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MODELING THE STRUCTURAL RELATIONSHIPS BETWEEN THE DYNAMICS OF AGRICULTURAL INSURANCE, THE AGRARIAN SECTOR AND THE LEVEL OF FOOD SECURITY IN UKRAINE

ABSTRACT

The article's goal is to develop the scientific and methodological approach (model) to determine the influence of agricultural insurance on the agrarian sector development as well as the level of food security in Ukraine to implement the appropriate agricultural management decisions.

Structural modelling has been chosen as the methodological tool of the article. The process of modelling was performed with the help of structural equations. The Structural Equation Modeling tools in the Statistica 12 program package were used to accomplish this task (Statistics, Advanced linear/nonlinear Models, Structural Equation Modeling).

The study found that an increase of 100% in the level of development of agricultural insurance results in a 30.8% increase in the indicators of agricultural production. When the development level of agricultural production increases by 100%, there is a corresponding 45.6% increase in food security. However, if the agricultural insurance development level is increased by 100%, the food security one will be increased by 13.7%. Thus, the hypothesis about the direct influence of agricultural insurance on the development of the agricultural sector and, through it, on the food security of Ukraine is fully confirmed. The authors of the article offer to assess the direction and strength of the relationships between the development levels of agricultural insurance, the agricultural sector and food security by developing a system of single-factor and multifactor regression equations using structural modelling. The impact of the level of agricultural insurance development on the development of the agricultural sector along with the level of food security in Ukraine has been confirmed, and the mechanism of state support for agricultural insurance should consider the results obtained. Simultaneously, the development of agricultural insurance should be implemented on a public-private basis in Ukraine.

Keywords: agricultural insurance, agrarian sector, food security, agricultural management, agricultural production, modelling, development, indicators, Ukraine

JEL Classification: G22, C30, O13, Q01, Q10

INTRODUCTION

The Ukrainian agrarian sector is the driving force of the state's economy and the key to its progressive advancement and structural transformation. At the same time, agricultural enterprises create jobs both in agriculture and related industries. In addition, they generate significant amounts of foreign currency earnings, strengthening the country's foreign trade balance; ensuring active foreign investments attraction, which leads to active innovative transformations in the industry, and stimulating the development of infrastructure and logistics in the country. At the same time, the contribution of the agrarian sector to the formation of Ukraine's food security is significant, as a sufficient level of agricultural products creates the basis for social stability in the country, especially under martial law. The development of the domestic agro-industrial complex is characterized by issues, including those related to agricultural risk insurance. It should be noted that financial protection against unfavourable natural events is particularly

relevant for Ukrainian farmers: as our country is characterized by risks associated with spring frosts, fluctuations in average daily temperatures, hurricanes, and other adverse weather conditions.

Therefore, it is essential to determine the nature and strength of the connections between the development of the agricultural sector, agricultural insurance, and food security in Ukraine.

LITERATURE REVIEW

Numerous scientific studies and publications by foreign and domestic authors pay attention to the assessment of the impact of agricultural insurance on the development of the agrarian sector and the level of food security in the country.

Based on the subject matter of the article, it is proposed to consider the relevant scientific works from the following perspectives:

- problematic aspects of the formation and development of the agrarian sector and the agricultural insurance system in Ukraine;
- ensuring the country's food security in this context.

The legal framework for agricultural insurance in Ukraine is established by the following key legal acts: the Law of Ukraine "On Insurance", the Law of Ukraine "On Specifics of State-Supported Insurance of Agricultural Products", the Resolution of the NBU Board "On Regulation on Implementation of Agricultural Products Insurance Activities with State Support" [39; 40; 38].

A literature review reveals that many scientific papers deal with the problems and general trends in the functioning of the insurance services market of Ukraine, particularly O. Kozmenko et al., 2009 [25]; M. Melnyk et al., 2021 [33]; O. Polinkevych et al., 2021 [44]; O. Prokopchuk et al., 2022 [45]; T. Yavorska et al., 2022 [63]; I. Tsymbaliuk et al., 2021 [56]. When discussing the growth of the Ukrainian insurance market, many researchers highlight the importance of establishing a successful agricultural risk insurance system in the country.

The issues of necessity, formation and development of agricultural insurance are discussed by many authors in the Ukrainian literature (O. Kozmenko & O. Pakhnenko, 2011 [24]; Y. Nesterchuk et al., 2018 [36]; A. Stelmashchuk, 2019 [54]; N. Shibaeva & T. Baban, 2020 [50]; L. Vdovenko, 2020 [60]) and foreign scientific literature (A. Matsuda & T. Kurosaki, 2019 [30]; B. Lou et al., 2022 [27]; H. J. Bucheli et al., 2023 [11]; M. Arych et al., 2023 [1]). By highlighting the current trends in agricultural insurance development, researchers state that to ensure the economic and food security of a state, as well as promote growth within the agricultural industry, it is imperative to provide adequate insurance coverage to agricultural enterprises.

The problems of modelling financial support for the agricultural sector, including through agricultural insurance, are discussed in the works of L. Katan et al., 2018 [21]; A. Belhadi et al., 2023 [5]; M. Rakotoarisoa & H. Mapp, 2023 [46]; O. Lyulyov et al., 2021 [28]; T. Vasilyeva et al., 2013 [59].

Based on the conducted analysis of the relevant literature, a conclusion can be made that agricultural insurance in Ukraine is at the initial stage of development, as evidenced by the level of insurance penetration rate in the agricultural sector of 5%, as well as the constantly changing legal framework for the functioning of insurance market members. Further investigation of the state support system for agrarians, coupled with improvements in the entire agricultural insurance market, should become the unequivocal direction for the progressive advancement of agricultural insurance in Ukraine.

Next, we turn to scientific studies that focus on the problems of agricultural sector development in Ukraine and globally: L. Wu et al., 2022 [62]; A. Ulinici, & L. Șavga, 2019 [58]; Y. Kolesnik et al., 2019 [22]; O. Dobrovolska & J. M. R. Espejo, 2018 [13]; U. Berezhnytska et al., 2022 [6]; V. Ievdokymov et al., 2021 [19]; S. Singh, 2022 [52]; D. Bhowmik, 2022 [7]; M. Dykha et al., 2021 [14]; Brodnanova et al., 2022 [9]; M. Maris, 2022 [29]; N. Paziura, et al., 2023 [42]. These works collectively provide valuable insights into the main trends and problems of the agricultural sector and highlight the key factors for intensifying the development of agribusiness, which are necessary for making effective decisions in agricultural management.

The literature review also covers scientific works related to sustainable development, including research on food security and the sustainable development of the agricultural sector: L. Melnyk, 2016 [31]; L. Melnyk et al., 2016 [32]; M. Lahouirich et al., 2022 [26]; R. Bardy & A. Rubens, 2022 [4]; A. Plastun et al., 2021 [43]; B. Bouchafaa, et al., 2023 [8]; Y.-X. Tu, et al., 2023 [57]; M. Brychko et al., 2023 [10]. A number of authors, while studying the state's economic and national security

issues, highlight the challenges of preventing and neutralizing potential threats to food insecurity: V. Orlov et al., 2021 [41]; I. Rekunenko, et al., 2022 [48]; F. Feng et al., 2023 [15]; Y. Samusevych, et al., 2023 [49], etc.

When it comes to the issues of guaranteeing food security in the country and its effect on the level of agricultural insurance, the following scientific works are worth highlighting: O. Aiyedogbon, J. et al., 2022 [37]; D. Warshawsky, 2022 [61]; I. Koomson et al., 2022 [23]; E. Balistreri et al., 2022 [2]; V. Gobela et al., 2022 [17]; T. Tambovceva et al., 2020 [55]; J. Chavas et al., 2022 [12]; F. Baquedano et al., 2022 [3].

The literature review demonstrates that the development level of agricultural insurance has a direct impact on the state's level of food security.

AIMS AND OBJECTIVES

The goal of this paper is to create a scientific and methodological model that can assess how agricultural insurance influences the growth of the agrarian sector and food security in Ukraine, with the aim of facilitating informed managerial decisions.

The article's objectives are as follows:

- to investigate the current trends of the Ukrainian agrarian sector development;
- to study the history (stages) and contemporary development tendencies of agricultural risk insurance in Ukraine;
- to assess the impact of agricultural insurance on the level of food security in Ukraine.

METHODS

In order to set the priorities for the current development of agricultural risk insurance in Ukraine and to describe certain processes, we will analyze the way it has been formed and the existing problems. First of all, it should be noted that, along with agricultural enterprises and insurance companies, the state is an involved party, since in case of farmers' bankruptcy, the insurance indemnity will be sufficient to repay loans, restore solvency, etc. Otherwise, all social and economic risks resulting from unfavourable weather conditions will have to be fully covered by public funds. Therefore, the governments of all developed countries unequivocally support agricultural insurance in the form of reimbursement of more than half of insurance payments, thereby ensuring security, rural development and reducing urbanization.

As a result, it is suggested that four phases of agricultural insurance growth in Ukraine be identified, based on the types of government assistance.

The initial phase covers 2005-2008 when it was initially proposed to compensate farmers for the costs of insuring crops against adverse natural events, but the lack of specialists and imperfect insurance contracts led to a total refusal of Ukrainian insurance companies to pay off losses incurred by agricultural enterprises.

The active phase of the second stage began in 2012, when the Law of Ukraine "On Peculiarities of Insurance of Agricultural Products with State Support" was adopted (No. 4391-VI of February 09, 2012), and ended in 2017, when the Ministry of Agrarian Policy and Food of Ukraine resumed close cooperation with the IFC (International Finance Corporation) in order to find a new form of agricultural insurance. During the second stage of the agricultural insurance development, there were attempts within the framework of the IFC Project "Development of Agricultural Sector Funding in Europe and Central Asia" [20] to adapt the agricultural insurance models of such countries as the United States, Canada, Spain and others to the conditions of Ukraine. During this stage, the criteria for obtaining licenses to ensure agricultural risks were finally determined, a centralized system for training underwriters was formed, insurance rates were developed in accordance with international actuarial requirements, and insurance products were unified. The main feature of this stage was the creation of the Agricultural Insurance Pool as a basic institution that was supposed to create a single analytical space and formulate common rules of conduct in the agricultural market. However, due to political influence, the participants of the Agricultural Insurance Pool were not the leaders of the insurance market, but captive insurers. Therefore, the instrument of state support for farmers did not work, as the current reputation of the insurers participating in the Agrarian Insurance Pool did not meet the needs of farmers, so they were not sure of the financial soundness of insurers.

In the third stage of the Ukrainian agricultural insurance development (2017-2020), the Ministry of Agrarian Policy and Food of Ukraine, together with the IFC, tried implementing the American practice of the Risk Management Agency (RMA) in the Ukrainian context. The main idea was to create an agrarian risk management unit within the Ministry of Agrarian

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Policy and Food, which was supposed to regulate and control all relations in the agricultural insurance market. However, this initiative was not supported by market participants and the National Bank of Ukraine.

The fourth stage, in our opinion, began with the change of the regulator in the insurance market in 2020. Thus, the National Financial Services Commission was liquidated, and its functions were transferred to the NBU. Hence, the fourth stage began in 2020 and is still ongoing. Its main characteristics are the liquidation of the Agrarian Insurance Pool and the establishment of clear requirements for agricultural risk insurers as part of the transformation of the Law of Ukraine "On Peculiarities of Insurance of Agricultural Products with State Support" dated August 1, 2021 [40]. In addition, in the same period, the National Bank of Ukraine adopted Resolution No. 108 dated October 20, 2021 "On Approval of the Regulation on Conducting Agricultural Insurance Activities with State Support" [38], which details the requirements for insurers to be provided with state support. By establishing a new regulatory framework for insurers and farmers seeking government subsidies, the NBU and the Ministry of Agrarian Policy and Food of Ukraine aim to attract only seasoned insurance firms with skilled staff, dependable reinsurance coverage, excellent service, and a track record of handling insurance claims for this risk type.

The continued growth of agricultural insurance in Ukraine should concentrate on identifying the best methods for providing government assistance to farmers and enhancing the management of the whole agricultural insurance market. Based on this and the relevant literature review, further development of the methodological framework for forming an information basis for making effective management decisions on potential growth areas for public-private collaboration in the realm of agricultural risk insurance is of paramount importance. We believe that this can be achieved by creating a scientific and methodological framework for evaluating how agricultural insurance affects the growth of the agrarian sector and food security.

It should be noted that identifying the relationship between the above three components, and establishing its strength and adequacy allows to form a set of input information for making informed management decisions regarding the regulatory system of both insurance market participants and relevant state regulatory institutions.

Therefore, based on the above, it is expedient to study the relationship between the following three components: the first component characterizes the insurance process itself, the second describes the level of economic activity in the agrarian sector, and the third component illustrates food security.

An adequate description of each of the three components of the study is an important element in obtaining reliable results for econometric modelling. Thus, the selection of a large number of indicators for calculations can lead to overloading the model and results in distortion, with a high probability that certain indicators will necessarily duplicate the development trends of others (leading to multicollinearity). In turn, a limited number of indicators will not provide adequate results, as they will not form the basis for identifying clear patterns.

Hence, the following indicators which characterize agricultural risk insurance were selected:

- insurance premiums (AI1) as a characteristic of the size of the studied type of insurance;
- insurance payments (AI2) as an indicator of the amount of covered losses from the risk's occurrence;
- payout level (AI3) as a characteristic of the attractiveness of this type of insurance for both insurers and the insured. The insurer analyzes its own profitability for a particular type of insurance based on the level of payments, and the insured determines the potential probability of reimbursement of its own losses in the event of an insured event.

The three most relevant indicators were selected to characterize the agricultural sector, namely:

- capital investments in the agrarian sector (DAS1), as an indicator of the priority of the sector's development, since significant investments will lead to the intensification of agricultural development;
- share of the agrarian sector in GDP (DAS2), as a characterization of the role and importance of this sector for the economy of the state;
- exports of agricultural products (DAS3), as an indicator of the importance of agricultural products for the foreign economic activity of the state.

It is proposed to determine food security using the integral index (FS1). This integral index includes four components: 1) economic accessibility (the financial ability of the population to buy food); 2) physical accessibility (availability of developed agricultural infrastructure and absence of barriers to food access); 3) quality and safety (variety, standardization and safety of food); 4) natural resources and sustainability (the ability of the state to withstand the risks of natural shocks).

The econometric tools proposed to be chosen to solve this problem are structural modelling. This method allows to confirm or refute the hypothesis regarding the nature and intensity of the connection between three or more parameters expressed through certain factor variables. The process of modelling with the help of structural equations is as follows: 1) visualization of structural and functional relationships between indicators of development of agricultural insurance, the agricultural sector as a whole and food security by means of a path diagram; 2) development of structural equations of causal relationships between indicators of development of agricultural insurance, the agricultural sector and food security based on the identification of multifactorial regression dependencies between exogenous and endogenous variables of the model; 3) verification of the model adequacy.

Considering the path diagram (Figure 1), the authors note that it is founded on the fundamental premise of the research, namely that the agricultural insurance development (AI) directly affects the development of the agricultural sector (DAS), and the latter directly affects the level of food security (FS). To test the validity of the hypothesis, empirical calculations were carried out.

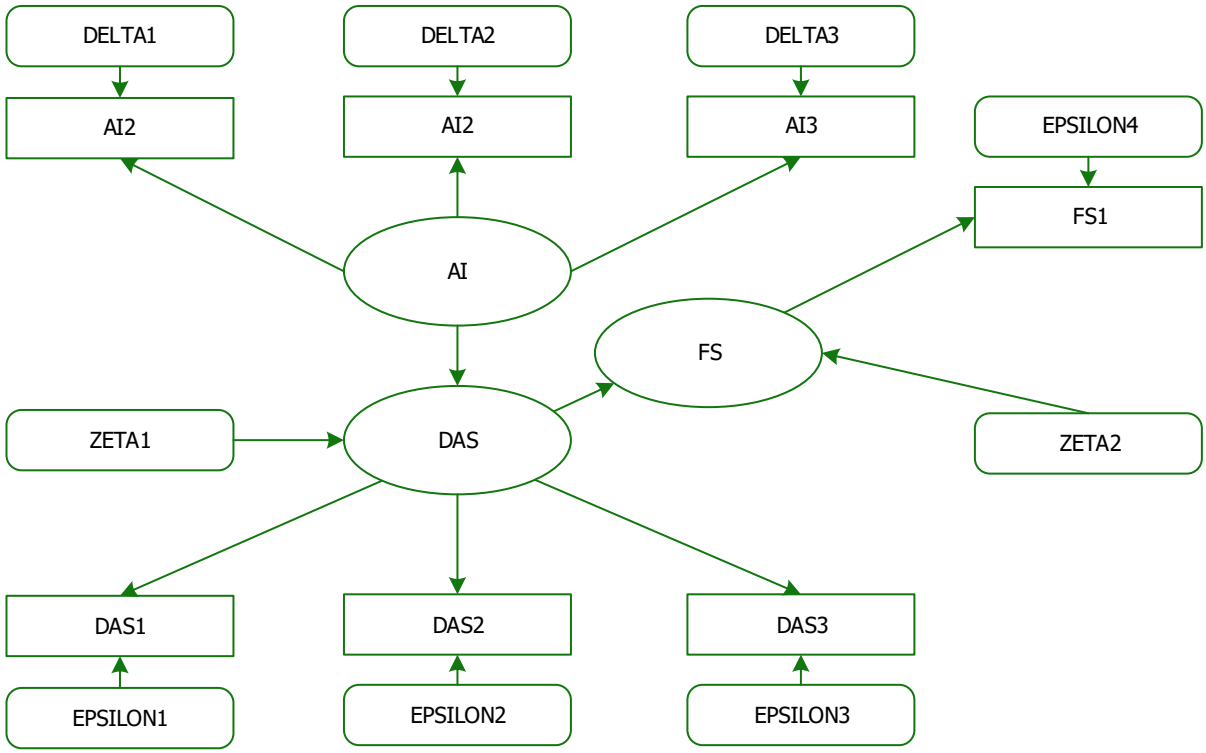

Figure 1. General scheme (path diagram) of the process of causal modelling of the interrelationships between agricultural insurance, the agrarian sector and food security. Notes: DELTA, EPSILON, ZETA - free coefficients of regression equations.

According to the data in Figure 1, a multivariate regression analysis is carried out by building structural equations in the context of agricultural insurance, the agricultural sector and food security, as well as statistical analysis of these elements as an integrated system. Thus, the relationship between the latent variable (the level of development of agricultural insurance) and such endogenous variables as the amount of insurance payments, insurance payments and the level of payments is established. Similar patterns are determined between the exogenous variable (level of development of the agrarian sector) and explicit factors: capital investment in the agrarian sector, the share of the agrarian sector in GDP, and the level of agrarian exports.

Next, it is necessary to determine the strength and direction of the relationship between three exogenous parameters: the level of development of agricultural insurance, the level of development of the agricultural sector, and food security.

In general, the resulting structural model will have the following form (formula 1):

$$\begin{cases} y_1 = b_{12}y_2 + b_{13}y_3 + \cdots + b_{1m}y_m + a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n + \varepsilon_1 \\ y_2 = b_{21}y_1 + b_{23}y_3 + \cdots + b_{2m}y_m + a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n + \varepsilon_2 \\ y_3 = b_{31}y_1 + b_{32}y_2 + \cdots + b_{3m}y_m + a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n + \varepsilon_2 \\ \cdots\ \cdots\ \cdots \\ y_m = b_{m1}y_1 + b_{m2}y_2 + \cdots + b_{m_1m-1}y_{m-1} + a_{m1}x_1 + a_{m2}x_2 + \cdots + a_{mn}x_n + \varepsilon_n \end{cases} \quad (1)$$

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On the right-hand side of Formula 1, the endogenous variables (ym) are denoted by the coefficients bij, and the exogenous variables (xm) by the coefficients aij, which are referred to as the model's structural coefficients. In turn, · – is a free coefficient, i.e., the model residuals.

A comprehensive test of the model's adequacy using numerous criteria allows not only to confirm or refute the appropriateness of the selected tools but also to establish the reliability of each of the conclusions drawn.

Analyzing the direction and strength of the influence of the studied components, it should be noted that, given the influence of the level of growth of agricultural risk insurance on the level of development of the agricultural sector, the main instruments of state support should be aimed at creating the most favourable environment for insurers covering agricultural risks. It is the active work of insurance companies that will minimize losses of agricultural producers and encourage them to improve the quality of their own activities, which is necessarily checked in the underwriting process. The strong interconnectedness of the market will necessitate the formation of a wide pool of insurers, a separate administrator operating on a public-private basis, and mandatory reinsurance of the agricultural pool's risks with global companies, with the subsequent involvement of the newly created state reinsurance company. Provided that the market functions efficiently with moderate prudential state control, this model will make it possible to maximize the existing pattern of development of agricultural risk insurance and the agricultural sector in the country.

If the relationship between the level of development of agricultural risk insurance and the agricultural sector is weak, this will be an argument in favour of using a model of targeted support for insurance companies engaged in agricultural risk insurance. If the level of development of agricultural risk insurance has a weak impact on the development of the agricultural sector, there will be no need to distribute public resources to support insurance companies, as the effect will be insignificant.

In the case of the opposite situation, if the calculations prove an average impact of the development of the agricultural sector on the dynamics of agricultural risk insurance, the main focus of state support should be on the activities of agricultural producers, and insurers will have to develop with the help of market incentives. That is, institutional conditions for insurance companies should be created, and the financial impetus for their development will come from agricultural producers, as they will need high-quality insurance coverage for further development.

Given the strong influence of the level of development of the agricultural sector on the level of development of agricultural risk insurance, the state should make maximum use of all instruments to support agricultural producers, including tax incentives, short-term state development programs, customs preferences, and further reform of the agricultural land market.

The low density of interconnections will prove the need for long-term agricultural development programs and long-term investments aimed at obtaining a significant effect over time.

Regarding food security, it would be fair to state that the impact of the agricultural sector on the sustainable development of Ukraine in general and food security, in particular, is undeniable, while formalizing the level of this impact is still an unresolved scientific task.

RESULTS

Turning to the practical implementation of the proposed approach, the authors present a rapid analysis of the research information base (Table 1). The period of analysis is 2015-2021. The limitation of the research period to 2021 is due to the fact that this statistical information was the latest available in official sources at the time of the dissertation completion. The source of the study was the official information of the State Committee for Statistics and Reports of the National Commission for State Regulation of Financial Services Markets and the National Bank of Ukraine.

Table 1 shows that during 2015-2018, agricultural risk insurance in Ukraine was characterized by a steady upward trend, but since 2019, this type of insurance has significantly decreased. Thus, even despite a certain revival in agricultural risk insurance in 2021, the amount of insurance payments for this type of insurance did not exceed the value in 2016. The volume dynamics of insurance payments and the level of payments can be analyzed simultaneously since the trends of these parameters are very similar. The year 2020 was abnormal in terms of the volume and level of insurance payments in the context of agricultural insurance, when significant amounts of agricultural land were damaged by floods and resulting in a payout rate of 201%. The years 2019 and 2021 were also significant in terms of payouts, with the level of agricultural risk insurance payouts exceeding 45%. For other periods of the study, the level of payments in terms of agricultural risk insurance did not exceed 40%.

Table 1. Indicators characterizing the level of development of agricultural risk insurance, the agrarian sector and food security. *(Source: compiled by the authors based on [16, 34, 35, 53])*

Year	Amount of insurance payments, UAH thousand	Amount of insurance payments, UAH thousand	Payout rate, %	Capital investments in the agricultural sector, UAH million	GDP generated by the agricultural sector, UAH million	Exports of agricultural products, USD thousand	Food security index, units
2015	142834	11932	8	30155	239806	14563145	52
2016	230032	16932	7	50484	279701	15281803	58
2017	259079	93589	36	64243	303419	17756854	53
2018	258512	39577	15	66104	360998	18611811	56
2019	226289	107611	48	59130	356563	22144180	60
2020	175154	351836	201	50680	393077	22179353	63
2021	205930	117646	57	59011	580519	27708932	62

Analyzing the indicators of the agricultural sector, the authors note that the downward trend of capital investment in the sector in 2019 and 2020 was due to the pandemic period when the economic activity of all business entities decreased. In all other years of the study, capital investment in the industry under consideration had a steady upward trend. The importance of the agricultural sector for Ukraine's economy is confirmed by its ever-growing contribution to the country's GDP. Over the past seven years, this figure has increased by 142%, maintaining a steady upward trend every year despite the crisis in the Ukrainian economy. In addition to the previous indicators, the key role of the agricultural sector in Ukraine is demonstrated by the export volume. Thus, having increased by 1.9 times, exports of agricultural products have a positive impact on the processes of economic stability by equilibrating the balance of payments, increasing budget revenues, replenishing foreign exchange earnings, etc.

Changes in Ukraine's agricultural sector have also led to positive changes in the country's food security over the past three years. Starting in 2019, Ukraine was included in the group of countries with a "good" level of the global integrated food security indicator, as its level reached 60 points.

Using this data set, we will conduct a structural modelling analysis to determine the relationship between the indicators of agricultural insurance, the agricultural sector, and food security. To achieve this objective, we will employ the capabilities of the Statistica 12 software suite, specifically Statistics, Advanced Linear/Nonlinear Models, and Structural Equation Modeling. We will generate a structural equation model, the parameters of which are depicted in Table 2.

Table 2. Model parameters related to the relationship between the development level of agricultural risk insurance, the agricultural sector and food security. Note: * the highlighted values are statistically significant with a probability of 95%. *(Source: [51])*

Indicators	Parameter Estimate	Standard Error	T Statistic	Prob. Level
(AI)-1->[AI1]	-74.683	145.841	-0.512	0.609
(AI)-2->[AI2]	545.219	383.864	1.420	0.156
(AI)-3->[AI3]	**0.910**	**0.286**	**3.185**	**0.001**
(DELTA1) -->[AI1]				
(DELTA2) -->[AI2]				
(DELTA3) -->[AI3]				
(DELTA1)-4-(DELTA1)	**188132.405**	**74780.167**	**2.516**	**0.012**
(DELTA2)-5-(DELTA2)	**1149011.508**	**509540.114**	**2.255**	**0.024**
(DELTA3)-6-(DELTA3)	0.502	0.000		
(DAS)-->[DAS1]				
(DAS)-7->[DAS2]	-0.083	0.118	-0.704	0.482
(DAS)-8-> [DAS3]	0.443	0.000		
(FS)-->[FS]				
(EPSILON1) -->[DAS1]				
(EPSILON2) -->[DAS2]				
(EPSILON3) -->[DAS3]				
(EPSILON4) -->[FS]				
(EPSILON1)-9-(EPSILON1)	**15843.151**	**6214.211**	**2.550**	**0.011**

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Table 2. Continued

Indicators	Parameter Estimate	Standard Error	T Statistic	Prob. Level
(EPSILON2)-10-(EPSILON2)	0.000	0.003	0.110	0.912
(EPSILON3)-11-(EPSILON3)	**0.497**	**0.214**	**2.323**	**0.020**
(EPSILON4)-12-(EPSILON4)	0.500	0.000		
(ZETA1) -->(DAS)				
(ZETA2) -->(FS)				
(ZETA1)-13-(ZETA1)	0.263	0.472	0.557	0.578
(ZETA2)-14-(ZETA2)	0.498	0.403	1.236	0.217
(AI)-15->(DAS)	0.308	0.472	0.652	0.514
(DAS)-16->(FS)	0.446	0.604	0.738	0.461

The data grouped in Table 2 allow us to build a model of structural equations of the relationship between agricultural risk insurance, the agricultural sector, and food security (formula 2):

$$\begin{cases} AI1 = -74.68 * AI + 188132.41 \\ AI2 = 545.22 * AI + 1149011.51 \\ AI3 = 0.910 * AI + 0.502 \\ DAS1 = DAS + 15843.15 \\ DAS2 = -0.083 * DAS \\ DAS3 = 0.443 * DAS + 0.497 \\ FS1 = FA + 0.500 \\ DAS = 0.308 * AI + 0.263 \\ FS = 0.446 * DAS + 0.498 \end{cases} \quad (2)$$

where AI is a latent variable characterizing the level of agricultural insurance development; DAS is a latent variable characterizing the level of the agricultural sector development; FS is a latent variable characterizing the level of food security.

Based on the resulting equation system, it can be accurately stated that a 100% rise in the level of agricultural risk insurance development results in a 30.8% increase in agrarian sector growth indicators. Similarly, a 100% rise in the level of agrarian sector development leads to a 45.6% increase in food security. At the same time, if the level of agricultural insurance development were to rise by 100%, food security would increase by 13.7%. Thus, our hypothesis about the direct impact of agricultural insurance on the agricultural sector development and, consequently, on the food security of Ukraine is fully confirmed.

It is necessary to further confirm the results obtained by assessing the adequacy of the model. Based on Table 3, where the basic summary statistics are grouped, it is fair to say that such indicators as p-level (actual value is less than 0.05 units), Chi-square (actual value is greater than 1) and standard deviation (actual value is insignificant) are fully consistent with the normative values. Thus, the calculations are reliable.

Table 3. Excerpt of Statistica 12 program on model adequacy testing: basic aggregate statistics (excerpt of calculations using Statistica 12 based on correlation). *(Source: [51])*

Parameters	Basic Summary Statistics
	Value
Discrepancy Function	27632.100
Maximum Residual Cosine	0.442
Maximum Absolute Gradient	209052.677
ICSF Criterion	-27616.240
ICS Criterion	8794.760
ML Chi-Square	359217.302
Degrees of Freedom	14.000
p-level	0.000
RMS Standardized Residual	187.425

In addition to the above criteria, let us also consider such indicators of model adequacy as the indices of non-centrality, which are shown in Table 4. The zero level of the MacDonald Index and the Gamma Index suggests that the model built is highly adequate for the second stage of the test.

Table 4. Excerpt of the Statistica 12 program for checking the model's adequacy: non-centrality indices (excerpt of calculations using the Statistica 12 program based on correlation). Notes: Lower 90% Conf. Bond ¬– lower 90% confidence interval, Point Estimate – point estimate, Upper 90% Conf. Bond – upper 90% confidence interval.

Parameters	Noncentrality Fit Indices		
	Lower 90 % Conf. Bound	Point Estimate	Upper 90 % Conf. Bound
Population Noncentrality Parameter	197583024.867	197595850.100	197608675.891
Steiger-Lind RMSEA Index	3756.737	3756.859	3756.981
McDonald Noncentrality Index	0.000	0.000	0.000
Population Gamma Index	0.000	0.000	0.000
Adjusted Population Gamma Index	-1.000	-1.000	-1.000

For the purpose of final confirmation of the reliability of the results obtained, we will conduct an additional adequacy analysis using the Joresky and Chi-square indicators shown in Table 5. Thus, the actual value of the first indicator tends to zero, and the second tends to one, i.e., these indicators also confirm the high level of adequacy for the developed structural equation model.

Table 5. Excerpt of the Statistica 12 program for checking the model's adequacy: additional indices of model fit. *(Source: excerpt of calculations using the Statistica 12 program based on correlation)*

Parameters	Single Sample Fit Indices
	Value
Joreskog GFI	0.000
Joreskog AGFI	-1.000
Akaike Information Criterion	27634.254
Schwarz's Bayesian Criterion	27634.942
Browne-Cudeck Cross Validation Index	27637.700
Independence Model Chi-Square	577.954
Independence Model df	21.000
Bentler-Bonett Normed Fit Index	-620.533
Bentler-Bonett Non-Normed Fit Index	-963.819
Bentler Comparative Fit Index	-643.943
James-Mulaik-Brett Parsimonious Fit Index	-413.689
Bollen's Rho	-931.300
Bollen's Delta	-634.812

Thus, it is fair to conclude that the influence of agricultural insurance development on the agricultural sector and food security in Ukraine has been confirmed, and the mechanism of state support for agricultural insurance should take into account the obtained results.

Considering the historical analysis of state support for agricultural insurance, proven in the modelling process the direct impact of agricultural insurance development level on agricultural sector development in Ukraine, as well as the fact that the growth rate of the national agricultural sector is much higher than the one of agricultural insurance, it is fair to state the following.

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DISCUSSION

The agricultural insurance development in Ukraine should be implemented on a public-private basis. The main subject of the state support mechanism for agricultural insurance should be a public-private administrator, which will unite representatives of the vast majority of insurance companies (possibly representatives of the largest self-regulatory organizations of insurers in Ukraine) and representatives of the Ministry of Agrarian Policy and Food of Ukraine and the National Bank of Ukraine. The newly created administrator should be empowered to formulate a strategy for the development of the agricultural insurance market, develop and approve standard insurance contracts, formulate unified approaches to assessing the cost of agricultural insurance and compensation for losses, conduct systematic training and professional development of emergency commissioners, conduct ongoing work among farmers on the need for insurance coverage of their activities, and exercise public control over the use of public funds [40; 38; 54].

The implementation of state support for agricultural insurance through the Agricultural Insurance Pool failed not because of the imperfection of the mechanism itself, but because of the significant political influence on this process and the inability of the National Commission for State Regulation of Financial Services and the Ministry of Agrarian Policy and Food to pursue a tough policy to attract the most efficient insurance companies at that time. In contemporary conditions, both the NBU and representatives of the Ministry have a significantly greater influence on the development of the insurance market, and insurers themselves want to work under common market rules, so the creation of a single public-private administrator will be much more successful [50; 60].

The existing individual approach to determining the insurer that can apply for state support in the process of agricultural insurance is not effective. Strict requirements for insurance companies applying for state subsidies only postpone the intensification of this process. These strict requirements are indeed important to ensure solvency guarantees, but at the present level of development of the Ukrainian insurance market, they are not realistic for most participants to fulfil.

Thus, the state will once again be forced to face significant social risks in case of bankruptcy of uninsured agricultural companies and spend significant financial resources to eliminate the consequences of adverse natural situations. These resources could be directed to the development of insurance companies willing to engage in agricultural insurance but currently lacking sufficient experience and reserves. If these companies are merged, a synergistic effect can be achieved, which will be manifested in a single management information system, collection and processing of metadata, training of agricultural risk insurance specialists, improvement of insurance literacy of agricultural producers, legislative initiatives, etc.

An essential part of the current system of subsidizing agricultural insurance is the creation of a state reinsurance company. Along with global reinsurers, a domestic state reinsurance company could absorb a significant share of risks, and the generated reserves would be invested in the recovery of Ukraine's economy, thus remaining within the country. At the same time, a state reinsurance company would act as an additional tool to control the solvency of insurance companies and could accumulate those risks that cannot be transferred to highly rated global insurers.

In the authors` opinion, only the involvement of the majority of Ukrainian insurance market participants in the process of agricultural insurance will allow to follow the trend of agricultural sector development, while minimizing the risks of agricultural companies and ensuring a high level of food security in Ukraine [15; 43; 55; 56; 63].

CONCLUSIONS

The direction and strength of the relationships between the development levels of the agrarian sector, agricultural insurance and food security of Ukraine were assessed by building a system of single-factor and multifactor regression equations using causal modelling. The results indicate that a 100% rise in the level of agricultural risk insurance development results in a 30.8% increase in agrarian sector growth indicators, and a 100% increase in the level of agrarian sector development leads to a 45.6% rise in food security. In this regard, a set of measures has been developed to enhance the system of assistance for local agricultural producers, and the necessity of forming a wide pool of insurers, a separate administrator operating on a public-private basis, and mandatory reinsurance of the risks of the agricultural pool with further involvement of the newly created State reinsurance company has been substantiated.

At the same time, the article confirms the influence of the development level of agricultural insurance upon the agrarian sector development and the level of food security in Ukraine, and therefore the mechanism of state support for agricultural insurance should consider the results obtained, and the development of agricultural insurance in Ukraine ought to be implemented on a public-private basis.

ADDITIONAL INFORMATION

AUTHOR CONTRIBUTIONS

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Formal Analysis: *Anton Marci*
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МОДЕЛЮВАННЯ СТРУКТУРНИХ ЗАВ'ЯЗКІВ МІЖ ДИНАМІКОЮ РОЗВИТКУ АГРОСТРАХУВАННЯ, АГРАРНОГО СЕКТОРА ТА РІВНЕМ ПРОДОВОЛЬЧОЇ БЕЗПЕКИ УКРАЇНИ

Метою дослідження є розробка науково-методичного підходу (моделі) щодо визначення впливу агрострахування на розвиток аграрної галузі та рівень продовольчої безпеки України для ухвалення відповідних управлінських рішень у сфері сільського господарства.

Методичним інструментарієм статті є структурне моделювання. Процес моделювання було здійснено за допомогою структурних рівнянь. Для реалізації поставленого завдання було використано інструментарій програмного комплексу Statistica 12 (Statistics, Advanced linear/nonlinear Models, Structural Equation Modeling).

У результаті проведеного дослідження встановлено, що зростання рівня розвитку страхування аграрних ризиків на 100% призводить до зростання індикаторів розвитку аграрної галузі на 30,8%. У свою чергу, збільшення на 100% рівня розвитку аграрної галузі спричиняє зростання рівня продовольчої безпеки на 45,6%. Однак, якщо рівень розвитку аграрного страхування збільшити на 100%, то продовольча безпека зросте на 13,7%. Таким чином, висунута гіпотеза про прямий вплив аграрного страхування на розвиток аграрної галузі й через це – на продовольчу безпеку України повністю підтверджена. Авторами статті запропоновано здійснювати оцінювання напряму та сили

взаємозв'язку між рівнями розвитку агрострахування, аграрної галузі та продовольчої безпеки шляхом побудови системи однофакторних та багатофакторних регресійних рівнянь за допомогою структурного моделювання. Вплив рівня розвитку аграрного страхування на розвиток аграрної галузі та рівень продовольчої безпеки в Україні підтверджений, і механізм державної підтримки страхування сільськогосподарської продукції повинен ураховувати отримані результати. При цьому розвиток агрострахування в Україні повинен реалізовуватися на державно-приватних засадах.

Ключові слова: агрострахування, аграрний сектор, продовольча безпека, аграрний менеджмент, аграрне виробництво, моделювання, розвиток, показники, Україна

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