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AN ASSESSMENT OF THE RELIABILITY OF EARLY WARNING MODELS ON THE EXAMPLE OF SMALL AND MEDIUM-SIZED ENTERPRISES IN THE INDUSTRY AND SERVICES SECTOR

Abstract

Background: An assessment of the prognostic reliability of early warning models.

Research purpose: To determine which of the early warning models has the highest prognostic reliability.

Methods: Literature review and verification of selected early warning tools. Fourteen models were used in the study: eight discrimination models, five logit models, and one scoring model. The study was based on financial data from a sample of 120 entities, classified as small and medium-sized enterprises from the industry and services sector.

Conclusions: The research results prove the effectiveness of early warning models in assessing the financial condition of enterprises. All models accurately diagnosed over 60% of the entities surveyed. The highest scores were achieved using the scoring model and discriminative models by Jagiełło. The results that show the percentage of accurate diagnoses will support the future selection of models on choosing the right tools to examine enterprises' financial standing.

Keywords: bankruptcy, early warning models, financial analysis, financial condition.

JEL classification: M400

1. Introduction

Diverse levels of financial standing characterize enterprises that operate in a market economy. Owners, managers, contractors, potential investors, and banks are interested in a given enterprise's financial situation. Apart from offering easy access to the market, a market economy can be distinguished by numerous threats that companies have to face, one of which is the threat of

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bankruptcy. In the modern economy, the emergence and disappearance of entities from the market is natural.¹ Therefore, every company that manages its finances appropriately must continuously control the processes taking place inside the organization. In Poland, since 2015, the number of bankruptcies has risen. The favorable economic environment did not improve the business situation in Poland, and the number of bankruptcies and company restructuring increased by 10.2%. In 2018 (Data from district courts, as of December 31, 2018). Business operations require adaptation to changing conditions that companies have not experienced before.

This paper analyzes selected enterprises from the industry and services sectors, mainly because these sectors constitute an important role in generating Gross Domestic Product. Secondly, the share of enterprises from both sectors accounts for a significant share in creating and maintaining jobs. Finally, 2018 brought industrial enterprises a 7% increase in bankruptcies compared to the previous year. In the services sector, this increase was 15%.² Hence, it is not surprising that the popularity of tools to support both the management and control of companies' finances is on the rise. Over the past two decades, early warning models of bankruptcy risk have become one of the more popular tools that make it possible to check the financial standing of a company. Therefore, the article evaluates selected models used to assess and forecast the financial condition of enterprises. The results of the study will allow for the classification of individual models based on the effectiveness of their forecasts.

2. Early warning models in the literature

In the literature, there are several articles on the subject of the emergence and development of the process, along with ways to implement early warning methods to predict the bankruptcy of enterprises. When assessing the degree of the bankruptcy of surveyed companies, many authors used an analysis based on financial data presented by the company to compare it with other companies. In the practice of forecasting bankruptcy of companies, the following types of models are mainly used: discriminative, then logit models, followed by artificial

¹ E. Altman, E. Hotchkiss, *Trudności finansowe a upadłość firm. Jak przewidzieć upadłość i jej uniknąć, jak analizować i inwestować w zadłużenie firm zagrożonych*, CeDeWu, Warszawa 2007, p. 22.

² **Raport roczny Coface**, *Upadłości i restrukturyzacje firm w Polsce w 2018 r.*, Warszawa 2019.

neural networks, and classification trees, or point models.³ The first two types serve as a prognostic tool of a stochastic nature (belonging to the group of statistical methods). On the other hand, neural networks and classification trees are nonparametric methods that focus on data mining. The neural network is a kind of information technology, reflecting the structure and operation of neural systems of living organisms. On the other hand, we have a classification tree, which reflects images of the recursive division of the examined set, obtained as a result of the gradual division of the multidimensional space of features into disjoint subsets until they are homogeneous due to the distinguishing feature.⁴

Aziz and Dar showed that when assessing a company's financial situation, models used in 64% of cases are statistic models. Next, there are soft calculation techniques (25%), and in 11% of cases, theoretical methods. Among the statistical methods, models based on a linear discriminative function are definitely the most frequently used to assess the financial condition of enterprises. The second-most popular are logit models.⁵ The first traditional quantitative models of creditworthiness assessment emerged in the 1930s. FitzPatrick is considered to be a precursor to such tools. However, it was not until the 1960s when international authors, including Altman, Edminster, Deakin, Springate, Weinreich, Taffler, or Tamari, started to create the most popular models.⁶

In Poland, the first discriminative model that enabled bankruptcy forecast was developed by Mączyńska. She used a multiplication model of simplified discriminative analysis to predict the bankruptcy of Polish companies.⁷ Gajdka and Stos's bankruptcy prediction model for Polish companies is an advanced application of Fisher's linear discriminative function,⁸ where the sample of industrial enterprises surveyed was equal to 40 entities listed on the Warsaw Stock Exchange, half of which were bankrupt and the other half "healthy" companies. Other researchers working on bankruptcy prediction included Waśniewski and

³ **J. Pocięcha**, *Problemy prognozowania bankructwa firmy metodą analizy dyskryminacyjnej*, Acta Universitatis Lodzianensis. Folia Oeconomica 2007/205, p. 8.

⁴ *Ibidem*, p. 17.

⁵ **M.A. Aziz, H.A. Dar**, *Predicting corporate bankruptcy – where we stand?*, Corporate Governance Journal 2006/6/1, pp. 18–33.

⁶ **W.K. Rogowski**, *Możliwości wczesnego rozpoznawania symptomów zagrożenia zdolności płatniczej przedsiębiorstwa*, Bank i Kredyt 1999/6, pp. 56–72.

⁷ **E. Mączyńska**, *Ocena kondycji finansowej przedsiębiorstw*, Życie Gospodarcze 1994/38, pp. 42–45.

⁸ **J. Gajdka, D. Stos**, *Wykorzystanie analizy dyskryminacyjnej w ocenie kondycji finansowej przedsiębiorstw*, in: **R. Borowiecki** (ed.), *Restrukturyzacja w procesie przekształceń i rozwoju przedsiębiorstw*, AE w Krakowie, Kraków 1996, pp. 56–65.

Skoczylas,⁹ and Hadasik,¹⁰ later under the name of Appenzeller, together with Szarzec.¹¹ Also noteworthy are the works of Hamrol, Piechocki, and Czajka,¹² as well as Hołda,¹³ Prusak,¹⁴ Szczerbak,¹⁵ Korol¹⁶ and Wędzki.¹⁷

The amount of available research and the large number of scientific publications demonstrate that the trend concerning the assessment of bankruptcy using early warning models is on the rise. The most popular tools for assessing a company's financial situation continue to be the discriminative models, followed by the logit, probit, or scoring methods. These scoring methods have been adopted by various financial institutions like banks or rating agencies, which use these methods to assign points to the institutions they survey. Such assessment can be useful, both when assessing a company's financial condition and when comparing it to other entities.¹⁸ Their adoption has become increasingly justified, regardless of the model or purpose. Dynamically changing economic conditions mean that the use of early warning models have become increasingly important as, generally speaking (except for extraordinary events), enterprises show signs of crisis long before their bankruptcy. Therefore, one of the primary tasks in business management should be to identify early signals of an impending crisis.¹⁹

⁹ **T. Waśniewski, W. Skoczylas**, *Analiza symptomów zagrożeń przedsiębiorstwa*, Rachunkowość 1993/12, pp. 437–443.

¹⁰ **D. Hadasik**, *Upadłość przedsiębiorstw w Polsce i metody jej prognozowania*, Zeszyty Naukowe, Prace Habilitacyjne, Z. 153, AE w Poznaniu, Poznań 1998, pp. 140–159.

¹¹ **D. Appenzeller, K. Szarzec**, *Prognozowanie zagrożenia upadłością polskich spółek publicznych*, Rynki Terminowe 2004/1, pp. 120–128.

¹² **M. Hamrol, B. Czajka, M. Piechocki**, *Upadłość przedsiębiorstwa – model analizy dyskryminacyjnej*, Przegląd Organizacji 2004/6, pp. 34–38.

¹³ **A. Hołda**, *Prognozowanie bankructwa jednostki w warunkach gospodarki polskiej z wykorzystaniem funkcji dyskryminacyjnej ZH*, Rachunkowość 2001/5, pp. 306–310.

¹⁴ **B. Prusak**, *Nowoczesne metody prognozowania zagrożenia finansowego przedsiębiorstw*, Difin, Warszawa 2005, pp. 92–131.

¹⁵ **M. Szczerbak**, *Przyczyny upadłości przedsiębiorstw (na podstawie doświadczeń syndyków i analizy dokumentacji sądowej)*, praca doktorska, SGH, Warszawa 2006, pp. 37–72.

¹⁶ **T. Korol**, *Systemy wczesnego ostrzegania przedsiębiorstw przed ryzykiem upadłości*, Oficyna Wydawnicza Wolters Kluwer, Warszawa 2010, pp. 135–229.

¹⁷ **D. Wędzki**, *Problem wykorzystania analizy wskaźnikowej do przewidywania upadłości polskich przedsiębiorstw – studium przypadków*, Bank i Kredyt 2000/5, pp. 54–61.

¹⁸ **R. Jagiello**, *Analiza dyskryminacyjna i regresja logistyczna w procesie oceny zdolności kredytowej przedsiębiorstw*, NBP, Warszawa 2013, pp. 3–101.

¹⁹ **E. Mączyńska, M. Zawadzki**, *Dyskryminacyjne modele predykcji upadłości przedsiębiorstw*, Ekonomista 2006/2, pp. 205–235.

3. Research material and methodology

The financial data of 120 enterprises were collected to assess prognostic reliability. The data came from 60 entities that had declared bankruptcy between 2011 and 2017. The sample included 30 enterprises operating in the industry sector and 30 from the service sector. The same number of healthy enterprises in both industries was collected as a reverse sample. All enterprises selected for the study were classified as small or medium-sized enterprises according to current criteria. The company data were selected from the database of the Emerging Markets Information Service–Poland. The number of enterprises used in the survey was dictated by, among others, the availability of data. This problem occurs mainly with companies that have been declared bankrupt. In this case, the main problem is the lack of financial data for the last years of operation, or that they are incomplete. Failed companies often fail to comply with reporting obligations because they simply disappear from the market. Often, obtaining such data is also difficult due to the lack of contact with managers. The early warning models were calculated based on the collected financial data, which covered five years. Detailed sector correspondence is presented in Table 1.

TABLE 1: *Classification of bankrupt enterprises according to the Polish Classification of Activities*

Description	Polish Classification of Activities	Number of entities	
		bankrupt	healthy
1	2	3	4
Industry sector enterprises			
Manufacture of food products	10	4	4
Manufacture of textiles	13	2	2
Manufacture of rubber and plastic products	22	6	6
Manufacture of metal	24	6	7
Manufacture of fabricated metal products, except machinery and equipment	25	2	3
Manufacture of machinery and equipment not elsewhere classified	28	4	3
Manufacture of furniture	31	6	5

TABLE 1 (cont.)

1	2	3	4
Service sector enterprises			
Computer programming and consultancy activities, and related activities	62	2	2
Real estate activities	68	4	4
Architectural and engineering activities; technical testing and analysis	71	2	2
Advertising, market research, and public opinion polling	73	4	3
Renting and leasing	77	2	3
Repair and maintenance of computers and personal and household goods	95	6	5
Other personal service activities	96	10	11

Source: own study based on the collected information.

Fourteen early warning models were verified in the study. The first warning models that were selected for the study were selected based on several factors:

- the models had been constructed for enterprises operating in the Polish economy;
- different types of models had to be included in the study;
- universal and industry-specific models were chosen to compare their effectiveness;
- the current literature on the subject; current scientific articles that treat early warning methods in terms of their predictive reliability were analyzed. On this basis, the selection of methods with the highest prognostic values was guided;
- as the research sample comprised enterprises from many voivodeships, models dedicated only to a particular voivodship were omitted (for example, Kasjaniuk's models).

The enterprise early warning system is not a concept that is identical to the terms bankruptcy prediction model or early bankruptcy warning model. The Early Warning System in Business is a set of early warning tools that can be

used or put into practice. Such a system may consist of one or several different models and early warning tools (including bankruptcy prediction models), such as models based on discriminative, logit, or artificial neural network analysis, and other tools.²⁰ This also applies to the comprehensive early warning system, which combines various models and tools, and one of its components is early bankruptcy warning models.²¹ Bankruptcy prediction models are used not only in the enterprises themselves, but they can also be useful for various institutions, e.g., supervisory and control institutions, as they make it possible to quickly identify changes that affect the deterioration of the financial condition of the surveyed entities.²² Early bankruptcy warning models were created primarily to forecast the risks of the bankruptcy of business entities. However, this does not exclude the possibility of using this type of tool for the dynamic assessment of the condition of enterprises. The advisability of using early warning models for bankruptcy concerns not only enterprises but also investors, lenders, and supervising institutions.²³ Table 2 provides a brief description of the methods covered by the study.

TABLE 2: *Characteristics of selected early warning models*

No.	Author / model name	Year of creation	The model formula*
1	2	3	4
1	Discriminative model by Hadasik (model 5)	1998	$Z_{DH} = 2.59323 + 0.335969W_1 - 0.71245W_2 - 2.4716W_3 + 1.46434W_4 + 0.002460969W_5 - 0.0138937W_6 + 0.0243387W_7$ $Z_{DH} > 0 \text{ good financial condition}$
2	Discriminative model by Appenzeller and Szarzec (model 1)	2004	$Z_{AS} = 2.60839 - 2.50761W_1 + 0.001411147W_2 - 0.00925162W_3 + 0.0233545W_4$ $Z_{AS} > 0 \text{ good financial condition}$

²⁰ P. Dec, *Kompleksowy system wczesnego ostrzegania przedsiębiorstwa*, in: A. Fierla (ed.), *Ryzyko w działalności przedsiębiorstw: wybrane aspekty*, Warszawa 2009, p. 91.

²¹ E.K. Laitinen, H.G. Chong, *Early-warning system for crisis in SMEs: Preliminary evidence from Finland and the UK*, *Journal of Small Business and Enterprise Development* 1998/1/6, p. 89.

²² R. Sahajwala, P. Bergh, *Supervisory Risk Assessment and Early Warning Systems*, *Basel Committee on Banking Supervision, Working Papers*, December 2000/4, p. 7.

²³ E. Altman, *Financial Ratios. Discriminant Analysis and the Prediction of Corporate Bankruptcy*, *Journal of Finance*, September 1968/4, pp. 589–609.

TABLE 2 (cont.)

1	2	3	4
3	Discriminative model by Sojak and Stawicki	2001	$Z_{\text{bad}} = -11.6499 - 0.1144W_1 + 0.5178W_2 - 20.4475W_3 - 0.0661W_4 + 0.0663W_5 - 50.4610W_6 + 1.8358W_7$ $Z_{\text{average}} = -2.3393 - 0.0586W_1 - 3.3608W_2 + 10.7088W_3 + 0.1455W_4 - 0.066W_5 + 4.5837W_6 + 2.4329W_7$ $Z_{\text{good}} = -5.992 - 0.0153W_1 + 2.0482W_2 + 9.637W_3 + 0.1714W_4 - 0.0091W_5 - 15.78W_6 - 0.0018W_7$ The enterprise belongs to the group for which it obtains the highest value of the classification function
4	Discriminative model INE PAN model "A" by Mączyńska and Zawadzki	2006	$Z_{\text{INE PAN A}} = -9.382 + 5.577W_1 + 1.472W_2 + 0.154W_3 + 0.31W_4 + 1.937W_5 + 1.598W_6 + 3.203W_7 + 0.436W_8 + 0.192W_9 + 0.14W_{10} + 0.386W_{11} + 1.715W_{12}$ $Z_{\text{INE PAN A}} > 0$ good financial condition
5	Poznański's discriminative model	2004	$Z_{\text{poznanski}} = -2.368 + 3.562W_1 + 1.588W_2 + 4.288W_3 + 6.719W_4$ $Z_{\text{poznanski}} > 0$ good financial condition
6	Discriminative model by Jagiełło for small and medium-sized enterprises from the industry sector	2013	$Z_{\text{RJ}} = -1.8603 + 12.296W_1 + 0.1675W_2 + 1.399W_3$ $Z_{\text{RJ}} < 0$ high probability of classifying a company in a group at risk of bankruptcy within one year
7	Discriminative model by Jagiełło for small and medium-sized enterprises from the service sector	2013	$Z_{\text{RJ}} = -2.24461 + 2.2122W_1 + 5.738W_2 + 0.07W_3 + 0.323W_4$ $Z_{\text{RJ}} < 0$ high probability of classifying a company in a group at risk of bankruptcy within one year
8	Discriminative model by Prusak for small and medium-sized enterprises (model 3)	2005	$Z_{\text{BP}} = -1.176 + 6.9973W_1 + 0.1191W_2 + 0.1932W_3$ $Z_{\text{BP}} > 0$ good financial condition
9	Logit model by Gruszczyński (model 6)	2003	$Z_{\text{MG}} = 4.3515 + 22.8748W_1 - 5.5926W_2 - 26.1083W_3$ $Z_{\text{MG}} > 0$, the audited entity has a good financial standing

10	Logit model by Stępień and Strąk (model 1)	2004	$Z_{SS} = -19 - 11W_1 + 6W_2 + 40W_3 + 19W_4$ $Z_{SS} > 0$, the audited entity has a good financial standing
11	Logit model by D. Wędzki (model 7)	2004	$Z_{DW} = -4.0 - 6.0W_1 + 9.387W_2 - 2.088W_3 + 1.317W_4 + 0.04W_5 - 4.217W_6$ $Z_{DW} < 0.5$ good financial standing, $Z_{DW} > 0.5$ bankruptcy
12	Logit model by Jagiełło for small and medium-sized enterprises from the industry sector	2013	$Z_{RJ} = -4.9873 + 27.7913W_1 + 0.2867W_2 + 5.2187W_3$ $Z_{RJ} < 0$ high probability of classifying a company in a group at risk of bankruptcy within one year
13	Logit model by Jagiełło for small and medium-sized enterprises from the service sector	2013	$Z_{RJ} = -7.5876 + 5.394W_1 + 22.263W_2 + 0.2439W_3 + 1.119W_4$ $Z_{RJ} < 0$ high probability of classifying a company in a group at risk of bankruptcy within one year
14	Scoring model, the point method of credit risk assessment, variant by A. Hołda	2001	<p>Hołda's credit assessment method is based on a modification of the classical method. It relies on calculating 12 financial indicators and then assessing their relation to the industry average. On this basis, individual measures are scored. An enterprise can be classified into one of the following groups:</p> <ul style="list-style-type: none"> – very low place when it gets 12–20 points; – standard place with 21–30 points; – high place reaching 31–40 points; – a very high place when it gets 41–48 points.

* Constructions of the individual variables used in the models can be found in the literature cited. Source: own study based on: Hadasik 1998; Appenzeller 2004; Sojak 2001; Mączyńska 2006; Hamrol 2004; Jagiełło 2013; Prusak 2005; Gruszczyński 2003; Stępień 2004; Wędzki 2004; Hołda 2001.

As Jagiełło's discriminative models were estimated for enterprises based on the sectors in which they operate, the models were analyzed accordingly – with the sample of industrial enterprises, a model for industry sector enterprises was applied, and for service enterprises, a model for enterprises from the service sector was used.

4. Results and discussion

Based on the results of the study, the classification was made according to the accuracy of diagnoses for the last year of the study (for bankrupt enterprises, it was the year of bankruptcy). Table 3 presents detailed data.

TABLE 3: *Classification of early warning models according to the diagnoses' reliability*

Position	Model's author	Type of model	Percent of accurate diagnoses	Number of accurate diagnoses	Number of incorrect diagnoses	
					type i error	type ii error
1	Hołda	Scoring model	91	109	4	7
2	Jagiello	Discriminative model for industry sector enterprises	90	108	4	8
3	Jagiello	Discriminative model for service sector enterprises	89	107	5	8
4	Maczyńska and Zawadzki	Discriminative model	87	104	6	10
5	Hamrol	Discriminative model	83	100	7	13
6	Jagiello	Logit model for industry sector enterprises	80	96	8	16
7	Jagiello	Logit model for service sector enterprises	78	94	10	16
8	Prusak	Discriminative model	77	92	10	18
9	Appenzeller and Szarzec	Discriminative model	75	90	14	16
10	Wędzki	Logit model	72	86	16	18
11	Sojak and Stawicki	Discriminative model	67	80	19	21
12	Hadasik	Discriminative model	64	77	21	22
13	Stępień and Strąk	Logit model	61	73	22	25
14	Gruszczyński	Logit model	60	72	24	24

Source: own study based on the results obtained.

The results of the study allowed for the classification of early warning models, as outlined above. The scoring model had the highest percentage of relevance. In 91% of cases, this model correctly assessed the subjects examined. Jagiełło's models came second and third – second place went to the model for industrial enterprises (90%), and the third was the model for service sector enterprises (89%). All three models were characterized by high accuracy of around 90%. Two discriminative models took the next places: Mączyńska and Zawadzki (87% accuracy) and Poznanski (83%). This was followed by Jagiełło's two logit models (80% and 78%) and the discriminative models by Prusak (77%) and Appenzeller and Szarzec (75%). Among the universal logit models, the best performance was demonstrated by Wędzki's model – 86 correct indications, which translated into 72% accuracy. Two logit models finish the ranking: Stępień and Strąg (61%) and Gruszczyński (60%).

Consequently, the model with the highest score was the point model. Next in terms of reliability came the discriminative models, followed by the logit models. Among discriminative models, the ones that take into account the sector characteristics, i.e., the models by Jagiełło, gave better results than the universal models. It is difficult to determine a single hierarchy of early warning models when comparing the results with other similar studies. It is quite common that the results of studies by different authors do not converge or only slightly overlap (cf. Antonowicz,²⁴ Czapiewski,²⁵ Balina,²⁶ Gołębiowski and Żywno,²⁷ Grzegorzewska and Runowski,²⁸ Hamrol

²⁴ **P. Antonowicz**, *Zastosowanie macierzy klasyfikacji przedsiębiorstw do oceny zdolności predykcyjnych 52 modeli z-score*, Zeszyty Naukowe Politechniki Rzeszowskiej 2010/272/1, Zarządzanie i Marketing, z. 17, pp. 402–412.

²⁵ **L. Czapiewski**, *Efektywność wybranych modeli dyskryminacyjnych w przewidywaniu trudności finansowych polskich spółek giełdowych*, in: **B. Bernaś** (ed.), *Zarządzanie finansami – teoria i praktyka*, Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu 2009/48, pp. 118–128.

²⁶ **R. Balina**, *Skuteczność wybranych modeli dyskryminacyjnych na przykładzie branży robót budowlanych*, in: **D. Zarzecki** (ed.), *Czas na pieniądź. Zarządzanie finansami. Upowszechnienie i transfer wyników badań*, Zeszyty Naukowe Uniwersytetu Szczecińskiego nr 689, Finanse, Rynki Finansowe, Ubezpieczenia nr 50, Wydawnictwo Uniwersytetu Szczecińskiego, Szczecin 2012, pp. 231–238.

²⁷ **G. Gołębiowski, K. Żywno**, *Weryfikacja skuteczności modeli dyskryminacyjnych na przykładzie wybranych spółek giełdowych*, Współczesna Ekonomia 2008/7, pp. 31–45.

²⁸ **E. Grzegorzewska, H. Runowski**, *Zdolności prognostyczne polskich modeli dyskryminacyjnych w badaniu kondycji finansowej przedsiębiorstw rolniczych*, Roczniki Nauk Rolniczych seria G, 2008/95/3/4, Warszawa, pp. 83–90.

or and Chodakowski²⁹). In some cases, these test results are only consistent in assessing the diagnostic reliability of early warning models. One of the reasons for the discrepancy is the incomparable sectoral structure of the sample of enterprises studied by individual authors.³⁰ In most cases, the models were less effective than the authors claimed when they were created. Only Jagiełło's models had the most similar results. He claimed that the effectiveness of the models was 92.5% for the industry sector and 91.25% for the service sector.³¹ In this study, the model for industry sector enterprises was 90% effective and 89% effective for service sector enterprises. This may indicate that the study should use models constructed based on a sample of enterprises with a similar profile of activity.

The results of this research can be compared to international studies. For example, Yap, Yong, and Poon surveyed Malaysian companies. Their results show that traditional discriminatory models are as effective as more advanced methods.³² On the example of hotel companies from Korea, Kim used early warning models and found that statistical methods are still useful when trying to forecast bankruptcy.³³ In addition to discriminant analysis, Back used newer forecasting techniques. The effectiveness of tools such as artificial neural networks or genetic algorithms is higher. However, the values of discriminant analysis do not differ significantly. The advantage of discriminatory models is their simplicity of use.³⁴ Lee and Choi present similar conclusions in their research. Discriminant analysis is only slightly less effective than advanced tools in assessing bankruptcy forecasts. However, its simplicity makes it such

²⁹ **M. Hamrol, J. Chodakowski**, *Prognozowanie zagrożenia finansowego przedsiębiorstwa. Wartość predykcyjna polskich modeli analizy dyskryminacyjnej*, *Badania Operacyjne i Decyzje* 2008, pp. 17–32.

³⁰ **J. Kitowski**, *Metody dyskryminacyjne jako instrument oceny zagrożenia upadłością przedsiębiorstwa*, Wydawnictwo Uniwersytetu Rzeszowskiego, Rzeszów 2015, p. 195.

³¹ **R. Jagiełło**, *Analiza dyskryminacyjna i regresja logistyczna w procesie oceny zdolności kredytowej przedsiębiorstw*, NBP, Warszawa 2013, pp. 3–101.

³² **Yap B. Chin-Fook, Yong D. Gun-Fie, Poon Wai-Ching**, *How Well Do Financial Ratios and Multiple Discriminant Analysis Predict Company Failures in Malaysia*, *International Research Journal of Finance and Economics* 2010/54, pp. 166–177.

³³ **S.Y. Kim**, *Prediction of hotel bankruptcy using support vector machine, artificial neural network, logistic regression, and multivariate discriminant analysis*, *The Service Industries Journal* 2011/31/3, pp. 441–468.

³⁴ **B. Back, T. Laitinen, K. Sere**, *Neural networks and genetic algorithms for bankruptcy predictions*, *Expert Systems with Applications* 1996/11/4, pp. 407–413.

a popular solution.³⁵ The assessment or verification of logit and probit models, and above all, discriminatory methods, is a widespread topic (see Abdullah, Halim, Ahmad, and Rus;³⁶ Rafiei, Manzari, and Bostanian;³⁷ Jo and Han,³⁸ Peel and Peel;³⁹ Keasey and Watson⁴⁰).

5. Summary

The results of the study confirm the effectiveness of early warning models in predicting bankruptcy. Based on the results, it can be concluded that the best credibility is demonstrated by models that take into account the specifics of the enterprise's functioning in a given industry, i.e., the scoring model and discriminative models for enterprises from the industry or services sector. More unsteady results are produced using universal models that are targeted at enterprises operating in various industries. Among the discriminatory models, two models by Jagiełło achieved the best results. Also, among the logit models, Jagiełło's models showed the best accuracy. The undoubted advantage of this type of model is the orientation to a specific industry. They are not universal methods that can be used to assess enterprises from various industries. However, matching the industry increases the model's effectiveness.

The effectiveness of these models also shows that data from a very large sample were used in the creation. The high efficiency of these models also certainly results from the fact that they are the latest models used in the study. As they were constructed in different economic conditions, older models are

³⁵ **S. Lee, W. Sung Choi**, *A multi-industry bankruptcy prediction model using backpropagation neural network and multivariate discriminant analysis*, *Expert Systems with Applications* 2013/40/8, pp. 2941–2946.

³⁶ **Nur Adiana Hiau Abdullah, Abd. Halim, Hamilton Ahmad, Rohani Md. Rus**, *Predicting Corporate Failure of Malaysia's Listed Companies: Comparing Multiple Discriminant Analysis, Logistic Regression and the Hazard Model*, *International Research Journal of Finance and Economics* 2008/15, pp. 201–217.

³⁷ **F.M. Rafiei, S.M. Manzari, S. Bostanian**, *Financial health prediction models using artificial neural networks, genetic algorithm and multivariate discriminant analysis: Iranian evidence*, *Expert Systems with Applications* 2011/38 (8), pp. 10210–10217.

³⁸ **H. Jo, I. Han**, *Bankruptcy prediction using case-based reasoning, neural networks, and discriminant analysis*, *Expert Systems with Applications* 1997/13/2, pp. 97–108.

³⁹ **M.J. Peel, D.A. Peel**, *Some Further Empirical Evidence on Predicting Private Company Failure*, *Journal Accounting and Business Research* 1987/18/69, pp. 57–66.

⁴⁰ **K. Keasey, R. Watson**, *The Prediction of Small Company Failure: Some Behavioural Evidence for the UK*, *Journal Accounting and Business Research* 1986/17/65, pp. 49–57.

characterized by lower accuracy. Therefore, it seems more reasonable to use mainly young models. Based on the results, it can also be concluded that, when attempting to assess the financial situation of a given entity, apart from traditional indicator analysis, it is worth reaching for other tools, including the presented synthetic models. When choosing early warning models, it is worth turning to current models, i.e., those constructed as recently as possible in economic conditions similar to those currently prevailing, not a few decades ago. This approach can contribute not only to the correct assessment of the state of finances, but it is also a good way to manage the finance area in an organization correctly and more effectively.

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Rafał PITERA

OCENA WIARYGODNOŚCI MODELI WCZESNEGO OSTRZEGANIA NA PRZYKŁADZIE MAŁYCH I ŚREDNICH PRZEDSIĘBIORSTW Z SEKTORA PRZEMYSŁU I USŁUG

Abstrakt

Przedmiot badań: Ocena wiarygodności prognostycznej modeli wczesnego ostrzegania.

Cel badawczy: Określenie, który z modeli wczesnego ostrzegania może charakteryzować się najwyższą wiarygodnością prognostyczną.

Metoda badawcza: Przegląd literatury i weryfikacja wybranych narzędzi wczesnego ostrzegania. W badaniu wykorzystano 14 modeli: 8 modeli dyskryminacji, 5 modeli logitowych i 1 model scoringowy. Badanie zostało oparte na danych finansowych pochodzących z próby 120 podmiotów sklasyfikowanych jako małe i średnie przedsiębiorstwa z sektora przemysłu i usług.

Wyniki: Wyniki badań dowodzą skuteczności modeli wczesnego ostrzegania w ocenie kondycji finansowej przedsiębiorstw. Wszystkie modele dokładnie zdiagnozowały ponad 60% badanych podmiotów. Najwyższe wyniki osiągnięto, stosując model scoringowy oraz modele dyskryminacyjne R. Jagiełło. Na podstawie otrzymanych wyników można w przyszłości dokonywać selekcji poszczególnych modeli przy wyborze narzędzi do badania sytuacji finansowej przedsiębiorstw, kierując się odsetkiem trafnych diagnoz.

Słowa kluczowe: upadłość, modele wczesnego ostrzegania, analiza finansowa, sytuacja finansowa.