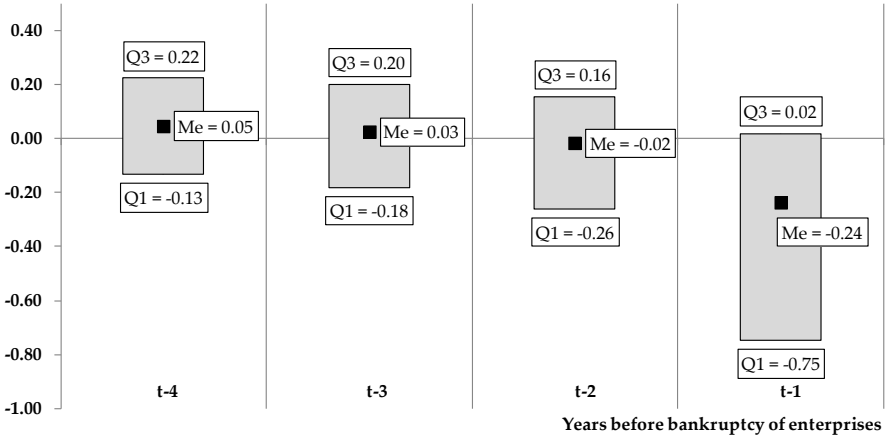

Figure 2. Variability of the working capital to total assets ratio in the period of 4 years prior to the adjudication of bankruptcy of enterprises in Poland

Source: Authors' own study based on the analysis of financial statements of 2,281 companies.

Working capital is closely correlated with the current liquidity ratio. The denominator of the indicator under analysis has to do with a difference, whereas in terms of liquidity, it concerns the ratio of current assets to current liabilities. In the case of the variable under analysis, in the vast majority of enterprises it is desirable to show positive working capital values that respectively translate into an overall

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liquidity exceeding the value of 1.0. By eliminating the outliers values, the average value of this indicator typically falls below the level of 0 as early as two years before bankruptcy, while in 25% of the cases observed, negative working capital occurred as early as 4 years before bankruptcy.

Calculation of the indicator X_2, relating retained earnings to the capital employed in business activities, has been modified in regard to the original Z_A Model. The level of net financial result was adopted in the numerator. This proposal is justified by Polish reporting, and it also has its supporters in the Polish literature on the subject as well as in analytical practice. Table 3 presents the statistics characterising the variability of ROA in the four years prior to the declaration of bankruptcy of a maximum of 2,041 enterprises (in the period $t_{(-2)}$) operating on the Polish market.

Table 3. Basic variability statistics of ROA – the return on total assets ratio in the period of 4 years prior to the adjudication of bankruptcy (t_0) of enterprises in Poland

No.	Category of statistics for the variable		Years before the adjudication of bankruptcy			
			$t_{(-4)}$	$t_{(-3)}$	$t_{(-2)}$	$t_{(-1)}$
1	N important observations		1,435	1,963	2,041	1,430
2	Missing data		1,304	776	698	1,309
3	5 percentile	(5% of observations)	-0.36	-0.47	-0.63	-1.13
4	**QI – quartile I**	**(25% of observations)**	**-0.05**	**-0.08**	**-0.15**	**-0.40**
5	**Me – median**	**(50% of observations)**	**0.01**	**0.01**	**-0.01**	**-0.17**
6	**QIII – quartile III**	**(75% of observations)**	**0.07**	**0.04**	**0.02**	**-0.02**
7	95 percentile	(95% of observations)	0.27	0.21	0.15	0.09
8	Interquartile range	(IRQ)	0.12	0.12	0.17	0.38
9	The lower range of typical values <Q1 – 1.5 × IRQ>		-0.22	-0.27	-0.41	-0.97
10	Upper range of typical values <Q1 + 1.5 × IRQ>		0.24	0.23	0.28	0.55
11	N important observations (without outliers values)		1,217	1,685	1,817	1,327
12	Number of outliers values removed		218	278	224	103
13	**Arithmetic average in the range without outliers values**		**0.01**	**-0.00**	**-0.04**	**-0.20**
14	Standard deviation in the range without outliers values		0.09	0.09	0.12	0.25
15	MIN – minimum in the range without outliers values		-0.22	-0.27	-0.41	-0.97
16	MAX – maximum in the range without outliers values		0.24	0.23	0.28	0.52

Source: Authors' own study based on the analysis of financial statements of 2,041 companies.

Every fourth enterprise under analysis incurred net loss as early as 4 years prior to the declaration of bankruptcy. Half of the entities examined achieved positive financial results in the period from $t_{(-4)}$ to $t_{(-3)}$, representing less than 1% of the amount of the capital employed. Similarly to all other variables that form the interior of the Z_A function, the index of ROA dynamics in failing entities significantly decreases its value one year before the declaration of bankruptcy. On average (without the value of outliers), this indicator decreased its value almost four times in the period $t_{(-1)}$ compared to the preceding year. This indicator is widely used in financial analysis, although its two modifications are used for interpretative purposes. Conversely, in order to eliminate the differences in tax issues, the ratio of gross result to total assets is assumed (sometimes as a supplement to ROA, and sometimes as a substitute).

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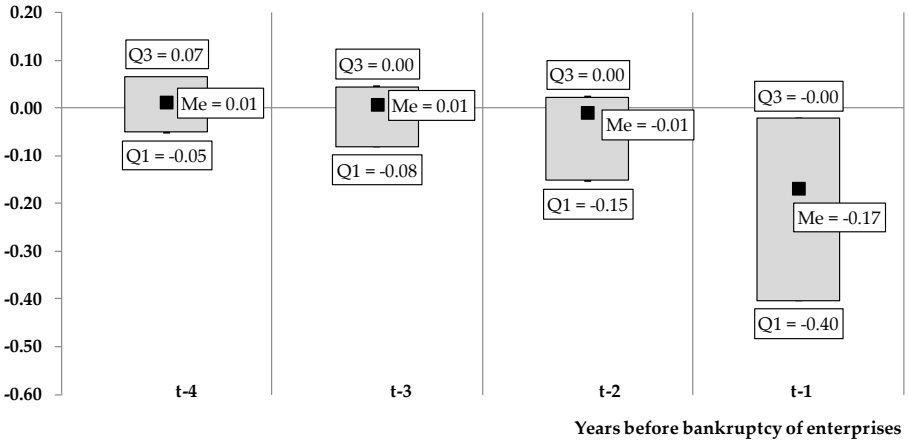

Figure 3. Variability of ROA – the return on total assets ratio in the period of 4 years before the adjudication of bankruptcy of enterprises in Poland

Source: Authors' own study based on the analysis of financial statements of 2,041 companies.

Another approach would include the plus value of the depreciation charges in order to make the level of the financial result achieved more realistic. These modifications, of course, had not been made in the studies described above, but consideration could be given their justifiability in terms of modification or simply taking into account other explanatory variables in this econometric model.

Another previously-discussed indicator is the measure used in the Z_A Model, which belongs to the group of asset productivity ratios. Altman proposed calculation of the ratio of the financial result before tax and prior to the calculation of the financial costs (EBIT) on the same basis assumed in the ROA, i.e. the total assets. The variability of this indicator relation, four years prior to bankruptcy, is presented in Table 4.

Table 4. Basic variability statistics of the EBIT to total assets ratio in the period of 4 years prior to the adjudication of bankruptcy (t_0) of enterprises in Poland

No.	Category of statistics for the variable		Years before the adjudication of bankruptcy			
			$t_{(-4)}$	$t_{(-3)}$	$t_{(-2)}$	$t_{(-1)}$
1	N important observations		1,435	1,963	2,041	1,430
2	Missing data		1,304	776	698	1,309
3	5 percentile	(5% of observations)	-0.29	-0.38	-0.51	-0.96
4	**QI – quartile I**	**(25% of observations)**	**-0.02**	**-0.04**	**-0.11**	**-0.32**
5	**Me – median**	**(50% of observations)**	**0.05**	**0.04**	**0.02**	**-0.11**
6	**QIII – quartile III**	**(75% of observations)**	**0.12**	**0.09**	**0.07**	**0.01**
7	95 percentile	(95% of observations)	0.39	0.32	0.24	0.19
8	Interquartile range	(IRQ)	0.14	0.14	0.18	0.33
9	The lower range of typical values <Q1 – 1.5 × IRQ>		-0.22	-0.25	-0.38	-0.81
10	Upper range of typical values <Q1 + 1.5 × IRQ>		0.32	0.30	0.34	0.50
11	N important observations (without outliers values)		1,238	1,685	1,826	1,320
12	Number of outliers values removed		197	278	215	110
13	**Arithmetic average in the range without outliers values**		**0.05**	**0.03**	**-0.00**	**-0.14**

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No.	Category of statistics for the variable	Years before the adjudication of bankruptcy			
		$t_{(-4)}$	$t_{(-3)}$	$t_{(-2)}$	$t_{(-1)}$
14	Standard deviation in the range without outliers values	0.10	0.10	0.13	0.23
15	MIN – minimum in the range without outliers values	-0.22	-0.24	-0.37	-0.81
16	MAX – maximum in the range without outliers values	0.32	0.30	0.34	0.50

Source: Authors' own study based on the analysis of financial statements of 2,041 companies.

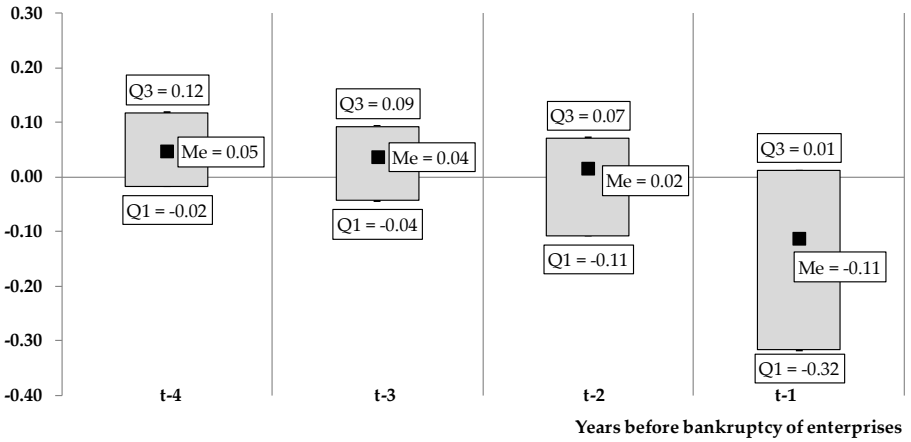

Figure 4. Variability of the EBIT to total assets ratio in the period of 4 years prior to the adjudication of bankruptcy of enterprises in Poland

Source: Authors' own study based on the analysis of financial statements of 2,041 companies.

Analysis of the characteristics presented in Table 4 and Figure 4 indicates high similarity of the variability of the indicators analysed in the 4 years preceding the bankruptcy of enterprises to the previously described ROA. EBIT as well, in relation to total assets, indicated negative values in 25% of the entities analysed as early as 4 years before their insolvency court decision, while a year before bankruptcy, half of the entities examined significantly reduced EBIT, which in the period $t_{(-1)}$ assumed negative values. In consequence, this shows that nowadays most econometricians approach the introduction of mutually correlated variables into the model with at least some reserve. In this case, it is possible to discuss, for example, introduction of explanatory variables to the function in exchange for this system, i.e. introduction of an indicator that in the denominator would refer to the size of debt, which could provide information on the entity's ability to repay the debt.

The share of equity in total liabilities (short- and long-term liabilities) constitutes a very important indicator, the derivatives of which are currently present in many Polish models of early warning of bankruptcy. This is due to the so-called balance-sheet bankruptcy defined by the provisions of the Polish Bankruptcy Law (BL). According to Art. 10 of the Bankruptcy Law, bankruptcy is declared in relation to the debtor who has become insolvent, i.e. (Art. 11.1 BL) – an entity that has lost the ability to

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perform its due monetary obligations. This, however, is not the only circumstance that may, in consequence, lead to bankruptcy, because in accordance with the wording of Art. 11.1. item 2 BL, bankruptcy of this type may take place when the value of monetary obligations exceeds the value of the debtor's assets and this condition persists for a period exceeding twenty-four months, even when these obligations are being settled on an ongoing basis. Therefore, in our opinion, the use of this variable in the Z_A Model, not only beforehand in the United States, but also in Poland today, has both economic and legal justification. Table 5 presents the volatility of the indicator defining the structure of business activity financing in the enterprises failing in Poland during the period of four years prior to the court decision on insolvency. It is worth emphasising, however, that this indicator in the numerator does not contain the market value of equity capital, but its balance-sheet value. Such modification of this indicator was adopted in Poland in relation to the Altman model under consideration.

Table 5. Basic variability statistics of the equity to total liabilities ratio in the period of 4 years prior to the adjudication of bankruptcy (t_0) of enterprises in Poland

No.	Category of statistics for the variable		Years before the adjudication of bankruptcy			
			$t_{(-4)}$	$t_{(-3)}$	$t_{(-2)}$	$t_{(-1)}$
1	N important observations		2,024	2,213	2,277	1,572
2	Missing data		715	526	462	1,167
3	5 percentile	(5% of observations)	-0.47	-0.56	-0.67	-0.85
4	**QI – quartile I**	**(25% of observations)**	**0.07**	**0.02**	**-0.06**	**-0.38**
5	**Me – median**	**(50% of observations)**	**0.29**	**0.25**	**0.18**	**-0.03**
6	**QIII – quartile III**	**(75% of observations)**	**0.71**	**0.61**	**0.47**	**0.22**
7	95 percentile	(95% of observations)	2.68	2.64	2.04	1.19
8	Interquartile range	(IRQ)	0.64	0.58	0.52	0.61
9	The lower range of typical values <Q1 – 1.5 × IRQ>		-0.90	-0.85	-0.84	-1.30
10	Upper range of typical values <Q1 + 1.5 × IRQ>		1.68	1.48	1.25	1.14
11	N important observations (without outliers values)		1,821	1,995	2,047	1,477
12	Number of outliers values removed		203	218	230	95
13	**Arithmetic average in the range without outliers values**		**0.31**	**0.24**	**0.15**	**-0.09**
14	Standard deviation in the range without outliers values		0.47	0.43	0.41	0.45
15	MIN – minimum in the range without outliers values		-0.90	-0.85	-0.84	-1.29
16	MAX – maximum in the range without outliers values		1.67	1.48	1.25	1.13

Source: Authors' own study based on the analysis of financial statements of 2,277 companies.

External (long- and short-term liabilities) financing is of course justified and should be positively assessed when the rate of return on the capital invested exceeds the cost of obtaining this capital, more precisely, is higher than the weighted average cost of capital (WACC). In relation to the entities being classified, however, it is reasonable to assume that a too-high level of external financing (liabilities) may mean a lower level of financial autonomy, i.e. a great er dependence on external (long- and short-term liabilities) financing, and in some cases a lower level of financial credibility. The same rule applies in credit scoring, where even with relatively good other financial parameters, a too-high level of debt disallows subsequent financing. In this

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indicator, however, the form of this financing was approached with good approximation (the denominator contains the total debt). Depending on the sector, however, some significant differences occur due to the deferred payment dates adopted by entities (i.e. the trade credits used). It is assumed that in Poland, in the small and medium-sized enterprise sector, about 50% of external financing (long- and short-term liabilities) entails short-term liabilities, with liabilities to contractors (suppliers) being the most significant. As such, various other early warning models currently use slightly less aggregate variables, e.g., those related to the value of short-term liabilities themselves. Inclusion of the liabilities to co-operators exclusively in the modified form of this indicator could also be considered. Such actions would be aimed at making the explanatory variable more flexible.

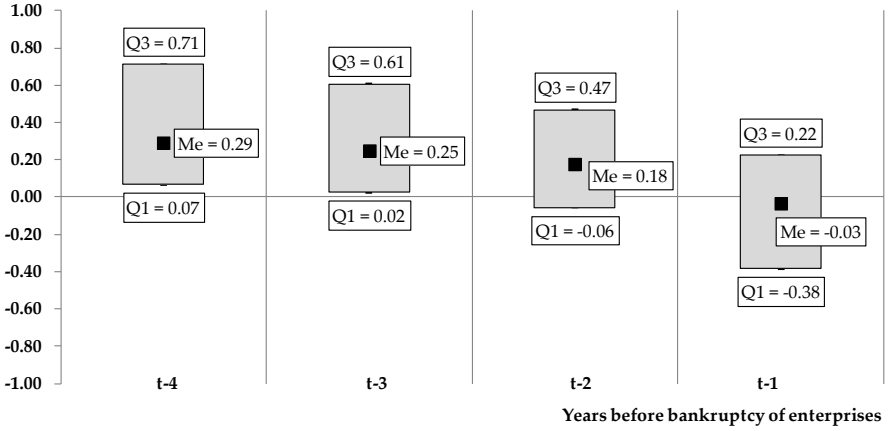

Figure 5. Variability of the Equity to total liabilities ratio in the period of 4 years prior to the adjudication

Source: Authors' own stud based on the analysis of financial statements of 2,277 companies.

The negative values of X4 occurring in 25% of failing companies in Poland 2 years before insolvency and in 5% of the observations as early as 4 years before bankruptcy indicate the cumulative financial problems of these entities increasing for a period longer than the one-year period assumed in discriminant models. Negative values of this ratio can only be assumed by those entities in whose balance-sheet structure negative equity occurred. It usually occurs as a result of a net loss in a given financial year, or an accumulated net loss in previous financial years, in excess of the value of the contributions made to the core capital. The Polish Commercial Companies Code assumes, among others, the possibility of establishing a commonly used structure of business in the form of a limited liability company. It can be set up when initial capital at the level of PLN 5,000 (i.e. about USD 1,300) is contributed (even by apportionment). As business practice shows, these entities most often operate with significantly higher financial flows, so it is not difficult for them to obtain a critical balance-sheet structure in which equity is negative and the threat of their balance-sheet bankruptcy materialises.

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The last variable of the Z_A Model is the overall-productivity indicator, which is the ratio of the revenues from the sales of products and services in relation to the total assets. This indicator, as with the above-discussed explanatory variables, is a stimulant, meaning that achievement of its highest values is postulated, which in turn means that its higher value corresponds to a more positive assessment. Table 6 and Figure 6 present the shaping of this indicator over the period of 4 years prior to the declaration of bankruptcy of 2,041 enterprises (in the period $t_{(-2)}$) on the Polish market.

Table 6. Basic variability statistics of the Productivity of assets ratio in the period of 4 years prior to the adjudication of bankruptcy (t_0) of enterprises in Poland

No.	Category of statistics for the variable		Years before the adjudication of bankruptcy			
			$t_{(-4)}$	$t_{(-3)}$	$t_{(-2)}$	$t_{(-1)}$
1	N important observations		1,435	1,963	2,041	1,430
2	Missing data		1,304	776	698	1,309
3	5 percentile	(5% of observations)	0.08	0.07	0.04	0.01
4	**QI – quartile I**	**(25% of observations)**	**1.21**	**1.01**	**0.90**	**0.69**
5	**Me – median**	**(50% of observations)**	**2.12**	**1.92**	**1.68**	**1.49**
6	**QIII – quartile III**	**(75% of observations)**	**3.33**	**3.06**	**2.74**	**2.60**
7	95 percentile	(95% of observations)	6.62	6.11	5.59	5.59
8	Interquartile range	(IRQ)	2.12	2.05	1.84	1.92
9	The lower range of typical values <Q1 – 1.5 × IRQ>		-1.98	-2.07	-1.87	-2.19
10	Upper range of typical values <Q1 + 1.5 × IRQ>		6.51	6.13	5.50	5.48
11	N important observations (without outliers values)		1,359	1,865	1,936	1,353
12	Number of outliers values removed		76	98	105	77
13	**Arithmetic average in the range without outliers values**		**2.20**	**2.01**	**1.80**	**1.61**
14	Standard deviation in the range without outliers values		1.45	1.38	1.28	1.24
15	MIN – minimum in the range without outliers values		0.00	0.00	0.00	0.00
16	MAX – maximum in the range without outliers values		6.50	6.11	5.50	5.43

Source: Authors' own study based on the analysis of financial statements of 2,041 companies.

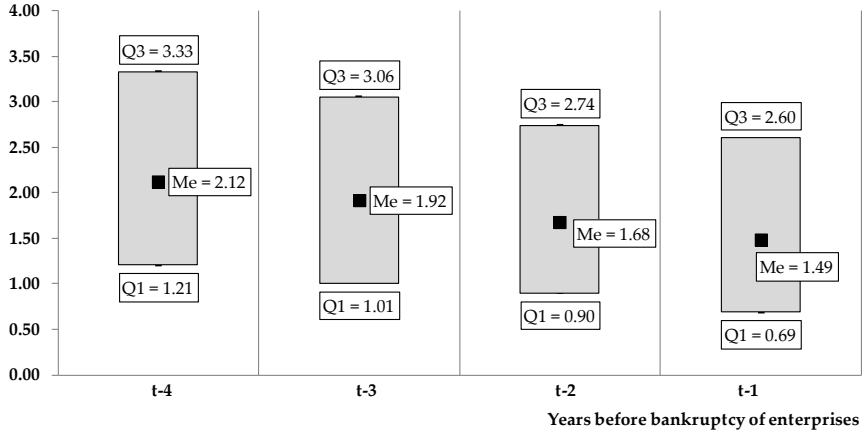

Figure 6. Variability of the Productivity of assets ratio in the period of 4 years prior to the adjudication of bankruptcy of enterprises in Poland

Source: Authors' own study based on the analysis of financial statements of 2,041 companies.

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The amount of the sales revenues relative to the capital potential of an enterprise depends on the scale of the enterprise's activity, often resulting from the demand for its products and services, but also from the degree of the entity's presence in the sector (of the extent of monopolisation, and whether the market is more dispersed or more concentrated). This indicator has some limitations. Its reduced value should be noticeable the year in which bankruptcy is declared and period $t_{(0)}$ is approaching. But, this is often not possible due to a decrease in the sales revenues and a decreasing balance-sheet value. This, in turn, may decrease the sale of selected fixed assets, an often appropriate result of a restructuring attempt, for example, through the use of Lean Management. Such revenues appear in the profit and loss account at the level of other operating revenues only, which means that they do not affect the value of the numerator, while the denominator is reduced. For this reason, the dynamics of the changes in this indicator observed from the period $t_{(-2)}$ to the period $t_{(-1)}$ are not as high as in the case of the other variables analysed in the study. When this happens, the assumption to be made is that nowadays another explanatory variable could be introduced into the model. A year before bankruptcy, the productivity of assets ratio lowers its value on average by 10.24% compared to the preceding year. The chain index of dynamics in this case behaves almost linearly (the dynamics index of this variable from the period $t_{(-3)}$ to the period $t_{(-2)}$ is almost identical, i.e. -10.65%), which means that this variable is not as sensitive to the approaching risk of insolvency (bankruptcy) as the other ratio relationships adopted in the Z_A Model.

Discussions

The research results presented in the study on the effectiveness and the assessment of entities in Poland of the predictive capacities ofAltman's Z_A Model constitute one of the widest verification studies in terms of the number of entities. The size of the research sample is extremely important. Bankrupt enterprises are not homogeneous, while the sources of perturbation and financial problems are often diverse (Dec, 2018). Assessment of the models in terms of their efficiency should therefore include as many objects as possible. In the time since the development of the model analysed in the study (1968), many new experiments in discriminant analysis have been carried out, resulting from subsequent versions of new early warning systems; (Altman et al., 2014, 2016). Attention is primarily drawn to the level of the correlation between the model's explanatory variables. For a function to be characterised by high classification capacity, there should not be too many variables in it (this condition is met by the Z_A Model), because otherwise variables with lower significance levels are introduced into the model, providing information that will not necessarily increase the synthetic efficiency of the models. Nevertheless, two very important issues deserve attention. First of all, models of this type (but not only) should not

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contain correlated variables, as they *de facto* provide a multiplied information load. It seems that correlation occurs between the explanatory variables in the Z_A Model (for instance, between X_2 and X_3, but also X_5, which are variables deriving from the same group of productivity and profitability assessment indicators). Secondly, in the case of enterprise bankruptcy, it also is difficult to distinguish what is the cause (the source) and what is the consequence of the loss of solvency leading (after commercial court's approval) to bankruptcy. The situation here would therefore be related to a correlation between the dependent and the explanatory variables. This problem has been more broadly explained by Zelias (1988). New modelling perspectives emerge as such, which, in ouropinion, should be aimed at: (1) development and improvement of the models dedicated to specific groups of enterprises (e.g. in relation to selected sectors, not to enterprises in general) (Franc-Dąbrowska & Porada-Rochoń, 2017; Kuciński, 2018; (Pitera et al., 2020); (2) an attempt to include qualitative variables in the models, but in such a way as to eliminate the computational subjectivity of the analyst using the model (Lichota, 2017); (3) development of cash-flow-based models based on dynamic flow assessment, and, to a lesser extent, on the ratios based on the balance-sheet data that show greater stability and lesser flexibility; (4) the search for the models' explanatory variables, based on dynamics indices as well as on model systems of inequalities (Antonowicz, 2015b); (5) the search for algorithms increasing the forecast horizon from 1 to 2 years before bankruptcy; previous attempts to apply discriminant analysis in this context have not yielded satisfactory results. This can be confirmed by the research carried out in this study, which clearly shows that the variability level of the indicators constituting the interior of the Z_A function changes (decreases) to the greatest extent during the period t-1, i.e. one year before the declaration of bankruptcy (Wójcicka, 2017). Currently, with regard to business practice and for market analysts, this time advance is too short, which *de facto* means that the information from the model about the potential (high) probability of bankruptcy is belatedly obtained.

Conclusions

Finally, in our opinion, it should be emphasised that more importance should be attached to the assessment of the classification capabilities of the models developed so far and to the holistic drawing of conclusions from the experience of various independent (as well as international) research groups, not by strict focus on development of new models. There still exists a gap in the literature on the subject in relation to the lack of sufficient cross-sectional verification studies (including many different models from different countries). Creation of own models, without careful cause-and-effect assessment regarding the classification capabilities of the existing models, significantly inhibits further progress in this research stream. As such, we would like to explain and justify the essence of the research undertaken in this study. It constitutes an important

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input to the debate on the premises for betterment and improvement of econometric models that are based, *inter alia*, on discriminant analysis and used for early detection of the symptoms of a threat of enterprise bankruptcy.

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