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ANALYSIS OF THE RISK OF COMPANY'S BANKRUPTCY IN POLISH FOOD AND BEVERAGE PRODUCTION SECTOR USING THE COX REGRESSION

Analysis of the risk of a company's bankruptcy in Polish food and beverages production sector (NACE, No. 15) has been carried out using econometric modelling in the form of the Cox regression. The purpose of this paper was to find factors (models) describing the risk of a company's bankruptcy. The described approach to modelling of the risk of bankruptcy is – in the case of quantitative variables – the use of "raw" positions from financial accounts.

Keywords: *analysis of the risk of company's bankruptcy*, *econometric modelling of company's bankruptcy*, *Cox proportional-hazards regression*

1. Introduction

An analysis of the risk of company's bankruptcy in the *manufacture of food products and beverages* sector (NACE, No. 15)** in Poland has been carried out using econometric modelling of bankruptcy via the Cox proportional-hazards regression. The essence of the research was to find the factors most negatively influencing companies in their environment (here: sector). This enabled an appropriately early reaction (so-called: models of early warning [20]).

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**The Polish food and beverages manufacturing sector is in 3rd place according to the number of bankruptcies (14 bankruptcies in 2006 recorded in the Coface Poland database) behind the sectors "Wholesale trade" (66 bankruptcies in 2006) and "Construction" (42 bankruptcies in 2006) [1].

The modelling of the risk of company's bankruptcy has been used since 1968. At that time, Professor Edward I. Altman constructed – based on a multidimensional discriminant function – the first synthetic function (model) of a company's financial condition. Such synthetic measures, defined based on a wide spectrum of modelling methods, enable estimation of financial condition of a firm and a measure of risk of its bankruptcy. The arguments of the synthetic function defining the risk of bankruptcy are significant factors associated with bankruptcy. Furthermore, some models – for example those based on the Cox proportional-hazards regression or logistic regression – have some other parameters describing relative changes in the risk of a company's bankruptcy as a result of changes in the values of their component variables.

The subject of this paper is the Cox model of proportional-hazards regression (introduced by Sir David R. Cox in 1972 [2]), a broadly applicable and the most widely used method of survival analysis. Typical methods of survival analysis involve creation of life tables, estimation of survival functions (e.g. the Kaplan–Meier estimator, Weibull survival reliability function) and regression models (e.g. Cox regression, exponential regression, normal and log-normal regression) (see e.g. [3, 4, 9, 12]). The Cox regression is often applied in medical research. However, the construction of models of risk of company's bankruptcy based on theCox proportional-hazards regression is an approach more rarely reported than their construction based on a discriminant analysis or logistic regression.

2. Goals and approach of the research

The purpose of this research was to determine the factors influencing the risk of bankruptcy for companies in the Polish food and beverages manufacturing sector (*Nomenclature statistique des Activités économiques dans la Communauté Européenne*, NACE) – European Classification of Economic Activities, No. 15 [6, 18]). Analysis of the risk of bankruptcy in this sector is conducted using econometric modelling via Cox proportional-hazards regression.

In the research, "raw" values from consolidated financial accounts are directly used (the approach of values from financial accounts) as variables in the analysis of risk of bankruptcy, instead of a broad collection of financial indexes (the indicatory approach). The advantage of using the approach of values from financial accounts is the fact that this approach is commonly neglected. Maybe, this paper will draw researchers' attention to financial values which directly inform a layman (for example, a small businessman without any higher education in the discipline of finance) as to where he should act to improve the financial condition of his company (e.g. answer questions such as: *Should I hold more cash in the current account or quite the contrary – invest it?*, *Should I choose long-term or short-term liabilities?*).

3. Research material

The research material originates from the ISI Emerging Markets databases (www.securities.com, March 2008). It consists of the published financial accounts of companies which run their businesses in Poland in the manufacture of food products and beverages sector. Altogether, information was collected from ca. 1108 companies from which 15 were in a state of bankruptcy. Selected variables with a potentially strong influence on bankruptcy have been collected in Table 1.

Table 1. The list of variables considered

No.	Variable	Unit	No.	Variable	Unit
1	Number of voivodeship[a]		15	Liabilities	
2	NACE category[b]		16	Shareholders' equity	
3	Days between financial accounts[c]	day	17	Liabilities and reserves	
4	Liquidation[d]		18	Long-term liabilities	
5	Assets		19	Short-term liabilities	
6	Fixed assets		20	Working capital	
7	Intangibles		21	Sales revenue	PLN
8	Tangible fixed assets		22	Operating profit	
9	Long-term receivables	PLN	23	Gross profit	
10	Long-term investments		24	Net profit	
11	Current assents		25	Cash flow from operating activity	
12	Inventories		26	Change in cash flow	
13	Short-term receivables		27	Opening cash	
14	Short-term investments		28	Closing cash	

[a]Artificial variable, alphabetic.

[b]Division according to kinds of activities in a sector.

[c]Time from the day of the first databases recorded, in ISI Emerging Markets' financial account to the day of the last recorded financial account. The variable is interpreted as the survival time of a company.

[d]Binary variable: 1 – indicates the bankruptcy of an economic entity, 0 – means the survival (continuance) of an economic entity.

Source: authors' work.

4. Econometric modelling

The Cox proportional-hazards regression is a method of survival analysis, being in general a statistical analysis of a variable which describes the time until the occurrence of a specified event (death, recurrence of a disease, recovery etc.). The following are examples of survival analysis: the analysis of patients' survival times after a complicated operation, comparing patients' survival times for two methods of tumour treatment [17] and defining the forecasting factors for people with a tumour ([16], p. 291–295). However, due to its universality, survival analysis finds use in other (apart from medicine and biology) disciplines, for example: in economic and social sciences, as well as in engineering, technology and industry ([13], p. 76). Thus, in this paper, a company is treated as a living organism and the length of its functioning can be interpreted as its survival time ([15], p. 164). The moment of a company's "death" is considered to be the time of its bankruptcy.

The estimation of the Cox regression models is based on, so-called, maximization of the partial likelihood. In carrying out this maximization, the first factor (baseline hazard rate) is ignored in the formula for the hazard function (Eq. (5)), and the relative failure rate is estimated.

The partial likelihood function is given by ([2], p. 259):

$$L(\beta)=\prod_{i=1}^{k}\left(\frac{\exp\left(\beta x_{(i)}\right)}{\sum_{j\in R_i}\exp\left(\beta x_{(j)}\right)}\right) \tag{1}$$

where: k – the number of events, $x_{(j)}$ – observation No. j whose "failure time"* is $t_{(j)}$.

Taking the logarithm of the likelihood function ([2], p. 259):

$$\ln L(\beta)=\sum_{i=1}^{k}\beta x_{(i)}-\sum_{i=1}^{k}\ln\left(\sum_{j\in R_i}\exp\left(\beta x_{(j)}\right)\right) \tag{2}$$

it is possible to calculate the estimators of the β parameters.

The method of estimating the probability of bankruptcy according to the Cox proportional-hazards regression is described below.

The survival reliability function is described using the following formula ([14], p. 3):

$$\underline{F}(t)=P(T>t)=1-F(t) \tag{3}$$

where: T – time of working (survival) until the occurrence of a failure (death). T is a random variable with non-negative values.

Define F to be the probability distribution function of the random variable T. It is assumed that $F(0) = 0$.

*Censoring: in censored observations we have some information about the survival time but its precise value is not known. It may happen that when the research ends, a "patient" (company) is still "alive". Then the patient's survival time is censored. We know that the survival time of this patient is at least as long as the duration of our research [17].

Moreover, it is known that ([14], p. 6):

$$\underline{F}(t) = \mathrm{e}^{-\int_0^t h(u)du}, \quad t \geq 0 \tag{4}$$

where $h(u)$ is the hazard function.

The general Cox model (hazard function) takes the following form:

$$h\left(\frac{t}{X}\right) = h_0(t)\,\mathrm{e}^{b_1X_1+b_2X_2+\ldots+b_nX_n} \tag{5}$$

where: $b_1, b_2, \ldots, b_n$ are structural parameters associated with independent variables X_1, $X_2, \ldots, X_n$; $h_0(t)$ denotes the baseline hazard function.

The hazard function can be interpreted as the conditional probability density function of the survival time under the condition it is longer than t. In other words, it is a function with the values proportional to the probability of failure (death) in a given (short) stretch of time. Here, the vector **X** denotes the vector of quantitative characteristics and schematically coded qualitative characteristics considered in the model analyzed ([15], p. 164–165).

Therefore,

$$\underline{F}(t) = \mathrm{e}^{-\int_0^t h_0(u)\mathrm{e}^{b_1X_1+b_2X_2+\ldots+b_kX_k}du} \tag{6}$$

Since in the statistical package SPSS 14.0 it is possible to estimate the values of the hazard function, the following dependence holds regarding the baseline hazard function (this follows from Eq. (5)):

$$h_0(t) = \frac{h\left(\frac{t}{X}\right)}{\mathrm{e}^{b_1X_1+b_2X_2+\ldots+b_kX_k}} \tag{7}$$

Thus the estimated survival function is given by:

$$\underline{F}(t) = \mathrm{e}^{-\int_0^t h_0(t)\left(\mathrm{e}^{b_1X_1+b_2X_2+\ldots+b_kX_k}\right)du} = \mathrm{e}^{-h_0(t)\left(\mathrm{e}^{b_1X_1+b_2X_2+\ldots+b_kX_k}\right)[u]_0^t} = \mathrm{e}^{-h_0(t)\left(\mathrm{e}^{b_1X_1+b_2X_2+\ldots+b_kX_k}\right)t} \tag{8}$$

In the model for the problem considered, estimation of the survival function consists of redesigning a definite integral which is the exponent in Eq. (8) The integral is split into a sum of integrals taken over one year periods due to companies publishing annual financial accounts in which of course the values of the variables X_1, $X_2,\ldots$, X_k (positions in a company's financial accounts) undergo changes. This generalization has been adopted because of having only single set of financial accounts for each company from each year. Summing up, for each company in the exponent we have the integral over the length of its survival time up to the previous report plus the integral based on the values of the variables (from the most recent financial accounts) over the period since these accounts have been published.

Finally, the proposed estimate of the probability of bankruptcy according to the Cox regression models takes the following form (from Eq. (3)):

$$F(t) = 1 - \mathrm{e}^{-h_0(t)\left(\mathrm{e}^{b_1X_1 + b_2X_2 + \ldots + b_kX_k}\right)t} \tag{9}$$

A company is forecasted to have gone bankrupt when the following inequality is satisfied:

$$F(t) = 1 - \mathrm{e}^{-h_0(t)\left(\mathrm{e}^{b_1X_1 + b_2X_2 + \ldots + b_kX_k}\right)t} > V_B \tag{10}$$

where V_B is the "threshold value" ("cut-off point") – the value of the probability of bankruptcy above which a company's bankruptcy is forecasted (usually this value is taken to be 0,5*).

5. Models of the risk of bankruptcy in the sector and their properties. Cox regression CRmod_1 and CRmod_2 models

Two Cox regression models have been selected because they do not differ much with respect to the value of the test statistic based on the logarithm of the likelihood function (–2ln*L*). The greater the value or the realization of this statistic, the greater is the credibility of the results. Furthermore, these models give slightly different information about the character of bankruptcy in this sector because they differ with respect to the collection of independent variables.

Table 2. Collective test of the statistical significance of the coefficients' for the CRmod_1 model

Model	–2ln*L*	Estimation		
		Chi-square	Degrees of freedom	*p*-Value
9	90.799	286.288	7	0.000

Source: author's study based on the SPSS 14.0 report and ([15], p. 166).

*This is the so-called "standard forecast rule" (the cut-off value is 0.5). However, in non-balanced trials the value of this cut-off point can be lower than 0.5 ([10], p. 80).

The CRmod_1 model came into being at the ninth step of a stepwise procedure (Table 2). It is characterized by the largest gain in the value of the likelihood statistic compared to models which had come into being in previous steps. Moreover, this model explains the variation in the risk of bankruptcy to a statistically significant degree.

Table 3. Variables in the CRmod_1 model

Variable	B	Standard error	p-Value	exp(B)
Fixed assets	-1.097×10^{-7}	4.820×10^{-8}	0.023	0.9999998903
Short-term receivables	-6.124×10^{-7}	1.782×10^{-7}	0.001	0.9999993876
Short-term investments	1.373×10^{-7}	2.402×10^{-8}	0.000	1.0000001373
Working capital	-9.487×10^{-8}	2.244×10^{-8}	0.000	0.9999999051
Sales revenue	-6.959×10^{-8}	3.741×10^{-8}	0.063	0.9999999304
Operating profit	-4.131×10^{-7}	7.367×10^{-8}	0.000	0.9999995869
Gross profit	2.163×10^{-7}	4.470×10^{-8}	0.000	1.0000002163

Source: author's study based on the SPSS 14.0 report.

The p-values associated with the coefficients in the model do not exceed 0.1, thus they are statistically significant at the assumed significance level $\alpha = 0.1$.

Table 4. Classification table for the CRmod_1 model

Values observed		Values forecasted		
		Liquidation		Percentage of correct classifications
		0	1	
Liquidation	0	616	244	71.6
	1	0	11	100.0
Total percentage				72.0
Threshold value $V_B = 0.5$.				

Source: author's study.

Using the CRmod_1 model, the accuracy of a company's classification to the "survivor group" is 71.6%, while the accuracy of classification to the "bankrupt group" is 100%.

Table 5. Collective test of the statistical significance of the coefficients for the model CRmod_2

Model	$-2\ln L$	Estimation		
		Chi-square	Degrees of freedom	p-Value
11	88.673	274.679	7	0.000

Source: author's study based on the SPSS 14.0 report.

The CRmod_2 model came into being at the eleventh step of a stepwise procedure. It is characterized by a lower value (88.673) of the likelihood statistic than the value of this statistic (90.799) for the CRmod_1 model. However, this is not a very big difference and both models can be considered to be equally valuable, especially since there are some differences between the variables selected. Moreover, this model (CRmod_2) explains variation in the risk of bankruptcy to a statistically significant degree.

Table 6. Variables in model 2

	B	Standard error	*p*-Value	Exp(B)
Short-term receivables	-5.812×10^{-7}	1.853×10^{-7}	0.002	0.9999994188
Short-term investments	1.265×10^{-7}	2.555×10^{-8}	0.000	1.0000001265
Shareholders' equity	-8.504×10^{-8}	2.259×10^{-8}	0.000	0.9999999150
Long-term liabilities	-1.727×10^{-7}	6.377×10^{-8}	0.007	0.9999998273
Sales revenue	-8.617×10^{-8}	3.993×10^{-8}	0.031	0.9999999138
Operating profit	-4.575×10^{-7}	8.269×10^{-8}	0.000	0.9999995425
Gross profit	1.977×10^{-7}	4.493×10^{-8}	0.000	1.0000001977

Source: author's study based on the SPSS 14.0 report.

The p-values associated with the coefficients in this model do not even exceed 0.05, so they are statistically significant at the assumed significance level $\alpha = 0.1$.

Table 7. Classification table for model 2

Values observed		Values forecasted		
		Liquidation		Percentage of correct classifications
		0	1	
Liquidation	0	636	224	74.0
	1	0	11	100.0
Total percentage		–		74.3
Threshold value $V_B = 0.5$.				

Source: author's study.

Both models are characterized by their perfect accuracy of forecasting firms that have gone bankrupt. However, the CRmod_2 model is better than CRmod_1 one at forecasting survival by 2.4% (20 companies).

It is worth paying attention to the fact that in the classification tables presented only 871 companies are taken into consideration, from which 11 (instead of 15) are bankrupt. This is a result of the fact that in the case of 237 companies the value of the variable "days between publishing financial accounts and present time" is 0. The Cox regression belongs to the set of methods of survival analysis. Because of this, the so-called survival time has to exist in order to use this method.

The estimator exp(B) (Tables 3, 6) expresses the change (increase or decrease) in risk when the value of the corresponding variable increases by one unit. For example, the estimate corresponding to the variable "fixed assets" in the CRmod_1 model (Table 3) is 0.9999998903. This means that when fixed assets increase by one unit (1 PLN), the risk of bankruptcy decreases by: 100% – (100%×0.9999998903) ≈ 0.000012%. Simultaneously, according to the CRmod_1 model, an increase in short-term investments by 10 000 PLN decreases the risk of bankruptcy by: 100% – [100%×(1.0000001373)^10000] ≈ –0,137% (the negative sign means that the risk of bankruptcy increases) ([15], p. 172). In the Tables 8, 9, the influence of increases in the values of variables included in the chosen Cox regression models on the risk of a company's bankruptcy is presented.

According to the CRmod_1 model, increases in the values of fixed assets, short-term receivables, working capital, sales revenue and operating profit have a negative influence on the probability of a company's bankruptcy (they increase the probability of survival). According to the CRmod_2 model shareholders' equity and long-term liabilities appear instead of fixed assets and working capital. The positive influence of fixed assets on survival in the food and beverages production sector definitely results from the fact that they are long-term assets, inter alia: grounds, buildings, technical devices and machines, means of transport, licences, concessions, patents, copyrights, trademarks, long-term financial assets (bonds, shares and other financial assets) ([5], p. 16–17). A high value of fixed assets gives evidence of a firm's strength. Some fixed assets also give protection to a company during crisis (with regard to the possibility of their sale). An increase in short-term receivables greatly improves the probability of a company's survival. Even high values of short-term receivables do not comprise a great danger, since as a rule they correspond to friendly connections in the delivery chain. The positive influence of the value of working capital on survival in this sector results from the very essence of this value. Working capital is made up of the difference between the value of current assets and the sum of short-term liabilities and reserves. Hence, a positive value means that the long-term capital (shareholder equity + long-term liabilities) at a company's disposition covers not only fixed assets, but also some fraction of current assets ([7], p. 98–100). The fact that increasing sales revenue has an advantageous influence on a company's functioning does not have to be discussed further. An increase in operating profit tells us that the profitability of the company's main activity has grown. The positive influence of shareholders' equity on the probability of survival in this sector mainly results from the fact that they reflect the value of a company who can derive funds from issuing shares to shareholders ([19], p. 47–48)). Shareholders' equity is, on one hand, protection for a company in the case of difficulties in repaying liabilities and on the other hand, is fundamental in obtaining loans from a bank. The positive influence of the value of long-term liabilities on the probability of survival in this sector results mainly from the fact that long-term liabilities are stable sources of financing assets (together with shareholders' equity they form long-term, stable capital reserved for financing) ([8], p. 109).

Table 8. Influence of an increase in the values of variables in the CRmod_1 model on the risk of a company's bankruptcy

Variable	*B*	exp(*B*)	Increase in the value of variable causes	Increase by [%]		
				1 PLN	10 000 PLN	1 000 000 PLN
Fixed assets	-1.097×10^{-7}	0.9999998903	decrease in risk by	0.000011%	0.011%	10.39%
Short-term receivables	-6.124×10^{-7}	0.9999993876		0.000061%	0.061%	45.80%
Short-term investments	1.373×10^{-7}	1.0000001373	increase in risk by	–0.000014%	–0.014%	–14.72%
Working capital	-9.487×10^{-8}	0.9999999051	decrease in risk	0.000009%	0.009%	9.05%
Sales revenue	-6.959×10^{-8}	0.9999999304		0.000007%	0.007%	6.72%
Operating profit	-4.131×10^{-7}	0.9999995869		0.000041%	0.041%	33.84%
Gross profit	2.163×10^{-7}	1.0000002163	increase in risk by	–0.000022%	–0.022%	–24.15%

Source: author's study.

Table 9. Influence of an increase in the values of variables in the CRmod_2 model on the risk of a company's bankruptcy

Variable	*B*	exp(*B*)	Increase in the value of variable causes	Increase by [%]		
				1 PLN	10 000 PLN	1 000 000 PLN
Short-term receivables	-5.812×10^{-7}	0.9999994188	decrease in risk by	0.000058	0.058	44.08
Short-term investments	1.265×10^{-7}	1.0000001265	increase in risk by	–0.000013	–0.013	–13.48
Shareholders' equity	-8.504×10^{-8}	0.9999999150	decrease in risk by	0.000009	0.008	8.15
Long-term liabilities	-1.727×10^{-7}	0.9999998273		0.000017	0.017	15.86
Sales revenue	-8.617×10^{-8}	0.9999999138		0.000009	0.009	8.26
Operating profit	-4.575×10^{-7}	0.9999995425		0.000046	0.046	36.71
Gross profit	1.977×10^{-7}	1.0000001977	increase in risk by	–0.000020	–0.020	–21.86

Source: author's study.

According to both models, increases in the values of short-term receivables and gross profit increase the probability of a company's bankruptcy. Short-term receivables are current flows of means (cash and securities), which are indispensable mainly to cover different current liabilities. On the other hand, a high level of short-term receivables points to the fact that there are available means which are not being used (*too much cash leads to costs due to forfeited possibilities, especially when these means can be invested and fetch income* ([11], p. 148)). Moreover, an increase in cash may be associated with the sale of fixed assets. The most controversial result is the one obtained regarding the variable gross profit. The estimate of the coefficient of this variable in the regression model clearly points to the disadvantageous influence on a company's survival chances resulting from an increase in gross profit. One interpretation may lie in the possibility of the existence of a black economy and creative bookkeeping. Large values of gross profit may be evidence that a company's finance management leads to an increase in the tax burden in comparison to, for instance, not quite honest competition etc. Using such an indirect interpretation, high taxes might be considered to be a hidden factor which has a negative influence on a company's financial situation in the considered sector.

6. Conclusions

The properties of the Cox proportional-hazards regression models described above allow us to formulate the following conclusions about the nature of bankruptcy in the discussed sector:

1. Factors associated with bankruptcy in the Polish food and beverages production sector, together with the direction and strength of their influence.

• The variables included in both Cox regression models are:

– those negatively associated with the risk of bankruptcy: fixed assets, short-term receivables, shareholders' equity, long-term liabilities, working capital, sales revenue and operating profit,

– those positively associated with the risk of bankruptcy: short-term receivables and gross profit.

• Generally – based on the estimator of exp(B) – in order of the strength of influence from the strongest to the weakest ones:

– among variables negatively associated with the risk of bankruptcy: short-term receivables, then: operating profit, long-term liabilities, fixed assets, working capital, sales revenue and shareholders' equity,

– among variables positively associated with the risk of bankruptcy: gross profit, then: short-term receivables.

However, it is important to remember that each model can only include the chosen component variables.

2. The Cox regression models are very good at forecasting the bankruptcy of companies from the Polish food and beverages production sector (the accuracy in the trial is 100%). They forecast a company's survival a little worse, but also to a satisfactory degree (with the accuracy above 71%).

3. The approach associated with the use of "raw" values from consolidated financial accounts (the approach of values from financial accounts) to modelling the survival/bankruptcy of companies – from the Polish food and beverages production sector – gives satisfactory results expressed by the models' accuracy and their interpretative value.

• The models' accuracy is noted in point 2.

• The interpretation of the influence of a component variable on the risk of bankruptcy is also presented in the paper.

4. The qualitative variables were not included in any – even those not described in the further analysis – models. It can be concluded that neither geographic location of companies (according to the variable number of voivodeship) nor activity which these companies run (according to the variable NACE category) have an influence on the risk of bankruptcy of these companies.

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