

The comparative analysis of the prediction effectiveness of selected discriminant analysis models

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Abstract: The main aim of the article was to verify the effectiveness of prediction of selected models of discriminant analysis on the example of a sample of 40 enterprises. The data of enterprises was obtained from the EMIS database and in the case of enterprises continuing their operations it concerned the year 2017, while in the case of bankrupt enterprises it was the data from the year before bankruptcy. The article presents models of discriminant analysis, which are classified as early warning systems about the risk of enterprise bankruptcy. The results allow to assess the financial situation of the company. Based on the results of a sample of forty companies, including ten for which an application for bankruptcy was filed, it was found that most of the discriminant models used in the article properly reflected the good or threatened financial condition of the company. The authors conclude that discriminatory models facilitate decision making but the models do not have 100% effectiveness.

Keywords: discriminant analysis, financial standing of companies, financial analysis

1. Introduction

Verification of the financial condition of enterprises is performed by many entities operating on the market. The results of the verification with the interpretation are used primarily by the business owners and managers to make decisions regarding further development directions and entities that intend to invest in the business, entities undertaking cooperation, institutions granting credits, loans and subsidies for the enterprise.

At the same time, too strong mutual relations between entities may lead to the so-called domino effect—the bankruptcy of one company may lead to another bankruptcy. Therefore, the problem of bankruptcy of the company, its definition and forecasting becomes an important issue from an economic point of view (Balina, 2012).

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The main aim of this article is to verify the diagnostic effectiveness of selected models of discriminant analysis on the example of a sample of 40 enterprises operating in Poland, of which 10 filed for bankruptcy. 26 discriminant models were analyzed. The calculations for enterprises conducting operations were made on the basis of the reports for 2016. These companies continued operations in 2017. The data of the company's continuing business activities were generated from the EMIS database and were generated according to the following criteria. Companies in the IT, automotive industries and WIG 20 were selected based on the size of assets, while in the case of WIG 20 companies, the research does not include banks and insurers. The data of the bankrupt enterprises were generated from the National Court Register and EMIS and cover the years 2003–2018.

A research hypothesis was also put forward that “with the passage of time, discriminant models are characterized by a lower prediction ability”.

2. Discriminatory models as a predictor of the company's financial situation

There are many methods of assessing the financial condition of a company, in the literature, e.g. traditional indicator analysis, discriminant analysis models, logistic regression models, point risk assessment methods. This article will present the results of the research on effectiveness of prediction selected models of discriminant analysis.

There have been many studies on the effectiveness of these models so far, which is confirmed by publications: Hamrol and Chodakowski, 2008; Balina, 2012; Kisielińska and Waszkowski, 2010; Piłera, 2018. The conducted research shows that discriminant models are characterized by a high degree of effectiveness in predicting the financial condition of enterprises. However, it should be remembered that the first model developed for the Polish economy was created in 1994 (Mączyńska), next in 1996 (Gajdka and Stos), 1998 (Hadasik), and 2004 (Appenzeller and Szarzec), so it was created in other economic realities, which means that these models could lose their diagnostic credibility.

In addition, there were statements in the domestic literature that “there is no single, only valid and best model of assessing the enterprise's risk of bankruptcy” (Mączyńska and Zawadzki, 2006) and it is not always possible to make an unambiguous assessment of the overall financial situation of the company, which takes into account parallel, various aspects of the business activity of enterprise (Korol, 2005). A. Hołda wrote that it is practically impossible to formulate one function that would preserve its prognostic values for decades in the conditions of the Polish economy (Hołda, 2001; Zarzecki, 2000). G. Gołębiowski and A. Tłaczała formulated the thesis that models constructed “no later than in the last decade” should be used (Gołębiowski and Tłaczała, 2005; Kitowski, 2011).

Therefore, the author carried out research aimed at determining whether discriminant models did not lose diagnostic credibility. Because early warning systems developed for a particular country should not be mechanically transferred to other countries, this article uses only models that take into account the specificity of the Polish economy (Spychała, 2013). According to D. Wędzki, the Altman models (1968) should not be used, because the American economy is so structurally different from the Polish one that it seems unlikely to obtain

the expected results of the model (Wędzki, 2005). Discriminatory models do not have disadvantage that has indicator analysis, namely difficulties in interpretation (Bombiak, 2010). Therefore, in countries with a developed market economy, in addition to traditional indicator analysis, the most popular analytical tools that allow to identify threats of the company's financial condition should be multi-criteria discriminant analysis (Rolbiecki, 2011), which allows the firm to qualify to one of two or to one of more research groups (Wajda, 2009).

The discriminatory function is the value that is the sum of the multiply of the indicators that characterize the economic and financial condition of the enterprise and the weights (discriminant factors) corresponding to these indicators. This value is the basis for deducting about the economic and financial situation of the enterprise through its confrontation with the threshold values adopted in the model (Żelazowska-Przewłoka, 2012). At the same time, these methods are attributed the value of universality and unchanging diagnostic credibility, regardless of the passage of time from their publication, which is unauthorized from a methodological point of view (Kitowski, 2013).

The linear discriminant function has the following form:

$$f(X) = a_0 + a_1X_1 + a_2X_2 \dots + a_nX_n, \quad (1)$$

where:

a —weight of the financial analysis ratio

x —financial analysis indicators

a_0 —constant.

Each object is described by the values of n variables (X) (Gajdka and Stos, 2003). Interpretation of the result is made on the basis of a comparison of the calculated value of the discriminant function $f(X)$ with the limit value, the level of which is determined by the author of the model (Zielińska-Sitkiewicz, 2012).

26 models of discriminant analysis available in the national literature, based on financial statements of 40 enterprises, were subject to verification.

The discriminant models used in the article differ not only in the number of financial analysis indicators used, but also in the period in which they were created, the number of entities that constituted the test group when estimating the parameters, a specific range of the value of assets and a specific sector or legal form of a commercial company.

Table 1. Discrimination functions applied

No.	Author and date of model construction	The limit value of the function that determines the safe financial condition	Formula of the discriminant function	Model effectiveness determined by the author
1.	E. Mączyńska. 1994	> 0	$Z_M = 1.5 \cdot W_1 + 0.08 \cdot W_2 + 10.0 \cdot W_3 + 5.0 \cdot W_4 + 0.3 \cdot W_5 + 0.1 \cdot W_6$	NDA
2.	R. Jagiełło. 2013	> 0	$Z_{JU} = -2.24461 + 2.122 \cdot W_1 + 5.738 \cdot W_2 + 0.07 \cdot W_3 + 0.323 \cdot W_4$ (services)	91.25%
3.	R. Jagiełło. 2013	> 0	$Z_{JP} = -1.8603 + 12.296 \cdot W_1 + 0.1675 \cdot W_2 + 1.399 \cdot W_3$ (industry)	92.50%
4.	E. Mączyńska and M. Zawadzki. INE PAN F. 2006	> 0	$Z_{PAN F} = 9.478 \cdot W_1 + 3.613 \cdot W_2 + 3.246 \cdot W_3 + 0.455 \cdot W_4 + 0.802 \cdot W_5 - 2.478$	85.20%
5.	E. Mączyńska and M. Zawadzki. INE PAN G. 2006	> 0	$Z_{PAN G} = 9.498 \cdot W_1 + 3.566 \cdot W_2 + 2.903 \cdot W_3 + 0.452 \cdot W_4 - 1.498$	88.40%
6.	M. Hamrol, B. Czajka and M. Piechocki. 2004	> 0	$Z_{HCzP} = 3.562 \cdot W_7 + 1.588 \cdot W_{16} + 4.288 \cdot W_5 + 6.719 \cdot W_{13} - 2.368$	96.00%
7.	D. Hadasik. 1998	> 0	$Z_{H1} = -2.50761 \cdot W_5 + 0.00141147 \cdot W_9 - 0.00925162 \cdot W_{12} + 0.0233545 \cdot W_{17} + 2.60839$	93.18%
8.	D. Hadasik. 1998	> 0	$Z_{H2} = 0.703585 \cdot W_1 - 1.2966 \cdot W_2 - 2.21854 \cdot W_5 + 1.52891 \cdot W_7 + 0.00254294 \cdot W_9 - 0.01140733 \cdot W_{12} + 0.0186057 \cdot W_{17} + 2.76843$	95.45%
9.	D. Hadasik. 1998	> -0.3842325	$Z_{H3} = -1.3301 \cdot W_5 + 0.04094 \cdot W_8 - 0.0038 \cdot W_{12} + 2.16525 \cdot W_{14} + 0.0235 \cdot W_{17} + 1.6238$	88.52%
10.	D. Hadasik. 1998	$> -0,374345$	$Z_{H4} = 0.365425 \cdot W_1 - 0.765526 \cdot W_2 - 2.40435 \cdot W_5 + 1.59079 \cdot W_7 + 0.00230258 \cdot W_9 - 0.0127826 \cdot W_{12} + 2.36261$	95.08%
11.	D. Hadasik. 1998	$> -0,354915$	$Z_{H5} = -2.62766 \cdot W_5 + 0.0013463 \cdot W_9 - 0.00922513 \cdot W_{12} + 0.0272307 \cdot W_{17} + 2.41753$	93.44%
12.	D. Hadasik. 1998	$> -0,42895$	$Z_{H6} = 0.335969 \cdot W_1 - 0.71245 \cdot W_2 - 2.4716 \cdot W_5 + 1.46434 \cdot W_7 + 0.00246069 \cdot W_9 - 0.0138937 \cdot W_{12} + 0.0243387 \cdot W_{17} + 2.59323$	96.72%
13.	D. Hadasik. 1998	> 0	$Z_{H7} = -2.3001 \cdot W_5 + 0.00153002 \cdot W_9 - 0.0104159 \cdot W_{12} + 0.0286736 \cdot W_{17} + 2.6571$	91.07%
14.	D. Hadasik. 1998	$> -0,227935$	$Z_{H8} = -1.98281 \cdot W_5 + 0.00118429 \cdot W_9 + 0.180604 \cdot W_{11} - 0.00847833 \cdot W_{12} + 1.53416 \cdot W_{14} + 0.0235729 \cdot W_{17} + 1.97095$	92.54%

15.	D. Appenzeller and K. Szarzec. 2004	> 0	$Z_{ASz1} = 1.286 \cdot W_1 - 1.305 \cdot W_2 - 0.226 \cdot W_3 + 3.015 \cdot W_4 - 0.005 \cdot W_5 - 0.009 \cdot W_6 - 0.661$	85.29%
16.	D. Appenzeller and K. Szarzec. 2004	> 0	$Z_{ASz2} = 0.819138 \cdot W_1 + 2.56661 \cdot W_2 - 0.00500208 \cdot W_3 + 0.000628865 \cdot W_4 - 0.00951358 \cdot W_5 - 0.556326$	88.23%
17.	T. Maślanka. 2008	> 0	$Z_{M4} = -1.44979 + 3.55401 \cdot W_4 + 2.14847 \cdot W_6 - 0.33302 \cdot W_7 + 4.81862 \cdot W_{17} + 0.05236 \cdot W_{26} + 2.52164 \cdot W_4$	91.25%
18.	T. Maślanka. 2008	> 0	$Z_{M24} = 2.26566 + 6.00203 \cdot W_6 - 0.57209 \cdot W_7 + 11.85751 \cdot W_{13} - 0.01632 \cdot W_2$	92.50%
19.	J. Gajdka and D. Stos. 1996	$< 0,32268$	$Z_{GS2} = 0.017803 \cdot W_1 + 0.588694 \cdot W_2 + 0.138657 \cdot W_3 - 4.31026 \cdot W_4 - 0.01038 \cdot W_5 + 0.43744$	85.00%
20.	J. Gajdka and D. Stos. 1996	$> 0,44$	$Z_{GS3} = 0.20098985 \cdot W_1 + 0.0013027 \cdot W_2 + 0.7609754 \cdot W_3 + 0.9659628 \cdot W_4 - 0.341096 \cdot W_5$	82.50%
21.	J. Gajdka and D. Stos. 1996	$> 0,45$	$Z_{GS4} = 0.7732059 - 0.0856425 \cdot W_1 + 0.0007747 \cdot W_2 + 0.9220985 \cdot W_3 + 0.6535995 \cdot W_4 - 0.594687 \cdot W_5$	92.50%
22.	J. Gajdka and D. Stos. 1996	> 0	$Z_{GS5} = -0.0005 \cdot W_1 + 2.0552 \cdot W_2 + 1.7260 \cdot W_3 + 0.1155 \cdot W_4 - 0.3342$	100.00%
23.	B. Prusak. 2004	$> -0,1$	$Z_{P1} = -1.568492770195 + 6.5244812965393 \cdot W_1 + 0.147970467805862 \cdot W_2 + 0.406149059534073 \cdot W_3 + 2.17539358139038 \cdot W_4$	100.00%
24.	B. Prusak. 2004	> 0	$Z_{P3} = 6.9973 \cdot W_1 + 0.1191 \cdot W_2 + 0.1932 \cdot W_3 - 1.176$	97.86%
25.	M. Tymoszuk. 2013	> 0	$Z_T = 14.71330 \cdot W_1 - 0.00157 \cdot W_2 - 0.03304 \cdot W_3 + 6.80845 \cdot W_4 - 7.35595$	85.29%
26.	T. Korol. 2010	$Z_{ban} < Z_{non}$	$Z_{ban} = -1.97 + 2.35 \cdot W_1 - 2.90 \cdot W_5 - 2.68 \cdot W_8 + 0.79 \cdot W_9$ $Z_{non} = -3.49 + 9.93 \cdot W_1 - 0.05 \cdot W_5 - 0.62 \cdot W_8 + 1.19 \cdot W_9$	86.79%

Source: Author's own elaboration.

3. Research results

The results of correct indications of the financial condition of companies made using the models presented in point 2 are presented in Table 2. The research sample consisted of 10 enterprises from the IT sector (AB, Action, Asseco, Magdalena Mucha Przedsiębiorstwo Wielobranżowe Batna, Dell Products [Poland], Zakłady Urządzeń Komputerowych Elzab, Flextronics International Poland, Introl, Nokia Solutions and Networks, NTT System),

10 enterprises from the automotive sector (Volkswagen Poznań, Trw Polska, Solaris Bus Coach, Sitech, Saint-Gobain Innovative Materials Polska, Nexteer Automotive Poland, MAN Trucks, Hutchinson Poland, Faurecia Wałbrzych, Firma Oponiarska Dębica), and 10 enterprises from the WIG 20 portfolio (CCC, CD Projekt, Energa, JSW, KGHM, Lotos, LPP, Orlen, PGE, Tauron), which in 2017 continued their activities, and 10 enterprises for which an application for bankruptcy has been filed (Euro Cargo, Instal, Kastor, Persena, Polkap, Resbud, Transsystem, Watex, ZM Dębica, Zielona Energia). The data of the operating companies were generated from the EMIS database and the National Court Register and were included in the sample based on the highest asset value criterion.

According to the research, the financial condition of enterprises representing the research sample from the IT industry, automotive industry and the WIG 20 portfolio is not endangered. It is true that some models indicated individual cases of bankruptcy, but taking into account the indications of other models, it should be stated that these were incorrect indications.

Table 2. Results of correct indications based on the results of discriminative models for the selected sample of 40 companies

No.	Model author (model number)	Correct indication of the condition of 40 enterprises ¹ —arranged in descending order
1.	E. Mączyńska (Z_M)	93%
2.	M. Hamrol, B. Czajka and M. Piechocki—the Poznań model (Z_{HCzP})	93%
3.	D. Hadasik (Z_{H5})	93%
4.	D. Hadasik (Z_{H8})	93%
5.	D. Appenzeller and K. Szarzec (Z_{ASz2})	92%
6.	T. Maślanka (Z_{M4})	92%
7.	E. Mączyńska and M. Zawadzki—INE PAN G ($Z_{PAN G}$)	91%
8.	D. Hadasik (Z_{H2})	90%
9.	D. Hadasik (Z_{H6})	90%
10.	D. Hadasik (Z_{H7})	90%
11.	E. Mączyńska and M. Zawadzki—INE PAN F ($Z_{PAN F}$)	89%
12.	D. Hadasik (Z_{H1})	88%
13.	D. Hadasik (Z_{H3})	88%
14.	D. Hadasik (Z_{H4})	85%
15.	R. Jagiełło (Z_{JU}) (Z_{JP})	85%

¹ In the case of companies that published a profit and loss account in the comparative variant, it was not possible to apply all discriminatory models.

16.	T. Maślanka (Z_{M24})	85%
17.	T. Korol	82%
18.	D. Appenzeller and K. Szarzec (Z_{ASz1})	79%
19.	J. Gajdka and D. Stos (Z_{GS4})	76%
20.	M. Tymoszuik (Z_T)	71%
21.	B. Prusak (Z_{P3})	66%
22.	J. Gajdka and D. Stos (Z_{GS5})	63%
23.	J. Gajdka and D. Stos (Z_{GS3})	52%
24.	B. Prusak (Z_{P3})	46%
25.	J. Gajdka and D. Stos (Z_{GS2})	38%

Source: Author's own elaboration.

According to the research, the highest efficiency was achieved by the models of E. Mączyńska, M. Hamrol, B. Czajka and M. Piechocki (the Poznań model) and D. Hadasik (5) and (8), which amounted to 93%. Taking into account the sample of 40 companies, the model of E. Mączyńska incorrectly classified one company which continued operations and two enterprises for which a bankruptcy application was filed. However, the Poznań model incorrectly classified two enterprises which continued operations and one bankrupt enterprise whereas the models 5 and 8 by D. Hadasik correctly classified all enterprises operating, while wrongly classified 3 bankrupt enterprises. It should be noted that these models were constructed by the authors in 1994, 1998 and 2004, respectively, 26, 22 and 16 years ago, which means that with the passage of time the models did not lose the ability to predict.

Thus, the research hypothesis was rejected.

A slightly lower efficiency, i.e. 92%, was demonstrated by D. Appenzeller and K. Szarzec model (2) and the T. Maślanka model (4). These models incorrectly classified 2 “operating” and 1 “bankrupt” enterprises.

In the top of ten models that most accurately represented the financial condition were also the INE PAN model G—91% and D. Hadasik models (2), (6) and (7)—90%. It should be noted that D. Hadasik's models correctly qualified enterprises which continued operations in 100%, while the incorrect indications concerned only bankrupt enterprises.

The correct classification from 76%–89% was presented by models of INE PAN F, D. Hadasik (1), (3) and (4), R. Jagiełło, T. Maślanka (24), T. Korol, D. Appenzeller and K. Szarzec (1), J. Gajdka and D. Stos (4). In this group, the model by D. Hadasik (3) correctly classified all operating enterprises, whereas the T. Korol model and J. Gajdka and D. Stos model (4) correctly classified all enterprises threatened with bankruptcy.

The remaining models were characterized by efficiency at the level of 38%–71%. The weakest predictive ability was demonstrated by the model of J. Gajdka and D. Stos (2). However, it should be noted, that most of the models included in this range correctly classified the

companies which applied for bankruptcy because the percentage of correct indications was in the case of B. Prusak model (1) and J. Gajdka and D. Stos models (2), (3) and (5)—100%, while for the models of M. Tymoszuik and B. Prusak (3)—80%.

It should also be noted that the models were estimated on the basis of a certain group of companies from various industries and with a specific asset value. Therefore, there may be a mismatch between the enterprise and the model. That is why it is so important to use several models to exclude a possible mismatch.

4. Conclusions

Taking into account the results, it can be concluded that not all discriminant models are a reliable source of information about the company's financial condition and do not allow predicting the risk of bankruptcy of the company. Of the 25 discriminant models covered by the study:

- 10 correctly reflected the financial condition of enterprises, as their prediction ability amounted to at least 90%. These were the models of E. Mączyńska, M. Hamrol, B. Czajka, M. Piechocki—the Poznań model, D. Hadasik (5) and (8), D. Appenzeller, K. Szarzec (2), T. Maślanka (4), E. Mączyńska, M. Zawadzki—INE PAN G, D. Hadasik (2), (6) and (7). Taking into account the date of the model's creation, it should be noted that among those listed there is the first model designed for enterprises operating in Poland, i.e. the model of E. Mączyńska from 1994, while the youngest one is the model by T. Maślanka (4) from 2008. Note that the companies included in each analytical sample on the basis of which the above forecasting models were built covered various sectors, hence it can be concluded that these models are universal and therefore their prognostic value is so high;
- 9 models presented efficiency ranging from 76% to 89%;
- 6 models were characterized by the prediction ability at a level below 75%, so at least one in four companies was misclassified.

In the opinion of the author who conducts the research, decisions made, for example, by managers, owners or financial institutions on the basis of models whose forecasting ability is below 75%, constitute too high a risk that it will be incorrect.

As indicated in the introduction, so far many attempts have been made to analyze the prediction ability of discriminant models. Changing economic realities means that individual models should be successively verified to be sure that they accurately reflect the financial condition of enterprises.

It should be emphasized that the models that showed the highest prediction ability were constructed by the authors in 1994, 1998 and 2004, respectively, which means that with the passage of time they did not lose their prediction ability. Thus, the research hypothesis was rejected.

Due to the fact that the models are not 100% effective, in order to accurately analyze the company's financial condition and avoid the risk of misdiagnosis, other available methods of financial analysis should be used.

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Skuteczność predykcji wybranych modeli analizy dyskryminacyjnej

Abstrakt: Celem artykułu była weryfikacja skuteczności predykcji wybranych modeli analizy dyskryminacyjnej na przykładzie próby 40 przedsiębiorstw. Dane przedsiębiorstw pochodziły z bazy danych EMIS i w przypadku przedsiębiorstw kontynuujących działalność dotyczyły 2017 roku, natomiast w przypadku przedsiębiorstw upadłych były to dane na rok przed upadłością. W artykule zaprezentowano modele analizy dyskryminacyjnej, które są zaliczane do systemów wczesnego ostrzegania o zagrożeniu upadłością przedsiębiorstwa. Otrzymane wyniki pozwalają na ocenę sytuacji finansowej przedsiębiorstwa, a więc mogą wpły-

wać na racjonalizację zarządzania przedsiębiorstwami i ich kontroli np. przez rady nadzorcze, biegłych rewidentów czy też sądy gospodarcze. Na podstawie wyników z próby czterdziestu przedsiębiorstw, w tym dziesięciu, dla których został złożony wniosek o upadłość, stwierdzono, że większość zastosowanych w artykule modeli dyskryminacyjnych właściwie odwzorowała dobrą lub zagrożoną kondycję finansową przedsiębiorstwa. Przeprowadzone badania wskazały, że modele dyskryminacyjne ułatwiają podejmowanie decyzji, niemniej należy mieć na uwadze, że nie odznaczają się one stuprocentową skutecznością.

Słowa kluczowe: analiza dyskryminacyjna, sytuacja finansowa przedsiębiorstwa, kondycja finansowa przedsiębiorstwa