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USING THE LOGISTIC MODELS TO ESTIMATE THE ECONOMIC SITUATION OF INDIVIDUAL FARMS

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ABSTRACT. In this article an attempt was made to use logistic models to measure and evaluate the economic situation of individual farms. Research was based on source data from 656 Polish farms that were keeping the accounts in 2001. The estimated model can be used by banks in order to evaluate the credibility of individual farms.

Key words: logit analysis, individual farm, estimation, accounts, economic situation

Introduction

Analysis of the economic situation of an individual farm, which results from its potential of production, informs about opportunities and possible threats, to which a farm is exposed. Inevitable changes in the agricultural sector force individual farms to search for sources of financing of their activity. They are often forced to raise loans with banks. It is the economic situation that determines farm's credibility, which is strictly connected with possibility of being given a credit. Each bank, while evaluating credibility, is attempting to define the level of the non-repayment risk. Doing so, it chooses its own set of indicators and criteria, which are used in the process of such evaluation **Jaworski** et **al.** (1998). Analysis of particular indicators often creates an erroneous picture of the debtor's situation, so banks have to use many different methods, such as for example credit-scoring or scoring methods **Siemińska** (2002). From this standpoint while evaluating individual farms' credibility, using logistic analysis can become very useful **Kowerski** (1998). Knowledge of a few important financial indicators that characterize individual farms is sufficient to evaluate their credibility.

This article attempts to show the uses of logit analysis for evaluation of the individual farms' economic situation. The research was based on source data from 656 Polish individual farms that were keeping the accounts in 2001 under the surveillance of the Institute of Agricultural and Food Economics.

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Methods

A logit analysis is a statistical regression method, in which a dependent variable is called a "latent" variable and what only can be observed is a binary variable (**Maddala** 2001):

$$y_i = \begin{cases} 1 & \text{if } y_i^* > 0 \\ 0 & \text{othervise} \end{cases}$$

where y_i^* is a value of "latent" variable which is not observed in the i^{th} unit (i = 1, 2, ..., n). In such a situation logistic regression model is suggested in order to describe chosen phenomenon. Model takes the following form:

$$P(Y = 1/X) = P_i(X) = \frac{1}{1 + e^{-(b_0 + b_1X_1 + b_2X_2 + ... + b_kX_k)}}$$

hence:

$$\log \frac{P_i}{1 - P_i} = b_0 + b_1X_1 + ... + b_kX_k$$

where:

$$\log \frac{P_i}{1 - P_i}$$

is natural logarithm of the odds ratio and is called a logit.

X_j – is a j-th independent variable (j = 1, 2, ..., k),

b_0 – is a constant of a logit model,

b_j – are coefficients of a logit model (j = 1, 2, ..., k).

Using an estimated model values of the odds ratio (Odds) can be calculated according to the following equation:

$$\text{Odds} = \frac{P_i}{1 - P_i}$$

The odds of an event occurring are defined as a ratio of the probability P_i (i = 1, 2, ..., n) that the event will occur to the probability that it will not in the i^{th} unit. This indicator takes on values from 0 to $+\infty$, what allows defining the odds as high or low.

For the estimated model Cox-Snell's and Negelkerke's goodness of fit indicators are also calculated. They take on values from interval <0;1> and are interpreted analogously to goodness of fit indicators in regression models.

Research

In order to conduct logit analysis properly, an analysed data set should be divided into groups **Norusis** (1999). The analysed group of individual farms was split into two groups according to annual net agricultural revenue gained in 2001 (Table 1). A dividing value was set at 10 000 PLN.

Table 1

Distribution of number of individual farms according to net agricultural revenue
Rozkład liczby indywidualnych gospodarstw rolnych według poziomu dochodu rolniczego netto

Group Klasa	Net agricultural revenue Dochód rolniczy netto (PLN)	Number of farms Liczba gospodarstw
1	< 10 000	330
2	> 10 000	326
Overall Ogółem	–	656

The first group includes 330 individual farms which net agricultural revenue was lower than 10 000 PLN, while the second one contains 326 individual farms which net agricultural revenue was higher than 10 000 PLN. On the basis of this division the assumption was made that group 1 includes individual farms in poor economic situation and with low credibility. Consequently, group 2 consist of individual farms in good economic situation, which are rather not endangered with loosing their credibility.

Results

The main target of research is to obtain the model that classifies individual farms and which can be then used to evaluate their economic situation. In order to specify the model, a set of variables presented in Table 2 was used. Selection of variables in attempt to obtain a desirable effect of logit analysis was based on statistical and common sense factors alike. The grouping variable introduced to the model takes on value 0 for the group 1 and 1 for group 2. Using the SPSS program, forward stepwise variable selection was used. As a result, the logit model was obtained. Estimation of its parameters is presented in Table 3.

In the obtained model, all variables and constant were characterized by level of significance close to zero (Table 3). The Nagelkerke R^2 amounted to 79.9%, what reflects a very good fit of the model to empirical data.

The logit model was prepared in such way that these P_i function values, obtained on the basis of the logit model, that are approximated to 0 refer to group 1 – that is to farms in poor economic situation, whereas P_i function values approximated to 1 refer to group 2 – that is to farms in good economic situation.

Table 2

Characteristic of variables used in logit analysis
Charakterystyka zmiennych wykorzystanych do analizy logitowej

Variable symbol Symbol zmiennej	Variable name Nazwa zmiennej	Variable characteristic Obliczanie wartości zmiennej (jednostki miary)
Y	Net agricultural revenue Dochód rolniczy netto	Binary variable (net agricultural revenue < 10 000 = 0, net agricultural revenue > 10 000 = 1) Zmienna zero-jedynkowa (dochód rolniczy netto < 10 000 = 0, dochód rolniczy netto > 10 000 = 1)
X_1	Agricultural land Powierzchnia gospodarstwa	ha
X_2	Manager's age Wiek kierownika	Years Lata
X_3	Share of farm's gross commodity production in overall production Towarowość produkcji globalnej	Ratio of farm's gross commodity production to farm's overall production (%) Udział produkcji towarowej brutto w produkcji globalnej gospodarstwa (%)
X_4	Share of agricultural revenue in personal revenue Udział dochodu rolniczego w dochodzie osobistym	Ratio of net agricultural revenue to personal revenue (%) Relacja dochodu rolniczego netto do dochodu osobistego (%)
X_5	Profit net ratio Wskaźnik rentowności netto	Ratio of net agricultural revenue to farm's overall income (%) Relacja dochodu rolniczego netto do przychodów ogółem gospodarstwa (%)
X_6	Return on assets (ROA) Wskaźnik rentowności aktywów ogółem	Ratio of net agricultural revenue to farm's overall assets (%) Relacja dochodu rolniczego netto do aktywów ogółem gospodarstwa (%)
X_7	Return on equity (ROE) Wskaźnik rentowności kapitału własnego	Ratio of net agricultural revenue minus self-work costs to farm's equity (%) Relacja dochodu rolniczego netto pomniejszonego o koszt pracy własnej do kapitału własnego gospodarstwa (%)
X_8	Assets turnover ratio Rotacja aktywów ogółem	Ratio of farm's overall income to farm's overall assets (%) Relacja przychodów ogółem do aktywów ogółem gospodarstwa (%)
X_9	Fixed assets turnover ratio (without ground) Rotacja majątku trwałego (bez ziemi)	Ratio of farm's overall income to mean state of fixed assets without ground (%) Relacja przychodów ogółem gospodarstwa do średniego stanu majątku trwałego bez ziemi (%)
X_{10}	Overall debt ratio Wskaźnik ogólnego poziomu zadłużenia	Ratio of overall debt to farm's overall assets (%) Relacja zadłużenia ogółem do aktywów ogółem gospodarstwa (%)

Table 3

Parameter estimates for the logistic model (based on the Institute of Agricultural and Food Economics data)
Oceny parametrów modelu logitowego (na podstawie danych IERiGŻ)

Variable symbol Symbol zmiennej	Variable name Nazwa zmiennej	Coefficient (b) Ocena parametru (b)	Standard error Błąd standardowy	Significance Istotność	Exp (b)	95.0% C.I. for Exp (b) Przedział ufności 95,0% dla Exp (b)	
						lower dolny	upper górny
X_1	Agricultural land Powierzchnia gospodarstwa	0.099	0.016	0.000	1.104	1.069	1.140
X_2	Manager's age Wiek kierownika	–0.057	0.015	0.000	0.945	0.918	0.972
X_4	Share of agricultural revenue in personal revenue Udział dochodu rolniczego w dochodzie osobistym	0.007	0.001	0.000	1.008	1.005	1.010
X_5	Profit net ratio Wskaźnik rentowności netto	0.260	0.024	0.000	1.297	1.239	1.359
–	Variable standing by constant Zmienna jedynkowa przy wyrazie wolnym	–5.090	0.879	0.000	0.006		

Positive, and statistically significant, influence on results that are being obtained from the logit model have three variables, namely: agricultural land, share of agricultural revenue in personal revenue and profit net ratio. This means that the higher the value that these variables take on, the higher the probability that a chosen farm is going to be included in group that contains individual farms in good economic situation. Opposite influence on classifying a chosen farm to a group of farms that gain higher agricultural revenue, has manager's age. The highest influence on a function value has profit net ratio. Number exp(b) that stands by i^{th} variable, is the factor by which the odds of gaining revenue exceeding 10 000 PLN change, if the i^{th} independent variable increases by one unit and other variables remain unchanged. For example, if farm's area (X_1) increases by one hectar of agricultural land, the odds *caeteris paribus* grow by a factor of 1.104. Overall correctness of classification amounted to 90.5% (Table 4). Both farms in good and bad economic situation were classified with high degree of correctness (higher than 90.00%).

Table 4
Correctness of classification of the P_i logit model (based on the Institute of Agricultural and Food Economics data)
Trafność klasyfikacji modelu logitowego P_i (na podstawie danych IERiGŻ)

Observed Rzeczywista		Predicted Modelowa	
		group 1 klasa 1	group 2 klasa 2
Group 1 Klasa 1	Bad economic situation Gorsza sytuacja ekonomiczna	298 (90.3%)	32
Group 2 Klasa 2	Good economic situation Lepsza sytuacja ekonomiczna	30	296 (90.8%)

Development of probability of gaining revenue that exceeds 10 000 PLN according to both agricultural land area and net profit ratio changes is presented on Figures 1 and 2. Chart 1 indicates that probability of gaining revenue higher than 10 000 PLN by an individual farm grows as its agricultural land grows. This probability is close to 1 for farms that contain more than 75 ha of agricultural land, whereas probability of gaining revenue that exceeds 10 000 PLN is growing rapidly after surpassing the value of profit net ratio equal to 10%. This probability takes on value of 1 while the level of profit net ratio is equal to 25%.

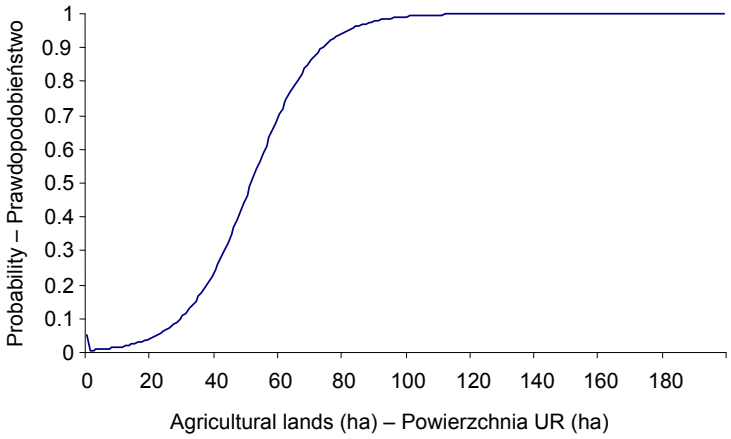

Fig. 1. Probability of gaining revenue higher than 10 000 PLN depending on agricultural land (X_1) (mean values of X_2, X_4, X_5) (ha)
(based on the Institute of Agricultural and Food Economics data)
Ryc. 1. Prawdopodobieństwo osiągnięcia przez gospodarstwo dochodu powyżej 10 000 zł w zależności od obszaru użytków rolnych (X_1)
(przyjęto wartości średnie zmiennych X_2, X_4, X_5) (ha)
(na podstawie danych IERiGŻ)

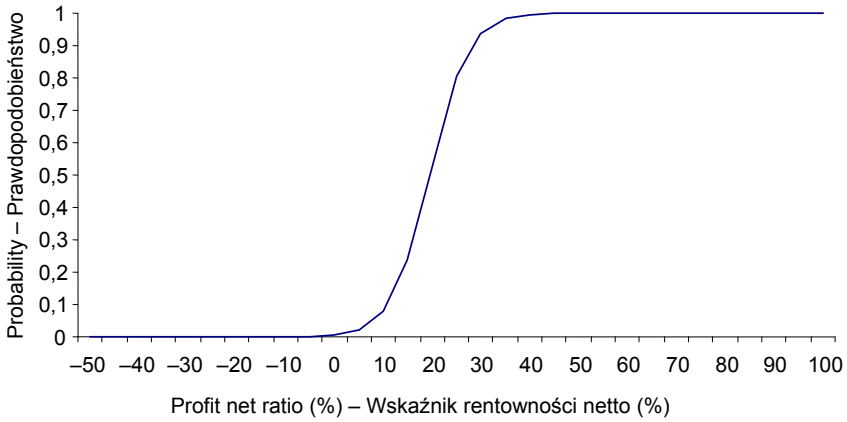

Fig. 2. Probability of gaining revenue higher than 10 000 PLN depending on profit net ratio (X_5) (mean values of X_1, X_2, X_4) (%) (based on the Institute of Agricultural and Food Economics data)

Ryc. 2. Prawdopodobieństwo osiągnięcia przez gospodarstwo dochodu powyżej 10 000 zł w zależności od wskaźnika rentowności netto (X_5) (przyjęto wartości średnie zmiennych X_1, X_2, X_4) (%) (na podstawie danych IERiGŻ)

Evaluation of chosen farm's using estimated P_i model

The estimated logit model was used in order to evaluate the economic situation of six chosen individual farms (Table 5). The logit model defined a farm A (cattle-porkish oriented production, agricultural land of 5.51 ha) and a farm B (poultrish oriented production, agricultural land of 21.05 ha) as farms in worse economic situation and without credibility. They both gained low net agricultural incomes and negative net revenues from their activities. They were characterized by low profitability and share of farm's gross commodity production in overall production. Their odds to be included in the group of farms with agricultural revenue that exceeds 10 000 PLN are close to 0 (0.023 and 0.045).

Farms C (beef-cereal oriented production) and D (milky oriented production) were classified as endangered with loosing of credibility. They were both characterized by higher net agricultural revenue profitability, return on assets and profit net ratio than farms A and B, however they both gained negative net revenue.

The logit model classified farms E and F as farms in good economic situation with high credibility. They both gained positive values of net agricultural revenue and net profit. The farm E (vegetable oriented production, agricultural land of 12.72 ha) reached almost 100% of share of farm's gross commodity production in overall production and the highest profitability indicators. Farm F (cereal oriented production) was larger (agricultural land of 113.99 ha), it had lower share of farm's gross commodity production in overall production (about 90%).

Table 5

Six chosen farms' characteristics and results from estimated function
(based on the Institute of Agricultural and Food Economics data)
Charakterystyki sześciu indywidualnych gospodarstw rolnych i wyniki oszacowanej funkcji (na podstawie danych IERiGŻ)

Data Dane	Farms – Gospodarstwa					
	A	B	C	D	E	F
1	2	3	4	5	6	7
Orientation of production Kierunek produkcji	pork-cattle trzodowo- -bydlęcy	poultry drobiarski	cereal-pork zbożowo- -trzodowy	milk mleczny	vegetables warzywny	cereal zbożowy
Net agricultural revenue (PLN) Dochód rolniczy netto (PLN)	4 042	5 030	12 433	8 650	43 931	202 517
Net revenue (PLN) Zysk netto (PLN)	–10 695.5	–21 782.5	–35 514.5	–13 100	30 356	152 267
Agricultural land (ha) Powierzchnia UR (ha)	5.51	21.05	17.97	21.11	12.70	113.99
Manager's age (years) Wiek kierownika (lata)	51	52	38	48	53	48
Share of farm's gross commodity production in overall production (%) Towarowość produkcji globalnej (%)	59.5	73.0	43.5	47.3	99.0	97.8

Table 5 – cont.

1	2	3	4	5	6	7
Share of agricultural revenue in personal revenue (%) Udział dochodu rolniczego w dochodzie osobistym (%)	12.9	79.5	36.3	32.2	81.6	84.4
Profit net ratio (%) Wskaźnik rentowności netto (%)	13.7	8.9	20.7	22.1	54.2	47.8
Return on assets (ROA) (%) Wskaźnik rentowności aktywów ogółem (%)	1.7	1.4	3.6	6.3	13.7	30.9
$\log P_i/(1 - P_i)$	–3.745	–3.040	0.201	0.277	7.870	16.64
P_i	0.023	0.045	0.550	0.569	0.999	0.999
Odds Wskaźnik szans	low b. niski	low b. niski	medium średni	medium średni	high b. wysoki	high b. wysoki

Using the logit model, a ranking of individual farms can be prepared. This ranking groups farms according to probability of gaining agricultural revenues higher than 10 000 PLN (Table 6). In the presented ranking worse results got small farms, characterized by negative net agricultural revenue and net profit. At the same time, the best results got individual farms that contained more than 75 ha of agricultural land.

Table 6

Ranking of individual farms according to probability of gaining net agricultural revenue exceeding 10 000 PLN (based on the Institute of Agricultural and Food Economics data)
Ranking gospodarstw według prawdopodobieństwa osiągnięcia dochodu rolniczego netto powyżej 10 000 PLN (na podstawie danych IERiGŻ)

Ranking	$\log P_i/(1 - P_i)$	P_i	Odds Wskaźnik szans	Orientation of production Kierunek produkcji	Agricultural land Powierzchnia UR	Net agricultural revenue Dochód rolniczy netto
1	16.83	~1	20 539 600	cereal-industrial zbożowo--przemysłowy	185.78	101 013
2	16.64	~1	16 984 117	cereal zbożowy	113.99	202 517
3	16.05	~1	9 406 969	pork trzodowy	136.18	160 591
4	14.97	~1	3 188 878	pork trzodowy	146.71	134 560
5	14.81	~1	2 714 241	cereal zbożowy	164.04	69 433
6	14.07	~1	1 293 403	cereal zbożowy	104.00	71 276
7	13.30	~1	600 710	milk mleczny	75.70	125 566
…	…	…	…	…	…	…
650	–26.85	~0	0	cereal zbożowy	6.90	–7 396
651	–27.99	~0	0	cereal-milk zbożowo-mleczny	7.62	–6 852
652	–28.67	~0	0	pork trzodowy	1.95	–5 343
653	–36.53	~0	0	cereal zbożowy	4.86	–7 347
654	–43.68	~0	0	cereal zbożowy	7.54	–6 446
655	–49.16	~0	0	industrial przemysłowy	2.85	–6 999
656	–51.58	~0	0	cereal zbożowy	2.71	–8 325

Conclusions

1. Presented logit model can be used as a tool to evaluate the economic situation of individual farms. It is characterized by high statistical significance of classification results.

2. The estimated model allows to evaluate whether a particular farm has credibility or not. The highest credibility can be obtained by unidirectional farms that display net agricultural revenue similar to net profit and high share of farm's gross commodity production in overall production.

3. Probability of gaining agricultural revenue that exceeds 10 000 PLN by an individual farm is growing simultaneously together with enlargement of agricultural land and it approximates to 1 for farms that contain more than 75 ha of agricultural land. Immediately after crossing the level of net profit ratio that is equal to 10% this probability is growing rapidly and till it reaches a value that is similar to 1. This appears at the level of net profit ratio equal to 25%.

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WYKORZYSTANIE ANALIZY LOGITOWEJ DO OCENY SYTUACJI EKONOMICZNEJ INDYWIDUALNYCH GOSPODARSTW ROLNYCH

S t r e s z c z e n i e

W pracy podjęto próbę zastosowania analizy logitowej do pomiaru i oceny sytuacji ekonomicznej indywidualnych gospodarstw rolnych. Badania zostały oparte na danych źródłowych pochodzących z 656 gospodarstw z terenu całej Polski, prowadzących rachunkowość w 2001 roku.

Prezentowany model logitowy może być zastosowany jako narzędzie diagnozowania sytuacji ekonomicznej indywidualnych gospodarstw rolnych. Pozwala również ocenić stopień wiarygodności kredytowej poszczególnych gospodarstw. Charakteryzuje go wysoka statystyczna istotność wyników klasyfikacji. Największą wiarygodnością kredytową charakteryzują się gospodarstwa jednokierunkowe, wykazujące dochód rolniczy netto na poziomie zysku netto oraz bardzo dużą towarowość produkcji.