SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2023
ORGANIZATION AND MANAGEMENT SERIES NO. 178

VERIFICATION OF THE EFFECTIVENESS OF DISCRIMINATION MODELS FOR FORECASTING BANKRUPTCY OF ENTERPRISES

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Purpose: An attempt to evaluate the effectiveness of financial analysis tools used to assess financial health and to forecast bankruptcy.
Methodology: The study used 31 of the most popular discriminatory models for bankruptcy prediction. The effectiveness of early warning models has been evaluated on the basis of financial data of economic entities operating on the territory of the Republic of Poland. The sample of the enterprises has comprised a total of 172 entities – both bankrupt and operating in good financial condition, located in 16 provinces. The data period was 2011-2020. The companies have represented various sectors of activity. Data was obtained from the Emis.com website.
Findings: Most of the models used have been highly effective in forecasting. However, none of the methods has been 100% effective. It has also been noted that the models estimated on the basis of a sample of enterprises from only one sector, the so-called sector models allocated to the evaluation of a specific industry, have not had a significantly higher percentage of correct diagnoses than universal models. In the last analyzed period, the three most effective methods are the so-called universal models that can be used in the evaluation of companies from various industries.
Practical implications: The results of the audit can be used, among others, in the assessment of the going concern of enterprises by business managers, business analysts, investors, and above all, statutory auditors when auditing financial statements.
Originality/value: The study provides an answer to the question of which models are characterized by high prognostic effectiveness. In addition, the obtained results allow to resolve the issue of the usefulness of models created in the 1990s. The large size of the research sample allows for the generalization of the results and their wider application than has been the case in the literature on the subject so far.

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

Category of the paper: Research paper.

1. Introduction

Running a business in the conditions of the market economy involves various types of risk. The risk of bankruptcy is one of the most important risks in this regard. In the dynamic conditions of the market economy, almost every economic entity is exposed to a number of different types of risk. One of the most important risks in this respect is the risk of business bankruptcy. To quote the phrase by Joseph A. Schumpeter, economic progress is a creative destruction in which the bankruptcy of enterprises is an integral part (Schumpeter, 1982). It is a completely natural phenomenon that acts as a means of natural selection (Mączyńska, Zawadzki, 2006). From the theoretical point of view, insolvency and bankruptcy of enterprises eliminate the weakest and ineffective units, thus increasing opportunities for new and more market-prepared economic entities. On the other hand, bankruptcy processes are largely associated with numerous negative consequences. These consequences concern not only the owners and managers of the enterprise. These effects are often borne by employees, their families, or business partners of a given enterprise. From this point of view, effective and timely counteracting bankruptcy processes becomes one of the most important problems in daily business activity. Diverse types of tools, largely based on financial data, are helpful in this regard. One of the most popular tools to date are the so-called early warning models. Models using a linear discriminant function are leading in this regard.

In connection with the above, the article deals with the issue of the evaluation of early warning models, and more specifically discriminatory models that are used to evaluate the financial situation of an enterprise and to forecast its bankruptcy. The main objective of the article has been an attempt to classify discriminant models based on their prognostic effectiveness. Despite the large amount of research in the reference literature in this area, it is difficult to find studies in which verification has been conducted on a sufficiently large sample. Moreover, in research, the selection of units for the sample has very often been limited to the data from one region or one industry. Therefore, it is doubtful whether the verifications made on this basis are of adequate quality and can be applied in practice. Therefore, in this article, it has been decided to verify 31 early warning models to be able to classify individual models as broadly as possible. Additionally, the evaluation has been conducted on a sample of 172 business entities located in 16 provinces.

2. The state of research in the literature

For several decades, discriminant models have been the most popular - both in the reference literature (Aziz, Dar, 2006), and among practitioners - the results of. research by B. Micherda conducted among certified auditors. They most often use, apart from traditional index analysis, discriminant models (Micherda, 2012). At this point, it is worth mentioning the most important research conducted so far.

The first notable results come from the study of P. Antonowicz, who verified 52 discriminatory models on a sample of 89 bankrupt companies from the Pomeranian Province that declared bankruptcy in 2003-2004 and 119 companies from the 2004 Gazele Biznesu (Business Gazelles) ranking (Antonowicz, 2010). A similar evaluation was also conducted by R. Balina, who assessed synthetic models on a sample of construction companies (Balina, 2012). W. Lichota based the study on the effectiveness of discriminatory models on data from 8 companies from the Podkarpackie Province that filed a petition for liquidation bankruptcy (Lichota, 2017). In turn, D. Zarzecki evaluated the effectiveness of discriminatory models on a sample of 21 companies (Zarzecki, 2003). T. Noga and K. Adamowicz evaluated early warning models based on a sample of companies from the wood industry (Noga, Adamowicz, 2021). The effectiveness of early warning models was also evaluated by S. Tomczak and E. Radosiński (Tomczak, Radosiński, 2017). Research on the effectiveness of models assessing the financial condition was also conducted by G. Gołębiowski and K. Żywno - a sample of 10 companies from the Warsaw Stock Exchange (Gołębiowski, Żywno, 2008). Also, L. Czapiewski examined 94 listed companies (48 at risk of bankruptcy and 46 with good financial condition), using early warning models (Czapiewski, 2009). J. Koralun-Bereźnicka evaluated the usefulness of early warning models on the basis of a sample of companies listed on the Warsaw Stock Exchange (Koralun-Bereźnicka, 2006). J. Wojnar assessed the effectiveness of discriminatory models on data from 50 listed companies (Wojnar, 2014). In turn, A. Kopiński and D. Porębski used early warning models to evaluate medical entities (Kopiński, Porębski, 2015). W. Lichota verified discriminatory models using a sample of 40 enterprises, of which 10 were subject to bankruptcy petitions to the court and 30 of them were characterized by a good financial condition. On the basis of the obtained results, the author evaluated the discriminant models as effective tools in assessing the financial situation of enterprises (Lichota, 2020).

Similar considerations on the possibility of using early warning models were the subject of research, among others by A. Kuciński, who assessed the usefulness of discriminatory models on the basis of companies listed on the NewConnect market (Kuciński, 2011). Other studies as part of the evaluation of the effectiveness of early warning models were conducted by G. Gołębiowski and A. Pląsek, who analyzed both Polish and foreign discriminatory models (Gołębiowski, Pląsek, 2018). The research on the effectiveness of early warning models,

which was carried out by J. Kitowski together with A. Pawul-Kowal and W. Lichota, concerned the assessment of the possibility of using Polish models, but also of the very popular method of E. Altman (Kitowski et al., 2022). Furthermore, it is also worth citing research related to early warning models by, among others, W. Rogowski (Rogowski, 1997), T. Korol (Korol, 2019) or B. Prusak (Prusak, 2018).

Despite the frequent use of early warning models in the reference literature and the assessment of their effectiveness based on them, many research results cannot be used. This is mainly due to the small sample size on the basis of which individual models were verified. Only a few authors used data from a sample of enterprises of more than 50 entities. Another limitation to the possibility of using multiple studies is the use of data from companies representing only one industry. The last argument that requires careful use of a particular result is the fact of using data from enterprises, the location of which in most cases is limited to only one or two provinces. In the further part of this article, the results of a study that was conducted considering the limitations mentioned above will be presented.

3. Research methods

The article assesses early warning models. For this purpose, 31 of the most popular models using the linear discriminatory function have been selected. The models selected for verification have been estimated on the basis of data from a sample of enterprises operating in Poland. This approach is consistent with most of the positions in the literature, which postulate that models estimated on the basis of the financial data of a given country should be used, or possibly foreign models can be used, but after their adaptation to the conditions of the economy of a given country (e.g. Nowak, 1997; Korol, 2010; Kitowski, 2011; Zaleska, 2012; Pitera 2014). The discriminatory models selected for the study are presented in Table 1.

Table 1.
Characteristics of early warning models used in the study

Model author	Possibilities of using the model	Function	Year of creation
E. Mączyńska	Universal	$Z = 1.5X_1 + 0.08X_2 + 10.0X_3 + 5.0X_4 + 0.3X_5 + 0.1X_6$	1994
M. Pogodzińska, S. Sojak	Universal	$Z = 0.644741X_1 + 0.912304X_2$	1995
J. Gajdka, D. Stos (Model 4)	Universal	$Z = 0.7732059 – 0.0856425X_1 + 0.0007747X_2 + 0.9220985X_3 + 0.6535995X_4 + 0.594687X_5$	1996
D. Hadasik (model 1)	Universal	$Z = -2.50761X_1 + 0.00141147X_2 – 0.00925162X_3 + 0.0233545X_4 + 2.60839$	1998
D. Hadasik (model 8)	Universal	$Z = -1.98281X_1 + 0.00118429X_2 + 0.180604_3 – 0.00847833X_4 + 1.53416X_5 + 0.0235729X_6 + 1.97095$	1998

Cont. table 1.

D. Wierzba	Universal	$Z = 3.26X_1 + 2.16X_2 + 0.3X_3 + 0.69X_4$	2000
A. Hołda	Universal	$Z = 0.605 + 0.681X_1 – 0.0196X_2 + 0.00969X_3 + 0.000672X_4 + 0.157X_5$	2001
S. Sojak, J. Stawicki	Universal	Z zła = $-11.6499 – 0.1144X_1 + 0.5178X_2 – 20.4475X_3 – 0.0661X_4 + 0.0663X_5 – 50.4610X_6 + 1.8358X_7$ Z średnia = $-2.3393 – 0.0586X_1 – 3.3608X_2 + 10.7088X_3 + 0.1455X_4 – 0.066X_5 + 4.5837X_6 + 2.4329X_7$ Z dobra = $-5.992 – 0.0153X_1 + 2.0482X_2 + 9.637X_3 + 0.1717X_4 – 0.0091X_5 – 15.78X_6 – 0.0018X_7$	2001
J. Gajdka, D. Stos (Model 5)	Universal	$Z = 0.0005X_1 + 2.0552X_2 + 1.7260X_3 + 0.1155X_4 – 0.3342$	2003
D. Appenzeller, K. Szarzec (Model 1)	Universal	$Z = 1.286X_1 − 1.305X_2 − 0.226X_3 + 3.015X_4 − 0.005X_5 − 0.009X_6 − 0.661$	2004
D. Appenzeller, K. Szarzec (Model 2)	Universal	$Z = 0.819X_1 + 2.567X_2 – 0.005X_3 + 0.0006X_4 – 0.0095X_5 – 0.556$	2004
M. Hamrol, B. Czajka, M. Piechocki	Universal	$Z = -2.368 + 3.562\ X_1 + 1.588X_2 + 4.288X_3 + 6.719\ X_4$	2004
B. Prusak (model 3)	Universal	$Z = -1.176 + 6.9973X_1 + 0.1191X_2 + 0.1932X_3$	2005
B. Prusak (model 4)	Universal	$Z = -0.3758 + 3.7657X_1 + 0.1049X_2 – 1.6765X_3 + 3.523X_4$	2005
E. Mączyńska, M. Zawadzki (INE PAN F)	Universal	$Z = 9.478X_1 + 3.613X_2 + 3.246X_3 + 0.455X_4 + 0.802\ X_5 – 2.478$	2006
E. Mączyńska, M. Zawadzki (INE PAN G)	Universal	$Z = 9.498X_1 + 3.566X_2 + 2.903X_3 + 0.452X_4 – 1.498$	2006
M. Kasjaniuk	Enterprises from the industry sector in the Podkarpackie Voivodeship	$Z = -0.70967X_1 – 0.33346X_2 + 2.31884X_3 + 1.17084X_4 – 0.03600X5 + 2.83332$	2006
M. Kasjaniuk	Enterprises from the industry sector from the Lubelskie Voivodeship	$Z = 0.010X_1 – 0.523X_2 + 0.443X_3 – 0.551X_4 +11.49X_5 + 2.532X_6 – 1.642X_7 + 8.873$	2006
T. Maślanka	Universal	$Z = −1.44979 + 3.55401X_1 + 2.14847X_2 − 0.33302X_3 + 4.81862X_4 + 0.05236X_5 + 2.52164X_6$	2008
T. Korol	Universal	$Zb = −1.97 + 2.35X_1 − 2.90X_2 − 2.68X_3 + 0.79X_4$ $Zn = −3.49 + 9.93X_1 − 0.05X_2 − 0.62X3 + 1.19X_4$	2010
A. Waszkowski	Universal	$Z = 0.821X_1 + 0.769X_2 + 0.349X_3 − 0.284X_4 + 0.23*8X_5$	2011
F. Wysocki, A. Kozera	Enterprises from the meat industry sector	$Z = 0.11890 – 3.3753X_1 + 0.86735X_2$	2012
M. Sukiennik	Enterprises from the mining industry	$Z = -0.67848 – 1.62561X_1 + 7.23048X_2 – 0.0042X_3 + 4.61266X_4 + 20.06342X_5 – 0.01874X_6$	2013
M. Tymoszuk	Universal	$Z = 14.71330X_1 – 0.00157X_2 – 0.03304X_3 + 6.80845X_4 – 7.35595$	2013
R. Jagiełło "Przemysł"	Enterprises from the industrial sector	$Z = −1.8603 + 12.296X_1 + 0.1675X_2 + 1.399X_3$	2013

Cont. table 1.

R. Jagiełło "Budownictwo"	Enterprises from the construction sector	$Z = -1.9943 + 3.799X_1 + 0.572X_2 + 0.04X_3 + 1.36X_4$	2013
R. Jagiełło "Handel"	Enterprises from the trade sector	$Z = -3.237 + 3.638X_1 + 2.473X_2 + 0.479X_3 + 0.404X_4$	2013
R. Jagiełło "Transport"	Enterprises from the transport sector	$Z = -2.266 + 1.645X_1 + 2.868X_2 + 0.21X_3 + 0.733X_4$	2013
R. Jagiełło "Usługi"	Enterprises from the service sector	$Z = -2.24461 + 2.122X_1 + 5.738X_2 + 0.07X_3 + 0.323\ X_4$	2013
M. Potoczna, S. Wiśniewska	Enterprises from the industrial sector	$Z = -0.5390X_1 - 0.1581X_2 + 0.0633X_3 - 0.1529X_4$	2017
S. Herman	Enterprises from the industrial sector	$Z = 1.293X_1 + 4.169X_2 - 0.432X_3 + 0.696X_4 + 0.322X_5 + 0.342$	2017

Source: Own study based on: Mączyńska (1994); Pogodzińska, Sojak (1995); Gajdka, Stos (1996); Hadasik (1998); Wierzba (2000); Hołda (2001); Sojak, Stawicki (2001); Stos, Gajdka (2003); Appenzeller, Szarzec (2004); Hamrol, Czajka, Piechocki (2004); Prusak (2005); Mączyńska, Zawadzki (2006); Kasjaniuk (2006); Maślanka (2008); Korol (2010); Waszkowski (2011); Sukiennik (2013); Tymoszuk (2013); Jagiełło (2013); Potoczna, Wiśniewska (2017); Wysocki, Kozera (2012); Herman (2017).

Among all the early warning models used, 20 of them have been the so-called *universal models* - with the possibility of applying to the assessment of economic entities from various industries - and 11 models that can be used when assessing the financial situation of enterprises from a specific sector. Additionally, in the case of two models of M. Kasjaniuk, the models, apart from being applied to specific sectors, may also be used in a specific region (the province where the company operates). The models selected for the study have been evaluated for the effectiveness of the forecasts. For this purpose, financial data have been collected from 172 entities, of which half declared bankruptcy and half of them were in good financial condition. Data were collected using the EMIS information service (www.emis.com). The data period was 2011-2020. Due to the fact that some of the models are applicable only to a specific sector, companies have been adapted to each model. The study has consisted in assessing the collected financial data of business entities over a 5-year period using individual discriminatory models and then assessing the correctness of classification of individual entities. The verified models have supplied the following types of assessments:

- the correct diagnosis;
- the misdiagnosis, including type I and type II errors;
- the lack of diagnosis, due to lack of data or the so-called area of uncertainty.

If the diagnosis was correct, the model classified a company with good financial condition as an enterprise 'not at risk of bankruptcy.' On the other hand, a company that filed a petition for bankruptcy was categorized as 'threatened with bankruptcy.' In the case of a wrong diagnosis, the model could assess the bankrupt enterprise as not threatened by bankruptcy (type II error), or the enterprise with a good financial condition as an entity 'at risk of bankruptcy' (type I error). The lack of diagnosis was the result of the inability to assess the examined unit due, among other things, to the incompleteness of the financial data. The lack of

an assessment could also be the result of a situation in which the result was in the so-called uncertainty area. The model in the area of uncertainty cannot define precisely the assessment of a given company. Several of the analyzed models in their assumptions use just such a range in which no diagnosis is obtained.

4. Results

This section presents the results of the verification of 31 early warning models. Due to the extensive data, Table 2 presents the data in a synthetic approach, allowing the reading of the most essential information resulting from the study. The results for the last 3 years of the study are presented.

Table 2.
Effectiveness of early warning models - selected years

Model author	Effectiveness of forecasts		
	3 years before bankruptcy	Two years before bankruptcy	One year before bankruptcy
E. Mączyńska	68%	72%	83%
M. Pogodzińska, S. Sojak	51%	57%	61%
J. Gajdka, D. Stos (Model 4)	71%	73%	77%
D. Hadasik (model 1)	69%	72%	78%
D. Hadasik (model 8)	65%	67%	79%
D. Wierzba	62%	64%	81%
A. Hołda	83%	89%	92%
S. Sojak, J. Stawicki	69%	75%	86%
J. Gajdka, D. Stos (Model 5)	77%	83%	89%
D. Appenzeller, K. Szarzec (Model 1)	75%	79%	83%
D. Appenzeller, K. Szarzec (Model 2)	72%	75%	80%
M. Hamrol, B. Czajka, M. Piechocki	80%	86%	94%
B. Prusak (model 3)	59%	67%	78%
B. Prusak (model 4)	65%	76%	79%
E. Mączyńska, M. Zawadzki (INE PAN F)	76%	82%	89%
E. Mączyńska, M. Zawadzki (INE PAN G)	79%	82%	93%
M. Kasjaniuk for Podkarpacie	77%	78%	83%
M. Kasjaniuk for the Lublin region	75%	76%	84%
T. Maślanka	78%	81%	85%
T. Korol	82%	87%	96%
A. Waszkowski	79%	85%	88%
F. Wysocki, A. Kozera	71%	72%	81%
M. Sukiennik	88%	89%	92%
M. Tymoszuk	89%	91%	93%
R. Jagiełło “Indusrty”	78%	86%	92%
R. Jagiełło “Construction”	81%	82%	86%
R. Jagiełło “Trade”	77%	82%	87%
R. Jagiełło “Transport”	75%	81%	87%
R. Jagiełło “Services”	72%	83%	89%
M. Potoczna, S. Wiśniewska	75%	79%	84%
S. Herman	83%	85%	91%

Source: Own study.

The data presented show that in the period of 3 years before bankruptcy the model of M. Pogodzińska and S. Sojak was the least effective, reaching an efficiency of 51%. In turn, the model that evaluated the best was the method of M. Tymoszuk with the result of 89%. Two years before bankruptcy, the poorest results were again achieved by the model of M. Pogodzińska and S. Sojak (57%). The highest value was also achieved by the model of M. Tymoszuk (91%). During this period, in each of the analyzed methods, the effectiveness achieved better prognostic values than in the previous period. All of the models analyzed achieved the best results one year before bankruptcy. Here, the precision of forecasts ranged from 61% (model of M. Pogodzińska and S. Sojak) to the level of 96% (model of T. Korol).

Table 3 presents the classification of early warning models based on the effectiveness of forecasts. The models, as in the previous tables, have been arranged according to the time of their creation to ensure consistency for all tables.

Table 3.
Classification of early warning models based on the obtained results

Autor modelu	Model place		
	3 years before bankruptcy	Two years before bankruptcy	One year before bankruptcy
E. Mączyńska	26	25	20
M. Pogodzińska, S. Sojak	31	31	31
J. Gajdka, D. Stos (Model 4)	22	24	30
D. Hadasik (model 1)	24	25	29
D. Hadasik (model 8)	27	28	26
D. Wierzba	29	30	23
A. Hołda	3	2	5
S. Sojak, J. Stawicki	24	22	15
J. Gajdka, D. Stos (Model 5)	12	9	9
D. Appenzeller, K. Szarzec (Model 1)	16	17	20
D. Appenzeller, K. Szarzec (Model 2)	20	22	25
M. Hamrol, B. Czajka, M. Piechocki	**7**	**5**	**2**
B. Prusak (model 3)	30	28	28
B. Prusak (model 4)	27	19	26
E. Mączyńska, M. Zawadzki (INE PAN F)	15	11	9
E. Mączyńska, M. Zawadzki (INE PAN G)	**8**	**11**	**3**
M. Kasjaniuk for Podkarpacie	12	21	20
M. Kasjaniuk for the Lublin region	16	19	18
T. Maślanka	10	15	17
T. Korol	**5**	**4**	**1**
A. Waszkowski	8	7	12
F. Wysocki, A. Kozera	22	25	23
M. Sukiennik	2	2	5
M. Tymoszuk	**1**	**1**	**3**
R. Jagiełło "Indusrty"	10	5	5
R. Jagiełło "Construction"	6	11	15
R. Jagiełło "Trade"	12	11	13
R. Jagiełło "Transport"	16	15	13
R. Jagiełło "Services"	20	9	9
M. Potoczna, S. Wiśniewska	16	17	18
S. Herman	3	7	8

Source: Own study.

The models that ranked in the first three positions in the last year of the study are shown in bold in Table 3. It is worth noting that the best forecast accuracy has been found in the so-called universal models, not dedicated to a specific industry. All these models are models created after 2000. The highest efficiency among the so-called sector models had the model of R. Jagiełło, designed for the evaluation of enterprises in the manufacturing industry sector, and the model of M. Sukiennik for the evaluation of enterprises in the mining sector. In each of the periods analyzed, the weakest results came from the model of M. Pogodzińska and S. Sojak. The model of M. Pogodzińska and S. Sojak was created in the 1990s. Similarly, to other models created in the same decade, they did not achieve the effectiveness that would allow them to get a better position than 20. Additionally, in the last period analyzed, the last three positions were taken by models created in the 1990s. This is certainly evidence that there is a certain period from the time of construction when such a model can be used. Beyond this time, such a model becomes poorly plausible.

Three years before bankruptcy, the models of M. Tymoszuk (89%), M. Sukiennik (88%) and S. Herman (83%) were the most effective. Thus, there were two universal models and one so-called sectoral model. In the following period, the models of M. Tymoszuk and of M. Sukiennik as well as of A. Hołda were again the most effective. So again, there were two universal models and one sector model. In the last year of the study, the most effective were the models of T. Korol, M. Hamrol, B. Czajka, and M. Piechocki (the Poznań model), as well as of E. Mączyńska and M. Zawadzki. In this case, all three models were so-called universal models. Sector models took the next places – of R. Jagiełło for enterprises from the manufacturing industry sector and of M. Sukiennik for enterprises from the mining industry. Universal models took the next places once again. The obtained results of the study allow for the conclusion that there is no significant difference between the effectiveness of models dedicated to the assessment of enterprises from a specific industry, and the so-called universal models, applicable in various sectors of activity. This means that sector models are not a guarantee of obtaining better forecasts for the assessment of the financial condition of enterprises. In some cases, sector models were even characterized by lower effectiveness than universal models.

5. Discussions

The study conducted allowed for the classification of early warning models according to the accuracy of the forecasts. There is a tendency that the longer the forecast period, the lower the effectiveness of the models. The results in this respect are consistent, among others, with the research of K. Adamowicz and T. Noga (Adamowicz, Noga, 2014, pp. 643-650, and also of T. Korol (Korol, 2010, pp. 148-150). Importantly, in the last year of the study, the so-called universal models achieved the best results. This is different from the views of,

inter alia, T. Noga and K. Adamowicz (Adamowicz, Noga, 2018), but at the same time consistent with the results of the research carried out by W. Lichota (Lichota, 2017), or B. Prusak (Prusak, 2005). A similar position to the possibility of using discriminatory models to evaluate enterprises from various sectors is expressed by A. Kopiński and D. Porębski (Kopiński, Porębski, 2015).

At the same time, the conducted study confirms the position of S. Jones, who stated that the excess of indicators used in early warning models - after exceeding a certain number - makes the model less reliable than, respectively, models with a smaller number of measures (Jones, 2017). In addition, the study allowed to refute the thesis that models that use data from the cash flow statement in their construction are characterized by a higher reliability than models that are based only on data from the balance sheet and the loss and profit account (Maślanka, 2008). Therefore, one should agree, inter alia, with the views of A. Hołda and R. Pitera, who, on the basis of the research carried out, also showed that there is no correlation between the use of cash flow statement data and the increase in the diagnostic effectiveness of early warning models (Hołda, 2001; Pitera, 2014).

The results of the study also indicate that reaching for models whose construction took place several decades ago is not the best solution. Most of the models developed in the 1990s showed poor prognostic efficiency. The results of research by other authors also largely confirm this opinion in this area (Grice, Dugan, 2001; Rutkowska, 2006; Korol, 2010; Kitowski, 2012).

6. Conclusions

Of the 31 models, 8 of them were characterized by effectiveness greater than 90% in the last period analyzed. 17 methods achieved a forecast effectiveness of 80% and more. None of the 31 models used in the study showed 100% accuracy of the forecasts in any of the analyzed years. However, all models achieved prognostic values above 50%. Importantly, the models dedicated to the assessment of the financial situation of enterprises from a specific sector or region did not show better results than the so-called universal ones. It is also worth emphasizing that the oldest models held low positions in the analyzed period, which proves that the moment of the model creation influences its effectiveness. It is also worth remembering to use, if possible, the models not older than a dozen years to assess the bankruptcy prediction. The study conducted also verified the issue of selecting the number of indicators for the model and the positions in this regard. Well, the number of measures used by individual methods does not significantly increase the accuracy of the early warning model forecasts. The results of the study even indicate that an excessive number of financial indicators in the method not only fails to improve the effectiveness of a given model but, in many cases, even reduces the effectiveness of a given model. However, it is also worth remembering that too few such indicators in the

models also limit the predictive effectiveness of early warning models. It is also worth referring to the analysis period. Namely, the latest data came from the period of both the Covid-19 pandemic and the effects of the outbreak of war in Ukraine. Such situations, which are difficult to predict, certainly have a negative impact on the financial situation of various entities in the economy. However, referring to this type of phenomenon to the reliability of early warning models, no significantly worse diagnoses were noticed in the assessment of the financial situation of the enterprises included in the research sample. It can be concluded that such phenomena do not have a significant impact on the poorer credibility of the tested models.

The study conducted seems to be a significant contribution to the issue of assessing the effectiveness of early warning models and using models that appear to be the most reliable in this regard. This is because the studies that are based, first of all, on a large number of entities are much more reliable than similar analyzes based on small samples. Secondly, some models that are inadequate to the collected samples are often used. And finally, in economic practice such early warning models, which are characterized by high credibility and, at the same time, best suited to the specifics of the enterprise being assessed, are equally infrequent. Moreover, it can be noticed that despite an exceptionally large set of tools allowing for the assessment of the company's financial situation, the tools other than discriminatory models are still used sporadically. It is the discriminatory models that are still the most popular type of methods that have been used for several decades. Their popularity may be due to their good effectiveness, which was also confirmed in the study, but it is also a result of the application simplicity of such models. The combination of these two aspects is the answer why this type of early warning models is of great interest to many people.

References

1. Adamowicz, K., Noga, T. (2014). Multivariate analysis of bankruptcy in companies in the wood sector. *Sylwan, 158(9),* pp. 643-650.
2. Adamowicz, K., Noga, T. (2018). Identification of financial indicators applicable to the construction of the bankruptcy prediction model of wood industry enterprises. *Folia Forestalia Polonica, Series A – Forestry, Vol. 60, No., 1,* pp. 61-72.
3. Antonowicz, P. (2010). The use of the enterprise classification matrix to assess the predictive abilities of 52 z-score models, *Scientific Papers of the Rzeszów University of Technology, Vol, 272/1, Management and Marketing, Iss. 17,* p. 19.
4. Aziz, M., Dar, H. (2006). Predicting corporate bankruptcy - where we stand? Co*rporate Governance Journal, Vol. 6, No. 1,* pp. 18-33.
5. Balina, R. (2012). The effectiveness of selected discriminatory models on the example of the construction work industry. In: D. Zarzecki (Eds.), Time for money. Finance

management. Dissemination and transfer of research results. *Scientific Journals of the University of Szczecin, Vol. 689, Finance, Financial Markets, Insurance, No. 50* (pp. 231-238). Publishing House of the University of Szczecin.

6. Czapiewski, L. (2009). Effectiveness of selected discriminatory models in predicting financial difficulties of Polish listed companies In: B. Bernaś (Eds.), Financial management - theory and practice. *Scientific Papers of Wrocław University of Economics No. 48,* pp. 118-128.
7. Gajdka, J. Stos, D. (1996). The use of discriminatory analysis in the assessment of the financial condition of enterprises In: R. Borowiecki (Eds.), *Restructuring in the process of transformation and development of enterprises* (pp. 56-65). Publishing House of the University of Economics in Krakow.
8. Gołębiowski, G., Pląsek, A. (2018). Effectiveness of selected discriminatory models on the example of the tourism industry. *Studies and Works. College of Management and Finance. No. 164,* pp. 9-24.
9. Gołębiowski, G., Żywno, K. (2008). Verification of the effectiveness of discriminatory models on the example of selected listed companies. *Contemporary Economics. No. 7,* pp. 31-45.
10. Grice, J., Dugan, M. (2001). The Limitations of Bankruptcy Prediction Models: Some Cautions for the Researcher. *Review of Quantitative Finance and Accounting, September,* pp. 151-166.
11. Hadasik, D. (1998). The use of multidimensional comparative analysis to assess the risk of a company bankruptcy. *Scientific Journals, Series 1, No. 261.* Poznań University of Economics, pp. 1-198.
12. Hamrol, M., Czajka, B., Piechocki, M. (2004). Business bankruptcy – the discriminatory analysis model. *Organization Review, No. 6,* pp. 35-39.
13. Herman, S. (2017). Industry specificity of joint-stock companies in Poland and forecasting their bankruptcy. *Scientific Journals of the University of Economics in Krakow, No. 11,* pp. 41-59.
14. Hołda, A. (2001). The use of discriminatory analysis in bankruptcy prediction - world experience. *Accounting Theoretical Notebooks, No. 5(61),* pp. 125-138.
15. Jagiełło, R. (2013). Discriminatory analysis and logistic regression in the process of assessing the creditworthiness of enterprises. *Materials and Studies, No. 286,* pp. 1-118.
16. Jones, S. (2017). Predicting Business Bankruptcy: A High-Dimensional Analysis. *Review Account Stud., No. 22,* pp. 1366-1422.
17. Kasjaniuk, M. (2006). Application of discriminatory analysis to modeling and forecasting the condition of enterprises. *Regional Barometer, No. 6,* pp. 95-100.
18. Kisielińska, J., Waszkowski, A. (2010). Polish models for forecasting bankruptcy of enterprises and their verification, *Scientific Papers of the Warsaw University of Life Sciences. Economics and Organization of Food Economy, No. 82,* pp. 17-31.

19. Kitowski, J. (2011). Barriers to the credible application of discriminatory methods to assess the financial condition of enterprises. In: D. Zarzecki (Ed.), Financial management. Investments, business valuation, value management. *Scientific Journals of the University of Szczecin, No. 639. Finance, Financial Markets, Insurance, No. 37* (pp. 217-227). Publishing House of the University of Szczecin.
20. Kitowski, J. (2012). Ways of including the criterion of industry specificity in the methods of assessing the financial condition of an enterprise. *Management and Finance, No. 4,* pp. 263-286.
21. Kitowski, J. (2017). The state of research on the diagnostic reliability of discriminatory models. *Annales Universitatis Mariae Curie-Skłodowska. Sectio H, No. LI, Vol. 5,* pp. 179-188.
22. Kitowski, J. (2018). An attempt to verify the diagnostic credibility of discriminatory models (on the example of companies from the WIG-automotive portfolio). *Entrepreneurship and Management, No. XIX. Vol. 10, Iss. 1,* pp. 177-191.
23. Kitowski, J., Kowal-Pawul, A., Lichota, W. (2022). Identifying Symptoms of Bankruptcy Risk Based on Bankruptcy Prediction Models - A Case Study of Poland. *Sustainability, No. 14, Vol. 1416,* pp. 1-18.
24. Kopiński, A., Porębski, D. (2015). An attempt to use discriminatory models in the financial analysis of independent public healthcare centers. *Finance, Financial Markets, Insurance, No. 74, Vol. 2,* pp. 459-469.
25. Koralun-Bereźnicka, J. (2006). Assessment of the possibility of using selected discriminatory functions in the analysis of Polish listed companies. *Studies and Works of the College of Management and Finance, No. 69,* pp. 18-28.
26. Korol, T. (2010). *Systems of warning enterprises against the risk of bankruptcy*. Warsaw: Wolters Kluwer Publishing House.
27. Korol, T. (2019). Dynamic Bankruptcy Prediction Models for European Enterprises. *Journal Risk Financial Manag., No. 12, Vol. 185,* pp. 1-15.
28. Kuciński, A. (2011). The use of multidimensional discriminatory models to assess the financial condition of enterprises on the example of selected companies listed on the NewConnect market. *Studies and Materials of the Polish Knowledge Management Association, No. 41,* pp. 146-163.
29. Lichota, W. (2017). Verification of the diagnostic effectiveness of selected models of discriminant analysis on the example of a sample of enterprises from the Podkarpackie Province. *Scientific Papers of the University of Economics in Wrocław, No. 472,* pp. 209-217.
30. Lichota, W. (2020). The comparative analysis of the prediction effectiveness of selected discriminant analysis models. *Scientific Journals of the Małopolska School of Economics in Tarnów, No. 4,* pp. 69-82.

31. Mączyńska, E. (1994). Company condition assessment. (Simplified methods). *Economic Life, No. 38,* pp. 42-45.
32. Mączyńska, E., Zawadzki, M. (2006). Discriminant models of business bankruptcy prediction. *Economist, No. 2,* pp. 205-235.
33. Maślanka, T. (2008). *Cash flow in the economic management of enterprises*. Warsaw: CH Beck.
34. Micherda, B. (Ed.) (2012). *Directions of evolution of financial reporting and auditing*. Warsaw.
35. Noga, T., Adamowicz, K. (2021). Forecasting bankruptcy in the wood industry. *European Journal of Wood and Wood Products, No. 79,* pp. 735-743.
36. Nowak, E. (1997). Multidimensional comparative analysis in modeling the financial condition of enterprises. *Annales Universitatis Mariae Curie-Skłodowska, Sectio H, No. 31,* pp. 111-123.
37. Pitera, R. (2014). Assessment of the possibility of using discriminatory methods in examining the financial condition of enterprises. *Works of the Industry Geography Commission of the Polish Geographical Society, No. 28,* pp. 184-199.
38. Pitera, R. (2018). Evaluation of the Reliability of Selected Discriminatory Methods in Assessing the Financial Condition of an Enterprise. *Annales Universitatis Mariae Curie-Skłodowska. Sectio H, No. LII. Vol. 5,* pp. 57-65.
39. Pogodzińska, M., Sojak S. (1995), The use of discriminant analysis in predicting bankruptcy of enterprises. *Acta Universitatis Nicolai Copernici - Economics XXV - Humanities and Social Sciences, No. 299,* pp. 53-61.
40. Potoczna, M., Wiśniewska, S. (2017). Application of discriminant analysis and logit model to forecast bankruptcy of Polish enterprises. In: S. Wawak (Ed.), *Diagnostic methods and techniques in organization improvement*. Warszawa: Mfiles.pl, pp. 39-47.
41. Prusak, B. (2005). *Modern methods of forecasting the financial threat of enterprises*. Warsaw: Difin.
42. Prusak, B. (2018). Review of Research into Enterprise Bankruptcy Prediction in Selected Central and Eastern European Countries. *Int. J. Financial Stud., No. 6, Vol. 60,* pp. 1-28.
43. Rogowski, W. (1997). Possibilities of early recognition of threat symptoms to the company's payment capacity. *Bank and Credit, No. 6,* pp. 56-72.
44. Rutkowska, J. (2006). Usefulness assessment of bankruptcy forecasting methods in Polish conditions. *Scientific Journals of the University of Economics in Krakow, No. 683,* pp. 47-62.
45. Schumpeter, J.A. (1982). *The Theory of Economic Development.* Piscataway, NJ, USA: Transaction Publishers.
46. Sukiennik, M. (2013). Discriminatory analysis and soft computing techniques in assessing the financial condition of Polish mines. *Scientific Papers of the University of Szczecin,*

No. 760. Finance, Financial Markets, Insurance, No. 59 (pp. 291-299). Publishing House of the University of Szczecin.

47. Tomczak, S., Radosiński, E. (2017). The effectiveness of discriminant models based on the example of the manufacturing sector. *Operations Research and Decisions, No. 3,* pp. 81-97.
48. Tymoszuk, M. (2013). Effectiveness of business bankruptcy forecasting models versus the passage of time – a comparison of popular Polish models of multidimensional discriminant analysis with the model built by the author. In: A. Adamska, E. Mączyńska (Eds.), *Bankruptcy, bankruptcy and restructuring of enterprises. Selected issues*. Warsaw: SGH Publishing House.
49. Waszkowski, A. (2011). Methods of classification models for enterprises insolvency prediction. *Acta Sci. Pol., Oeconomia*, No. 10, pp. 95-106.
50. Wierzba, D. (2000). Early detection of companies at risk of bankruptcy based on the analysis of financial indicators - theory and empirical research. *Science Notebooks, No. 9,* Publishing House of the University of Economics and Computer Science in Warsaw.
51. Wojnar, J. (2014). Assessment of the effectiveness of discriminant analysis models for forecasting the financial threat of listed companies. *Scientific Journals of the Małopolska School of Economics in Tarnów, No. 24. Vol. 1*, pp. 219-231.
52. Wysocki, F., Kozera, A. (2012). The use of discriminant analysis in the assessment of bankruptcy of meat industry enterprises. *Journal of Agribusiness and Rural Development, No. 4*, pp. 167-182.
53. Zaleska, M. (2012). *Economic and financial assessment of the enterprise by a bank analyst*. Warsaw: SGH Publishing House.
54. Zarzecki, D. (2003). A discriminatory analysis as a method of bankruptcy risk assessment. *Time for money. Finance management. Measuring Results and Evaluating Enterprises, Vol. 1.* Publishing House of the University of Szczecin, pp. 173-182.