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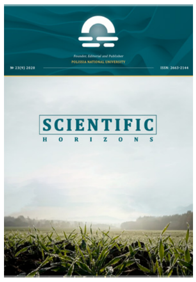

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Identification and interpretation of internal factors influencing the agricultural insurance market in Ukraine

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Abstract. The functioning of the agricultural insurance market in Ukraine is an objective reality and a necessity due to the urgent need to create a safe environment for agricultural production. The ability to consolidate financial resources in the field of insurance contributes to increased responsibility for probable risks distributed in space and time, so it is worth considering insurance relations in the agricultural sector. The purpose of the study is to theoretically and methodologically justify the processes of identifying internal factors influencing the further functioning of the agricultural insurance market in Ukraine. The methodological perspective of this study is based on

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the use of general scientific and specific methods of cognitive activity: abstract-logical, economic-statistical, structural-functional, deduction, induction, and formalisation. A panel database was formed for the period 2012-2021 broken down by the regions of Ukraine. The territorial features of changes in the ratio between insured and sown areas in the western, central, eastern, and southern regions of Ukraine are reflected. Based on the results of the conducted modelling (two models are presented simultaneously: a regular model and a one-year lag model), the influence on the insured area of such factors as sown area, yield, gross harvest, and internal price for agricultural products is established. A comparative characteristic of the statistical qualities of the presented models was made using indicators such as "Residual standard error", "Multiple R-squared", and "Adjusted R-squared". The results of the regression analysis showed the statistical significance of certain factors in motivating agricultural commodity producers to participate in the insurance process. The practical value of the proposed measures lies in formulating practical recommendations for enhancing cooperation among stakeholders in the agricultural insurance market during wartime and post-war periods

Keywords: agricultural insurance; insured area; insurance market stakeholders; agricultural risks

INTRODUCTION

The key priorities of the present and the future are to achieve sustainable capacity to meet the social, economic, and environmental needs of humanity in the face of inevitable challenges of modern civilisation. The formulated statement largely applies to the process of agricultural production. This is because, according to the UN forecasted data, the world population will reach 9.8 billion by 2050 and 11.2 billion by 2100. This indicates the objective need for a global increase in agricultural production to meet the current and potential demand for food products.

A systemic solution to the outlined problem requires the consistent use of effective financial and economic instruments capable of efficiently and, most importantly, timely counteracting various natural and anthropogenic risks. The long-standing experience of countries worldwide (such as the United States, Canada, China, European Union countries, Africa, and Latin America) demonstrates that addressing the challenges of modern civilisation requires the use of diverse forms and methods of insuring agricultural commodity producers. The values of insurance are primarily directed at creating an effective mechanism for accumulating and using financial resources distributed in space and time upon the occurrence of insurance events.

A critical review of studies demonstrates a significant interest of researchers in the functioning of insurance relations in the agricultural sector. O. Slobodianiuk *et al.* (2018) consider agricultural insurance as a primary mechanism for managing agricultural risks and protecting income from crop loss, repaying loans taken for agricultural business development, and ensuring food security. The insurance of agricultural products is interpreted as one of the essential risk management strategies related to food worldwide (Ker & Tolhurst, 2019). According to A. Möhring *et al.* (2020), insurance is capable of successfully reducing various shocks to agriculture caused by unforeseen events, including market fluctuations, natural disasters, and other disturbances. H. Wong *et al.* (2020) and M. King & A. Singh (2020) argue that compared to 'ex post' compensation, 'ex ante' insurance is a much more effective risk management tool.

Arguments in favour of the widespread use of the agricultural production insurance system can be outlined in the following sequence: climate change increases the likelihood of extreme weather events for agricultural commodity producers (Vroege & Finger, 2020), such as droughts, floods, strong winds, and more (Malhi *et al.*, 2021). In addition, it is worth highlighting the risks associated with price instability and the negative impact of new technologies on the activities of agricultural commodity producers, resulting in high costs for their acquisition and implementation in the production process, increased training expenses, and dependence on advanced technologies (Boyd & Bellemare, 2020; Mironkina *et al.,* 2020).

In the conditions of a state of war, Ukraine recognises its global mission to provide various countries with agricultural products. This fact significantly strengthens the argument for the use of security instruments in agricultural production, including insurance. The relevance of this study is based on the necessity of interpreting and identifying internal factors influencing the agricultural insurance market in Ukraine and justifying its further development in line with the needs for insuring agricultural risks.

The purpose of this paper is the theoretical and methodological substantiation of the processes of identifying internal factors influencing the further functioning of the agricultural insurance market in Ukraine. The hypothesis of this study assumes the existence of interconnections between sown areas, yields, gross harvest, and the internal price in the agricultural sector, and the influence of these factors on decision-making in the field of insuring agricultural risks.

MATERIALS AND METHODS

For the theoretical substantiation of the role and importance of agricultural production insurance in a risk-prone environment, the abstract-logical method was used. The application of inductive and deductive methods allowed the identification of key legal, institutional, financial-economic regularities in the development of relationships between stakeholders in agricultural insurance. The economic-statistical method was used to reflect trends in the coverage of insurance for sown areas in the regions of Ukraine. The structural-functional method was used to justify the financial and economic guidelines for the development of agricultural insurance in post-war Ukraine. The formalisation method provided the opportunity for theoretical generalisations, formulation of proposals, and conclusions.

Modelling of the functioning of parameters of the agricultural product insurance market was performed using a panel database for the period 2012-2021, considering 24 regions of Ukraine. Given the level of filling official sources with statistical data, it should be noted that the data used exhaust all possible terms. Data on the insured area, harvested area, gross harvest, and yield broken down by regions and crops are only available for 2021.

The predictor was determined to be the insured area (Y), and the factors selected included the sown area, gross harvest, yield, and the price of crops such as cereals (S_cer_E, V_cer_E, Y_cer_E), wheat (S_wheat_E, V_wheat_E, Y_wheat_E, Price_wheat), corn for grain (S_corn_grain_E, V_corn_grain_E, Y_corn_grain_E, Price_corn_grain), corn for silage (S_corn_fod_E, V_corn_fod_E, Y_corn_fod_E), barley (S_barley_E, V_barley_E, Y_barley_E, Price_barley), rye (S_ ryeW_E, V_ryeW_E, Y_ryeW_E, Price_rye), oats (S_oat_E, V_ oat_E, Y_oat_E, Price_ oat), buckwheat (S_buck_E, V_buck_E, Y_buck_E, Price_ oat), soybeans (S_soya_E, V_soya_E, Y_ soya_E, Price_ soya), rapeseed (S_rap_E, V_rap_E, Y_rap_E, Price_ rap), and sunflower (S_sunfl_E, V_sunfl_E, Y_sunfl_E, Price_sunfl). As a result, a panel database was obtained with a depth of 240 (24 regions for 10 years), a width of 48 indicators, and a total database capacity of 11,520 unique numerical values. It should be noted that all prices were presented in real 2012 prices, which eliminates the influence of inflationary processes in the country's economy.

Given the substantial volume of the database, this study used the econometric method of stepwise regression for factor selection. In this study, stepwise regression was used to reduce the number of variables and improve model quality by selecting the most statistically significant variables. The described algorithm allows for systematic factor selection and determining their influence on the dependent variable within multiple linear regression (Gooch, 2011). After obtaining statistically significant factors (predictors) through stepwise regression, the next step in building the econometric model used an econometric approach – panel data analysis to construct a regression model based on the entities of a single population (24 regions) over consecutive time periods (2012-2021). Based on the Hausman test (Wooldridge, 2010) in the analysis of panel data, the fixed effects regression method was chosen. This method allows investigating relationships between variables for each group, considering fixed effects (Cameron & Trivedi, 2013).

The information basis of the study included the regulations of Ukraine (Law of Ukraine No. 4391-VI, 2012; Resolution of the Cabinet of Ministers of Ukraine No. 1342, 2021), analytical data from the Ministry of Agricultural Policy and Food of Ukraine in cooperation with the Project "Development of Agricultural Sector Financing in Europe and Central Asia", implemented with the support of the World Bank and the International Finance Corporation (IFC) (Agricultural insurance market of Ukraine, 2018), official reporting materials from the State Statistics Service of Ukraine (State Statistics Service of Ukraine, 2012-2021), reports from the International Federation of Cooperative and Mutual Insurance (European Market Share, 2022), analytical data from insurance companies in Ukraine providing services in agricultural insurance ("ARX", 2022; "KRAYINA", 2022; "ORANTA", 2022; "PZU Group", 2022; "UNIVERSALNA", 2022), and studies of foreign and Ukrainian researchers on the studied subject and their findings.

RESULTS

Considering the multifaceted relationships among stakeholders in agricultural insurance, aligning their insurance interests is essential to boost business and investment activities in the agricultural insurance market. These interests, from the perspective of agricultural producers, manifest in enhanced and diversified insurance protection, including coverage for various types of risks and different insurance service options. For insurance companies, a priority task is to expand coverage for agricultural risks, which ensures the formation of the necessary resource base to meet their financial obligations under existing agricultural insurance contracts.

Globally, the level of agricultural insurance development is often assessed by the ratio of insured to sown areas. For instance, in the United States, this ratio stands at 88.0%, in Canada at 72.2%, in China at 45.5%, and in Greece at 100% (World Bank Group, 2023). High levels of insurance coverage for agricultural risks have led to a nearly fourfold increase in the accumulation of global insurance payments from 8.7 billion USD to 31.9 billion USD between 2009 and 2019 (World Bank Group, 2023). Achieving this level of capitalisation in insurance payments became possible through various models of agricultural insurance, including liberal, public-private partnerships, mandatory insurance, and the rational combination of traditional and index-based insurance products.

In Ukraine, the ratio of insured to sown areas over the past two decades has remained below 5%. The variation of this parameter across regions during the study period (2012-2021) is rather heterogeneous. The study period was chosen before the start of the COVID-19 pandemic and the full-scale military invasion of the Russian Federation on the territory of Ukraine. It is worth noting that during the period from 2012 to 2019, annual data from the Ministry of Agrarian Policy and Food of Ukraine in collaboration with the "Development of Agricultural Sector Financing in Europe and Central Asia" project served as the source of information regarding the development of agricultural insurance in Ukraine. In 2019, the project was suspended.

To conduct further research in this segment of the insurance market, analytical data directly from Ukrainian insurance companies were used. These companies, including "ARX", "KRAYINA", "ORANTA", "PZU Group", and "UNIVERSALNA", positioned their services in the agricultural insurance market. The combined market share of these insurance companies in terms of insured areas exceeded 95%. The analysis of the state of insurance coverage for agricultural risks was performed based on geographic characteristics. In western regions, particularly Lviv, Ternopil, Rivne, and Khmelnytskyi, the level of insured areas ranged from 0.25% to 12.50%. The presented indicators are the highest among all regions of Ukraine. This can be explained primarily by the relatively high adaptability of agricultural commodity producers in western regions to European traditions in risk management and mitigation (State Statistics Service of Ukraine, 2021).

Among the northern and central regions of Ukraine, Vinnytsia, Zhytomyr, Dnipropetrovsk, Kyiv, Poltava, Sumy, and Chernihiv stood out, where the parameter under study ranged from 1.99% to 6.75% (State Statistics Service of Ukraine, 2021). These regions concentrate significant proportions of sown areas (in terms of the total area of Ukraine), which somewhat complicates the mechanism of interaction among stakeholders in the insurance process. This highlights the need for the development of a modern, well-branched infrastructure (i.e., clear coordination of actions among key stakeholders, insurance intermediaries, state and non-state institutions, etc.) for the agricultural insurance market and the improvement of communication between interested stakeholders.

The lowest level of insured areas during the study period was observed in the eastern and southern regions of Ukraine, in particular: Donetsk, Luhansk, Odesa, Mykolaiv, Kharkiv, and Kherson regions. The ratio of insured persons to acreage was in the range of 0.14% to 4.17%. This low level of insurance coverage for agricultural risks can be attributed to several reasons (State Statistics Service of Ukraine, 2021). First, many vegetable and pumpkin crops, which are widely grown in southern regions of Ukraine, exhibit high resistance to risks. This necessitates the development of innovative insurance products (e.g., index-based insurance) capable of aligning the financial and economic interests of stakeholders in the insurance process to the maximum extent. Second, the military aggression by the Russian Federation against Ukraine, starting in 2014, had quite negative consequences for the development of agricultural insurance. Therefore, the analysis of the level of insured agricultural areas in a territorial context for the years 2012-2021 attests to the untapped potential for the development of agricultural insurance in Ukraine compared to developed countries worldwide. Instead, it should be noted that over the study period, there was positive growth in cultivated areas, increased crop yields, and gross harvests. These changes are characteristic of grain crops, such as wheat, corn, rapeseed, and sunflower.

B. Iganiga & D. Unemhilin (2011) used an approach in which all factors in the model were lagged by one year. This means that, for example, the price of a particular agricultural crop in the previous year affects the decision of agricultural producers to insure their crops in the current year. To obtain scientifically significant results in the study, two models are presented: a standard model (Fig. 1) and a one-year lag model (Fig. 2). In the standard model, only the current values of the factors are considered, without considering their past values. In addition to examining long-term effects and identifying a more complete dependence between the factors, a one-year lag model is also used.

```
Call:
lm(formula = Y ~ V_cer_E + V_sunfl_E + V_soya_E + S_soya_E +
    S_rap_E + S_oat_E + Y_buck_E + Price_soya + Price_barley +
    S_barley_E + Price_wheat + Y_soya_E, data = DataBase)

Residuals:
    Min      1Q  Median      3Q     Max
-44.265 -13.420  -1.177  10.284  74.892

Coefficients:
               Estimate Std. Error t value Pr(>|t|)
(Intercept)   2.310e+01  8.039e+00   2.873  0.00449 **
V_cer_E      -5.568e-06  2.694e-04  -0.021  0.98353
V_sunfl_E     5.267e-03  8.598e-04   6.125 4.52e-09 ***
V_soya_E      8.633e-03  1.523e-03   5.670 4.79e-08 ***
S_soya_E      1.240e-02  2.775e-03   4.468 1.30e-05 ***
S_rap_E       1.809e-01  6.574e-02   2.752  0.00645 **
S_oat_E       3.198e-01  3.367e-01   0.950  0.34324
Y_buck_E     -1.389e+00  5.187e-01  -2.678  0.00801 **
Price_soya   -1.366e-03  1.109e-03  -1.231  0.21961
Price_barley  9.629e-03  3.636e-03   2.648  0.00872 **
S_barley_E   -7.259e-02  3.572e-02  -2.032  0.04344 *
Price_wheat  -7.520e-03  4.296e-03  -1.751  0.08151 .
Y_soya_E     -2.444e-01  1.717e-01  -1.424  0.15594
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 19.87 on 206 degrees of freedom
Multiple R-squared:  0.5326,    Adjusted R-squared:  0.5054
F-statistic: 19.56 on 12 and 206 DF,  p-value: < 2.2e-16
```

Figure 1. *Results of modelling the impact of cultivated areas, gross harvest, crop yields, and prices for agricultural crops on the insured area*

Source: *calculated based on data ("ARX", 2022; "KRAYINA", 2022; "ORANTA", 2022; "PZU Group", 2022; "UNIVERSALNA", 2022; Agricultural insurance market of Ukraine, 2018; Chvertko et al., 2019; State Statistics Service of Ukraine, 2012-2021)*

The one-year lag model allows for the evaluation of the impact of past values of factors on the current dependent variable. This is particularly useful in the analysis of agricultural markets, where decisions on crop cultivation and harvest depend on many factors that occur over several years. The one-year lag model helps to track and account for time delays in the influence of factors on the dependent variable. This will contribute to identifying long-term trends, cycles, and other time-related dependencies that may be present in the studied agricultural system. Therefore, the inclusion of the one-year lag model allows for a more comprehensive understanding of the relationships between the factors and the dependent variable, and a better understanding of the processes and phenomena that affect the formation of the agricultural insurance market in Ukraine.

To compare the statistical quality of the two models, the focus can be on the following indicators (Table 1).

```
Call:
plm(formula = Y ~ V_soya_E + Y_cer_E + S_soya_E + V_sunfl_E +
    V_rap_E + S_cer_E + Price_soya + Price_sunfl, data = DataBase, model = "within")

Residuals:
    Min      1Q  Median      3Q     Max
-39.486 -14.015   0.068  12.118  60.442

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept) 21.1645891  6.7233699   3.148  0.00191 **
V_soya_E     0.0104234  0.0013949   7.473 2.70e-12 ***
Y_cer_E     -2.4666881  0.5017462  -4.916 1.89e-06 ***
S_soya_E     0.0151210  0.0026388   5.730 3.83e-08 ***
V_sunfl_E    0.0042900  0.0004344   9.875  < 2e-16 ***
V_rap_E      0.0065907  0.0020841   3.162  0.00182 **
S_cer_E      0.7913803  0.3017930   2.622  0.00944 **
Price_soya  -0.0029927  0.0011134  -2.688  0.00782 **
Price_sunfl  0.0029191  0.0010322   2.828  0.00518 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 19.68 on 192 degrees of freedom
Multiple R-squared:  0.5585,    Adjusted R-squared:  0.5401
F-statistic: 30.36 on 8 and 192 DF,  p-value: < 2.2e-16
```

***Figure 2.** Results of modelling the impact of cultivated areas, gross harvest, crop yields, and prices for agricultural crops with a one-year lag on the insured area*

***Source:** calculated based on data ("ARX", 2022; "KRAYINA", 2022; "ORANTA", 2022; "PZU Group", 2022; "UNIVERSALNA", 2022; Agricultural insurance market of Ukraine, 2018; Chvertko et al., 2019; State Statistics Service of Ukraine, 2012-2021)*

***Table 1.** Comparative characteristics of the statistical qualities of the presented models*

Indicator	Model 1 (direct)	Model 2 (lagged – one year)
Residual standard error	19.87	19.68
Multiple R-squared	0.5326	0.5585
Adjusted R-squared	0.5054	0.5401

***Source:** calculated based on data ("ARX", 2022; "KRAYINA", 2022; "ORANTA", 2022; "PZU Group", 2022; "UNIVERSALNA", 2022; Agricultural insurance market of Ukraine, 2018; Chvertko et al., 2019; State Statistics Service of Ukraine, 2012-2021)*

The first indicator, "Residual standard error", indicates the average difference between observed values and predicted values in the model. In this case, the value is slightly lower in model 2 (19.68 compared to 19.87), which may indicate better accuracy in the predictions of this model. The second indicator, "Multiple R-squared", indicates the proportion of the variation in the dependent variable that can be explained by the independent variables used. In model 2, the value of this indicator (0.5585) is higher, indicating a better ability of model 2 to explain the change in the dependent variable. The third indicator, "Adjusted R-squared", is a corrected version of the multiple R-squared coefficient, which considers the number of independent variables and the degrees of freedom of the model. The value of this indicator is also higher in model 2 (0.5401 compared to 0.5054), indicating a more adequate use of variables in model 2. Therefore, considering these indicators, model 2 has better statistical quality compared to model 1. The results of the regression analysis indicate the statistical significance of certain factors that influence the insured area of agricultural crops. Table 2 presents the statistical significance of each of the factors and justifies its impact on the dependent variable.

Table 2. Reflection of the results of regression analysis of the statistical significance of certain factors influencing the insured area

No.	Factors influencing the insured area	Coefficient Value	Financial-economic interpretation of coefficients
1	Gross soybean yield (thousand t) V_soya_E	0.0104	An increase in soybean yield by 1 thousand t contributes to an increase in the insured area of agricultural crops by 0.0104 thousand ha.
2	Grain crop yield (c/ha) Y_cer_E	-2.4667	An increase in grain crop yield by 1 c/ha leads to a decrease in the insured area of agricultural crops by 2.4667 thousand ha.
3	Soybean area (thousand ha) S_soya_E	0.0151	An increase in the area sown with soybeans by 1 thousand ha contributes to an increase in the insured area of agricultural crops by 0.0151 thousand ha.
4	Sunflower gross yield (thousand ha) V_sunfl_E	0.0043	An increase in sunflower gross yield by 1 thousand ha leads to an increase in the insured area of agricultural crops by 0.0043 thousand ha.
5	Rapeseed area (thousand ha) S_rap_E	0.0066	An increase in rapeseed gross yield by 1 thousand ha leads to an increase in the insured area of agricultural crops by 0.0066 thousand ha.
6	Grain crop area (thousand ha) S_cer_E	0.7914	An increase in the area sown with grain crops by 1 thousand ha leads to an increase in the insured area of agricultural crops by 0.7914 thousand ha.
7	Soybean price (thousand UAH per t) Price_soya	-0.0068	An increase in soybean price by 1 thousand UAH per ton leads to a decrease in the insured area of agricultural crops by 0.0068 thousand ha.
8	Sunflower price (thousand UAH per t) Price_sunfl	0.0041	An increase in sunflower price by 1 thousand UAH per ton leads to an increase in the insured area of agricultural crops by 0.0029 thousand ha.

***Source:** calculated based on data ("ARX", 2022; "KRAYINA", 2022; "ORANTA", 2022; "PZU Group", 2022; "UNIVERSALNA","2022; Agricultural insurance market of Ukraine, 2018; Chvertko et al., 2019; State Statistics Service of Ukraine, 2012-2021)*

The results of the presented regression analysis indicate that an increase in gross soybean yield, sunflower price, and the areas sown with grain crops, soybeans, and rapeseed showed a positive relationship with farmers' readiness to increase insurance coverage of agricultural crops. On the other hand, there was a negative relationship observed in the research, indicating that as grain crop yield and soybean prices increase, the areas that farmers are willing to insure decrease. Identified dependencies are formed under the significant influence of conjunctural features of the functioning of the agrarian market. Thus, with balanced prices for agricultural products and a well-established logistics system for their sale, the demand for insurance protection is likely to increase. If these conditions are not met, the demand for insurance among producers may tend to decrease.

Considering the above regression analysis, it should be noted that there is a different impact of changes in the internal prices of soybeans and sunflowers. From an economic perspective, soybean and sunflower prices have different impacts on the model of factors influencing the insured area of agricultural crops due to the varying responses of agricultural producers to price changes. In the case of soybean prices, there is a negative correlation. The regression coefficient Price_soya = -0.0068 indicates that an increase in soybean prices by 1 000 UAH per ton leads to a decrease in the insured area of agricultural crops by 0.0068 thousand hectares. This suggests that as soybean prices rise, agricultural producers choose to reduce the area they insure. This decision may be associated with the fact that an increase in soybean prices raises the costs of cultivating this crop, and agricultural producers may be less inclined to cultivate a larger area of soybeans that they subsequently insure. In the case of sunflower prices, there is a positive dependence. The regression coefficient Price_sunfl = 0.0041 indicates that an increase in sunflower prices by 1 000 UAH per ton leads to an increase in the insured area of agricultural crops by 0.0041 thousand hectares. The interpretation of this indicator implies that as sunflower prices rise, agricultural producers choose to expand the area they insure. This reaction is due to the fact that an increase in sunflower prices boosts income from cultivating this crop, and agricultural producers may be more interested in cultivating a larger area of sunflowers that they subsequently insure. These decisions regarding insuring their cultivated areas are made by agricultural producers to protect themselves from risks associated with the cultivation of agricultural crops. The insurance mechanism allows policyholders to receive compensation for losses in the event of specific occurrences, including adverse weather conditions, plant diseases, and pests.

Therefore, the final decision regarding the insurance of agricultural risks is made based on a complex interplay of factors related to natural and climatic influences on the results of the previous year's production, which ultimately impacts the price as the basis for potential profitability. The construction of a regression model involves evaluating and verifying certain assumptions, which helps ensure its reliability and adequacy. This analysis can help identify potential issues or shortcomings in the model, which should be considered when interpreting the results and making management decisions (Fig. 3).

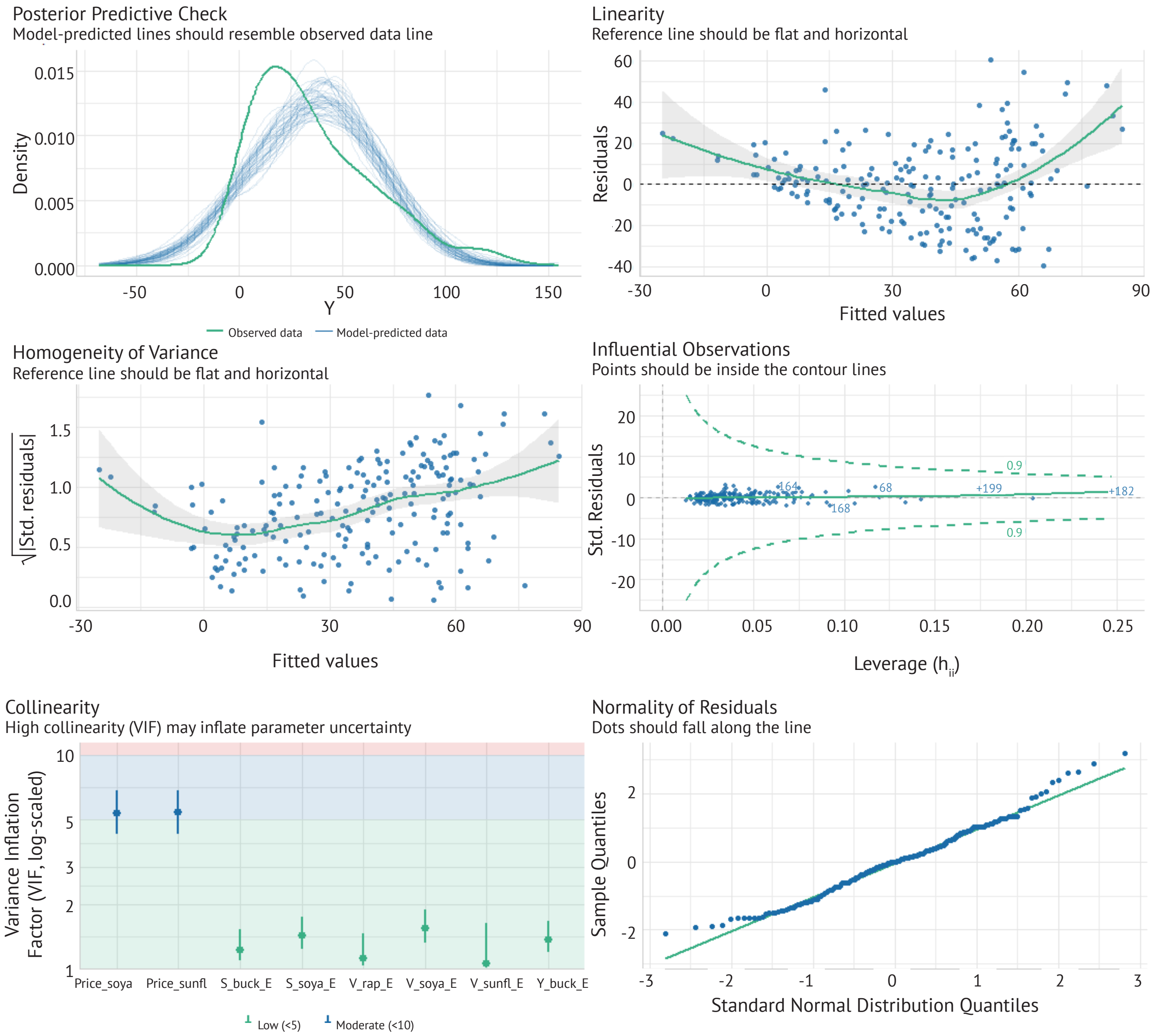

Figure 3. *Visual analysis of statistical properties of the model*
Source: *calculated based on data ("ARX", 2022; "KRAYINA", 2022; "ORANTA", 2022; "PZU Group", 2022; "UNIVERSALNA", 2022; Agricultural insurance market of Ukraine, 2018; Chvertko et al., 2019; State Statistics Service of Ukraine, 2012-2021)*

To analyse the graphical panel that displays various aspects of model assumptions, it is advisable to focus on each graph separately and consider the following points: Normality of Residuals – analysis of the normal distribution graph of residuals, which is presented as a histogram of residuals and a Q-Q plot (quantile-quantile plot), where the quantiles of residuals are compared with quantiles of the normal distribution. The visualisation of the graph indicates that the residuals are distributed normally, and the points on the Q-Q plot approximately lie on the line. Normality of random effects (Influential Observations): the analysis of the corresponding graph shows the absence of structural elements in the sample that significantly affect the variation of the dependent variable (none of the points fall outside the permissible range).

Linear dependence (Linearity): the graph demonstrates a linear regression smooth curve that reflects how the dependent variable changes according to independent variables. The graph indicates a linear and adequate functional relationship. Homogeneity: the graph shows residuals concerning the dependent variable and indicates that the distribution of residuals is uniform across all levels of the dependent variable. Uniformity in the distribution of residuals suggests the absence of heteroscedasticity. Collinearity: the graph indicates the absence of correlation between predictors and suggests the absence of multicollinearity. To assess the reliability of the obtained model, a comparison was made between real and modelled insured areas of agricultural land at the national level (the sum of insured areas for the year across 24 regions) (Fig. 4).

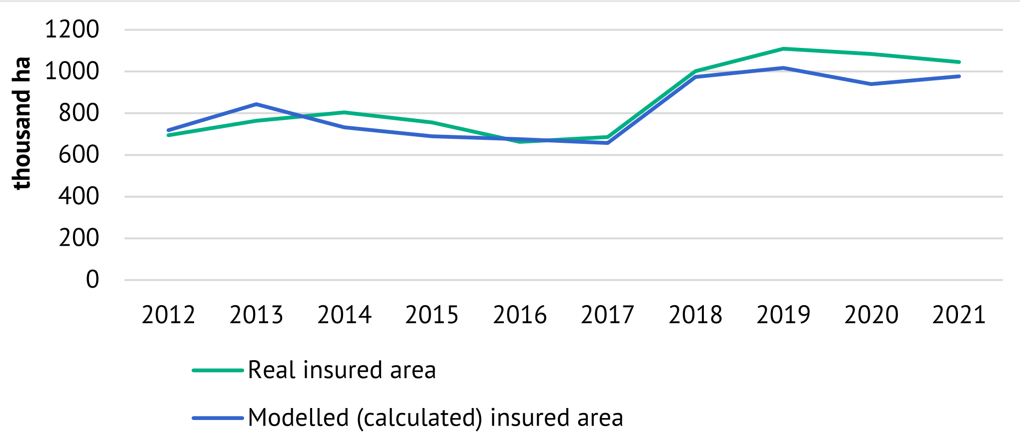

Figure 4. *Comparison of real and simulated insured area of agricultural land at the national level (Ukraine)*
Source: *calculated based on data ("ARX", 2022; "KRAYINA", 2022; "ORANTA", 2022; "PZU Group", 2022; "UNIVERSALNA", 2022; Agricultural insurance market of Ukraine, 2018; Chvertko et al., 2019; State Statistics Service of Ukraine, 2012-2021)*

The average reliability index of the model, determined as the absolute deviation of real insured areas of agricultural land in Ukraine from the modelled values, is 6.8%. This suggests a fairly high reliability of the model and can be used to develop proposals and tools for stimulating the development of the agricultural insurance market in Ukraine. Empirical results from this study confirm the hypothesis regarding the relationships between cultivated areas, yields, gross harvest, and internal prices in the agricultural sector and the influence of these factors on the level of insurance protection in the agricultural sphere. This provides a basis for scientifically substantiating the prospects for the development of agricultural insurance in Ukraine in both wartime and peacetime. Based on the results of the regression analysis model, the following practical recommendations can be formulated to enhance interaction among stakeholders in the agricultural insurance market.

Firstly, increasing the financial and economic interest in insurance among agricultural producers is possible under the condition of a positive trend in cultivated areas, gross harvest, and price parity for agricultural products. Activation of business and investment attractiveness in the insurance market is achieved through a rational combination of organisational, technological, and financial-economic measures. In organisational terms, the focus should be on establishing interdistrict branches of insurance companies to expand insurance coverage for agricultural risks and ensure broad access to insurance services both offline and online. The technological component of insurance companies' activities involves the development and positioning of innovative insurance services (both traditional and index-based) capable of meeting the demand of agricultural producers for insurance protection. The financial-economic aspect of insurance relations in the agricultural sector is driven by the need to address two key issues: firstly, ensuring broad access for potential policyholders to a diversified range of insurance services (in terms of price, coverage, etc.); secondly, guaranteeing the financial viability of insurers and ensuring their profitability and sustainability in the segment of agricultural insurance contract servicing.

Secondly, stakeholders in the agricultural insurance market are interested in expanding cultivated areas and maintaining high crop yields for grains and technical crops. This objective necessitates the objective need for the establishment of mutually beneficial cooperation among insurers, policyholders, and the government. Collaboration among participants in the insurance process within this specified triangle is fundamental to the successful functioning of the agricultural insurance market. It is acknowledged that under conditions of a state of war, such cooperation is complicated due to both objective and subjective reasons; however, its necessity is evident, given the need for effective mitigation of agricultural risks and the formation of a compensation mechanism for losses in the event of insurable events. It is worth noting that Ukrainian legislation provides for the mechanism of such cooperation, particularly under the Law of Ukraine "On Specifics of Agricultural Product Insurance with State Support" from February 9, 2012, No. 4391-VI (2012), and the Resolution of the Cabinet of Ministers of Ukraine "On Approving the Procedure for Providing State Support for Agricultural Product Insurance" from December 9, 2021, No. 1342 (2021). Key advantages of such cooperation include: a) reducing the cost of insurance services for farmers; b) expanding insurance coverage for agricultural risks; c) enhancing the insurance protection of agricultural producers. Furthermore, in the post-war period, coordination between state and non-state institutions in the agricultural insurance market can be based on the principles of public-private partnerships.

Thirdly, the activities of insurance companies in the context of a state of war should consider the existing threats and offer corresponding insurance services aimed at improving safety conditions for agricultural production. This primarily concerns the possibility of utilising the following approaches to enhance insurance protection for farmers: Firstly, the successful implementation of the "Grain Initiative" project requires active involvement of insurance companies in insuring the export of agricultural products and logistical risks resulting from military actions. Secondly, direct losses from military aggression in agriculture (as of February 2023) amounted to $8 billion, of which $4.2 billion was attributed to destroyed agricultural machinery and equipment (Dmytrasevich, 2023). Therefore, it is relevant for agricultural producers to diversify their insurance coverage, which should encompass both agricultural products and the main production assets. Thirdly, military actions necessitate ongoing demining efforts, including in cultivated areas. Hence, insurance companies face the task of developing insurance programmes aimed at minimising the risks associated with demining territories. Fourthly, post-war recovery and attracting investments into the agricultural sector will undoubtedly require a well-established system for insuring agricultural risks.

The further functioning of the agricultural insurance market in Ukraine depends significantly on the infrastructure supporting the insurance process. This primarily involves improving communication systems (exchange of ideas, information, knowledge, etc.) among stakeholders in the insurance market, enhancing their motivation to enter into and renew agricultural insurance contracts. Questions regarding the digitalisation of insurance relations in the agricultural sector, such as providing services remotely, automated risk underwriting, the application of blockchain technology, and the use of smart contracts for timely identification of insurance events and processing of insurance claims, are becoming increasingly relevant.

Fifthly, self-organisation plays an important role in organising insurance relations in the agricultural sector. Examples of such self-organisation can be mutual insurance societies, which are quite active in their professional activities in countries like Germany, France, the Netherlands, and others (European Market Share, 2022). The most significant advantages of using this form of organisation for insurance relations in the agricultural sector include: 1) sellers and buyers of insurance services being the same entity; 2) the ability to apply an individual approach to selecting risks for insurance coverage; 3) ensuring accessibility and flexibility in forming tariff policies for insurance services; 4) exercising control over the formation and use of the insurance fund, and more.

Consequently, the role of insurance as a financial-economic instrument for risk mitigation due to objective circumstances will continue to increase. The results of the modelling conducted indicate that for the vast majority of agricultural producers, favourable conditions in entrepreneurial activities (prices for agricultural products, gross yields, crop yields, etc.) are significant arguments supporting insurance. In this context, insurance should be considered as an additional option for agricultural producers to mitigate the consequences of adverse events (unexpected expenses) in the event of an insurance claim. These outlined issues require scientific discussion and justification, which is the subject of the next section of this study.

The formation of insurance relations in the agricultural sector requires the identification and justification of key factors influencing the development of the agricultural insurance market. Analysis of scientific sources indicates that these factors include: Farmer's income and farm size, which play a significant role in shaping the demand for insurance in developing markets (Stojanović *et al.,* 2019); Financial and economic performance indicators of farms (Baráth *et al.,* 2017); The proportion of non-agricultural income in the farmer's household (Njegomir & Demko-Rihter, 2018); The cost of agricultural production, crop yield, soil quality, and planting intensity (Was & Kobus 2018); Transparency of insurance products (Linhoff *et al.,* 2022); The amount of insurance compensation in the event of an insurance claim (Stoeffler & Opuz, 2022).

Studies on cause-and-effect relationships in the field of agricultural risk insurance provide grounds to assert that the functioning of the agricultural insurance market depends on factors such as crop acreage, yield, gross production, and the domestic price of agricultural products. R. Goodhue & G. Rausser (2003) identified three probable dependencies in the agricultural insurance market: first, a decrease in acreage can increase the cost of insurance due to a higher risk of crop losses. Secondly, if the yield is lower than expected, the cost of insurance may increase. Third, changes in product prices may affect the level of risk for agricultural producers and the cost of insurance. A. Ker & T. Tolhutst (2019) emphasised that agricultural insurance can protect farmers' incomes and stabilise their production expectations, thereby promoting food production. L. Fields *et al.* (2012) share a similar perspective, asserting that the functioning of the insurance market can reduce risks associated with natural disasters and adverse weather conditions, which can increase profitability for farmers and boost agricultural production. It is widely accepted in the scientific community that insurance is the best way to ensure the continuity, balance, and stability of the agricultural market (Shirinian & Klymash, 2018).

The scientific arguments presented provide a clear understanding of the existence of many factors (farmers' incomes, agricultural product prices, gross yields) that influence the functioning of the agricultural insurance market. Research on these factors is a necessary condition for the scientific interpretation of insurance relations in the agricultural sector. A consolidating position among many researchers such as S. Kislingerová and J. Špička (2022), H. Wang *et al.* (2022), I. Ivashkiv *et al.* (2021) is that the effectiveness of the agricultural insurance mechanism in mitigating agricultural risks depends on the ability to make management decisions considering various factors of natural, technological, agronomic, financial-economic, and others. Therefore, the focus of scientific discussion is oriented towards identifying key factors influencing the development of the agricultural insurance market, utilising potential insurance opportunities to minimise natural-climatic and production-economic risks in the agricultural sector, and diversifying forms and methods to enhance the insurance protection of agricultural producers.

CONCLUSIONS

The study established that Ukraine exhibits a certain territorial diversification in the relationship between insured and sown areas. The highest level during 2012-2021 was recorded in western regions (specifically, Lviv, Ternopil, Rivne, and Khmelnytskyi), where this indicator ranged from 0.25 to 12.50%. In contrast, the lowest level of insurance coverage was observed in eastern and southern regions (including Donetsk, Luhansk, Odesa, Mykolaiv, Kharkiv, and Kherson), ranging from 0.14 to 4.17%. The variability of this indicator depended on several factors, including the level of adaptation of agricultural producers to European traditions in insurance, the state of infrastructure readiness to provide agricultural insurance services, the riskiness of specific agricultural crops, and the availability of adequate services for their insurance protection, and the military actions on the territory of Ukraine.

To identify the internal factors influencing the agricultural insurance market in Ukraine, two parallel panel models were applied (based on the 24 regions of Ukraine): a standard model and a one-year lag model. In the modelling process, it was found that factors such as sown area, yield, gross harvest, and the price of agricultural products influence the level of insured area. Based on the results of the regression analysis, the statistical significance of certain factors (gross harvest and prices of soybeans and sunflower, yield and sown areas of cereal crops, and sown areas of soybeans, sunflower, and rapeseed) in influencing the insured area was established. This provides grounds to assert that expanding sown areas, increasing gross harvests, and improving crop yields are favourable factors for stimulating demand for insurance services among agricultural producers. Failure to meet one or more of these factors can lead to a decrease in motivation for insurance. The results of the modelling were validated at the national level, confirming a high level of reliability of the modelled indicators (insured areas). The calculation of the module of the ratio of real indicators to modelled ones is 6.8%, indicating that the model's reliability is 93.2%. The obtained results of modelling (regression coefficients) allowed for the formulation of practical recommendations to stimulate the development of the agricultural insurance market in Ukraine.

The modern model of the agricultural insurance market requires an increase in business and investment activity of participants in the insurance process, enhanced interaction within the "insurers, insured, state" triangle. Emphasis is placed on the need to enhance insurance protection for agricultural producers in conditions of a state of war, including the insurance of agricultural product exports, agricultural machinery and equipment, investment insurance, and more. Notably, the role and necessity of modernising infrastructure and improving communication ties between participants in the insurance space are increasing, and diversifying the organisational and legal forms of insurance companies' activities. Future studies will focus on utilising inclusive opportunities for the development of the agricultural product insurance market in Ukraine.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Ідентифікація та інтерпретація внутрішніх факторів впливу на аграрний страховий ринок в Україні

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Анотація. Функціонування ринку аграрного страхування в Україні є об'єктивною реальністю та необхідністю з огляду на нагальну потребу у формуванні безпекового середовища для виробництва сільськогосподарської продукції. Здатність до консолідації фінансових ресурсів у сфері страхових відносин сприяє посиленню відповідальності за ймовірні ризики, які розподілені у просторі й часі, тому варто розглянути страхові відносини у аграрній сфері. Метою дослідження було теоретико-методологічне обґрунтування процесів ідентифікації внутрішніх факторів впливу на подальше функціонування аграрного страхового ринку в Україні. Методологічний ракурс представленого дослідження базується на використанні загальнонаукових та специфічних методах пізнавальної діяльності: абстрактно-логічному, економіко-статистичному, структурнофункціональному, дедукції, індукції та формалізації. Сформовано панельну базу даних за період 2012-2021 рр. у розрізі 24 областей України. Відображено територіальні особливості зміни рівня співвідношення між застрахованими та посівними площами у розрізі західних, центральних, східних та південних областей України. Базуючись на результатах проведеного моделювання (представлено паралельно дві моделі: звичайна модель та модель з лагом в один рік), встановлено вплив на застраховану площу таких факторних ознак, як: посівна площа, врожайність, валовий збір та внутрішня ціна на сільськогосподарську продукцію. Здійснено порівняльну характеристику статистичних якостей представлених моделей, використовуючи показники: «Residual standard error», «Multiple R-squared» та «Adjusted R-squared». За результатами регресивного аналізу виявлено статистичну значущість певних факторів щодо мотивації сільськогосподарських товаровиробників брати учать у страховому процесі. Практична цінність запропонованих заходів полягає у формулюванні практичних рекомендацій щодо посилення взаємодії між стейкхолдерами ринку аграрного страхування у воєнний та повоєнний період часу

Ключові слова: аграрне страхування; застрахована площа; стейкхолдери страхового ринку; сільськогосподарські ризики