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The Optimal Parameters of Agricultural Insurance of the Products in the Ukraine

NATALIA V. TRUSOVA[1], NATALIA M. RUBTSOVA[2], MYKOLA O. RUBTSOV[3], IRYNA O. CHKAN[4], NATALIIA H. RADCHENKO[5], SVITLANA O. OSYPENKO[6]

[1,2,4,5,6]Department of Finance, Banking and Insurance, DMYTRO MOTORNYI TAVRIA STATE AGROTECHNOLOGICAL UNIVERSITY, Ukraine

[3]Department of Mathematics and Physics, BOGDAN KHMELNITSKY MELITOPOL STATE PEDAGOGICAL UNIVERSITY, Ukraine

ABSTRACT

The article deals with the complex indicative forecasting of agricultural insurance parameters, which have approximate empirical dependences of variables and provide approximation of actuarial calculations of the franchise, in order to optimize the rates of insurance compensation for losses in agricultural production. The tools for minimizing the risks of agricultural production are substantiated. The typology of instruments for regulating the risks of agricultural production by transferring their risk distribution in the institutional environment and market infrastructure is studied. It is proved that vertical integration has a positive effect of compensation for losses of agricultural production, taking into account alternative diversification combinations with actual variables and the occurrence of a certain insurance event. Multicriteria optimization of the parameters of partial distribution of risks of agricultural production, which simultaneously provide the maximum possible value of the expected return with a minimum value of the risk of the portfolio of assets of agricultural enterprises, is fulfilled. The utility function for accidental consequences in agricultural insurance is substantiated, as it guarantees the effective indicator of income at variable values of uncertainty. Approximate empirical dependences of variables are determined, which provide approximation of actuarial calculations of the franchise, in order to optimize the rates of insurance indemnity in agricultural production. Models of indicative forecasting of optimal parameters of agricultural insurance on the market of agricultural products of Ukraine on insurance payments and insurance premiums, which have a decreasing function, have been developed; insured sum and franchise have dynamic fluctuations.

Keywords: Risks; Insurance indemnity; Insurance premium; Franchise; Market.

JEL Classification: Q13, Q14, G13, G22.

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Los Parámetros Óptimos del Seguro Agrícola de los Productos en Ucrania

NATALIA V. TRUSOVA[1], NATALIA M. RUBTSOVA[2], MYKOLA O. RUBTSOV[3], IRYNA O. CHKAN[4], NATALIIA H. RADCHENKO[5], SVITLANA O. OSYPENKO[6]

[1,2,4,5,6]Department of Finance, Banking and Insurance, DMYTRO MOTORNYI TAVRIA STATE AGROTECHNOLOGICAL UNIVERSITY, Ukraine

[3]Department of Mathematics and Physics, BOGDAN KHMELNITSKY MELITOPOL STATE PEDAGOGICAL UNIVERSITY, Ukraine

RESUMEN

El artículo trata de la compleja previsión indicativa de los parámetros de los seguros agrarios, que tienen dependencias empíricas aproximadas de las variables y proporcionan una aproximación de los cálculos actuariales de la franquicia, con el fin de optimizar las tasas de indemnización del seguro por pérdidas en la producción agraria. Se fundamentan los instrumentos para minimizar los riesgos de la producción agrícola. Se estudia la tipología de los instrumentos para regular los riesgos de la producción agraria mediante la transferencia de su distribución de riesgos en el entorno institucional y la infraestructura de mercado. Se demuestra que la integración vertical tiene un efecto positivo de compensación de pérdidas de la producción agrícola, teniendo en cuenta combinaciones alternativas de diversificación con variables reales y la ocurrencia de un determinado evento de seguro. Se cumple la optimización multicriterio de los parámetros de distribución parcial de los riesgos de la producción agrícola, que proporcionan simultáneamente el máximo valor posible de la rentabilidad esperada con un valor mínimo del riesgo de la cartera de activos de las empresas agrícolas. Se fundamenta la función de utilidad de las consecuencias accidentales en el seguro agrario, ya que garantiza el indicador efectivo de la renta en valores variables de incertidumbre. Se determinan las dependencias empíricas aproximadas de las variables, que proporcionan la aproximación de los cálculos actuariales de la franquicia, con el fin de optimizar las tasas de indemnización del seguro en la producción agrícola. Se han desarrollado modelos de previsión indicativa de los parámetros óptimos de los seguros agrícolas en el mercado de productos agrícolas de Ucrania sobre los pagos de seguros y las primas de seguros, que tienen una función decreciente; la suma asegurada y la franquicia tienen fluctuaciones dinámicas.

Palabras clave: Riesgos; Indemnización del Seguro; Prima del Seguro; Franquicia; Mercado.

Clasificación JEL: Q13, Q14, G13, G22.

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1. Introduction

The development of the national agricultural segment of the insurance market, which is rapidly transforming on the basis of financial nature and in-depth internal transparency and efficiency of agricultural insurance, reduces the impact of production and economic risks on agricultural production and economic stabilization of agriculture. However, the insufficient level of use of agricultural insurance instruments in agriculture causes factors that have a direct and indirect impact on the process of expanded reproduction of the production cycle, the formation of financial results of agricultural enterprises. The slow development of insurance in agriculture of Ukraine is explained by shortcomings in the organization and coordination of cooperation of the main participants in the insurance market, as agricultural production is a very risky business. At the same time, the insurance of agricultural products is one of the ways to minimize risks, allowing making agricultural business less risky. While some of these tools minimize certain risks, others reduce a number of risks at the same time, through business diversification, financial mechanism, vertical integration and public-private partnership contracts, hedging, liquidity, crop insurance and producers' income (Rudenko, 2020).

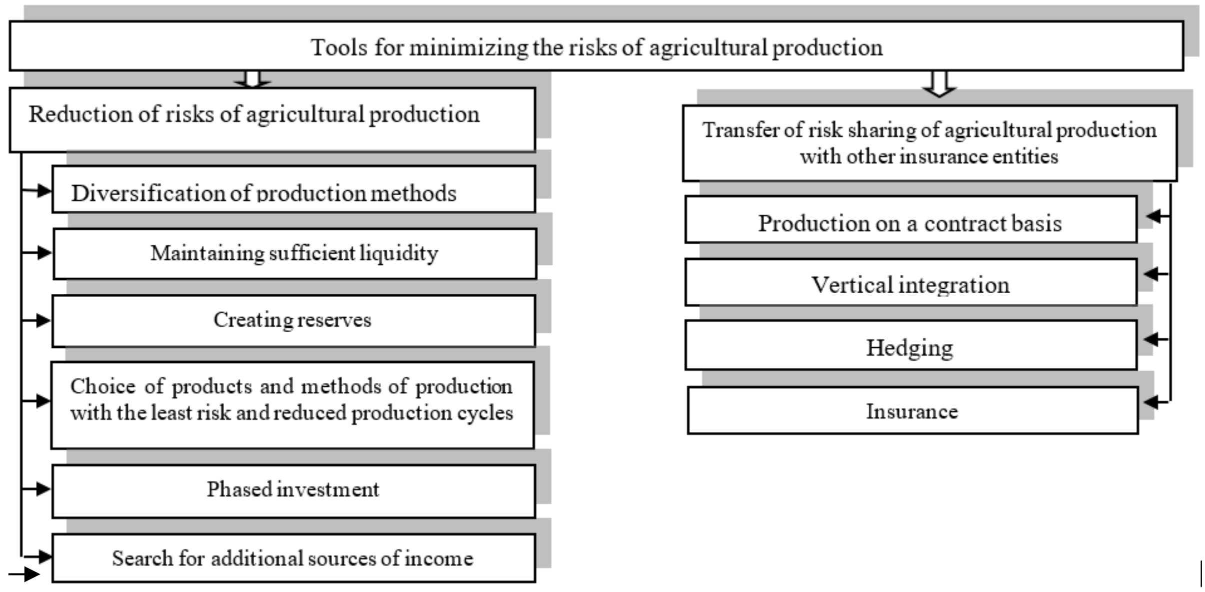
As a rule, climatic and market risks have different effects on the production of different types of agricultural products and, accordingly, their negative impact in some areas is offset by a positive one in others. To minimize risks and obtain stable financial results, agricultural enterprises choose in-depth specialization, while maintaining existing methods and volumes of production. Instead, the diversification of agricultural activities has both economic and social benefits – provides greater employment, the realization of a wider range of social and material needs of farmers. A number of characteristic features, such as seasonality of production, long period of capital turnover, high risk and dependence on natural conditions, determine the need for borrowed resources for agricultural production. The potential of the agricultural market is growing every year, increasing the volume of cash and commodity loans, however, the needs of producers in borrowed funds are not fully met, so agricultural insurance is almost the only alternative source to cover shortages and minimize risks of the production cycle. Accordingly, improving the efficiency of agriculture and ensuring the protection of the economic interests of agricultural producers requires a revision of the risk management mechanism (Sivash et al., 2019; Gendler et al., 2019).

The theoretical foundations of the essence and importance of agricultural insurance as a tool to reduce the risks of agricultural production and probabilistic magnitude of crop losses in the assessment of the lost area of crops was paid much attention by such scientists as: Yu. Aleskerova (2013), O.V. Voitko, R.M. Motoryn, Z.P. Baranyk, (2006; 2001), J. Cummins, A. Bekkerman, B. Goodwin, N. Piggott (2008), O. Mahul (2009), S. Dercon (2002), V. Kostetskyi (2012), M. Miranda, J. Glauber (1997), O. Sakhno (2010), V. Smith, B. Goodwin (1996), Re. Swiss, R. Voutilainen (2007), P. Varangis, D. Larson, J. Anderson (2002). The study of natural and climatic factors of development and vital activity of biological systems, which are the source of agricultural products and determine the probability of traditional business risks, common to all sectors of agriculture was made by T. Dudar (2019), H. Mazniev (2017), O. Shubravska (2017), O. Polinkevych (2018), O. Shpykuliak and M. Hrytsaienko (2016), P. Sabluk (2010). The priority of our study is to conduct a comprehensive indicative forecasting of agricultural insurance parameters, which have approximate empirical dependences of variables and provide an approximation of the actuarial calculation of the franchise, in order to optimize insurance rates for agricultural production.

2. Materials and Methods

Agricultural insurance is the best way to ensure the continuity, balance and stability of the agricultural market and one of the effective methods of covering losses in the agricultural sector, as insurance companies form the necessary reserves for future payments without resorting to external and internal loans. The main purpose of agricultural insurance is to partially or fully compensate the entity for losses due to the realization of risks. The objective economic necessity of using insurance in agricultural production is explained by the insufficient ability of the state and the market to ensure the maneuverability of financial resources of economic entities. Therefore, there are two main groups of risk regulation: reduction of risks of agricultural production and transfer of risk sharing with other economic entities (Fig. 1).

Figure 1 Tools for minimizing the risks of agricultural production



Source: developed by the authors based on Sakhno, 2010; Shubravska, 2017; Bahvalov, 2007; Rubtsova, 2018; Statistical publication of…, 2018.

Risk management tools for agricultural production can be used by producers themselves, while risk-sharing tools involve an appropriate institutional environment and market infrastructure. Thus, vertical integration in the formation of agricultural holdings, allows partially minimizing price risks, as well as reducing the financial risks of member companies of agricultural holdings (Barbotkina et al., 2020). A positive effect is also achieved through diversification, which involves combining different production areas in order to reduce serious fluctuations in income levels. This tool is based on the theory of portfolio investment (Markowitz, 1992; Barashkin & Samarin, 2005; Kasakova et al., 2019), and allows to reduce risks by investing in such industries, the situation in which develops in almost diametrically different directions (and is expressed in the negative correlation of income) at certain events. The most common tool for risk sharing is agricultural insurance of agricultural production – providing policyholders (insured) with adequate insurance coverage in case of negative economic consequences caused by certain risks (Shalbolova et al., 2014; Rudenko et al., 2016). Portfolio theory allows multi-criteria optimization of the parameters of partial distribution of risks of agricultural production, which simultaneously provide the maximum possible value of the expected return with a minimum value of the asset portfolio risk (standard deviation), (Kasimov, 1998; Durakovic et al., 2018). The mathematical formulation of the problem has the form:

1. expected return on assets portfolio (average sample), (Kasimov, 1998) (Eq. 1):

$$m_p = M \times W^t \to max \tag{1}$$

2. asset portfolio risk (variance) (Dudar, 2019) (Eq. 2):

$$S_p^2 = W \times V \times W^t \to min \tag{2}$$

3. with restrictions (Dudar, 2019) (Eqs. 3, 4):

$$\sum_{i=1}^{n} W_i = 1, \tag{3}$$

$$W_i \geq 0, \quad i = 1, \dots, n, \tag{4}$$

where: $W_{n\times x}$ – vector of the share of assets in the wanted portfolio; $m_{n\times x}$ – vector of expected return on assets selected in the portfolio; matrix of covariance's of return on assets; n– number of assets.

The multi-purpose optimization model can be solved either graphically (with the transformation of one of the objective functions into a functional constraint), or by combining both objective functions (1)-(2), into one, consolidated utility function (Kasimov, 1998) (Eq. 5).

$$f(W) = m_p(W) - a \times S_p(W) \rightarrow max, \quad (5)$$

It is assumed that the values (coordinates of the vector) found as a result of solutions (3)-(5) will be optimal in the following. Therefore, this function is also a forecasting function. Accordingly, the question of the effectiveness of such a forecast in the practical insurance activities in the market of agricultural products is put (Kasimov, 1998). In addition, agricultural insurance is one of the important tools to cover risks in a market economy and is gradually increasing its presence in the financial sector of Ukrainian economy. Minimizing the negative consequences of unforeseen events in agricultural production is possible by reducing the risks of the dependence of the technological cycle on increasing the resources of agricultural enterprises. That is, the developed insurance market can become one of the conditions for further increase of financial resources in agricultural production (Vovchak and Zaviiska, 2005; Pashtetsky et al., 2020).

3. Results

Agricultural insurance, like most other instruments in the field of risk transfer, is based on the phenomenon of risk aversion. This means that the decision-making farmer has a negative attitude to possible accidental fluctuations in economic performance and is willing to compromise to reduce them. This is observed, above all, in the case when the fluctuations are so significant that they can significantly affect the financial capacity of the farmer (Tastulekov et al., 2019). This relationship is reflected in the principle of useful expectations. According to the principle of useful expectations for each agricultural business entity that makes decisions, under certain conditions there is a monotonically increasing function of the usefulness of accidental consequences in monetary form. It allows evaluating and ranking possible alternatives by the fact that the usefulness of each of them is evaluated on a single scale of preferences. The criterion is the expected value of utility, which is determined as follows (Eq. 6).

$$Eu_{(a_i)} = \sum p_j \times u(x_{ij}), \quad (6)$$

where: Eu – expected utility; a_i– *i*-th alternative; x_{ij}– the result of the *j*-th result on the *i*-th alternative; p_j– the probability of the *j*-th result. By inverting the utility function, the value is determined – f the guaranteed equivalent (Morhenshtern and Fon Neiman, 2012; Shumpeter, 2001) (Eq. 7).

$$CU = U^{-1}[U], \quad (7)$$

The value of the utility function for individual consequences x_1 and x_2 is marked by points A and B. The point D characterizes the usefulness of the expected value for both consequences, i.e. (Eq. 8).

$$u(E(x)) = u(p_1x_1 + p_2x_2). \quad (8)$$

The points on the line AB are a combination of the form (Eq. 9).

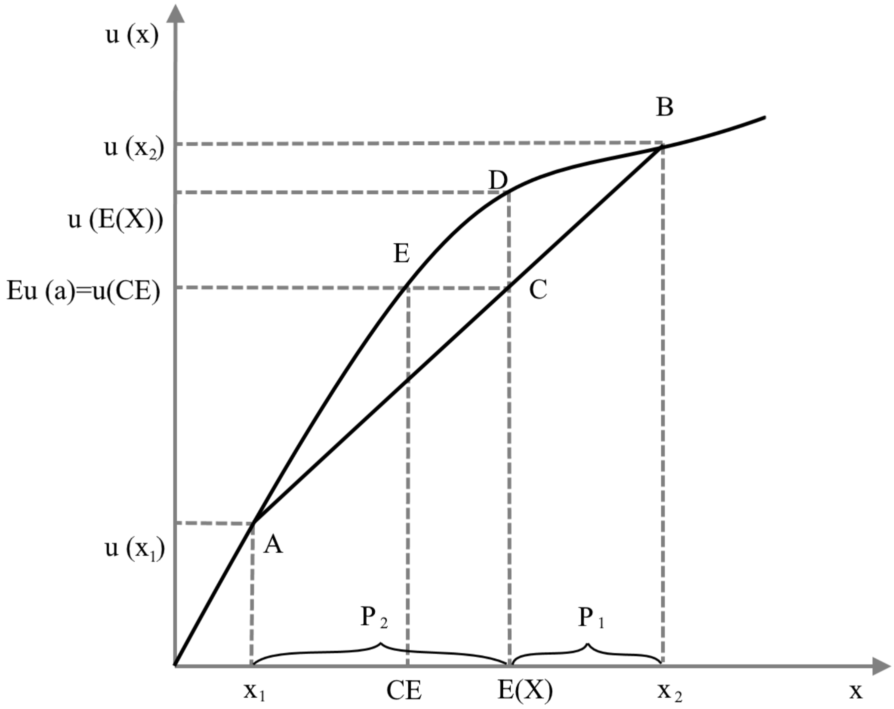
$$a \times u(x_1) + (1 - a) \times u(x_2), \quad (9)$$

where $0 \leq a \leq 1$. At the point C this combination has the form (Eq. 10).

$$p_1 \times u(x_1) + p_2 \times u(x_2), \quad (10)$$

i.e., the expected utility for both consequences Eu.

Figure 2 Random utility function, expected utility and guaranteed equivalent



Source: built by the authors according to Morhenshtern and Fon Neiman, 2012; Shumpeter, 2001.

When the utility function is concave down, the expected utility will always be lower than the utility for the expected result$Eu \leq u(E(x))$. Business entities whose preferences for alternatives with random effects can be displayed using the concave down utility function are called risk avoids. The convexity utility function characterizes risky business entities (expected utility is higher than utility in expected outcome). In the case of linearity of the utility function, business entities are risk-neutral. The guaranteed equivalent on the graph – the point CE– shows the income on the guaranteed result, which has the same value of the utility function as the income with an element of uncertainty (Orazgaliyeva & Yessimzhanova, 2018).

In the financial interpretation, the guaranteed equivalent expresses the guaranteed income, which the decision-maker entity estimates equally with the expected value of the alternative with a random result. The difference between the expected value of the alternative and the corresponding value of the guaranteed equivalent is called the risk premium (Eq. 11).

$$CE = E(x) - \pi. \quad (11)$$

In the graph, the risk premium π is the interval between points CE and $E(x)$ (Morhenshtern and Fon Neiman, 2012; Shumpeter, 2001).

The risk is most fully characterized by the law of distribution of the random amount of damage, which establishes a relationship between the possible values of the random amount of damage and the corresponding probabilities. The integral distribution function of a random variable is a function of the probability distribution of an event that a random variable (for example, a loss) does not exceed a certain value. The risk is most fully characterized by the law of distribution of the random amount of damage, which establishes a relationship between the possible values of the random amount of damage and the corresponding probabilities (Akhpanbaeva & Esimzhanova, 2016). The integral distribution function of a random variable is a function of the probability distribution of an event that a random variable (for example, a loss) does not exceed a certain value. From the integral distribution function of random damage by differentiation by a variable value the function of its density, which allows to easily calculating the probability of occurrence of a value of damage is determined. To select the projected parameters of agricultural insurance for agricultural production, we assume that the variable X is the years of research of insurance indicators and Y – the indicators themselves. Empirical calculations are certain dependencies (Table 1).

Table 1 Interpretation empirical calculations by certain dependencies

x	x_1	x_2	...	x_n
y	y_1	y_2	...	y_n

Source: developed by the authors based on Kirillov, 2012; Rubtsov et al., 2015.

By numerical values from the Table 1, it is possible to reveal tendencies of dependences of variables, but for their further use it is desirable to have analytical expressions of these dependences. We consider the formulas that are most often used according to the recommendations (Kirillov, 2012; Vereshchaha et al., 2019) (Eqs. 12-18).

Table 2 Empirical dependences of variables that provide an approximation of actuarial calculations

	$\bar{x}_s$	$\bar{y}_s$	Type of empirical formula	Method of alignment
1.	$\frac{x_1+x_n}{2}$ (arithmetic mean)	$\frac{y_1+y_n}{2}$ (arithmetic mean)	$y = ax + b$	
2.	$\sqrt{x_1x_n}$ (geometric mean)	$\sqrt{y_1y_n}$ (geometric mean)	$y = ax^b$	$Y = \alpha + bX$, where $X = lg\,X$, $Y = lg\,y$, $\alpha = lg\,a$
3.	$\frac{x_1+x_n}{2}$ (arithmetic mean)	$\sqrt{y_1y_n}$ (geometric mean)	$y = ab^x$ or $y = ae^{\beta x}$, where $\beta = ln\,b$	$Y = \alpha + \beta x$, where $Y = lg\,y$, $\alpha = lg\,a$, $\beta = lg\,b$
4.	$\frac{2x_1x_n}{x_1+x_n}$ (harmonic mean)	$\frac{y_1+y_n}{2}$ (arithmetic mean)	$y = a + \frac{b}{x}$	$Y = ax + b$, where $Y = xy$
5.	$\frac{x_1+x_n}{2}$ (arithmetic mean)	$\frac{2y_1y_n}{y_1+y_n}$ (harmonic mean)	$y = \frac{1}{ax+b}$	$Y = ax + b$, where $Y = \frac{1}{y}$
6.	$\frac{2x_1x_n}{x_1+x_n}$ (harmonic mean)	$\frac{2y_1y_n}{y_1+y_n}$ (harmonic mean)	$y = \frac{x}{ax+b}$	$Y = ax + b$, where $Y = \frac{x}{y}$
7.	$\sqrt{x_1x_n}$ (geometric mean)	$\frac{y_1+y_n}{2}$ (arithmetic mean)	$y = a\,ln\,x + b$	$Y = aX + b$, where $X = lg\,x$

Source: grouped by authors according to data of Kirillov, 2012; Burtniak and Malytska, 2009.

$$y = ax + b; \tag{12}$$

$$y = ax^b; \tag{13}$$

$$y = ab^x; \tag{14}$$

$$y = a + \frac{b}{x}; \tag{15}$$

$$y = \frac{1}{ax+b}; \tag{16}$$

$$y = \frac{x}{ax+b}; \tag{17}$$

$$y = a\,ln\,x + b \qquad (18)$$

Empirical dependences of variables that provide an approximation of actuarial calculations are presented in Table 2.

This approach is roughly oriented, because intermediate data are not taken into account when establishing empirical dependence. If the value (Eq. 19)

$$\varphi(x_1, \bar{x}_n) = x_s \qquad (19)$$

is not among the data x_i, then the corresponding value can be determined by linear interpolation (Rubtsov et al., 2015; Vereshchaha et al., 2019; Afanasev and Yuzbashev, 2010; Bahvalov, 2007; Burtniak and Malytska, 2019) (Eq. 20).

$$\hat{y}_s = y_i + \frac{y_{i+1} - y_i}{x_{i+1} - x_i}(\bar{x}_s - x_i), \qquad (20)$$

where: x_i and x_{i+1} – are intermediate values, between which there are $\bar{x}_s$ $(x_i < \bar{x}_s < x_{i+1})$.

The choice of the formula is made under the condition $|\hat{y}_s - \bar{y}_s| \to min$, the coefficients are determined by the method of least squares, and the solution of systems of linear equations – by the method of Gauss. As a result of calculations, analytical dependences were received (Tables 3-6)

Table 3 Forecasting the optimal parameters of agricultural insurance for insurance payments

Indicators of agricultural insurance		Calculation algorithm	Sum of squares of deviations	Direction of the curve
3.1	Insurance payments, thousand EUR	$y = 3797.6 - 342.091x$	18882804.22	falls
		$y = e^{8.5692 - 0.272655x}$	24784132.64	falls
3.2	Average payment for 1 contract, thousand EUR	$y - 142{,}483x + 2086.454$	12269212.62	falls
		$y = e^{7.6614 - 0.1728x}$	14061868.73	falls
3.3	Average payment for 1 ha, EUR	$y = e^{2.11873 - 0.29717x}$	50.16	falls
		$y = 6.0127 - 0.5762x$	38.79	falls
3.4	Average payment for 1 insurance company, thousand EUR	$y = -23.362x + 279.247$	107725.51	falls
		$y = e^{5.85807 - 0.239884x}$	141630.64	falls

Source: authors' own calculations.

Table 4 Forecasting the optimal parameters of agricultural insurance by the sum insured

Indicators of agricultural insurance		Calculation algorithm	Sum of squares of deviations	Direction of the curve
4.1	Total sum insured, thousand EUR	$y = 270.811 - \frac{99.648}{x}$	66242.14	growth
		$y = e^{5.4627 - 0.006612x}$	74268.47	falls
4.2	Average sum insured for 1 contract, thousand EUR	$y = 96.5426 + 51.1721 \cdot ln\,x$	21243.16	growth
		$y = 87.773444 \cdot x^{0.406012}$	23689.27	growth
		$y = 227.67 - \frac{166.74}{x}$	19793.25	growth
		$y = e^{4.6481 + 0.07999x}$	27549.20	growth
4.3	Average sum insured per 1 ha, EUR	$y = 422.666 - 14.206 \cdot x$	70264.51	falls
		$y = e^{6.033933 - 0.041933x}$	73940.38	falls
4.4	Average sum insured for 1 insurance company, billion EUR	$y = 24.697 - \frac{13.563}{x}$	1150.46	growth
		$y = 16.987 + 2.47444 \cdot ln\,x$	1248.20	growth
		$y = e^{2.845133 + 0.012848x}$	1340.25	growth

Source: authors' own calculations.

Table 5 Forecasting the optimal parameters of agricultural insurance by insurance premium

Indicators of agricultural insurance		Calculation algorithm	Sum of squares of deviations	Direction of the curve
5.1	Insurance premiums, billion EUR	$y =- 0.3304x + 9.44$	113.11	falls
		$y = e^{2.1068-0.033527x}$	120.34	falls
5.2	Average premium per 1 contract, thousand EUR	$y = -0.34112 + 3.7236 \cdot ln\,x$	63.37	growth
		$y = 3.1433023 \cdot x^{0.290529}$	31.50	growth
		$y = e^{1.29167+0.053151x}$	33.29	growth
5.3	Average premium per 1 ha, EUR	$y =- 0.6488x + 13.9287$	140.99	falls
		$y = e^{2.6043-0.063988x}$	149.77	falls
5.4	Average premium per 1 insurance company, billion EUR	$y = 739.305 - \frac{322.816}{x}$	1362320.15	growth
		$y = 614.543 + 20.001 \cdot ln\,x$	1432527.77	growth
		$y = e^{6.396267-0.013958x}$	1494849.37	falls

Source: authors' own calculations.

Table 6 Forecasting the optimal parameters of agricultural insurance by franchise

Indicators of agricultural insurance		Calculation algorithm	Sum of squares of deviations	Direction of the curve
6.1	Franchise, billion EUR	$y = e^{4.9742-0.080964x}$	25684.85	growth
		$y = 107.961 - \frac{10.053}{x}$	28646.36	growth
6.2	Franchise for 1 contract, thousand EUR	$y = 6350508 + 4.76041 \cdot ln\,x$	6181.93	growth
		$y = 53.157595 \cdot x^{0.143829}$	6564.83	growth
		$y = e^{4.1592+0.005691x}$	6557.86	growth
6.3	Franchise for 1 ha, EUR	$y =- 15.061x + 228.757$	24420.97	falls
		$y = e^{5.5246-0.118345x}$	29734.47	falls
6.4	Franchise for 1 insurance company, billion EUR	$y = 10.097 - \frac{3.526}{x}$	390.95	growth
		$y = 9.7226B - 0.435853 \cdot ln\,x$	398.63	falls
		$y = e^{2.355667-0.061358x}$	403.01	falls

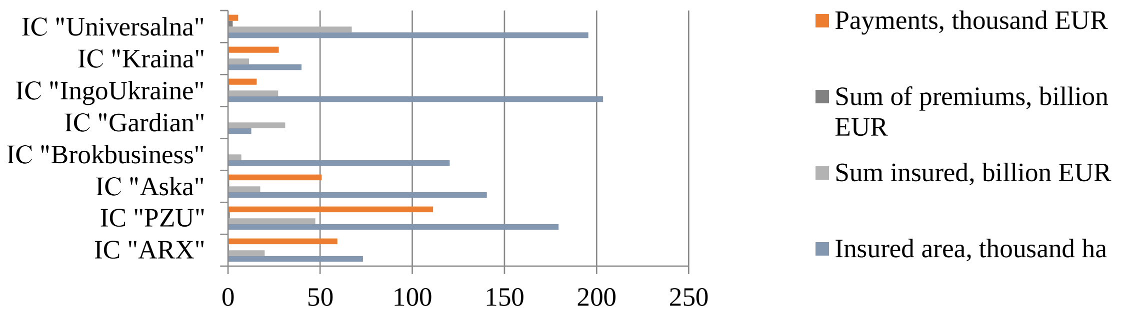
Source: authors' own calculations.

Thus, agricultural insurance provides financial protection against risky consequences that lead to loss. The cost of loss has a probabilistic variable, which is determined and reimbursed after the occurrence of the insured event.

4. Discussion

The effectiveness of insurance protection of agricultural producers in market conditions depends on the level of development of the economic system in general and the agricultural insurance system in particular. In agriculture in developed market economies, the insurance system is the main tool for preventing property risks and an integral part of the management mechanism. Thus, insurance in Ukraine covers only 5% crops, in Spain – to 80%, the USA – to 70%, the Canada – to 60% (Rubtsova, 2019). Despite the fact that Ukraine is an agricultural country and has great potential, the agricultural insurance industry has not yet acquired strategic importance, and therefore there is an urgent need to involve the domestic agricultural sector in agricultural insurance services. Only 25% of Ukrainian insurance companies have licensed conditions for voluntary insurance of agricultural products (Fig. 3).

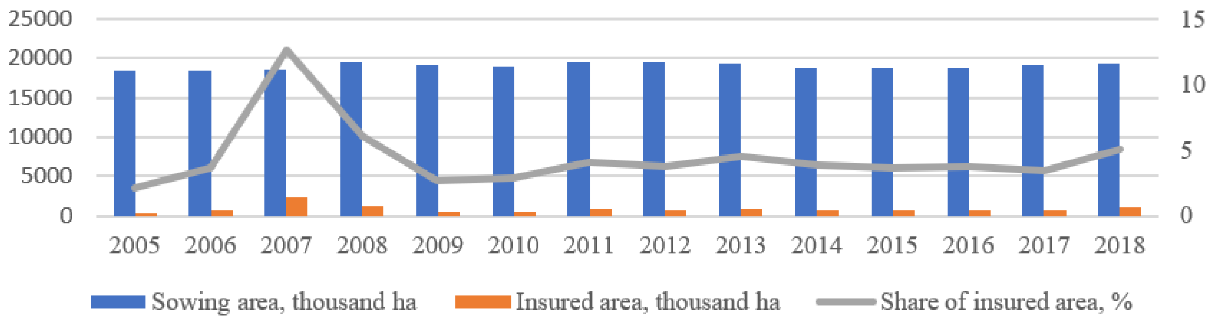
Figure 3 Volumes of voluntary agricultural insurance of agricultural products in Ukraine, 2018



Source: developed by the authors based on Dercon, 2002.

Continuity of agricultural production is violated by seasonality, a high degree of dependence of production on climatic conditions, low rates of technical and technological renewal, which leads to constant search for alternative sources of financial resources, which are insurance products. It should be noted that in 2010-2016 the share of concluded agricultural insurance contracts for risks of agricultural production was equal to 70.7% of the total insurance in Ukraine. In 2017-2018, farmers became more actively involved in government financing programs for agricultural producers, including the forward procurement program, which allowed to partially intensify the work of the agricultural insurance market and increase the number of contracts by 20.7% and 25.9% (Rubtsova, 2018; Saparbayev et al., 2020). Participation in government programs also increased the level of insurance coverage of agricultural land (to 5.04% in 2018), in 2009-2017 this share was only 2.5% (Fig. 4), while in European countries this figure exceeds 60-70%, in Cyprus and Israel it is equal to 100% (Trusova et al., 2020; Starychenko et al., 2021).

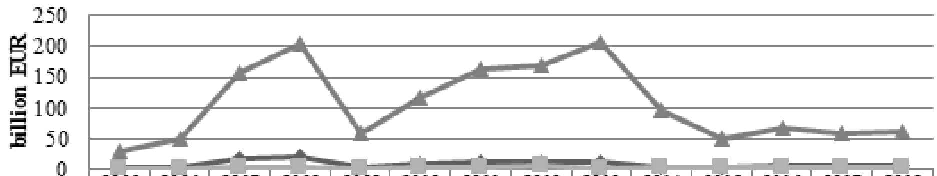
Figure 4 The share of insured areas in Ukraine, 2005-2018



Source: developed by the authors based on Collection "Ukraine-2018", 2019; Rubtsova et al., 2020.

The growth of public-private partnerships in Ukraine contributes to the growth of the agricultural insurance market, thus ensuring an increase in insurance premiums in the agricultural market. However, the level of agricultural insurance development in Ukraine is much lower than in the developed world; in particular, there is a low level of crop insurance, which reduces the effectiveness of risk and production costs, as well as optimizing the parameters of sufficient compensation in agriculture. It should be noted that when the number of concluded contracts decreases, the receipt of insurance premiums decreases (Fig. 5). The sharp decline in the performance of the agricultural insurance market in 2014-2015 is also associated with geopolitical changes in Ukraine, namely the annexation of the Autonomous Republic of Crimea and hostilities in the east of the country, as well as a sharp rise in the national currency (Mishchenko et al., 2021).

Figure 5 Dynamics of the agricultural insurance market in Ukraine by insurance premiums, insurance payments and franchise, billion EUR

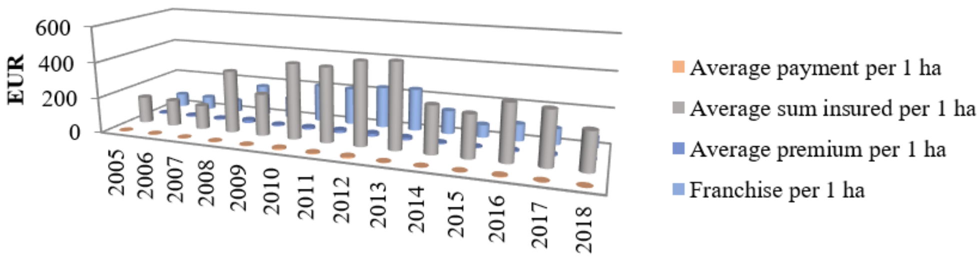


	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Insurance premiums	2.003	4.497	16.869	20.161	3.865	7.975	12.261	12.661	12.759	4.645	3.207	5.549	6.809	6.496
Insurance payments	0.435	1.291	2.648	2.48	1.41	4.062	3.433	5.191	1.238	3.53	4.14	2.453	3.34	2.73
Franchise	29.374	48.888	158.22	204.554	59.809	116.539	164.086	168.574	207.027	97.195	49.144	66.167	59.322	62.3

Source: developed by the authors based on Collection “Ukraine-2018”, 2019; Agricultural insurance, 2019.

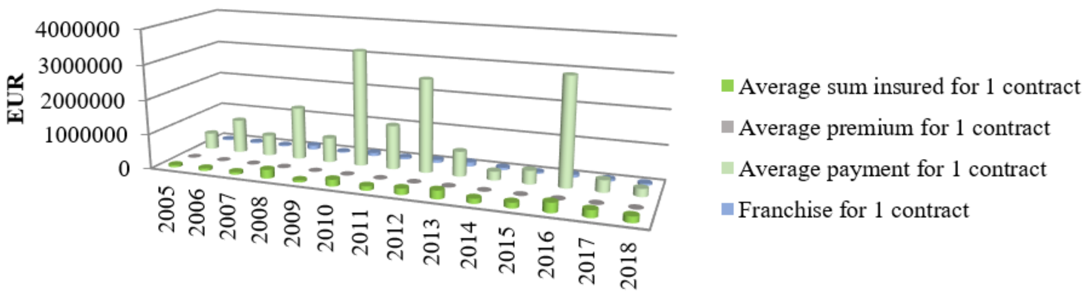
The negative trend in the functioning of the agricultural insurance market in 2011-2016 is caused by farmers' distrust of insurance companies, which forces them to minimize production risks by concluding credit agreements with the participation in state financing programs for agricultural producers (Diegtiar et al., 2020; Shtal et al., 2020). In 2018, one agricultural enterprise will have only 6.67 EUR per 1 ha of insured area when concluding an insurance contract for risks of agricultural production and – 213.18 EUR per 1 ha per table of insurance coverage (Figs. 6-8). At the same time, rapid climate change in Ukraine, increasingly abnormal hail tornadoes, powerful storms that cause damage to crops (just before harvest) encourage agricultural enterprises to turn to insurance services to minimize their risks of agricultural production.

Figure 6 The amount of agricultural insurance of 1 hectare of insured area in Ukraine, EUR



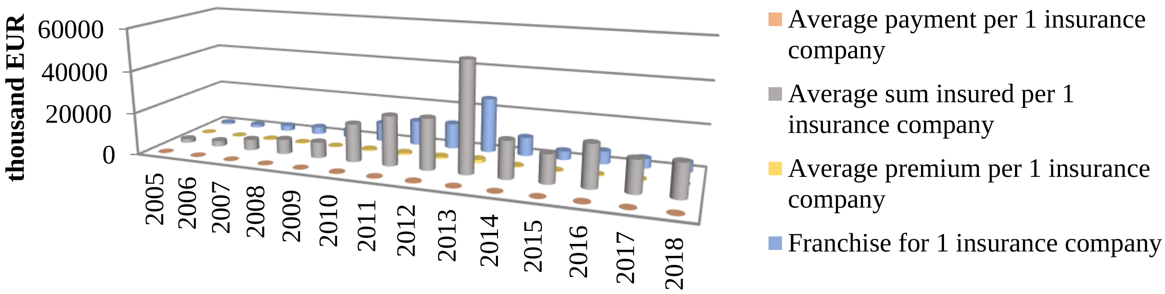
Source: developed by the authors.

Figure 7 The amount of agricultural insurance under the insurance contract risks of agricultural production in Ukraine, EUR



Source: developed by the authors.

Figure 8 The amount of insurance payment to compensate for the risks of agricultural production by insurance companies in Ukraine, thousand EUR



Source: developed by the authors.

The insurance market of Ukraine offers for farmers a program of comprehensive insurance of crops for the winter (provides for insurance of costs incurred by the farm for sowing and growing winter crops). Insurance is carried out during the elimination and damage of winter crops (i.e., the destruction of 50% (or more) of plants from their original density). The amount of insurance premium to be paid by the agricultural producer depends on the insurance rate, which ranges from 1.7% to 7%, the size of the franchise, the region and culture. In 2016-2018, the share of agro-insurance contracts for grain crops in total was 63.7-72.8%, insured areas – 76.3-81.0%, insurance premiums – 70.1-86.8% (Table 7).

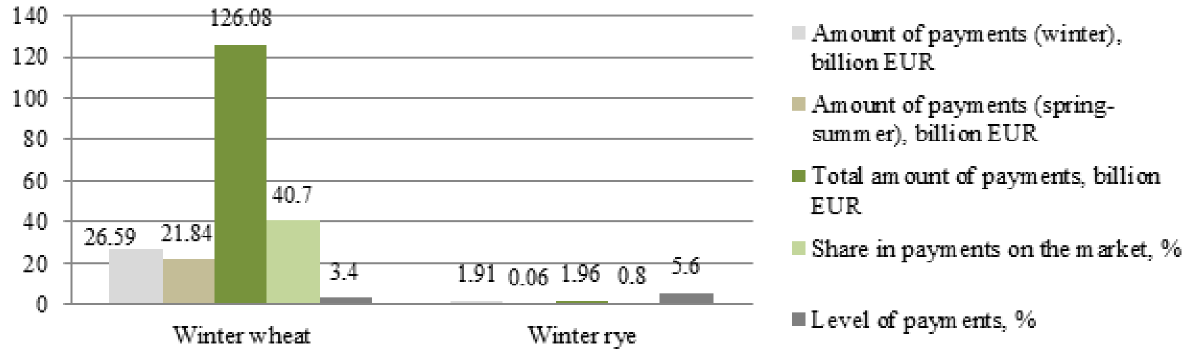
Table 7 Volumes of agricultural insurance of grain crops in Ukraine for 2016-2018

Crop	Number	Area, ha	Sum insured, billion EUR	The amount of premiums, thousand EUR	Average premium rate, %	The amount of premiums per hectare, EUR / ha	Sum insured per hectare, EUR / ha
2016							
Winter wheat	471	481065	98.86	3561.14	3.6%	7.39	205.48
Winter barley	18	7779	1.07	31.49	2.9%	4.07	137.50
Winter rye	9	1727	0.30	10.19	3.4%	5.91	172.64
Spring barley	11	2348	1.13	19.05	1.7%	8.13	479.92
Spring wheat	6	4825	3.21	74.90	2.3%	15.52	665.11
Corn	54	34529	18.56	149.03	0.8%	4.31	537.43
Buckwheat	8	2129	1.14	42.61	3.7%	20.01	534.18
2017							
Winter wheat	453	414538	104.77	3729.36	3.6%	9.0	252.73
Winter barley	24	9417	1.35	48.57	3.6%	5.17	142.93
Winter rye	20	5866	1.09	36.38	3.3%	6.20	185.83
Spring barley	13	3661	1.83	28.39	1.6%	7.77	499.43
Spring wheat	6	2841	0.78	17.91	2.3%	6.30	275.6
Corn	1	136	0.017	1.10	6.5%	8.07	123.87
Buckwheat	89	70209	50.99	2044.27	4.0%	29.13	726.4
2018							
Winter wheat	614	712106	118.57	4172.92	3.5%	5.85	166.49
Winter barley	40	8466	1.36	42.31	3.1%	5.01	161.08
Winter rye	13	2547	0.43	15.40	3.5%	6.04	170.41
Spring barley	8	6089	2.38	72.76	3.1%	11.95	391.67
Spring wheat	5	512	0.14	2.62	1.9%	5.13	267.08
Corn	114	59082	32.45	659.16	2.0%	11.17	549.19
Buckwheat	1	207	0.03	0.97	3.2%	4.70	147.01

Source: developed by the authors based on Collection "Ukraine-2018", 2019; Rubtsova et al., 2020.

Farmers pay special attention to the amount of compensation by insurance companies for losses as a result of insured events (Fig. 9).

Figure 9 Average indicators of insurance payments in Ukraine in terms of cereals for 2016-2018



Source: developed by the authors based on Collection "Ukraine-2018", 2019; Rubtsova et al., 2020.

The largest share in the total payments on the grain market is made by winter wheat insurance contracts (from 66.0% in 2016 to 17.1% in 2018). The second crop for which agricultural enterprises have received insurance compensation for the last two years is winter rye. The level of payments depends on the number of insured events that occurred during the term of the contract. In the countries of the European Union, it is formed within 40-60% and at catastrophic events (for example storms, floods, frosts, and droughts) can exceed 100%. Natural and climatic conditions in Ukraine are risky, but formal insurance contracts, with a high level of franchise, do not allow obtaining qualitative insurance coverage.

According to the results of indicative forecasting, empirical dependences of variables are obtained, which provide an approximation of 16 actuarial parameters of agricultural insurance risks of agricultural production (by the smallest sum of squares of deviations). The calculation sequence according to the formula (12) occurred 8 times, according to the fourth – 5 times, according to the second – 1 time, according to the third – 1 time and according to the seventh – 1 time. However, the graphical representation of the empirical data according to the formula (12) shows the inefficiency of its practical use, because in all cases it is a descending function, which increases the probability of obtaining a negative result.

Accordingly, to further approximate the results, the third formula (14), is used, which is the logical conclusion, i.e., it is an indicative parametric dependence, presented as exponents of values X, that cannot be negative, but only have a decreasing or increasing level. Comparing the 14 formula with formulas 15, 13 and 18 it was noted that the sum of the squares of the deviations is not significant; the error is only 10% deviations.

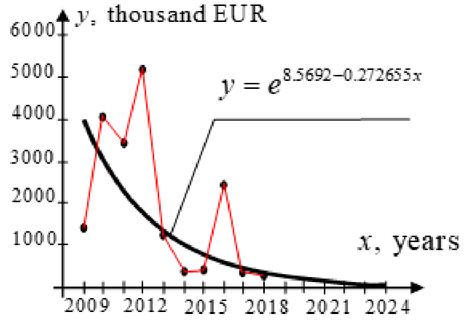
For compactness of record and unification, we will write down the calculation formula in the form (Afanasev and Yuzbashev, 2010; Burtniak and Malytska, 2019; Mykhailov et al., 2021; Koshkalda et al., 2021) (Eq. 21).

$$y = e^{A+Bx}, \tag{21}$$

where: A and B are the coefficients.

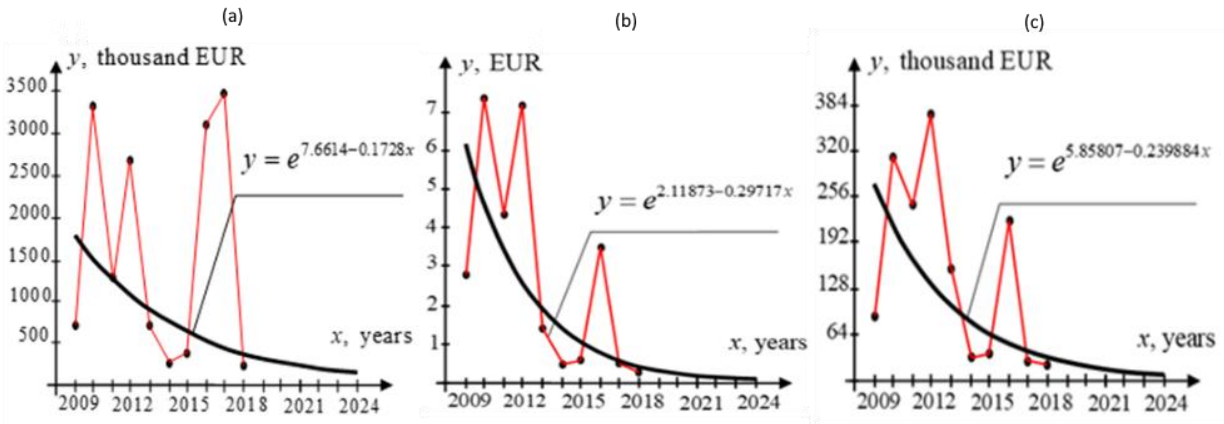
In the presented models of indicative forecasting of optimal parameters of agricultural insurance on the market of agricultural products of Ukraine – insurance payments and insurance premiums have a decreasing function, the sum insured and the franchise - dynamic fluctuations. The presentation of forecast actuarial calculations is shown in Fig. 10-17 in the order of their location in Table 3-6.

Figure 10 Insurance payments



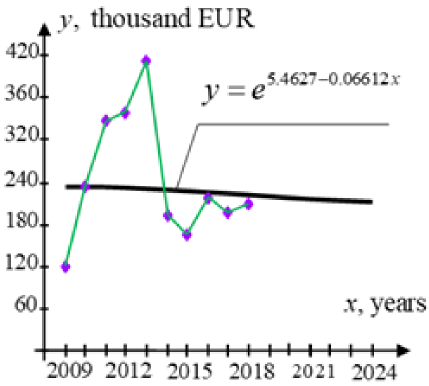
Source: calculated by authors.

Figure 11 Average payment for (a) 1 contract; (b) 1 ha; (c) 1 insurance company.



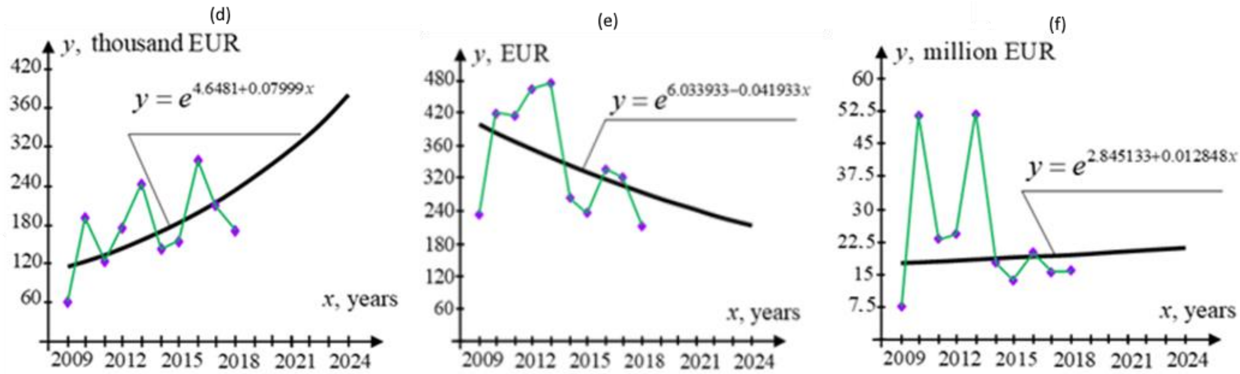
Source: calculated by authors.

Figure 12 Total sum insured



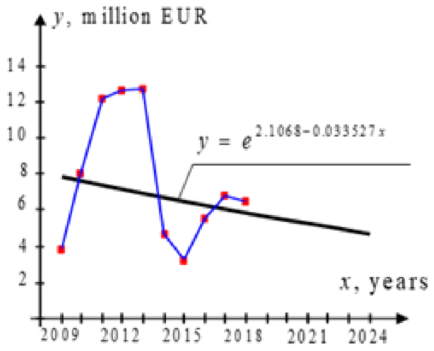
Source: calculated by authors.

Figure 13 Average sums insured for (d) 1 contract; (e)1 ha; (f) 1 insurance company.



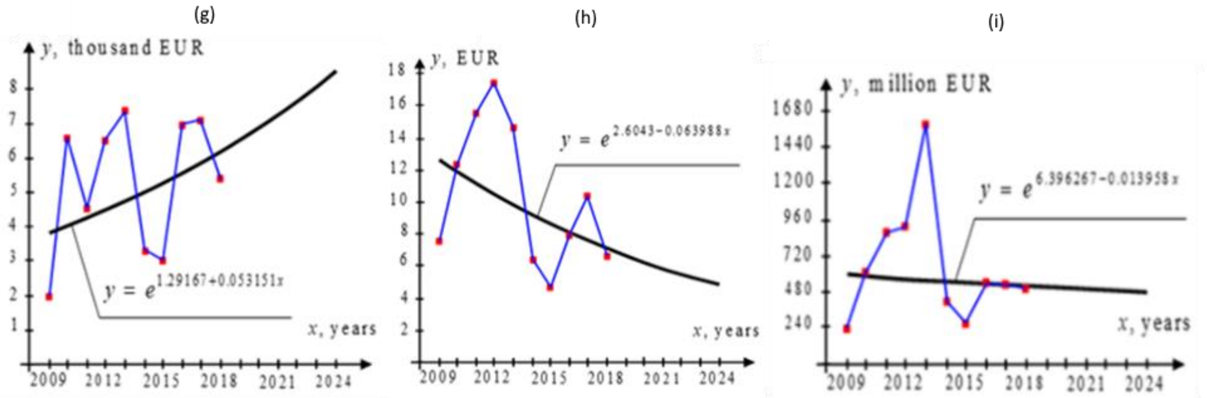
Source: calculated by authors.

Fig. 14 Insurance premiums



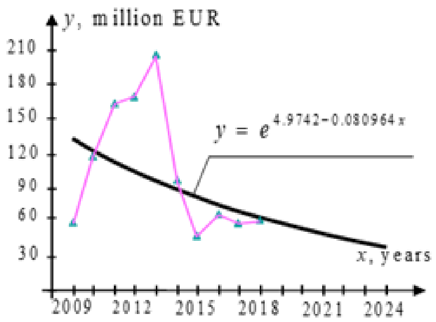
Source: calculated by authors.

Figure 15 Average premiums per (g) 1 contract; (h) 1 ha; (i) 1 insurance company.



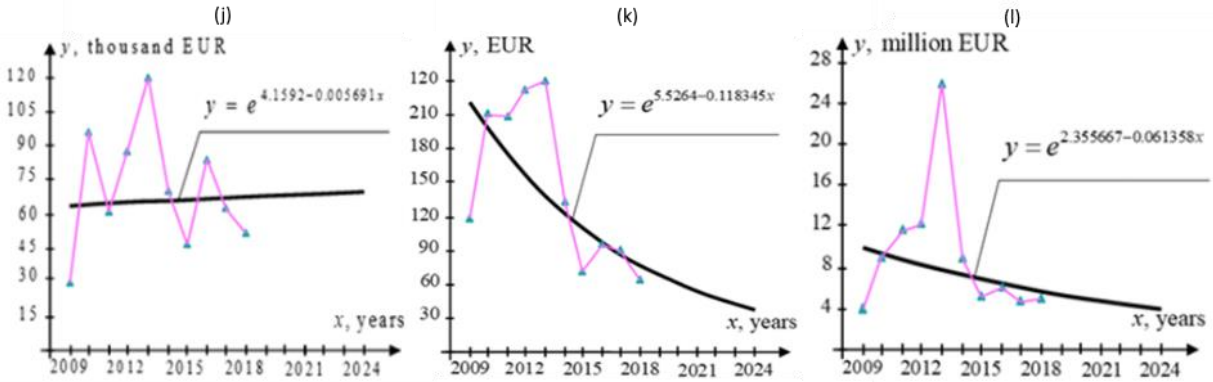
Source: calculated by authors.

Figure 16 Franchise



Source: calculated by authors.

Figure 17 Franchise for (j) 1 contract; (k) 1 ha; (l)1 insurance company.



Source: calculated by authors.

Thus, for the period 2019-2024, the optimization parameters of agricultural insurance risks of agricultural production in terms of total insurance amounts remain almost unchanged (Fig. 17), a similar trend is observed with declining volumes of insurance premiums (Fig. 21). This proves the correctness of the actuarial calculations to establish the optimal value of the insurance rate, in order to maintain the equivalence of the distribution of insurance compensation risks and costs of agricultural production between the participants in the process of agricultural insurance (Chkan, 2016). It should be noted that in agricultural insurance, an unconditional franchise is used, the amount of which ranges from 0 to 50%. The 50% franchise is fictitious, as its use hardly covers the insurance losses received by the agricultural producer. The high level of franchise significantly reduces the amount of compensation, so when concluding agricultural insurance, a contract under forward contracts in Ukraine, a standard unconditional franchise is used – 30%. According to forecast calculations, the size of the franchise in monetary terms will decrease (Fig. 25), which will allow agricultural enterprises to receive insurance compensation in a larger amount.

However, the dynamics of insurance payments shows the opposite trend - their value will decrease and in 2024 will be 67.14 thousand EUR (Fig. 10). After all, the amount of insurance payments depends not only on the size of the franchise, but also on climatic conditions and on many anthropogenic factors. Indeed, the behavior of farmers to ensure production is significantly determined by the risk of climate change. Therefore, the use of effective preventive measures in production, if possible, to finance the effects of climate risks without stopping the production process will allow the introduction of new technologies in the production process in order to obtain qualitative insurance services. Thanks to the incoming information flow in real time about the latest technologies of insurance services, it is possible to timely prevent and compensate the financial losses in the overall technological cycle of agricultural production

5. Conclusion

Thus, the processes of optimizing the parameters of agricultural insurance of agricultural products are not accidental and depend on many natural and anthropogenic factors. Reproductive production process in terms of future prevention of financial losses and damages has errors and inaccuracies in the calculation of their assessment. So, the growing trend of agricultural insurance of agricultural products brings the results of economic activity of agricultural entities (with increasing information flow) to the direct dependence of their variables on the amount of insurance payments and tariffs in the near future forecasting. Changing the parameters of agricultural insurance does not require a new justification of the method, because the selected dependencies are universal and their values are not directed to infinity and cannot be equal to zero.

At the present stage of agricultural development in Ukraine, it is necessary to use innovation in the system of agricultural insurance of grain crops, including robotics, index insurance, precision agriculture and innovative insurance products. Agricultural insurance with a methodological and practical approach can already be a reliable protection for agricultural business and profitable for insurance companies. The potential of this type of insurance is quite significant, as the agricultural business itself is developing rapidly and contains many risks. The development of innovative agricultural insurance will contribute to the continuous, balanced and stable development of the agricultural market and the financial stability of economic entities in the world.

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