

COVID-19 and the risk of bankruptcy for agricultural enterprises in Poland. Does the type of activity matter?

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Abstract. The COVID-19 pandemic has caused significant disruptions in the operation of agricultural enterprises. The objective of this study was to examine the impact of the COVID-19 pandemic on the capacity of Polish agricultural enterprises to mitigate the risk of bankruptcy. The sample comprised over four thousand enterprises operating during the period 2014-2021. The enterprises were grouped by their primary activity, while the risk of bankruptcy was measured using Altman's Z-score. The financial data on enterprises was sourced from the EMIS database, and the macroeconomic indicators were taken from Statistics Poland data. The impact of the COVID-19 pandemic on the Z-score was examined using panel regression with fixed effects. Unlike in the case of enterprises operating in other countries, the research has shown that changes in social, economic and regulatory conditions triggered by the COVID-19 pandemic have enhanced the capacity of Polish agricultural enterprises to mitigate the risk of bankruptcy. The extent of such influence depended on the nature of agricultural activity undertaken by the enterprise. The most significant surge in mitigation capacity was observed for enterprises specialising in plant production: cultivation of cereals, legumes, oil crops and other plants, as well as cultivation of fruit trees, bushes and vegetables. Furthermore, enterprises that combine agricultural crop cultivation and animal husbandry, as well as those engaged in forest management, hunting, and timber harvesting, also exhibited positive changes.

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1. INTRODUCTION

The COVID-19 pandemic has had a multidimensional impact on the economy – it has weakened human capital, constricted the activity of enterprises and public institutions, and led to a profound shift in lifestyle and professional routines. Travel restrictions and interruptions in supply chains led to the destabilisation of the business sector, deterioration of financial liquidity, and increased risks of bankruptcy, especially in the case of small and medium-sized enterprises (Alves et al., 2020; ECB, 2020; NBP, 2020). In the first year of the pandemic, the risk of insolvency increased, on average, by 21% in the European SME sector. This was caused by a number of factors, including a sharp reduction in the number of customers, an increase in production and labour costs, and a decline in access to funding (Kaya, 2022).

The labour intensity of agricultural activities meant that the greatest barrier to the normal operation of agricultural enterprises arose from employee absenteeism resulting from illnesses of employees and farmers' family members, limited population mobility, and the need to maintain social distance in interpersonal contact. The introduction of preventive sanitary regulations restricted the ability of farmers to directly sell agricultural products at farmers' markets and, above all, to employ domestic and foreign seasonal workers to harvest cereals, vegetables, fruit and other agricultural products. Research by the Food and Agriculture Organization of the United Nations indicates that the restrictive visa policies applicable to seasonal workers resulted in significant labour shortages and a decline in the volume of fruit and vegetable harvests and new plantings. For Canada, the United States and Europe, the shortage of workers from Eastern European and African countries amounted to approximately 1 million people (FAO, 2020). The pandemic's detrimental impact was so strong that the launch of the COVID-19 vaccination programs and government support for small and medium-sized enterprises only partially offset the negative effects and did not eliminate the extraordinarily high risk of enterprise bankruptcy (ECB, 2021).

On the other hand, in the case of Polish agriculture, the need to comply with additional sanitary and organisational regulations imposed during the COVID-19 pandemic only slightly weakened the growth rate of total agricultural production and its sales. It was created largely by increased demand for food products, the higher production value of the food processing industry, and higher export of food products than in previous years (Kozak, 2023). The widespread introduction of remote professional work and school and academic education also contributed to improving the performance of agricultural enterprises. The inability to use restaurants and bars, and society staying at home longer, motivated people to prepare their own meals, which led to a change in the structure of food and agricultural products sold (Johansson et al., 2024).

The multidirectional and diversified impact of the COVID-19 pandemic on agriculture motivates us to examine how the COVID-19 pandemic affected the risk of bankruptcy of agricultural enterprises in Poland. Additionally, considering the ongoing changes in the sales structure of food products, it seems important to investigate which types of agricultural activities give enterprises a greater chance of operating more safely during a macroeconomic shock. The study covered over four thousand agricultural enterprises operating in Poland in 2014-2021, and the source of data on enterprises was the EMIS database. The risk of corporate bankruptcy was assessed using the Z-score index adapted to study non-financial enterprises from emerging countries (Altman et al., 2016). Using panel regression, it was examined whether and in what direction the shock caused by the COVID-19 pandemic influenced the level of bankruptcy risk of enterprises operating in particular types of agricultural activity. The research showed that the overall regulatory and macroeconomic conditions in which agricultural enterprises operated reduced the risk of bankruptcy of agricultural enterprises, specifically those mainly engaged in plant cultivation (including cereals, legumes, oilseeds, fruit trees, and shrubs and vegetables) and agricultural activities combined with animal husbandry. The small number of studies on the impact of the COVID-19 pandemic on the operational safety of agricultural enterprises in Europe makes this study an important contribution to the

literature on the subject. The presented conclusions can be used in the process of developing programs to maintain food security in the event of a possible crisis situation caused by a pandemic or military operations. The remainder of the article is structured as follows: The next chapter presents the conclusions from the literature review on the impact of the COVID-19 pandemic on agricultural enterprises, followed by the methodology of conducting statistical research and the results obtained, along with their discussion. All considerations are summarised in the conclusion.

2. LITERATURE REVIEW

Changes in the macroeconomic situation of regions, production volumes and employment levels of enterprises, especially micro-enterprises and SMEs, were the most common subjects of research on the effects caused by the COVID-19 pandemic. Conclusions from most of the studies indicate that restrictions on the movement of people and restrictive visa policies for temporary workers from developing countries have significantly deteriorated the liquidity and financial results of SMEs and, consequently, increased the risk of their bankruptcy (Blanco et al., 2020; Fernández et al., 2021). Interruptions of supply chains and the lack of opportunities for cooperation limited the possibilities of using economies of scale and lowered the cost efficiency and profitability of enterprises in the SME sector (Juergensen et al., 2020). During the pandemic in OECD countries, micro and small enterprises, especially those run by women and ethnic minorities, struggled with worse conditions for obtaining public aid than large entities. They were also covered by fewer government anti-crisis programs (OECD, 2021). Similar unequal treatment of smaller entities took place in agriculture, among others, in Sub-Saharan African countries. Small farms had difficult access to certified seed, fertilisers and agricultural advisory services. In many cases, this led to their impoverishment and increased social stratification (Mutegi et al., 2024).

In the case of agriculture, studies on the impact of the COVID-19 pandemic, in most cases, concerned changes in the production volume of domestic agriculture or its individual types. Cortignani et al. (2020) noted that in the first two quarters of 2020, Italian farms were affected by a significant decline in income, mainly due to the lack of employment opportunities for seasonal workers for harvesting. As a result, they were forced to reorient their activities towards new types of crops that could only be carried out by the work of family members and permanent employees. In turn, Ogada et al. (2021) indicated that in Kenya, the lack of opportunities to employ seasonal workers and access to the market for production inputs resulted in significant financial losses on farms specialising in vegetable farming. The lack of seasonal employment opportunities has also contributed to financial losses in agricultural enterprises in India (Kumar et al., 2021).

The disruption of supply chains was another negative effect of the COVID-19 pandemic on agricultural businesses. Kumar et al. (2020) found that in India, supply chain disruptions and labour constraints worsened the performance of all types of farms, especially those with high labour intensity, such as dairy farming, poultry farming, floriculture, horticulture and fishing. Wang et al. (2020) noted that in China, disruption of supply chains resulting from road blockades increased sanitation requirements and increased production costs, and the lack of working capital contributed to significant losses for dairy producers. In India, sanitation roadblocks have contributed to significant losses on farms, the highest being among producers of fresh and perishable products (Priyadarshini and Abhilash, 2021).

Sanitary restrictions also limited the sales of agricultural products during the COVID-19 pandemic. In India, Kumar et al. (2021) found that the closure of rural markets and the decline in food supply often led to drastic increases in food prices in cities, leading to serious impoverishment of the poorest groups of society there. Blazy et al. (2021) found that restrictions on movement and interpersonal contact made it difficult to conduct distribution through conventional channels and reduced direct sales of agricultural production. This contributed to the reduction of the cultivated area and the limitation of production solely

for one's own needs. Gu and Wang (2020), examining the impact of the COVID-19 pandemic on the results and financial situation of cooperatives specialising in vegetable production in Shanghai, found that the pandemic had a negative impact - especially on the sales stage - contributing to a greater differentiation between the producer price and the market price. The pandemic has also highlighted the difference in sales prices between traditional and e-commerce channels, causing a significant decline in the income of small-scale farmers, leading to an increase in their poverty.

The reason for financial losses suffered by agricultural enterprises was also the lack of proper risk management during the crisis. Shafi et al. (2020), based on the research on small and medium-sized agricultural enterprises in Pakistan, found that 83% of them were not prepared to operate in the conditions of the pandemic crisis. In turn, Vavrek et al. (2021) showed that during the pandemic, agricultural cooperatives in Slovakia were characterised by significantly weakened resistance to the risk of bankruptcy. Moreover, Srebro et al. (2021) pointed out that a similar problem exists among agricultural companies listed on the Belgrade Stock Exchange. The COVID-19 pandemic has reduced their financial stability, making them more sensitive to the risk of bankruptcy.

For some agricultural sector enterprises, the COVID-19 pandemic has become an opportunity for their development. In Tanzania, the decline in tourism income was an impetus for the growth of farms. To compensate for financial losses, some enterprises have successfully undertaken crop cultivation, animal husbandry/breeding and fishing (Chebby et al., 2024). In turn, Nielsen et al. (2023) found that in the aquaculture sector in Denmark and Spain, the pandemic contributed to a change in the sales structure and an increase in the share of cheaper varieties, which contributed to an increase in the sector's total sales and profits.

A small number of articles presented research results on the impact of the COVID-19 pandemic on the level of resistance of agricultural enterprises to the risk of bankruptcy. Mirza et al. (2023), using the Altman model to measure the risk of bankruptcy of enterprises from the SME sector in 15 EU countries, found that in the case of the agricultural sector between 2019 and 2020, the probability of bankruptcy increased from 6.7% to 9.4%. In turn, Hatab et al. (2020), examining 166 small and medium-sized agricultural enterprises in Egypt, noted that the diversification of production and a significant share of export sales, modernisation of equipment and maintaining a high level of financial liquidity allowed the limitation of losses caused by the pandemic and reduced the risk of bankruptcy of agricultural farms.

Among the few studies on the impact of the COVID-19 pandemic on the risk of bankruptcy of enterprises in Poland, Nehrebecka (2021), examining the quality of the Polish banks' loan portfolios and the risk of bankruptcy of enterprises from all sectors of the economy, including agriculture, showed that during the pandemic, the probability of insolvency of large and medium-sized enterprises increased 1.5 times, and in the case of small enterprises - 3 times. In turn, Szczepaniak et al. (2020), examining the effects of the COVID-19 pandemic among food enterprises in the first months of its presence in Poland, found that aid programs, as well as growing domestic and foreign demand for Polish food products and the price competitiveness of Polish food exports, reduce the likelihood of their bankruptcy.

Taking into account the results of the literature review, the following research hypotheses were formulated:

Hypothesis 1: Changes in the macroeconomic and legal situation occurring during the COVID-19 pandemic had a positive impact on the reduction of the risk of bankruptcy of agricultural enterprises.

Hypothesis 2: The level of risk of bankruptcy of agricultural enterprises depended on the type of business they conducted.

3. METHODOLOGY

Although research on the risk of bankruptcy was initiated in the first half of the 20th century, it was only the use by Altman (1968) of an indicator aggregating many variables describing the financial and market situation of a company that allowed for a comprehensive assessment of the risk of bankruptcy to which the company was exposed. The parameters of this indicator have been improved and adjusted several times to take into account the specificity of the analysed economic sector and the economy of the region (Altman, 1983; Altman et al., 2016). Following the use by Mirza et al. (2023) to study agricultural firms, the model applied in the research refers to Altman et al. (2016), which was prepared for the analysis of non-financial sector enterprises in emerging market countries. In the context of examining the bankruptcy risk of agricultural enterprises in Poland, we also consider the equation by Altman et al. (2016) to be the most appropriate form, given that the previous forms were developed to describe listed or retail companies.

The equation takes the following form:

$$Z\text{-score} = 3.25 + 6.56 \cdot X_1 + 3.26 \cdot X_2 + 6.72 \cdot X_3 + 1.05 \cdot X_4 \quad (1)$$

where: *Z-score* - bankruptcy risk indicator, X_1 - working capital/total assets, X_2 - retained earnings/total assets, X_3 - operating profits/total assets, X_4 - book value of equity/book value of total liabilities.

The Z-score allows the classification of a company according to the probability of bankruptcy in the near future:

Z-score > 5.85 – low risk of company bankruptcy,

3.75 < Z-score < 5.85 – moderate risk of company bankruptcy,

Z-score < 3.75 - high risk of company bankruptcy.

Once Z-score values were known, we first applied a two-tailed t-test to identify significant differences between mean Z-score values before (2014-2019) and during the COVID-19 pandemic (2020-2021). Then, to assess the impact of the pandemic on the level of Z-score bankruptcy risk, panel estimation with fixed effects was used according to the equation:

$$Z\text{-score}_{it} = \beta \cdot x_{it} + \theta \cdot macro_t + \gamma \cdot covid_t + \mu_i + \varepsilon_{it} \quad (2)$$

where: for the time t and company i: x_{it} – explanatory variables at the company level: assets – natural logarithm of the real value of the unit's total assets adjusted by the GDP deflator, leverage – ratio of equity to total assets, ROA – return on assets measured as net income to total assets, eff_asset – asset efficiency measured as sales to total assets, sh_liab – share of short-term liabilities in total liabilities; $macro_t$ – macroeconomic variables: GDP – real GDP growth rate, inflation – annual inflation rate of agricultural production; $covid_t = 1$ for 2020 and 2021 and 0 for other years; μ_i – unobservable and not included in the regression equation for an individual effect specific to a given company i; ε_{it} – random component of the model.

The choice of fixed-effects model estimation is based on the Hausman test, which states that the null hypothesis is that the difference in coefficients is not systematic, i.e. that the random-effects model is a correct estimation method. The null hypothesis is resoundingly rejected in our case (chi-2 statistic = 1295.06, p-value = 0.0000 in the case of the full sample model), thus pointing at fixed-effects estimation as a better choice.

The statistical tests of the panel regressions have revealed that models do not fulfil conditions of homoscedasticity (modified Wald test for groupwise heteroskedasticity with the null hypothesis of homoscedasticity: chi-2 statistic = 4.1e+36, p-value = 0.0000) and lack of autocorrelation (Wooldridge test for autocorrelation in panel data with the null hypothesis of no autocorrelation: F-stat = 13.427, p-value =

0.0003). To correct for this bias, the clustered standard error estimates, which are robust to disturbances being heteroscedastic and autocorrelated, were applied. In the context of fixed effects estimation, they specifically allow for the within-group correlation (here, group means each firm), relaxing the usual requirement for the independence of observations.

Prior to estimations, the outlier observations for *Z*-score values were identified using the rule of 1.5 times the interquartile range (IQR) of the data. All observations below the first quartile decreased by 1.5 times the interquartile range ($Q1 - 1.5 \cdot IQR$) and above the third quartile enlarged by 1.5 times the interquartile range ($Q3 + 1.5 \cdot IQR$) were discarded.

The research sample consists of enterprises divided into six sectors depending on the type of agricultural production they conduct (Table 1). The most numerous group with the largest number of annual observations contains enterprises specialising in the cultivation of cereals, legumes, oil plants and other plants (sector 2). In turn, the least numerous are enterprises specialising in fish farming and fishing (sector 5), as well as in forest management, hunting, and logging (sector 6). Sector 2&4 was created to separate enterprises dealing with the cultivation of all types of plants, covering the agricultural plants, as well as fruit and vegetables.

Table 1

Number of observations by type of agricultural production

Year	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5	Sector 6	Sector 2&4	Full sample
2014	175	731	299	118	54	16	849	1393
2015	152	704	266	110	53	19	814	1304
2016	47	203	85	32	16	8	235	391
2017	238	737	261	152	63	36	889	1487
2018	351	1077	395	247	90	58	1324	2218
2019	369	1105	407	261	91	63	1366	2296
2020	377	1105	408	268	100	63	1373	2321
2021	408	1123	418	286	101	76	1409	2412
Total	2117	6785	2539	1474	568	339	8259	13822

Sector 1 – animal breeding; Sector 2 – cultivation of cereals, legumes, oil crops and other plants; Sector 3 – cultivation of agricultural crops combined with animal breeding (mixed activities); Sector 4 – cultivation of fruit trees, bushes and vegetables; Sector 5 – fish farming and fisheries; Sector 6 – forest management, hunting and timber harvesting; Sector 2&4 – combination of Sector 2 and Sector 4 – plant production.

Source: own calculations based on EMIS data.

4. EMPIRICAL RESULTS AND DISCUSSION

Based on equation (1), average *Z*-scores were calculated for each year for the full sample and for each group of enterprises. Figure 1 presents the average *Z*-scores for enterprises depending on the type of production during the period 2014-2021. Through the entire period, companies that conducted mixed agricultural activities (sector 3) achieved the highest *Z*-scores (between 12 and 13). As sector 2 is the most numerous, the average values for this sector were close to the performance of the full sample. The worst performers appeared to be companies from sectors 4 and 6; however, their *Z*-scores never fell below 5.85, which still placed them in the green (safe) zone in terms of bankruptcy risk. The upward trend of most lines in the chart in 2020-2021 indicates that during the COVID-19 pandemic, most companies in the research sample increased their *Z*-score values, which means that they reduced the risk of bankruptcy.

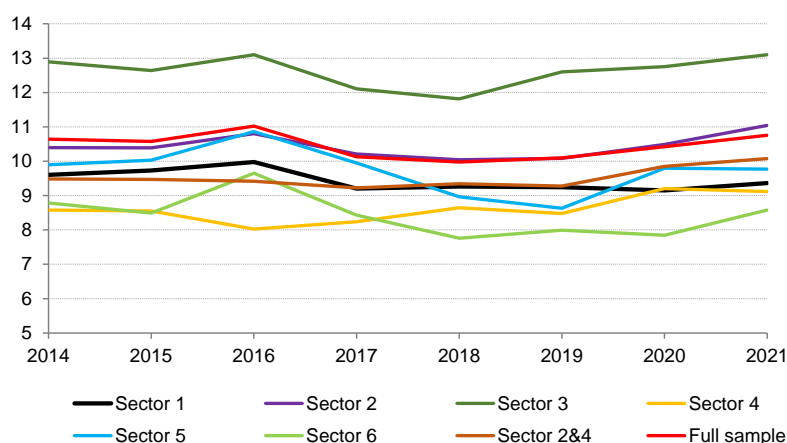


Figure 1. Average Z-score values by type of agricultural activity conducted by enterprises

Sector definitions as in Table 1.

Source: own calculations based on EMIS data.

Table 2 presents descriptive statistics for the entire sample and individual sectors of agricultural production. Enterprises specialising in animal breeding (sector 1) have the highest asset value. In contrast, entities involved in forest management, hunting, and logging (sector 6) possess assets almost four times smaller. The highest rate of return on assets (ROA) was achieved by enterprises conducting mixed agricultural activities (sector 3), and the lowest and the only negative one was achieved by fruit and vegetable enterprises (sector 4). The most profitable companies were also characterised by the highest sales efficiency and the highest share of equity in their balance sheet, indicating higher capacity in covering unexpected external losses. The lowest share of equity was recorded by enterprises with the largest (sector 1) and smallest value of assets (sector 6). The share of short-term liabilities in total liabilities was similar in all sectors and remained in the range of 50 to 60 per cent.

Table 2

Descriptive statistics of the panel regression variables

Full sample							Sector 1					
Variable	N	Mean	Med	SD	Min	Max	N	Mean	Med	SD	Min	Max
Z-score	13822	10.37	9.41	6.84	-9.45	31.94	2117	9.33	8.32	6.25	-9.01	31.85
assets	14088	13.29	5.32	41.35	-1.571	1481.2	2147	20.327	8.27	59.39	0	982.68
eff_asset	14076	.991	.458	8.24	-3.20	846	2144	1.992	.823	8.97	0	384
ROA	14088	4.317	3.82	117.16	-1244	1368.0	2147	2.548	2.84	120.05	-5248	1368.1
leverage	14076	.51	.61	.42	-9.0	12.83	2144	.44	.51	.42	-9.0	1.03
sh_liab	14071	51.167	45.22	150.98	-949.2	14070	2146	56.089	60.57	42.816	-949.2	107.52
Sector 2							Sector 3					
Z-score	6785	10.40	9.38	6.75	-9.455	31.944	2539	12.59	11.738	6.926	-8.515	31.92
assets	6915	11.32	5.69	22.19	-1.571	501.36	2583	14.46	5.33	65.276	.009	1481.2
eff_asset	6909	.78	.34	10.55	-3.21	846	2583	.58	.48	.61	0	10.55
ROA	6915	5.17	3.58	23.31	-583.8	512.52	2583	8.77	6.84	14.673	-169.1	95.56
leverage	6909	.52	.61	.43	-4.8	12.83	2583	.62	.72	.334	-1.55	1.143
sh_liab	6907	48.03	34.16	210.32	-75.82	14070	2579	51.83	50.97	37.26	0	100
Sector 4							Sector 5					
Z-score	1474	8.74	7.23	7.22	-9.41	31.91	568	9.56	8.86	5.98	-5.78	30.18
assets	1515	13.27	3.99	29.72	-.04	281.52	582	10.54	2.99	29.35	0	292.12
eff_asset	1513	.92	.45	2.08	0	37	581	.85	.53	1.33	0	17.51
ROA	1515	-4.91	2.08	322.27	-1244	161.95	582	3.12	3.42	21.709	-293.9	92.73
leverage	1513	.47	.45	.45	-3.1	1.66	581	.51	.56	.34	-.82	1.14
sh_liab	1512	53.99	58.515	40.87	0	144.83	581	53.471	44.82	87.47	0	1429.8

Sector 6							Sector 2&4					
Z-score	339	8.26	7.41	6.77	-9.22	30.87	8259	10.16	9.08	6.87	-9.45	31.94
assets	346	5.16	1.29	17.97	.01	289.51	8430	11.67	5.37	23.73	-1.57	501.36
eff_asset	346	2.41	1.544	3.21	0	34.51	8422	.81	.36	9.59	-3.26	846
ROA	346	7.46	5.98	27.406	-119	109.58	8430	3.35	3.35	138.26	-	512.52
leverage	346	.35	.41	.49	-3	1	8422	.5	.58	.443	-4.8	12.835
sh_liab	346	62.22	84.36	41.54	0	100	8419	49.14	37.53	191.31	-75.82	14070

N – number of observations; Med – median; SD – standard deviation; Min – minimum; Max – maximum; sector definitions as in Table 1.

Source: own calculations based on EMIS data.

The two-sided t-tests for the alternative hypothesis of the *mean Z-score (pre-COVID) < mean Z-score (COVID)* were conducted for the full sample of enterprises and sub-samples divided based on the type of agricultural production. The results of the tests (Table 3) show that in most cases, the mean Z-score for the COVID-19 pandemic period is statistically and significantly higher than during the pre-pandemic period. Such direction of dependency occurs in the full sample, as well as in the groups of enterprises conducting plant production, i.e. cultivation of cereals, legumes, oil crops and other plants (sector 2), cultivation of fruit trees, bushes and vegetables (sector 4), and cultivation of agricultural crops combined with animal breeding (mixed activities) (sector 3).

Table 3

The two-sided t-tests for the alternative hypothesis of the *mean Z-score (pre-COVID) < mean Z-score (COVID)*

Full sample				Sector 1		
Variable	N	Mean	SD	N	Mean	SD
Pre-COVID	9089	10.26	6.726	1332	9.37	6.23
COVID	473	10.592	7.061	785	9.26	6.29
t-statistic		-2.62			0.38	
Pr (T < t)		0.004			0.650	
Sector 2				Sector 3		
Pre-COVID	4557	10.223	6.686	1712	12.427	6.735
COVID	2228	10.768	6.880	826	12.929	7.298
t-statistic		-3.092			-1.666	
Pr (T < t)		0.001			0.048	
Sector 4				Sector 5		
Pre-COVID	920	8.490	6.968	367	9.446	5.908
COVID	554	9.160	7.623	201	9.784	6.135
t-statistic		-1.689			-0.638	
Pr (T < t)		0.046			0.262	
Sector 6				Sector 2&4		
Pre-COVID	200	8.278	6.223	5477	9.932	6.764
COVID	139	8.246	7.528	2,782	10.448	7.062
t-statistic		0.041			-3.182	
Pr (T < t)		0.516			0.001	

Sector definitions as in Table 1.

Source: own calculations based on EMIS data.

The aim of the next stage of the research was to test the first hypothesis, indicating that all circumstances and conditions caused by the COVID-19 pandemic had a positive impact on the resistance of agricultural enterprises to the risk of bankruptcy, and the second hypothesis, indicating that this impact depended on the type of production conducted by the enterprises. For this purpose, a panel estimation with fixed effects was used according to equation 2, covering the full research sample and individual groups of enterprises (Table 4).

Table 4

Panel model estimations

Variables	Total	S.1	S.2	S.3	S.4	S.5	S.6	S.2&4
COVID	0.468*** (0.105)	0.099 (0.108)	0.642*** (0.155)	0.446*** (0.148)	0.334* (0.171)	0.127 (0.230)	0.470* (0.271)	0.565*** (0.136)
assets	-0.011 (0.174)	-0.291 (0.194)	-0.305 (0.249)	0.755** (0.374)	-0.171 (0.232)	-0.631** (0.241)	0.086 (0.375)	-0.176 (0.215)
eff_asset	-0.007 (0.005)	-0.029*** (0.005)	-0.005** (0.002)	-0.475* (0.280)	-0.012 (0.070)	0.023 (0.114)	0.053 (0.046)	-0.004* (0.002)
ROA	0.104*** (0.004)	0.120*** (0.010)	0.103*** (0.007)	0.099*** (0.008)	0.100*** (0.005)	0.100*** (0.006)	0.095*** (0.005)	0.104*** (0.006)
leverage	6.519*** (2.458)	9.847*** (1.141)	3.784 (2.670)	15.389*** (1.048)	11.765*** (0.642)	12.233*** (1.396)	9.923*** (1.075)	4.890* (2.702)
sh_liab	0.001 (0.001)	0.002 (0.003)	0.000 (0.001)	0.015*** (0.004)	0.011** (0.005)	-0.002 (0.007)	0.002 (0.004)	0.001 (0.001)
GDP	0.008 (0.010)	-0.034** (0.015)	0.037*** (0.014)	0.001 (0.019)	-0.004 (0.021)	-0.024 (0.028)	-0.071 (0.050)	0.027** (0.012)
inflation	0.023*** (0.004)	0.006 (0.007)	0.028*** (0.006)	0.032*** (0.008)	-0.013 (0.009)	0.016 (0.016)	0.005 (0.012)	0.022*** (0.006)
constant	6.202*** (1.037)	4.820*** (0.632)	7.927*** (1.269)	0.279 (0.926)	3.390*** (0.478)	3.883*** (0.705)	3.974*** (0.477)	7.049*** (1.157)
N	13,801	2,116	6,774	2,535	1,470	567	339	8,244
Groups	2,808	448	1,325	499	337	114	85	1,662
F-stat	110.650	445.922	59.499	81.297	176.571	99.606	154.640	75.290
R-sq.	0.624	0.709	0.462	0.684	0.783	0.757	0.844	0.550

S.1 – S.2&4 stand for sectors 1 – 2&4, sector definitions as in Table 1, standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Source: own calculations based on EMIS data.

First, we observe that our models fit the data well. R-squared statistics are high for most of the subsamples – the lowest value of 46.2% is for the sector 2 estimations, but for the full model, the value is 62% and for other sectors, it often exceeds 70%. Thus, large proportions of Z-score variations are explained by the explanatory variables. F-statistics are also very high, indicating that the independent variable coefficients are jointly not equal to zero.

Discussion of results

The panel estimations show that coefficients at the main variable of interest, “COVID”, are positive and statistically significant for the full sample and for all sectors, apart from sectors 1 and 5 (animal breeding and fish farming and fisheries, respectively). The obtained results confirm the first hypothesis, indicating that all social, economic and legal conditions occurring during the COVID-19 pandemic had a positive impact on the resistance of agricultural enterprises to bankruptcy. The direction of the pandemic impact on the situation of agricultural enterprises is opposite to the research results obtained by Vavrek et al. (2021) and Srebro et al. (2021) for Slovak and Serbian agricultural enterprises, respectively. This fact may result, among others, from the cost and quality competitiveness of Polish food on the domestic and foreign

markets (Szczepaniak et al., 2020), the increase in household demand for food (Jędruchiewicz et al., 2024) and food exports (Kozak, 2023), as well as public liquidity support for the SME and agriculture sectors in the form of anti-crisis shields. The greater resistance of agricultural enterprises to the risk of bankruptcy can also be associated with the higher dynamics of growth in global production of Polish agriculture during the COVID-19 pandemic than on average in 2014-2019, i.e. 6.1% and 5.1%, respectively (Statistics Poland, 2022).

Moreover, the research results confirm the second hypothesis, indicating that the impact of the COVID-19 pandemic on the resistance of enterprises to the risk of bankruptcy depends on the type of agricultural activity. The regression results indicate that the resilience of enterprises conducting exclusive (sectors 2 and 4) or partial plant production (sectors 3 and 6) increased during the pandemic. However, the impact of the COVID-19 pandemic on the risk of bankruptcy of enterprises conducting animal breeding (sector 1) and fish farming and fisheries (sector 5) is undetermined. Such dependencies may result from diversified changes in consumer demand for food products during this period, i.e. an increase in the case of plant products in 2020-2021, and a decrease in 2020 and an increase in 2021 in the case of animal products (Kozak, 2023). Moreover, a more favourable impact of the COVID-19 pandemic on the bankruptcy resistance of enterprises specialising in plant or mixed production rather than exclusively animal production may result from difficulties in the distribution of animal products. The need to comply with sanitary requirements that are more difficult to implement in the case of animal than plant production and restrictions on direct sales could reduce sales revenues and could be a source of additional operating costs (Jędruchiewicz et al., 2024).

Estimation of regression models showed that the Z-score values were statistically significantly influenced by variables characterising the situation of individual enterprises and the macroeconomic environment in which they operated. The size of the enterprise's assets had a statistically significant impact on the Z-score value, positively in the case of enterprises specialising in agricultural crops combined with animal breeding (mixed activities) (sector 3) and negatively when specialising in fishing (sector 5). In the case of a more numerous and larger group of enterprises in terms of assets, it should be expected that the increase in the size of the enterprise increases the possibility of reducing operating costs, diversifying production types and achieving a synergy effect. This result is largely consistent with the conclusions of the Juergensen et al. (2020) study, which indicated that the inability to use the effects of scale caused by administrative restrictions contributed to an increase in the risk of bankruptcy of enterprises operating in the EU countries. In the case of fishing enterprises (sector 5), greater resistance to the risk of bankruptcy of smaller entities may result from the fact that these enterprises, being on average much smaller in size, when faced with limited access to seasonal employees, were able to independently carry out their activities with the help of family members, unlike larger ones requiring additional seasonal employment, as was proven by Cortignani et al. (2020) in the case of Italian farms.

The regression results yielded relatively intuitive results for return on assets (ROA) and share of equity in assets. Both of these variables increase the resistance to the enterprise's risk of bankruptcy. Higher financial profits allow for an increase in investment in fixed assets and the value of equity capital. Greater equity capital increases the enterprise's resistance to the impact of unexpected external shocks. The positive impact of the increase in the share of short-term liabilities in total liabilities in some agricultural enterprises may result from the increase in the share of financing enterprises with cost-free short-term trade credit in an environment of tightening credit policy by banks. The results of surveys conducted periodically by central banks, including the National Bank of Poland and the European Central Bank, indicate that lending policy standards and conditions for obtaining loans by small and medium-sized enterprises were usually more demanding than for large enterprises (ECB, 2020; NBP, 2021; Alves et al., 2020).

However, the impact of the asset efficiency ratio (sales to assets) is difficult to explain. For most agricultural enterprises, a lower value of this coefficient contributes to an increase in the Z-score. Some explanation for this may be the fact that most of the public aid was directed mainly to the SMEs and the agriculture sectors. Especially in the case of smaller enterprises, this aid was crucial for their liquidity and resistance to the risk of bankruptcy.

The macroeconomic environment also had a significant impact on the increase in enterprises' resistance to the risk of bankruptcy. The positive impact of an annual inflation rate on agricultural production might result from the fact that price increases allow enterprises to obtain higher sales revenues and, consequently, higher profits and a greater ability to absorb shocks resulting from the COVID-19 pandemic. Moreover, the regression results indicate a multidirectional impact of GDP growth on the resistance to bankruptcy risk among some agricultural enterprises. In the case of animal production, the impact is negative and positive in the case of plant production and fruit and vegetable production. A certain explanation for such directions of dependencies may be the fact of increasing demand for plant products at the expense of animal products. As society becomes richer and more interested in vegetarian food, the demand for animal food products is gradually decreasing, which affects the profitability and financial situation of enterprises specialising in such production.

5. CONCLUSION

The COVID-19 pandemic has introduced significant disruptions in the activities of agricultural enterprises. Given that a wide range of research has focused on the financial situation and market assessment of non-financial production enterprises, this work fills a gap in the economic literature by presenting the results of the pandemic's impact on the resistance of over four thousand Polish agricultural enterprises to the risk of bankruptcy during 2014-2021, as measured by the Altman method. Financial data on enterprises comes from the EMIS database, and macroeconomic data from Statistics Poland. The impact of the COVID-19 pandemic on the Z-score value was examined using panel regression with fixed effects.

Unlike in the case of enterprises operating in other countries, the research has shown that changes in social, economic and regulatory conditions caused by the COVID-19 pandemic have improved the resistance of Polish agricultural enterprises to the risk of bankruptcy. This result may be related to the continued price and quality competitiveness of Polish food products during the pandemic and the increase in food demand on domestic and foreign markets.

The strength of the pandemic's impact on enterprises' resistance to the risk of bankruptcy depended on the type of agricultural activity they conducted. During the pandemic, the resistance increased among enterprises specialising exclusively in plant production, i.e. cultivation of cereals, legumes, oil crops and other plants (sector 3) and cultivation of fruit trees, bushes and vegetables (sector 4), as well as those with mixed activities, i.e. agricultural crops combined with animal breeding (mixed activities) (sector 4) and forest management, hunting and timber harvesting (sector 6). Such directions of dependencies may result from an increase in demand for plant food products while decreasing demand for animal products and greater difficulties in the direct and indirect sales of animal products during the pandemic.

Moreover, the change in the Z-score was significantly influenced by the characteristics of enterprises and the situation of the macroeconomic environment in which they operated. The increase in the Z-score was driven by improved profitability of assets, a higher share of equity in the financing structure, and, in the case of enterprises conducting mixed activities, by an increase in the value of assets and the share of short-term liabilities in total liabilities. The decrease in the Z-score was caused by the increase in the ratio of sales to assets, and in the case of fish farming and fisheries, by the increase in assets. The macroeconomic

environment had a positive impact by increasing the prices of agricultural products and increasing GDP in the case of plant production and decreasing GDP in the case of animal production.

The research conclusions can be used by agricultural enterprises in the process of preparing contingency plans in the event of possible external shocks, as well as by public administration units in plans to ensure food security.

The authors are aware of some weaknesses of the study, resulting largely from the imperfections of the database, which includes, among others, the inequality of the time series of variables characterising enterprises, as well as significant differences in the size of the surveyed enterprises.

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