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Chapter 7

Effectiveness of Polish discriminant models in the analysis of companies listed on the Warsaw Stock Exchange

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7.1. Introductory remarks

The economic events in 2020 and 2021 related to the Covid-19 pandemic make it necessary to rethink the threats that may affect business bankruptcies. The main reasons have been the economic unit's management failures and increased competitiveness in the sector. Until now, the overriding goal of each company was to increase its value. In 2020, some companies could continue to achieve their goal, while many struggled to survive. After the pandemic, customer relations, the balance of power in the market, management styles, and work techniques are likely to change. We dealt with a significant economic slump in 2008–2010, but its causes varied in the current millennium. It means that bankruptcies or the need to go through restructuring processes will accompany us all the time, with greater or lesser intensity. Statistical and econometric models help analyse the enterprises' risk of bankruptcy.

The primary purpose of this chapter is to assess the effectiveness of Polish discriminant models for selected companies listed on the Warsaw Stock Exchange because it could help investors not lose their capital. The study attempts to prove that the effectiveness of Polish discriminant models varies and changes in individual years. The second

thesis states that discriminant models' realistic effectiveness is lower than the authors declared. The correct selection of bankruptcy forecasting models will protect investors from losing their capital. Since 1991, when the stock exchange started, some small, newly established, and big companies, listed on the stock exchange for many years, have gone bankrupt.

The study covered 10 Polish discriminant models described in the national literature. The research was conducted in two ways: for all the surveyed companies and sectors. In the sectoral approach, the companies were grouped as follows: construction, trade, production, and services. The following research methods were used in the study: descriptive research with collecting and analysing data from the financial statements and document analysis.

7.2. The reasons for the bankruptcy

The reasons for the bankruptcy have changed in particular periods of the company's activity, country, and world. A precise translation of this is the Covid-19 pandemic of 2020–2022 and the financial crisis of 2008–2010. Now the cause of bankruptcy could be the war in Ukraine.

In the literature (Hołda, 2006; Hołda & Micherda, 2007; Kowalak, 2008), the term 'cause of bankruptcy is used interchangeably' with the terms 'determinant of default' or 'symptoms of financial problems'. These terms indicate that there will be something wrong with the enterprise. That may eventually result in bankruptcy proceedings, followed by the liquidation of the enterprise.

In the literature, there are various classifications of the causes of the bankruptcy of enterprises. The most frequently quoted division is internal (endogenous) and external (exogenous) (Mączyńska & Morawska, 2015, p. 58). Exogenous reasons concern the impact of the environment on the economic unit. Among them, the following factors can be distinguished:

- Of a global nature, including, among other things, international financial crises like 2008–2010, pandemics like Covid-19 today, and political risks associated with government changes. The scope of this subgroup also includes problems related to terrorist attacks. Currently, industries such as aviation, tourism, gastronomy, hospitality are the most significant issues.
- Macroeconomic which affect the activities of enterprises within the boundaries of a given country, covering business cycles. Changes within a given include, among other things, rising inflation (this is the situation in Poland today), and fluctuations in investments.

- Industry, covering only enterprises operating within a given industry. These factors relate, for example, to bankruptcy related to intense competition. These factors refer to mezzo factors (Klepka, 2013, p. 265).
- Regional, for example, the lack of access to qualified employees, demanding access to consulting companies, banks, and logistics companies. These problems may concern enterprises operating in small towns, where there may also be problems with transport, cooperation with the local community, etc.
- Microeconomic, related to direct competition on the market, and cooperation with suppliers and recipients.

External reasons for bankruptcy may also be random, utterly independent of the prevailing economic situation in the country and the world. Such factors include floods (as in 1997 in Poland), fires, and earthquakes. These factors are often short-term, unpredictable, and impossible to predict. The current situation related to the Covid-19 virus, which was never taken into account in Poland before March 2020, can be considered to be such a reason. It may result in loss of customers and processing capacity. Companies may also be unable to re-establish cooperation with suppliers and customers at some point.

The second group of factors is endogenous factors related to what is happening in the enterprise. These reasons are often decisive in determining whether an individual will continue to operate in the face of future adversity. Identifying these factors and their influence on decisions is more accessible than exogenous factors. The speed of detecting elements affects the rate of implementing corrective mechanisms. The reasons for this type include errors related to management, inadequate or lack of internal control, employing employees with insufficient qualifications, using outdated production technologies, and failure to adapt to changes in the field of computerisation of work.

Nahotko distinguishes between short-term and long-term factors (Nahotko, 2003, pp. 48–50). Short-term factors occur suddenly in an enterprise, and their duration is short. The emergence of such elements is difficult to predict and may cause temporary financial difficulties, which, however, under certain conditions, may lead to bankruptcy. In most cases, the management boards of companies deal with this type of factor, although it may depend on the financial reserves held, the scale of operations, industry, etc. Such a situation applies, for example, to temporary cash shortages, which affects problems with maintaining a safe liquidity level. Long-term factors are possible to detect in the short term, but the introduction of changes usually takes a long time and may require external help in consulting companies and experts. Sometimes, the changes are made to adapt to a detected factor rather than overcome it. Such a situation may be the current pandemic. Some industries and their

units have had to accept new operating conditions for over a year (e.g., the catering industry provides take-away services).

According to Kowalak (2008), factors can combine and influence each other. Relatively rarely, the bankruptcy of a company is influenced by one aspect. It could catalyse a chain of events revealing that other factors may also influence financial distress. For example, deficiencies in management may emerge when other factors already occur (the introduction of new taxes, duties, and fees by the government).

Mączyńska points out that other factors occur in the first stage of a crisis in an enterprise, i.e., in the early symptoms, others in the second stage, i.e., in the escalation stage, and unlike in the actual crisis stage (Mączyńska, 2008, p. 32, 2013, p. 20).

7.3. Polish discriminant models

Ten discriminant models most often described in Polish literature were used for the research. They developed over the last 30 years after the political transformation. The most frequently described model established in the mid-90s of the previous century was the one created by Mączyńska from the Warsaw School of Economics. This model consists of six financial indicators, and its form is as follows (Kowalak, 2008, 2020, p. 82; Wojnar, 2014):

$$Z_M = 1.5 \cdot X_1 + 0.08 \cdot X_2 + 10 \cdot X_3 + 4 \cdot X_4 + 0.3 \cdot X_5 + 0.1 \cdot X_6,$$

where: X_1 – (operating profit + depreciation) / total liabilities,
X_2 – total assets / total liabilities,
X_3 – gross profit / total liabilities,
X_4 – gross profit / revenues,
X_5 – stocks / revenues.
X_6 – revenues / total assets.

The bankruptcy risk assessment for the Z_M measure is as follows (Kopczyński, 2017, p. 31):

$Z_M < 0$ – bankruptcy,
$0 < Z_M < 1$ – grey zone,
$Z_M > 1$ – non-bankruptcy.

In the following years, Mączyńska made further attempts to develop discriminant models. Together with Zawadzki, she developed an INE PAN model consisting of four financial indicators. This function was as follows:

$$Z_{MZ} = 9.498 \cdot X_1 + 3.566 \cdot X_2 + 2.903 \cdot X_3 + 0.452 \cdot X_4 - 1.498,$$

where: X_1 – operating profit / total assets,
X_2 – own equity / total assets,
X_3 – (net profit + depreciation) / total assets,
X_4 – current assets / short-term liabilities.

In this model, the value that separates economic units at risk of bankruptcy from companies with good financial standing is zero.

Gajdka and Stos were among the first in the 1990s to publish a discriminant model based on information from the financial statements of Polish companies. As a result of the research, they developed a function with the following form (Gajdka & Stos, 1996; Korol & Prusak, 2018, p. 108):

$$Z_{GS} = -0.0856425 \cdot X_1 + 0.0007747 \cdot X_2 + 0.92220985 \cdot X_3 - 0.6535995 \cdot X_4 - 0.594687 \cdot X_5 + 0.7732059,$$

where: X_1 – revenues / total assets,
X_2 – short-term liabilities x 360 / operating costs,
X_3 – net profit / total assets,
X_4 – gross profit / revenues,
X_5 – total liabilities / total assets.

If the Z_{GS} value is lower than 0.45, there is a risk of enterprise bankruptcy. In the case of a higher value, the financial condition of the economic entity assesses as good.

Another discriminant model used in the study is the model of Pogodzińska and Sojak, in which they proposed the following function (Pogodzińska & Sojak, 1995, p. 56; Wojnar, 2014, p. 221):

$$Z_{PS} = 0.644741 \cdot X_1 + 0.912304 \cdot X_2,$$

where: X_1 – (current assets – stocks) / short-term liabilities,
X_2 – gross profit / revenues.

The risk of bankruptcy is assessed as follows:

$Z_{PS} < -0.454$ – bankruptcy risk,
$-0.454 < Z_{PS} < 0.09$ – grey area,
$Z_{PS} > 0.09$ – no risk of bankruptcy.

Hadasik prepared another model used in the study. It results from her research in 1991–1997 among enterprises from Poznań. One of the functions she published has the following form (Hadasik, 1995; Korol, 2010, p. 102; Tłuczak, 2013, p. 426):

$$Z_H = 0.365425 \cdot X_1 - 0.765526 \cdot X_2 - 2.40435 \cdot X_3 + 1.59079 \cdot X_4 + 0.00230258 \cdot X_5 - 0.0127826 \cdot X_6 + 2.36261,$$

where: X_1 – current assets / short-term liabilities,
X_2 – (current assets – stocks) / short-term liabilities,
X_3 – total liabilities / total assets,
X_4 – working capital / total liabilities,
X_5 – short-term receivables / revenues,
X_6 – stocks / revenues.

If the value of the Z_H function is less than zero, the enterprise is at risk of bankruptcy. A higher value means that the examined enterprise has a good financial condition.

The next discriminant model used in the study is the model of Wierzba. The function developed by him was based on four financial indicators and looks as follows (Wierzba, 2000, pp. 79–105; Hamrol & Chodakowski, 2008, p. 21; Wojnar, 2014, p. 222):

$$Z_W = 3.26 \cdot X_1 + 2.16 \cdot X_2 + 0.3 \cdot X_3 + 0.69 \cdot X_4,$$

where: X_1 – (operating profit – depreciation) / total assets,
X_2 – (operating profit – depreciation) / revenues,
X_3 – current assets / total liabilities,
X_4 – working capital / total assets.

Suppose the value of the function is lower than zero, the assessed enterprise threat with bankruptcy. In the case of a higher value, its financial condition is good.

Hołda's models are the ones of the most frequently used in analysing the risk of bankruptcy. He is the creator of discriminant models, decision trees, and point models. One of its functions, most often cited, has the following form (Kowalak, 2020, p. 83):

$$Z_{HA} = 0.681 \cdot X_1 - 0.0196 \cdot X_2 + 0.00969 \cdot X_3 + 0.000671 \cdot X_4 + 0.157 \cdot X_5 + 0.605,$$

where: X_1 – current assets / short-term liabilities,
X_2 – total liabilities / total assets,
X_3 – net profit / average total assets,
X_4 – average short-term liabilities / operating costs,
X_5 – revenues / average total assets.

The author determined the following values of the ranges in the assessment of bankruptcy risk:

$Z_{HA} <= -0.3$ – bankruptcy risk,
$-0.3 < Z_{HA} <= 0.1$ – grey area,
$Z_{HA} > 0.1$ – no risk of bankruptcy.

Hamrol, Czajka, & Piechocki (2004) examined 100 companies, half of which declared bankruptcy, and the other half was in good financial condition. As a result of the research, the following discriminant function was obtained (Hamrol et al., 2004, p. 37; Wojnar, 2014, p. 224):

$$Z_{HCP} = 3.562 \cdot X_1 + 1.588 \cdot X_2 + 4.288 \cdot X_3 + 6.719 \cdot X_4 - 2.368,$$

where: X_1 – net profit / total assets,
X_2 – (current assets – stocks) / short-term liabilities,
X_3 – (own equity + long-term liabilities) / total assets,
X_4 – operating profit / revenues.

In this model, zero is the value that separates enterprises with predicted bankruptcy and companies with good financial conditions.

Another model included in the research is Prusak's model, consisting of two functions: one forecasting one year before bankruptcy and the other predicting two years before the default. The first function has the following form (Prusak, 2005; Kisielińska & Waszkowski, 2010, p. 21):

$$Z_{P1} = 6.5244813 \cdot X_1 + 0.1479705 \cdot X_2 + 0.4061491 \cdot X_3 + 2.1753976 \cdot X_4 - 1.5684928,$$

where: X_1 – operating profit / total assets,
X_2 – operating costs / short-term liabilities,
X_3 – current assets / short-term liabilities,
X_4 – operating profit / revenues,

and second

$$Z_{P2} = 1.4382993 \cdot X_1 + 0.1878468 \cdot X_2 + 5.0228595 \cdot X_3 - 1.8713366985321,$$

where: X_1 – (net profit + depreciation) / total assets,
X_2 – operating costs / short-term liabilities,
X_3 – operating profit / revenues.

In the case of the first Prusak's model, the assessment is as follows:

$Z_{P1} < -0.13$ – the risk of bankruptcy,
$-0.13 <= Z_{P1} < 0.65$ – grey zone,
$Z_{P2} >= 0.65$ – no risk of bankruptcy,

and in the case of the second:

$Z_{P1} < -0.7$ – the risk of bankruptcy,
$-0.7 <= Z_{P1} < 0.295$ – grey area,
$Z_{P2} >= 0.295$ – no risk of bankruptcy.

7.4. Assessment of the risk of bankruptcy of selected companies listed on the Warsaw Stock Exchange

There are nine Polish discriminatory models analysed, described in the section 7.3. The primary purpose of the research is to check the predictive capacity of a specific model from five years to a year before bankruptcy. The second purpose is to study the effectiveness of assessing the risk of default. The research used the information in the financial statements for 2016–2019 included in the Notoria Financials database *via* the licensed EMIS INTELLIGENT database. A research sample consists of 26 companies declared bankrupt and 26 with good or very good financial conditions. The companies that declared bankruptcy were removed from the list of the Warsaw Stock Exchange in 2016–2019 (the data were prepared by K. Pędziwiatr).

The research sample was divided into four sectors: construction, trade, manufacturing, and services. The population in each group was as follows:

- construction: six companies with bankruptcy and six companies with good financial standing,
- trade: six companies with declared bankruptcy and six with excellent financial condition,
- production: seven companies with bankruptcy and eight companies with a perfect financial situation,
- services: seven companies with bankruptcy and six companies with good financial standing.

The assessment results of the effectiveness of Polish discriminant models in the study of listed companies are presented in Table 7.1.

Table 7.1. Effectiveness of Polish discriminant models (%)

Models by	Years before bankruptcy				
	5	4	3	2	1
Mączyńska	60	51	55	55	55
Pogodzińska, Sojak	53	56	62	65	75
Hadasik	57	55	68	68	83
Wierzba	57	55	68	72	79
Hołda	51	51	51	51	53
Gajdka, Stos	58	62	53	47	47
Hamrol, Czajka, Piechocki	56	62	71	77	85
Mączyńska, Zawadzki	53	64	72	81	85
Prusak	–	–	–	55	50

Gray cells indicate the highest performance of the model for the year.

Source: own presentation.

The calculations presented in Table 7.1 show that the most effective discriminant model in the entire period under study was that of Mączyńska and Zawadzki. The models by Hołda, Gajdka, and Stos showed the lowest effectiveness.

Table 7.2 presents the results concerning the assessment of the effectiveness of discriminant models in the construction sector. According to the calculations, the most effective model for assessing construction sector companies was that by Mączyńska and Zawadzki. The models by Hołda and Hamrol, Czajka and M. Piechocki turned out to be the least effective.

Table 7.2. Effectiveness of Polish discriminant models in the construction sector (%)

Model by	Years before bankruptcy				
	5	4	3	2	1
Mączyńska	55	75	91	91	82
Pogodzińska, Sojak	58	54	63	71	79
Hadasik	67	50	75	83	92
Wierzba	58	67	75	83	92
Hołda	50	50	50	50	50
Gajdka, Stos	58	58	50	42	33
Hamrol, Czajka, Piechocki	58	67	75	92	92
Mączyńska, Zawadzki	67	83	83	100	100
Prusak	–	–	–	75	67

Gray cells indicate the highest performance of the model for the year.

Source: own presentation.

Table 7.3 presents the effectiveness of Polish discriminant models in the commercial sector. The analysis of the figures included in the table shows that the most effective five and four years before the bankruptcy was the model of Gajdka and Stos. The effectiveness of this model decreased in the following years. Mączyńska and Zawadzki's model showed the highest efficiency three and two years before the bankruptcy. A year before the bankruptcy, Hadasik and Hamrol, Czajka, and Piechocki were the most effective models.

Table 7.4 presents the effectiveness of Polish discriminant models in the manufacturing sector. The calculations show that the most effective model was that by Hamrol, Czajka, and Piechocki, which in the four years before bankruptcy led to the highest probability of the proper allocation of a company to a given group of companies. The models by Gajdka, Stos, and Hołda were the least effective.

Table 7.3. Effectiveness of Polish discriminant models in the commercial sector (%)

Models by	Years before bankruptcy				
	5	4	3	2	1
Mączyńska	58	58	75	75	67
Pogodzińska, Sojak	38	54	67	67	67
Hadasik	50	58	67	67	83
Wierzba	58	67	67	67	73
Hołda	50	50	50	50	50
Gajdka, Stos	83	75	50	50	42
Hamrol, Czajka, Piechocki	33	58	75	75	83
Mączyńska, Zawadzki	42	58	83	83	75
Prusak	–	–	–	67	58

Gray cells indicate the highest performance of the model for the year.

Source: own presentation.

Table 7.4. Effectiveness of Polish discriminant models in the manufacturing sector (%)

Models by	Years before bankruptcy				
	5	**4**	**3**	**2**	**1**
Mączyńska	60	40	53	60	67
Pogodzińska, Sojak	53	57	53	67	80
Hadasik	53	53	60	67	87
Wierzba	53	47	60	73	80
Hołda	53	53	53	53	60
Gajdka, Stos	47	60	60	47	47
Hamrol, Czajka, Piechocki	71	64	64	71	93
Mączyńska, Zawadzki	60	60	53	73	80
Prusak	–	–	–	53	53

Gray cells indicate the highest performance of the model for the year.

Source: own presentation.

Table 7.5 presents the effectiveness of Polish discriminant models in the service sector. As the calculations show, five years before the bankruptcy, the most effective model is that by Pogodzińska and Sojak. Four years before the bankruptcy, Mączyńska's model is the most effective. For the three and two years before bankruptcy, the most effective models turned out to be the models by Hamrol, Czajka, Piechocki, Hadasik, Wierzba, and Mączyńska and Zawadzki (71%). The weakest model was that by Hołda, which proved to be effective at the level of 50% in each period. The most predictive

models for one year before bankruptcy are those by Hamrol, Czajka, Piechocki, and Mączyńska and Zawadzki.

Table 7.5. Effectiveness of Polish discriminant models in the service sector (%)

Models by	Years before bankruptcy				
	5	4	3	2	1
Mączyńska	43	64	64	71	64
Pogodzińska, Sojak	61	57	68	57	71
Hadasik	57	57	71	57	71
Wierzba	57	43	71	64	71
Hołda	50	50	50	50	50
Gajdka, Stos	50	57	50	50	64
Hamrol, Czajka, Piechocki	57	57	71	71	86
Mączyńska, Zawadzki	43	57	71	71	86
Prusak	–	–	–	43	57

Gray cells indicate the highest performance of the model for the year.

Source: own presentation.

Bankruptcies in 2020–2021 do not have to be caused by the Covid-19 pandemic, as financial problems do not arise overnight. It is especially true of large companies that do not face issues such as micro- and small enterprises. It is worth noting that some of the enterprises improved their financial condition during the pandemic.

This chapter aimed to draw attention to the financial problems of Polish companies listed on the Warsaw Stock Exchange. Before the pandemic, some companies had financial problems that could be detected using Polish discriminant models. The pandemic could, at best, have hastened bankruptcy but also delayed it. Like other business units, enterprises noted on Warsaw Stock Exchange may use various proceedings under the restructuring or bankruptcy law.

As a result of the study, it proves that the models' predictive effectiveness is different. It has also shown that the impact on the efficacy of the models depends on the sector. The model of Mączyńska and Zawadzki, and model of Hamrol, Czajka and Piechocki showed the highest predictive ability. This effectiveness was higher than 85% one year before the bankruptcy for all companies. The highest efficiency of 93% demonstrates Hamrol, Czajka and Piechocki's model for the manufacturing sector. The model of Gajdka and Stos showed the lowest effect on the 47% level (less than 50%). The low effectiveness represent models of Pogodzińska and Sojak, of Hołda, and of Prusak.

The research shows that investors invested in the Warsaw Stock Exchange should use at least two discriminant models to make decisions based on them effectively: the model of Mączyńska and Zawadzki, and the model of Hamrol, Czajka and Piechocki. These models are effective for all sectors tested in the research.

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