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Verification of the effectiveness of re-estimated discriminant models on the example of the food manufacturing sector

Introduction

The aim of this article was to select the best re-estimated discriminant models that point out the declining financial standing of a company three years before bankruptcy occurs. Therefore, comprehensive survey was made to assess the large number of discriminant models. First, 33 discriminant models were selected. Second, the coefficient of models were re-estimated based on a training sample of 202 companies. Third, the classification matrix method was chosen in order to compare the models. Fourth, the best models were single out on the basis of results of test sample that consists of nearly 1,400 companies.

The research objective formulated in this way will allow to address the following research questions:

1. Does re-estimation of model coefficients significantly affect the efficiency of models?
2. Does the effectiveness of re-estimated models is similar to the efficiency given by the authors of the models?

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1. Literature review

The effectiveness of bankruptcy prediction models has been constantly analyzed. The verification of accuracy of the models was usually performed on a small test research sample. The test sample often did not exceed 200 companies and it was a homogeneous sample consisting of only the capital companies. Therefore, extensive verification of existing models using large sample test is needed.

Within past few decades, researchers around the world examined various prediction bankruptcy models starting from well-known Altman models across 25 and up to 120 companies [Altman, 1993; Altman, Hotchkiss,

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2006] in the calculations, as well as other models such as Springate model – accounting for 40 companies [Springate, 1978], Legault and Score model – 173 companies [Legault, Score, 1987], Taffler model – 92 companies [Taffler, 1983], etc. The analysis of accuracy of the models has also been carried out by others researchers, among others, Grice and Ingram [2001]; Reisz and Perlich [2007]; Wu, Gaunt, Gray [2010]; Lyandres and Zhdanov [2013]; Altman, Iwanowicz-Drozdowska, Laitinen and Suvas [2017]. Focusing on verification of the efficiency of models on a much larger research sample, mostly by analyzing the Altman model over time on a sample of 979, 1,002 companies; 5,784 companies; 50,611 companies; 146,836 companies; 3 191 743 companies.

In Poland, the usefulness of such models has been carried out by, among others, Pieńkowska [2004] on 68 companies; Pieńkowska [2005] – 203 companies [2005]; Dec [2007] – 40 companies; Hamrol and Chodakowski [2008] – 36 companies; Rusek [2010] – 36 companies; Balina [2012] – 60 companies; Tomczak, Przybysławski, Górski [2012] – 100 companies; Tymoczuk [2013] – 34 companies; Juszczyk and Balina [2014] – 120 companies; Noga et al. [2014] – 98 companies; Wojnar [2014] – 50 companies; Tomczak [2014] – 1,600 companies; Kisielińska [2016] – 110 companies; Tomczak and Radosiński [2017] – 10,600 companies; Altman et al. [2017] – 86,497 companies.

The latest analysis published by Altman et al. was carried out using only Altman models. This study was performed on 3 191 743 companies including a total of 32 European and 3 Non-European countries (China, Colombia and the U.S.). The results of the study shown that a general international model works well with prediction ability of 75, and exceptionally well for some above 90. The usefulness of the model may be significantly enhanced with country-specific estimation.

It is worth pointing out that analysis of usefulness of the models has been carried out both by their authors and other researchers. Generally, the verification of models has been based only on a small research sample. In many cases, the test sample did not exceed two hundred enterprises. Furthermore, according to the analysis of literature, leaving coefficients unchanged may cause a decline in the usefulness of models, because models tend to lose their usefulness with the passage of time from the moment of their construction. Considering this fact, models will be re-estimated and evaluated on the basis of much larger research sample, in order to investigate of the performance of re-estimated models.

2. Methodology of research

The aim of the study was to select the most useful re-estimated discriminant models that indicate the declining situation financial of food manufacturing enterprises three years prior to bankruptcy. Therefore, thirty four discriminant models (five foreign models and twenty eight Polish models): Altman, Altman EM [Altman, 1993], Appenzeller and Szarzec 1, 2 [Appenzeller, Szarzec, 2004], Gajdka, Stos 1–4 [Gajdka, Stos, 1996a, b; Gajdka, Stos, 2003], Hadasik 1–5 [Hadasik, 1998], Hołda [Hołda, 2001], INE PAN 1–7 [Mączyńska, Zawadzki, 2006], Janek and Żuchowski [Janek, Żuchowski, 2000], Legault, Score [Legault, Score, 1987], Mączyńska [Mączyńska, 1994], Pogodzińska, Sojak [Pogodzińska, Sojak, 1995], Poznan [Hamrol et al., 2004], Prusak 1–4 [Prusak, 2005], Springate [Springate, 1978], Taffler [Taffler, 1983], Wierzba [Wierzba, 2000] were compared and rated by analysing the accuracy of type I and type II.

In order to compare and to analyse the accuracy of type I and type II of models, the classification matrix method was chosen. This method is the most common used to compare and classify models [Altman, 1968; Altman, 1993; Mączyńska, Zawadzki, 2006] but not the only one [Prusak, 2005]. Such analysis enables evaluation of the accuracy of type I and type II of models over time and thus identifies a list of models that assess the businesses financial situation in the most accurate way. Type I accuracy (AI) is the percentage of properly classified bankrupt businesses, while type II accuracy (AII) is the percentage of non-bankrupt businesses correctly classified.

Analysis of type I accuracy is based on 565 insolvent companies in the period 2007–2018, whereas the analysis of type II accuracy is based on 990 companies still operating in the period 2012–2017 (this sample excluded some of the companies which declared bankruptcy in the period 2008–2018)[1]. The financial reports of food manufacturing companies were analysed. Since 2005, food manufacturing is second largest sector in which manufacturing companies have gone bankrupt [Tomczak, 2018]. The accuracy of the models was tested over a three-year period before the bankruptcy of companies. Models were ranked according to the highest average value of their type I, type II and overall performance in the three years prior to their bankruptcy.

The coefficient of analysed models were re-estimated based on a training sample of 202 companies of food manufacturing sector. One half of them (101 companies) had gone bankrupt in the period 2008–2017 and the other

[1] The financial statements of companies were drawn from the EMIS database (EMIS stands for Emerging Markets Information Service, a Euromoney Institutional Investor Company, www.emis.com).

half still operating ones (in good financial situation). The still operating ones were selected to be similar to (paired with) the insolvent businesses. In the process of selecting these businesses, the following criteria were used: industry and the reporting period, as well as the financial standing and size of the business.

The coefficients in the models were re-estimated using Statistica 13. First, the indicators occurring in the models were calculated. Second, outliers were removed using data cleaning in Statistica 13 in order to obtain a similar normal distribution. Third, new coefficients were calculated using canonical analysis. Fourth, the models were re-calculated based on a training sample of 202 companies. Verification of the effectiveness of re-estimated discriminant models has been made on the basis of test sample. The test sample consisted of analysis of accuracy type I 456 bankrupt companies and analysis of accuracy type II 889 still operating companies.

In the end, the results of re-estimated models were compared with the results of unchanged models for test sample and the values given by their Authors. The statistical significance will be examined by using t-Student tests.

3. Results

The accuracy of selected 33 models was tested in the three years before the bankruptcy of businesses and in the period 2017–2012 for companies still operating in the food manufacturing sector. Models were ranked according to the highest mean values of their accuracy of type I (Table 1), accuracy of type II (Table 2) and total accuracy (Table 3). This is to select the best models that much earlier than a year or two prior to the bankruptcy indicate the deteriorating situation of the company. The results of re-estimated models were compared with the values given by their authors and also with the results of the unchanged coefficients of models for test sample (Table 4). The outcomes presented in this way will help to provide answers to the research questions.

Table 1. The type I accuracy [%] of the top 10 among 33 models (464 bankrupt companies)

No.	Model	3 years	2 years	1 year	Mean 1–3
1	Altman EM	79.93	77.44	**83.98**	**80.45**
2	INE PAN1	**83.94**	**80.77**	71.43	78.71
3	Altman	79.56	76.23	78.35	78.05
4	Legault & Score	82.89	75.21	74.74	77.62
5	Springate	80.22	77.61	73.95	77.26
6	Mączyńska	82.01	74.73	73.81	76.85

No.	Model	3 years	2 years	1 year	Mean 1–3
7	INE PAN4	78.00	73.94	78.15	76.70
8	Gajdka & Stos1	80.88	75.00	72.86	76.24
9	Taffler	76.10	74.37	77.54	76.00
10	Prusak2	74.64	75.37	76.32	75.44

Source: Own elaboration.

Table 2. The accuracy of type II [%] of the top 10 among 33 models (889 still operating companies)

No.	Model/Period	2017	2016	2015	2014	2013	2012	Mean 2017–2012
1	Prusak3	89.47	89.77	94.97	92.42	93.81	93.85	92.38
2	Poznan	88.57	86.90	88.89	86.84	86.84	87.70	87.62
3	Prusak2	91.30	84.66	86.52	86.29	84.38	85.57	86.45
4	Prusak4	76.32	85.23	88.27	87.37	85.57	83.59	84.39
5	Appenzeller & Szarzec1	88.67	83.77	82.51	81.49	81.82	78.27	82.75
6	Appenzeller & Szarzec2	86.67	82.32	83.68	81.49	82.18	78.15	82.41
7	Legault & Score	78.66	76.47	74.14	72.67	71.15	67.41	73.42
8	Prusak1	74.70	70.59	72.22	72.54	71.63	67.28	71.49
9	Hadasik2	65.85	62.86	62.09	62.32	59.47	53.18	60.96
10	Hadasik5	65.85	62.86	62.09	62.32	59.47	53.18	60.96

Source: Own elaboration.

The data shown in Table 1, which presents the presents the type I accuracy of models for the test sample, indicate that one half of the models were constructed by foreign authors and four of them were ranked in the top five (two Altman's models; Legault, Score model; Springate model). The other half were designed by Polish researchers. The highest accuracy of type I for correctly classifying bankrupt companies was achieved by the Altman EM model – a type I accuracy of almost 80.45% over the three years prior to bankruptcy. Altman's model was built up especially for emerging markets. In turn, INE PAN1 model was only one designed by Polish researchers that was ranked in top five of accuracy of type I – nearly 80% over the three years prior to bankruptcy.

However, the models that were characterized by the highest accuracy of type I did not occupy high positions in the classification of type I accuracy (Table 2). The Legault, Score and Prusak 2 models were only ones that

can be seen in top ten of accuracy of type II. Furthermore, only Legault, Score model were in top 10 of accuracy of type II from all analysed model designed by foreign authors. It worth to notice that the accuracy of type I and type II of the model was at almost the same level. This model was built up for businesses that go bankrupt and still operating companies in Canada. Therefore, the model can be used as a baseline against which to assess the usefulness of Polish models. In addition, the Prusak 3 models was characterized by the highest accuracy of type II – 92% of correctly recognition of still operating enterprises.

The total accuracy of the selected models before (on the left side of table) and after (on the right side of table) re-estimation of coefficients is presented in table 3. The models were ranked according to the highest aggregated mean values of their performance after the re-estimation of coefficients.

Table 3. The total accuracy (TA) of the top 10 among 33 models

No	Model	Mean (AI) 1–3 before	Mean (AII) 2017–2012 before	Mean (TA) before	Mean (AI) 1–3 after	Mean (AII) 2017–2012 after	Mean (TA) after
1	Prusak2	72.29	63.61	67.95	75.44	86.63	81.04
2	Prusak3	58.73	92.73	75.73	68.84	92.09	80.47
3	Appenzeller & Szarzec1	39.25	90.86	65.05	72.56	83.65	78.10
4	Appenzeller & Szarzec2	39.58	89.15	64.36	71.89	83.27	77.58
5	Prusak4	69.75	77.44	73.59	67.85	84.55	76.20
6	Legault & Score	44.38	80.95	62.67	77.62	74.62	76.12
7	Poznan	13.67	98.61	56.14	61.52	87.61	74.57
8	Prusak1	51.44	47.17	49.30	70.29	72.34	71.31
9	INE PAN4	9.37	99.89	54.63	76.70	58.08	67.39
10	Altman	30.42	92.00	61.21	78.05	56.38	67.21

Source: Own elaboration.

Analysing the results of the overall comparison of the models, it should be mentioned that the highest total accuracy was characterized by two models of Prusak – Prusak 2 model (81.04%) and Prusak 3 (80.47%). These models were designed for manufacturing sector. In addition to these models, in the forefront of the most useful models are: the Appenzeller & Szarzec 1 model (78.10%), the Appenzeller & Szarzec 2 model (77.58%), the Prusak 4 model (76.20%), the Legault & Score model (76.12%) and Poznan model

(74.57%). However, they are characterized by lower correct recognition of companies in comparison to the most useful models. The other models do not recognize businesses sufficiently well.

In addition, analyzing the results, it can be noticed that the models are characterized by better recognition of enterprises after re-estimation of their coefficients. Furthermore, in most cases, there is a large disproportion at recognizing bankrupt enterprises and still operating companies. If models recognize businesses which have a good financial condition well, are less effective at identifying companies with poor financial situation. Similarly, models which are characterized by high correct recognition of bankrupt companies tend to be less useful at identifying still operating companies. There are some exceptions, such as the Legault model, but after the re-estimation of its the coefficients.

The total accuracy of the selected models is presented in table 4, according to values given by Authors' models, before (on the left side of table) and after (on the right side of table) re-estimation of coefficients in a year prior to bankruptcy. The models were ranked according to the highest aggregated mean values of their performance in a year prior to bankruptcy after the re-estimation of coefficients. It should be said that in order to analyse the impact of re-estimation of coefficients on the effectiveness of models t-Student test has applied (the hypothesis will be tested against the significance of 0.05). This test is a frequently used method for analysing dissimilarities between the averages of two groups (in this particular case differences between two defined groups: before and after re-estimation of models but also re-estimation of models and values given by Authors' of models). This test one can estimate whether the difference in means of analysed groups is statically significant. The t-Student test was applied by the use of the Statistica.

By analyzing the above table 4, one can pointed out that mean values of 33 models before re-estimation of coefficients were compared with mean values of 33 models after re-estimation of coefficients by t-Student test. The accuracy of type I, type II and total accuracy were analyzed. The differences between intervals are statistically relevant. It means that one should re-estimate model before he will use it. This statement is the answer to the first research question. Then, mean values of 33 models after re-estimation of coefficients were compared with mean values given by Authors' of models. The differences between groups are statistically significance. It means that that the values given by Authors' of models are statistically higher than the values of re-estimated models. This statement is the answer to the second research question.

Table 4. Comparison of total accuracy of models for a year prior to bankruptcy of the top 10 among 33 models

No.	Model	Accor. To Author	AI (before) a year	AII (before) a year	TA (before) mean	AI (after) a year	AII (after) a year	TA (after) mean
1	Prusak2	88.46	73.16	63.61	68.38	76.32	86.63	81.47
2	Prusak3	97.86	61.18	92.73	76.96	69.20	92.09	80.64
3	Appenzeller & Szarzec1	85.29	41.67	90.86	66.26	71.43	83.65	77.54
4	Appenzeller & Szarzec2	88.23	44.24	89.15	66.70	73.33	83.27	78.30
5	Prusak4	95.71	69.62	77.44	73.53	68.35	84.55	76.45
6	Legault & Score	83.00	42.63	80.95	61.79	74.74	74.62	74.68
7	Poznan	96.00	18.98	98.61	58.80	61.31	87.61	74.46
8	Prusak1	94.87	54.93	47.17	51.05	71.36	72.34	71.85
9	INE PAN4	87.50	10.92	99.89	55.41	78.15	58.08	68.12
10	Altman	93.95	33.33	92.00	62.67	78.35	56.38	67.37
Mean of 33 models		91,61%	38,11%	75,68%	56,89%	69,11%	60,59%	64,85%

Source: Own elaboration.

Table 5. The re-estimated coefficients of financial ratios used in the top 10 among 33 re-estimated discriminant models.

Ratio / Model	M1	M2	M3	M4	M5	M6	M6	M8	M9	M10
X1	0.92								–0.22	
X2	0.01	–0.03			–0.03			0.00		
X3	6.59	5.86			11.85					
X4		1.06	1.05	0.98				0.99	0.14	
X5			–0.55							
X6			6.61							
X7			2.70				0.40			
X8			0.00	0.00						
X9			–1.02	0.19						
X10				9.22				8.71		
X11				0.00						
X12					–3.56					
X13					–6.24			0.69	1.03	

Ratio / Model	M1	M2	M3	M4	M5	M6	M6	M8	M9	M10
X14						5.17			5.30	
X15						2.87				
X16						–0.78				
X17							0.05			
X18							3.63			
X19							11.17			
X20									2.34	
X21									0.32	
X22									0.22	
X23									–0.32	–0.33
X24										3.19
X25										7.36
X26										4.39
X27										0.19
stała	–0.70	–1.72	–1.92	–2.06	1.25	–2.10	–2.82	–1.84	–5.26	–0.63

Source: Own elaboration.

Table 5 shows the financial ratios and the re-estimated coefficients of the ten best models for classifying companies are based on. Twenty seven ratios are used altogether of which only four can be found in three models. It should be noticed that ratio number 5 (current liquidity ratios) appears in five different models. The frequency of its appearance may indicate its predictive and discriminative ability. But the values of it were not stable over time [Tomczak, 2017].

4. Discussion

So far, many prediction bankruptcy models have been constructed to recognize the financial standing of businesses. However, only few of them accurately identify the weaken financial situation of a business long enough in advance and only those models can be considered as useful.

The survey presents the best 10 out of 33 models but only 7 of them were characterized by acceptable level of predictive and discriminant power in the three years prior to bankruptcy of a company, but the differences between the accuracy of these models are insignificant. In top 10 only two models developed outside Poland were ranked – Legault & Score model and Altman model. The second one is the best known in the world prediction bankruptcy model. However, in the study Altman model is marked by lower correct recognition rates in comparison to the most efficient models.

The efficiency of re-estimated model was improved in comparison to results obtained by Tomczak, Radosiński [2017] but were not so good in comparison to the figures presented by Altman et al. [2017]. In turn, Legault & Score is one of the few models that equally well recognizes bankrupt and still operating companies. The model also was ranked in top 5 in the outcome shown by Tomczak, Radosiński [2017].

Whereas when it comes to assess the results of Polish models, The Prusak 3 and Prussak 4 models also appear in the top 5 ranking. Besides of Prusak models also Poznan model can be treated as useful according to the results of Kisielińska [2016] – the effectiveness of correct classification was 82.7%. It is worth pointed out that two last mentioned studies the coefficients of models were unchanged.

The study have some limitations:

1. Survey was covered only analysis of discriminant models.
2. Only one method was used to compare the models.
3. The effectiveness of the models before and after the crisis was not analyzed.

Therefore, future research will include not only the analysis of discriminant models but also logit models, decision trees and others in the time of crisis and after, using more than one method to compare models.

Conclusions

This article presents a comprehensive comparison of 33 re-estimated discriminant models based on analysis of accuracy of type I, accuracy of type II and total accuracy. The test sample consisted of the analysis of 464 bankrupt enterprises and the analysis of 889 still operating enterprises. In total, 1353 companies were analysed. Two models of Prusak – Prusak 2 model (81.04%) and Prusak 3 (80.47%) were characterized by the highest total accuracy. It should be pointed out that the differences between the mean values of 33 models before re-estimation of coefficients and the mean values of 33 models after re-estimation of coefficients are statistically relevant. In addition, the differences between mean values of 33 models after re-estimation of coefficients and the mean values given by Authors' of models are statistically significance.

References

Altman E. (1968), *Financial ratios, discriminant analysis and the prediction of corporate bankruptcy*, „Journal of Finance", Vol. 23, No. 4.

Altman E. (1993), *Corporate financial distress and bankruptcy* (2nd ed.), John Wiley & Son, New York.

Altman E.I., Hotchkiss E. (2006), *Corporate financial distress and bankruptcy* (3rd ed.), John Wiley & Son, New York.

Altman E.I., Iwanowicz-Drozdowska M., Laitinen E.K., Suvas A. (2017), *Financial Distress Prediction in an International Context: A Review and Empirical Analysis of Altman's Z-Score Model*, „Journal of International Financial Management & Accounting", Vol. 28.

Appenzeller D., Szarzec K. (2004), *Prognozowanie zagrożenia upadłością polskich spółek publicznych*, „Rynek Terminowy", nr 1.

Balina R. (2012), *Skuteczność wybranych modeli dyskryminacyjnych na przykładzie branży robót budowlanych*, „Zeszyty Naukowe Uniwersytetu Szczecińskiego, Finanse, Rynki finansowe, Ubezpieczenia", nr 50.

Dec P. (2007), *Dylematy weryfikacji i wyboru modeli predykcji bankructwa przedsiębiorstw*, VIII Kongres Ekonomistów Polskich. Warszawa 29–30.11.2007.

Gajdka J., Stos D. (1996a), *Wykorzystanie analizy dyskryminacyjnej do badania przydatności przedsiębiorstwa na bankructwo,* in: J. Duraj (red.), *Przedsiębiorstwo na rynku kapitałowym,* UŁ, Łódź.

Gajdka J., Stos D. (1996b), *Wykorzystanie analizy dyskryminacyjnej w ocenie kondycji finansowej przedsiębiorstw*, AE, Kraków.

Gajdka J., Stos D. (2003), *Ocena kondycji finansowej polskich spółek publicznych w okresie 1998–2001,* in: D. Zarzecki (red.), *Czas na pieniądz, Zarządzanie finansami, Mierzenie wyników i wycena przedsiębiorstw*, US, Szczecin.

Grice J.S., Ingram R.W. (2001), *Tests of the generalizability of Altman's bankruptcy prediction model*, „Journal of Business Research", Vol. 54.

Hadasik D. (1998), *Upadłość przedsiębiorstw w Polsce i metody jej prognozowania,* „Zeszyty Naukowe Akademii Ekonomicznej w Poznaniu", AE, Poznań, Seria II.

Hamrol M., Chodakowski J. (2008), *Analiza dyskryminacyjna. Przegląd najważniejszych modeli,* „Przegląd Organizacji", nr 3.

Hamrol M., Czajka B., Piechocki M. (2004), *Upadłość przedsiębiorstwa – model analizy dyskryminacyjnej,* „Przegląd Organizacji", nr 6.

Hołda A. (2001), *Prognozowanie bankructwa jednostki w warunkach gospodarki polskiej z wykorzystaniem funkcji dyskryminacyjnej Zh,* „Rachunkowość", nr 5.

Janek J., Żuchowski M. (2000), *Analiza dyskryminacyjna i jej zastosowania w ekonomii,* Wydział Matematyki i Nauk Informacyjnych Politechniki Warszawskiej, Warszawa.

Juszczyk S., Balina R. (2014), *Prognozowanie zagrożenia bankructwem przedsiębiorstw w wybranych branżach,* „Ekonomista", nr 1.

Kisielińska J. (2016), *The effectiveness of corporate bankruptcy models,* „Economic and Regional Studies", Vol. 9, No. 1.

Legault J.C.A., Score A. (1987), *Warning System for Small Business Failures,* Bilanas, June.

Lyandres E., Zhdanov A. (2013), *Investment opportunities and bankruptcy prediction*, „Journal of Financial Markets", No. 16.

Mączyńska E. (1994). *Ocena kondycji przedsiębiorstwa,* „Życie Gospodarcze", nr 38.

Mączyńska E., Zawadzki M. (2006), *Dyskryminacyjne modele predykcji bankructwa przedsiębiorstw,* „Ekonomista", nr 2.

Noga T., Adamowicz K., Jakubowski J. (2014), *Metody dyskryminacyjne w ocenie sytuacji finansowej przedsiębiorstw sektora leśno-drzewnego*, „Acta Scientiarum Polonorum Silvarum Colendarum Ratio et Industria Lignaria", nr 13(1).

Pieńkowska M. (2004), *Przewidywanie kryzysu*, „Nowe Życie Gospodarcze", nr 13.

Pieńkowska M. (2005), *Weryfikacja skuteczności funkcji dyskryminacyjnych opracowanych dla rynku polskiego,* in: K. Kuciński, E. Mączyńska (red.), *Zagrożenie upadłością*, SGH, Warszawa.

Pogodzińska M., Sojak S. (1995), *Wykorzystanie analizy dyskryminacyjnej w przewidywaniu bankructwa przedsiębiorstw,* „Acta Universitatis Nicolae Copernici, Ekonomia", nr 25.

Prusak B. (2005), *Nowoczesne metody prognozowania zagrożenia finansowego przedsiębiorstw,* Difin, Warszawa.

Rusek O. (2010), *Przydatność modeli dyskryminacyjnych w zarządzaniu przedsiębiorstwem,* „Zeszyty Naukowe SGGW – Ekonomika i Organizacja Gospodarki Żywnościowej", nr 85.

Reisz A.S., Perlich C. (2007), *A market-based framework for bankruptcy prediction*, „Journal of Financial Stability", No. 3.

Springate G.L.V. (1978), *Predicting the Possibility of Failure in a Canadian Firm*, Unpublished M.B.A. Research Project, Simon Fraser University, Canada.

Taffler R.J. (1983), *The assessment of company solvency and performance using a statistical model*, „Accounting and Business Research", Vol. 15, No. 52.

Tomczak S.K. (2014), *The early warning system*, „Journal of Management and Financial Sciences", No. 16.

Tomczak S.K. (2017), *The stability of the financial indicators over time*, in: Z. Wilimowska, L. Borzemski, J. Świątek (eds.), *Information Systems Architecture and Technology, Proc. 38th International Conference on Information Systems Architecture and Technology, ISAT 2017,* Advances in Intelligent Systems and Computing, Springer, No. 657.

Tomczak S.K. (2018), *Statistics on bankruptcy of companies in Poland*, „Management Sciences", No. 3.

Tomczak S.K., Przybysławski B., Górski A. (2012), *Comparative analysis of the bankruptcy prediction models, Information systems architecture and technology*, in: Z. Wilimowska (ed.),*The Use of IT Models for Organization Management* , PWr, Wrocław.

Tomczak S.K., Radosiński E. (2017), *The effectiveness of discriminant models based on the example of the manufacturing sector*. „Operations Research and Decisions", No. 3.

Tymoczuk M. (2013), *Skuteczność modeli prognozowania upadłości przedsiębiorstw a upływ czasu – porównanie popularnych polskich modeli wielowymiarowej analizy dyskryminacyjnej z modelem zbudowanym przez autorkę,* in*: A.* Adamska, E. Mączyńska (eds.), *Upadłości, bankructwa i naprawa przedsiębiorstw. Wybrane zagadnienia*, SGH, Warszawa.

Wierzba D. (2000), *Wczesne wykrywanie przedsiębiorstw zagrożonych upadłością na podstawie analizy wskaźników finansowych – teoria i badania empiryczne*, „Zeszyty Naukowe Wyższej Szkoły Ekonomiczno-Informatycznej w Warszawie", nr 9.

Wojnar J. (2014), *Ocena skuteczności modeli analizy dyskryminacyjnej do prognozowania zagrożenia finansowego spółek giełdowych*, „Zeszyty Naukowe Małopolskiej Wyższej Szkoły Ekonomicznej w Tarnowie", nr 1(24).

Wu Y., Gaunt C., Gray S. (2010), *A comparison of alternative bankruptcy prediction models*, „Journal of Contemporary Accounting and Economics", No. 6.

Zięba M., Tomczak S.K., Tomczak J.M. (2016), *Ensemble boosted trees with synthetic features generation in application to bankruptcy prediction*, „Expert Systems with Applications", No. 58.

Summary

The article assesses 33 re-estimated discriminant models for the food manufacturing sector. Nearly 1,400 companies have been examined within this sector – including 464 bankrupt companies. The statistical differences between the groups were tested by using t-Student test. The results obtained show that it is worth re-estimate coefficient before the model will use to assess financial situation of a company. In turn, the values given by Authors' of models are statistically higher than the values of re-estimated models, which means that the value given by the Authors' of models seems to be difficult to reach based on analysis of big research sample.

Keywords

insolvency, accuracy, bankruptcy prediction models, food manufacturing sector