Check for updates
DOI: https://doi.org/10.34069/AI/2024.74.02.21
How to Cite:
Gazuda, S., Erfan, V., Gazuda, M., Hertseh, V., & Zavadska, O. (2024). Modeling the impact of the agricultural sector on the development of the regional economic systems. *Amazonia Investiga*, *13*(74), 248-263. https://doi.org/10.34069/AI/2024.74.02.21

Modeling the impact of the agricultural sector on the development of the regional economic systems

Modelando el impacto del sector agrícola en el desarrollo de los sistemas económicos regionales

Received: January 4, 2024 Accepted: February 21, 2024

Written by:
Serhii Gazuda[1]
https://orcid.org/0000-0001-8148-6783
Vitalii Erfan[2]
https://orcid.org/0000-0002-8580-378X
Mykhailo Gazuda[3]
https://orcid.org/0000-0003-3947-5997
Viktoriia Hertseh[4]
https://orcid.org/0000-0003-4613-2829
Olena Zavadska[5]
https://orcid.org/0000-0001-8786-9005

Abstract

The purpose of the article is to study the role of the agricultural sector in the development of regional economic systems. The article uses general scientific and specific research methods, including: abstraction, analysis and synthesis, generalization, statistical and comparative analysis, dialectical and graphic. Within the framework of the study, it is proposed to investigate the impact of the agricultural sector on the regions' development using the correlation-regression analysis method. The use of the specified methodology made it possible to simulate the regularity of the influence of the volume of agricultural products sold on the gross regional product.

The authors investigated the challenges faced by the agricultural sector since the full-scale invasion of Russia on the territory of Ukraine, among which the following are highlighted: the danger of the farmers' work, limited access to land plots, equipment, fuel and fertilizers,

Resumen

El propósito del artículo es estudiar el papel del sector agrícola en el desarrollo de los sistemas económicos regionales. El artículo utiliza métodos de investigación científicos generales y específicos, que incluyen: abstracción, análisis y síntesis, generalización, análisis estadístico y comparativo, dialéctico y gráfico. En el marco del estudio, se propone investigar el impacto del sector agrícola en el desarrollo de las regiones utilizando el método de análisis de correlación-regresión. El uso de esta metodología permitió simular la regularidad de la influencia del volumen de productos agrícolas vendidos sobre el producto regional bruto.

Los autores investigaron los desafíos que enfrenta el sector agrícola desde la invasión a gran escala de Rusia en el territorio de Ucrania, entre los que se destacan: el peligro del trabajo de los agricultores, el acceso limitado a terrenos, equipos, combustible y fertilizantes. , campos minados de tierras agrícolas, disminución de las cosechas, pérdidas

[1] PhD in Economics, Associate Professor, Department of Economics, Entrepreneurship and Trade, Uzhhorod National University, Uzhhorod, Ukraine.
[2] PhD in Economics, Associate Professor, Department of Economics, Entrepreneurship and Trade, Uzhhorod National University, Uzhhorod, Ukraine.
[3] Doctor of Economics, Professor, Department of Economics, Entrepreneurship and Trade, Uzhhorod National University, Uzhhorod, Ukraine.
[4] PhD in Economics, Senior Lecturer, Transcarpathia Institute of Postgraduate Pedagogical Education, Uzhhorod, Ukraine.
[5] PhD in Economics, Associate Professor, Department of Entrepreneurship, Trade and Logistics, Lutsk National Technical University, Lutsk, Ukraine.

minefields of agricultural land, crop decline, significant economic losses, insufficient resources, destroyed or damaged agricultural enterprises. The share of regions in agricultural production was analyzed, the leader and the outsider regions were distinguished. The study analyzed the impact of the agricultural sector on the development of the Carpathian Economic Region of Ukraine, which includes the Lviv, Chernivtsi, Transcarpathian and Ivano-Frankivsk regions. The results of the study demonstrate a significant relationship between the parameters of the volume of agricultural products sold and the gross regional product in Lviv (0.8801), Chernivtsi (0.8962), Transcarpathian (0.9674) and Ivano-Frankivsk (0.8985) regions. Also, the results of the calculations prove that the defined regression model is significant and corresponds as closely as possible to the real functioning model for all four regions.

Keywords: agricultural sector, agriculture, agricultural business, region, regional economic system, branding of agricultural regions.

económicas importantes, recursos insuficientes, empresas agrícolas destruidas o dañadas. Se analizó la participación de las regiones en la producción agrícola y se distinguieron las regiones líderes y las marginadas. El estudio analizó el impacto del sector agrícola en el desarrollo de la región económica de los Cárpatos de Ucrania, que incluye las regiones de Lviv, Chernivtsi, Transcarpacia e Ivano-Frankivsk. Los resultados del estudio demuestran una relación significativa entre los parámetros del volumen de productos agrícolas vendidos y el producto regional bruto en las regiones de Lviv (0,8801), Chernivtsi (0,8962), Transcarpacia (0,9674) e Ivano-Frankivsk (0,8985). Además, los resultados de los cálculos demuestran que el modelo de regresión definido es significativo y se corresponde lo más fielmente posible al modelo de funcionamiento real para las cuatro regiones

Palabras clave: sector agrícola, agricultura, empresas agrícolas, región, sistema económico regional, marca de regiones agrícolas.

Introduction

The agricultural sector plays a significant role in the development of Ukraine's economy and its regions. There are regions in which the agricultural sector is developing so rapidly and successfully that it creates a regional brand. Ukraine provides not only the domestic market with food products, but also demonstrates successful exports in this direction. It should be noted that the agricultural sector is the main source of employment for the rural population and contributes to the development of rural areas. The agricultural sector has a positive impact on the health of the population due to the production of environmentally friendly products. The majority of modern agricultural enterprises implement innovative technologies, which contribute to increasing the efficiency of management, reducing costs and increasing the yield of crops. This increases the competitiveness of the Ukrainian agricultural sector on the world market. However, since the full-scale invasion of Russia on the territory of Ukraine, the agricultural sector has faced numerous challenges and extremely difficult operating conditions. Among the main problems, it is appropriate to single out: dangerous of farmers' work, limited access to land plots, equipment, fuel and fertilizers, minefields of agricultural lands, reduced harvest, significant economic losses, insufficient resources, destroyed or damaged agricultural enterprises, etc. However, despite the listed problems, agricultural enterprises, due to the support of international partners, are trying to function and provide the population with high-quality and affordable products. This once again proves the important role of the agricultural sector in the economy of the country and its regions.

The purpose of the article is to study the role of the agricultural sector in the regional economic systems' development.

Literature review

Many domestic and foreign scientists' study various aspects of agriculture development. Let's consider some of them. The potential of agriculture in contributing to the integrated development of the regional rural economy was analyzed within the scope of the study (Loizou Efstratios et al., 2019). Scientists prove the importance of agriculture and its significant role in the economic growth of the region. The results of the authors' research in four mountain regions of Switzerland (Flury et al., 2008) demonstrate the importance of agriculture in the regional economy. The article proves that the role of agriculture is determined not only by direct employment and created added value, but also by its impact on the rest of the economy. In support of study (Bansah et al., 2023), it is pertinent to note that small-scale agriculture is largely rain-fed, and erratic rainfall and rising

temperatures significantly affect crop production and farmers' incomes.

The authors' study (Pradeleix et al., 2023) analyzed the potential impact of irrigated farming systems on the environment. The authors assessed the impact of the agricultural region under current conditions, and considered two perspective scenarios. According to the authors (Wanghai et al., 2023), agricultural production depends on a variety of natural conditions in the arid areas of northwest China. The authors note the lack of coordination between agricultural production and the ecological environment as one of the urgent problems. Scientists have studied the peculiarities of the development of modern agriculture with the aim of balancing ecological constraints and efficient use of resources. Scientific work (Cervelli et al., 2023) is devoted to the study of the analysis of spatial policy and purposeful processes of landscape planning and land use in the context of the development of the agricultural sector. The authors of the article offer approaches to landscape planning and modern solutions to environmental problems. Within the framework of article (Aidat et al., 2023), the system of greenhouse production, its significant advantages for production in terms of quality and quantity, creating a very important socio-economic dynamic in the respective regions, is investigated. According to the authors (Sutradhar et al., 2023), assessment of regional differences and recognition of underdeveloped areas are an important aspect of achieving sustainable regional development in agriculture. Scientists evaluate the spatial distribution of agricultural development and investigate the factors responsible for this variability.

Article (Verma et al., 2023) argues that agriculture, forestry and other land use is one of the most important sectors for food security. To reduce greenhouse gas emissions in the agricultural sector, the authors of the study propose to develop cost-effective mitigation strategies and adaptation measures through investments for adequate land and environmental management.

The result of the article (Zhang et al., 2023) is to prove that the green development of agriculture and rural areas and economic growth are the main challenges that are common in developing countries. According to the authors, in the future it is vital to promote the transformation of the agricultural sector, while reducing the risk of deterioration of the coordinated relationship with economic growth. The main goal of the article (Zafeiriou et al., 2023) is to investigate the relationship between the use of pesticides in agriculture per hectare of arable land and GDP per capita in rural areas for twenty-five EU countries. The authors are convinced that it is advisable to take measures related to the education of farmers, which will contribute to increasing their awareness of environmental issues. Fully supporting the results of research (Muhammedov et al., 2023; Butko et al., 2019), we would like to note that the role of agriculture in ensuring food security, as well as creating jobs and generating income from exports makes the analysis of the impact of this industry on the socio-economic development of the country particularly relevant. The authors are convinced that effective management of resources, productivity improvement, creation of new jobs, product promotion and production expansion are important areas of the future development of the agricultural sector.

However, despite significant results in this direction of research, the issue of economic and mathematical modeling of the impact of agriculture on the Ukraine's regions development requires further research and analysis.

Methodology

The article uses general scientific and specific research methods, including: abstraction, analysis and synthesis, generalization, statistical and comparative analysis, dialectical and graphic. Within the framework of the study, it is proposed to investigate the impact of the agricultural sector on the regions' development using the method of correlation and regression analysis. The use of the specified methodology will allow modeling the regularity of the impact of the volume of agricultural products sold on the gross regional product. Based on the analysis of the available statistical information, it should be noted that the outlined influence at the regional level can be described using the construction of one-factor models, and for their accuracy we consider it appropriate to use the cubic type. The stages of calculations are presented in Fig. 1.

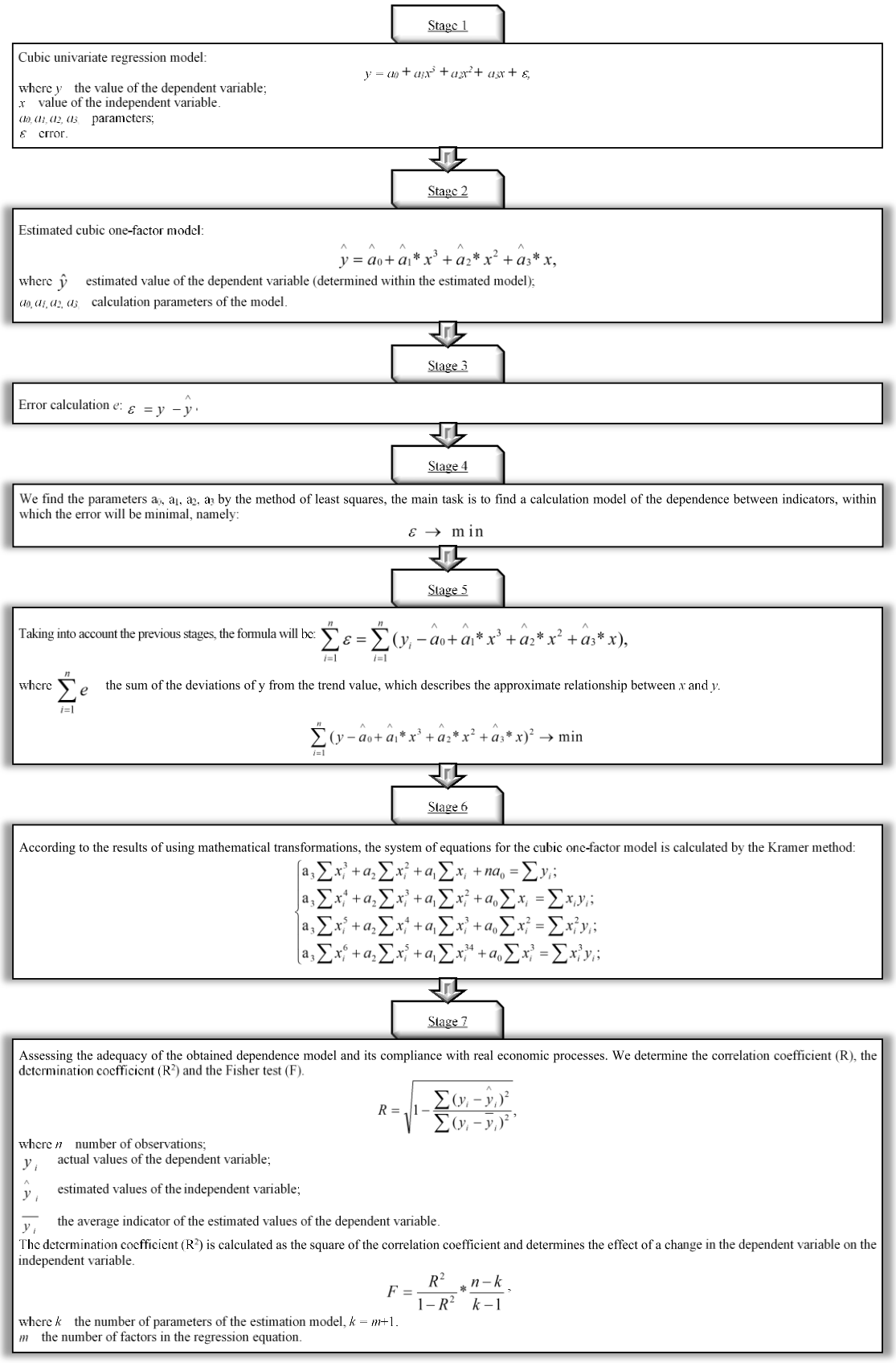

Figure 1. Stages of implementation of economic and mathematical modeling of the impact of agriculture on the regions development.
Source: systematized by the authors.

So, the specified methods and the presented phasing of the scientific research made it possible to analyze the development of the agricultural sector and investigate the impact on the regional economic systems' development.

Results and discussion

The agricultural sector has a great impact on the regional economy, providing a significant share of the country's gross domestic product and export potential. The cultivation of various agricultural products in Ukraine allows to provide the population with high-quality and affordable food products and contributes to ensuring the country's food security. If we analyze the share of regions in agricultural production, the leading regions include Vinnytsia (8.3%), Dnipropetrovsk (6.2%), Poltava (5.9%), Kyiv (5.7%), Khmelnytsky (5.6%), Kirovograd and Kharkiv (5.2%) regions. The regions with the smallest share in agricultural production are: Transcarpathian (1.1%), Chernivtsi (1.6%), Luhansk (1.9%) and Ivano-Frankivsk (2.0%) regions (Fig. 2).

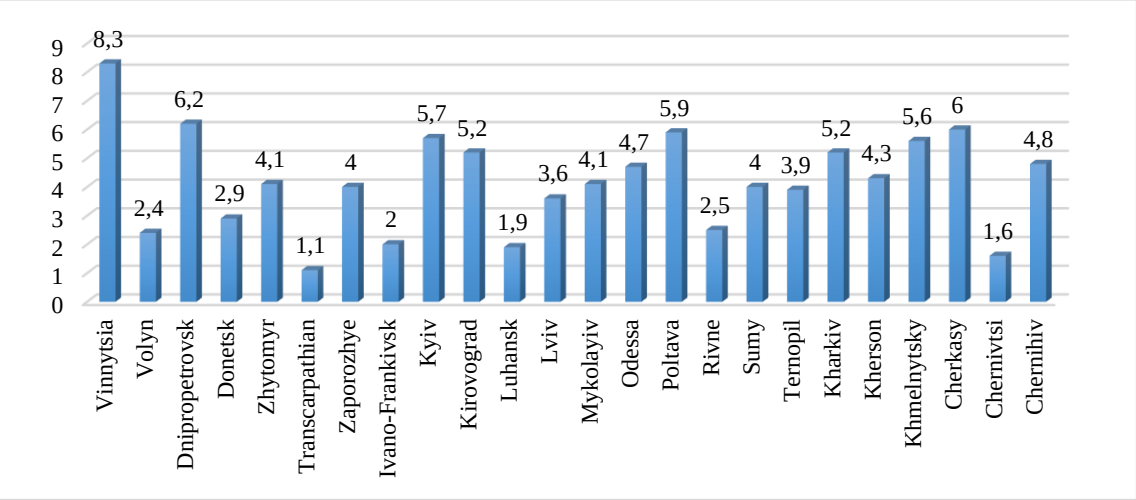

Figure 2. Share of regions in the agricultural production.
Source: calculated on the basis (State Statistical Service of Ukraine).

Within the framework of the study, we analyze the impact of the agricultural sector on the development of the Carpathian Economic Region of Ukraine, which includes the Lviv, Chernivtsi, Transcarpathian and Ivano-Frankivsk regions. The initial data for calculations, namely the volume of the gross regional product (GRP) and the volume of realized agricultural products (AP) for the period 2012-2021 are given in the Table 1.

Table 1.
Dynamics of the gross regional product and the volume of agricultural products sold in the Carpathian Economic Region.

Year	**Chernivtsi region**		**Transcarpathian region**		**Ivano-Frankivsk region**		**Lviv region**	
	GRP, mln $	AP, mln $	GRP, mln $	AP, mln $	GRP, mln $	AP, mln $	GRP, mln $	AP, mln $
2012	1633.5	169.6	2655.6	329.5	4005.7	250.9	7687.6	357.7
2013	1685.9	142.3	2622.5	321.4	4068.1	266.5	7760.9	393.0
2014	1753.9	191.5	2811.2	327.7	4387.3	399.7	8499.2	755.6
2015	1107.5	135.9	1732.6	103.7	2744.1	263.7	5666.7	447.0
2016	558.2	45.0	851.2	22.4	1350.9	100.7	3018.2	157.9
2017	820.1	61.7	1234.9	35.4	1830.9	159.5	4226.9	241.1
2018	849.9	58.8	1314.7	32.9	1966.4	150.4	4443.0	284.5
2019	1135.5	59.4	1671.4	45.6	2362.5	171.1	5843.6	316.9
2020	1369.4	104.5	1885.2	57.3	2747.7	222.7	7180.9	368.4
2021	1406.4	76.7	1948.6	50.2	3083.7	176.9	7641.6	417.3

Source: calculated on the basis (State Statistical Service of Ukraine (n/f)).

The analysis of the impact of the volume of agricultural products sold on the gross regional product for the Lviv region is carried out as follows. The value of auxiliary values necessary for calculations is presented in the Table 2.

Table 2.
Results of calculations of auxiliary values (Lviv region)

i	x_i	y_i	x_i^2	x_i^3	x_i^4	x_i^5	x_i^6	x_iy_i	$x_i^2y_i$	$x_i^3y_i$
1	358	7688	128164	45882712	16426010896	5880511900768	2105223260474944	2752304	985324832	352746289856
2	393	7761	154449	60698457	23854493601	9374815985193	3684302682180849	3050073	1198678689	471080724777
3	756	8499	571536	432081216	326653399296	246949969867776	186694177220038660	6425244	4857484464	3672258254784
4	447	5667	199809	89314623	39923636481	17845865507007	7977101881632129	2533149	1132317603	506145968541
5	160	3018	25600	4096000	655360000	104857600000	16777216000000	482880	77260800	12361728000
6	241	4227	58081	13997521	3373402561	812990017201	195930594145441	1018707	245508387	59167521267
7	285	4443	81225	23149125	6597500625	1880287678125	535881988265625	1266255	360882675	102851562375
8	317	5844	100489	31855013	10098039121	3201078401357	1014741853230169.1	1852548	587257716	186160695972
9	368	7181	135424	49836032	18339659776	6748994797568	24836300855505024	2642608	972479744	357872545792
10	417	7632	173889	72511713	30237384321	12608989261857	5257948522194369	3182544	1327120848	553409393616
∑	3742	61960	1628666	823422412	476158886678	305408361016852	209965715303667230	25206312	11744315758	6274054684980

Source: calculated by the authors

$$\begin{cases} a\sum x_i^3 + b\sum x_i^2 + c\sum x_i + nd = \sum y_i; \\ a\sum x_i^4 + b\sum x_i^3 + c\sum x_i^2 + d\sum x_i = \sum x_i y_i; \\ a\sum x_i^5 + b\sum x_i^4 + c\sum x_i^3 + d\sum x_i^2 = \sum x_i^2 y_i; \\ a\sum x_i^6 + b\sum x_i^5 + c\sum x_i^4 + d\sum x_i^3 = \sum x_i^3 y_i. \end{cases} \Leftrightarrow$$

$$\Leftrightarrow \begin{cases} 823422412a + 1628666b + 3742c + 10d = 61960, \\ 476158886678a + 823422412b + 1628666c + 3742d = 25206312, \\ 305408361016852a + 476158886678b + 823422412c + 1628666ci = 11744315758, \\ 209965715303667230a + 305408361016852b + 476158886678c + 823422412d = 6274054684980. \end{cases}$$

$$\Delta = \begin{vmatrix} 823422412 & 1628666 & 3742 & 10 \\ 476158886678 & 823422412 & 1628666 & 3742 \\ 305408361016852 & 476158886678 & 823422412 & 1628666 \\ 209965715303667230 & 305408361016852 & 476158886678 & 823422412 \end{vmatrix} = 2,3059383239206676e + 30;$$

Solving the system of linear equations by Kramer's method:

$$\Delta a = \begin{vmatrix} 61960 & 1628666 & 3742 & 10 \\ 25206312 & 823422412 & 1628666 & 3742 \\ 11744315758 & 476158886678 & 823422412 & 1628666 \\ 6274054684980 & 305408361016852 & 476158886678 & 823422412 \end{vmatrix} = 1,0533228241132923e + 26 \Rightarrow$$

$$\Rightarrow a = \frac{\Delta a}{\Delta} = \frac{1,0533228241132923e + 26}{2,3059383239206676e + 30} \approx 0;$$

$$\Delta b = \begin{vmatrix} 823422412 & 61960 & 3742 & 10 \\ 476158886678 & 25206312 & 1628666 & 3742 \\ 305408361016852 & 11744315758 & 823422412 & 1628666 \\ 209965715303667230 & 6274054684980 & 476158886678 & 823422412 \end{vmatrix} = -1,9293163646730278e + 29 \Rightarrow$$

$$\Rightarrow b = \frac{\Delta b}{\Delta} = \frac{-1,9293163646730278e + 29}{2,3059383239206676e + 30} \approx -0,0837;$$

$$\Delta c = \begin{vmatrix} 823422412 & 1628666 & 61960 & 10 \\ 476158886678 & 823422412 & 25206312 & 3742 \\ 305408361016852 & 476158886678 & 11744315758 & 1628666 \\ 209965715303667230 & 305408361016852 & 6274054684980 & 823422412 \end{vmatrix} = 1,2365180089518777e+32 \Rightarrow$$

$$\Rightarrow c = \frac{\Delta c}{\Delta} = \frac{1,2365180089518777e+32}{2,3059383239206676e+30} \approx 53,6232;$$

$$\Delta d = \begin{vmatrix} 823422412 & 1628666 & 3742 & 61960 \\ 476158886678 & 823422412 & 1628666 & 25206312 \\ 305408361016852 & 476158886678 & 823422412 & 11744315758 \\ 209965715303667230 & 305408361016852 & 476158886678 & 6274054684980 \end{vmatrix} = -9,23408658055352e+33 \Rightarrow$$

$$\Rightarrow d = \frac{\Delta d}{\Delta} = \frac{-9,23408658055352e+33}{2,3059383239206676e+30} \approx -4004,4812.$$

So, the cubic one-factor regression equation, which describes the influence of the volume of agricultural products sold on the gross regional product (GRP) of the Lviv region, will be:

GRP= – 0.0837AP2 + 53.6232AP – 4004.4812,
GRP – gross regional product of Lviv region;
AP - volume of agricultural products sold in Lviv region.

Fig. 3 shows the dependence between two indicators, namely the influence of the volume of agricultural products sold on the gross regional product of the Lviv region.

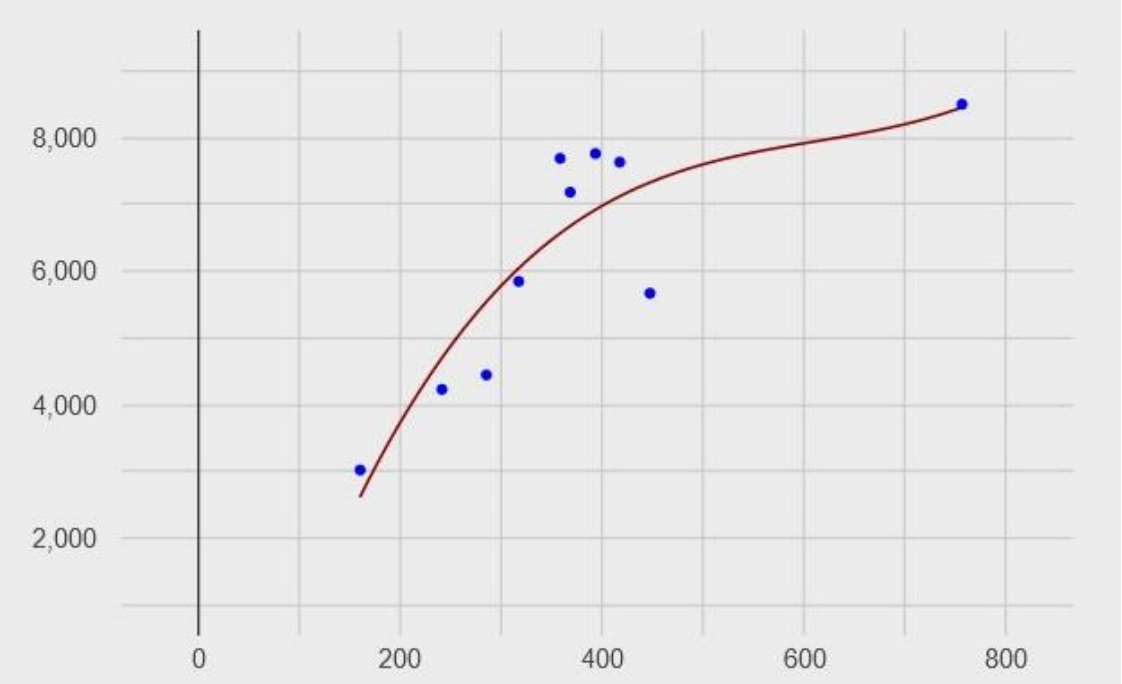

Figure 3. Graphic representation of the influence of the volume of agricultural products sold on the gross regional product of the Lviv region.
Source: developed by the authors.

Table 3.
The value of auxiliary values for evaluating the significance of correlation parameters (Lviv region)

i	i	x_i	y_i	$\hat{y}$	$x_i-\bar{x}$	$(x_i-\bar{x})^2$	ε_i	ε_i^2	A_i	$\Delta\varepsilon_i$
1	358	7688	6565,3528	1492	2226064	1122,6472	1260336,7061	0,146	—	—
2	393	7761	6919,734	1565	2449225	841,266	707728,4512	0,1084	-281,3812	79175,3829
3	756	8499	8452,6978	2303	5303809	46,3022	2143,8942	0,0054	-794,9638	631967,4046
4	447	5667	7327,3877	-529	279841	-1660,3877	2756887,3868	0,293	-1706,6899	2912790,5085
5	160	3018	2620,4485	-3178	10099684	397,5515	158047,169	0,1317	2057,9392	4235113,7054
6	241	4227	4698,6191	-1969	3876961	-471,6191	222424,592	0,1116	-869,1706	755457,5051
7	285	4443	5539,6775	-1753	3073009	-1096,6775	1202701,563	0,2468	-625,0584	390697,9952
8	317	5844	6041,5269	-352	123904	-197,5269	39016,8588	0,0338	899,1507	808471,9006
9	368	7181	6674,7428	985	970225	506,2572	256296,3596	0,0705	703,7841	495312,007
10	417	7632	7119,8128	1436	2062096	512,1872	262335,6851	0,0671	5,93	35,1643
∑	—	—	—	—	30464818	—	6867918,6658	1,2144	—	10309021,5735

Source: calculated by the authors

The correlation coefficient:

$$R=\sqrt{1-\frac{\sum(y_i-y_i)^2}{\sum(y_i-\bar{y})^2}}=\sqrt{1-\frac{6867918,6658}{30464818}}$$

The determination coefficient:

$$R^2=0,8801^2\approx 0,7746.$$

Fisher's F-test:

– critical (tabular)

$$F_{tabl}=F(a,k_1,k_2)=F(0,05,3,6)\approx 4,7571.$$

– factual $F_{fact}=\frac{R^2}{1-R^2}\cdot\frac{k_2}{k_1}=\frac{0,7746}{1-0,7746}\cdot\frac{6}{3}\approx 6,8716.$

where k_1 = m = 3, k_2 = n – m – 1 = 12– 3 – 1 = 8, (a=0.05)
m – the number of parameters in the variables of the regression equation.

Next, for the analysis of the influence of the volume of agricultural products sold on the gross regional product, we take the Chernivtsi region.

The value of the auxiliary values necessary for calculations is presented in Table 4.

Table 4.
Results of calculations of auxiliary values (Chernivtsi region)

	i	x_i	y_i	x_i^2	x_i^3	x_i^4	x_i^5	x_i^6	x_iy_i	$x_i^2y_i$	$x_i^3y_i$
1	169	1634	28561	4826809	815730721	137858491849	23298085122481	276146	46668674	7887005906
2	142	1686	20164	2863288	406586896	57735339232	8198418170944	239412	33996504	4827503568
3	191	1754	36481	6967871	1330863361	254194901951	48551226272641	335014	63987674	12221645734
4	136	1108	18496	2515456	342102016	46525874176	6327518887936	150688	20493568	2787125248
5	45	558	2025	91125	4100625	184528125	8303765625	25110	1129950	50847750
6	62	820	3844	238328	14776336	916132832	56800235584	50840	3152080	195428960
7	59	850	3481	205379	12117361	714924299	42180533641	50150	2958850	174572150
8	59	1136	3481	205379	12117361	714924299	42180533641	67024	3954416	233310544
9	105	1369	11025	1157625	121550625	12762815625	1340095640625	143745	15093225	1584788625
10	77	1406	5929	456533	35153041	2706784157	208422380089	108262	8336174	641885398
∑	1045	12321	133487	19527793	3095098343	514314716545	88073231543207	1446391	199771115	30604113883

Source: calculated by the authors

$$\begin{cases} a\sum x_i^3+b\sum x_i^2+c\sum x_i+nd=\sum y_i;\\ a\sum x_i^4+b\sum x_i^3+c\sum x_i^2+d\sum x_i=\sum x_iy_i;\\ a\sum x_i^5+b\sum x_i^4+c\sum x_i^3+d\sum x_i^2=\sum x_i^2y_i;\\ a\sum x_i^6+b\sum x_i^5+c\sum x_i^4+d\sum x_i^3=\sum x_i^3y_i. \end{cases}\Leftrightarrow$$

$$\Leftrightarrow\begin{cases} 19527793a+133487b+1045c+10d=12321;\\ 3095098343a+19527793b+133487c+1045d=1446391;\\ 514314716545a+3095098343b+19527793c+133487d=199771115;\\ 88073231543207a+514314716545b+3095098343c+19527793d=30604113883. \end{cases}$$

Solving the system of linear equations by Kramer's method:

$$\Delta = \begin{vmatrix} 19527793 & 133487 & 1045 & 10 \\ 3095098343 & 19527793 & 133487 & 1045 \\ 514314716545 & 3095098343 & 19527793 & 133487 \\ 88073231543207 & 514314716545 & 3095098343 & 19527793 \end{vmatrix} = 3,814277662511121e+23;$$

$$\Delta a = \begin{vmatrix} 12321 & 133487 & 1045 & 10 \\ 1446391 & 19527793 & 133487 & 1045 \\ 199771115 & 3095098343 & 19527793 & 133487 \\ 30604113883 & 514314716545 & 3095098343 & 19527793 \end{vmatrix} = 565339319481689240000 \Rightarrow$$

$$\Rightarrow a = \frac{\Delta a}{\Delta} = \frac{565339319481689240000}{3,814277662511121e\ +\ 23} \approx 0,0015;$$

$$\Delta b = \begin{vmatrix} 19527793 & 12321 & 1045 & 10 \\ 3095098343 & 1446391 & 133487 & 1045 \\ 514314716545 & 199771115 & 19527793 & 133487 \\ 88073231543207 & 30604113883 & 3095098343 & 19527793 \end{vmatrix} = 2,1736585449016174e+23 \Rightarrow$$

$$\Rightarrow b = \frac{\Delta b}{\Delta} = \frac{-2,1736585449016174e\ +\ 23}{3,814277662511121e\ +\ 23} \approx -0,5699;$$

$$\Delta c = \begin{vmatrix} 19527793 & 133487 & 12321 & 10 \\ 3095098343 & 19527793 & 1446391 & 1045 \\ 514314716545 & 3095098343 & 199771115 & 133487 \\ 88073231543207 & 514314716545 & 30604113883 & 19527793 \end{vmatrix} = 2,78788459895433e+25 \Rightarrow$$

$$\Rightarrow c = \frac{\Delta c}{\Delta} = \frac{2,78788459895433e\ +\ 25}{3,814277662511121e\ +\ 23} \approx 73,0908;$$

$$\Delta d = \begin{vmatrix} 19527793 & 133487 & 1045 & 12321 \\ 3095098343 & 19527793 & 133487 & 1446391 \\ 514314716545 & 3095098343 & 19527793 & 199771115 \\ 88073231543207 & 514314716545 & 3095098343 & 30604113883 \end{vmatrix} = -6,458135938364854e+26 \Rightarrow$$

$$\Rightarrow d = \frac{\Delta d}{\Delta} = \frac{-6,458135938364854e+26}{3,814277662511121e\ +\ 23} \approx -1693,1478.$$

The cubic one-factor regression equation, which describes the impact of the amount of agricultural products sold on the gross regional product (GRP) of the Chernivtsi region, will be:

GRP= 0.0015AP3 – 0.5699AP2 + 73.0908AP – 1693.1478

GRP – gross regional product of the Chernivtsi region;

AP – the volume of agricultural products sold in Chernivtsi region.

Fig. 4 shows the dependence between two indicators, namely the influence of the volume of agricultural products sold on the gross regional product of the Chernivtsi region.

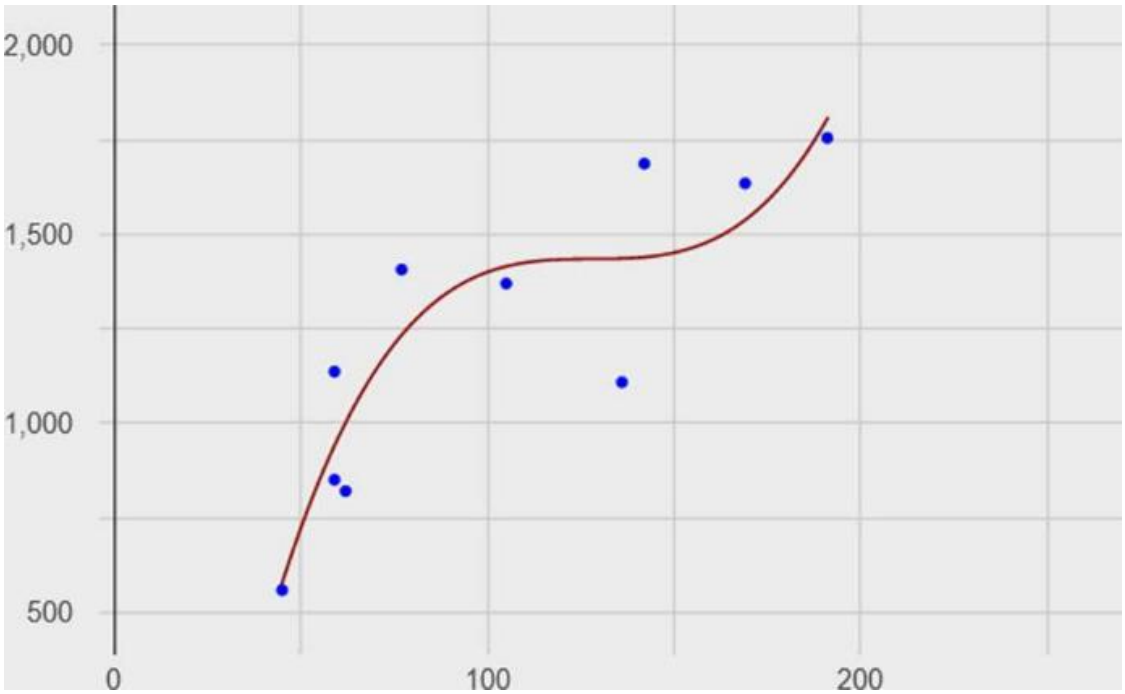

Figure 4. Graphic representation of the influence of the amount of agricultural products sold on the gross regional product of the Chernivtsi region.
Source: developed by the authors.

Table 5.
The value of auxiliary values for evaluating the significance of correlation parameters (Chernivtsi region)

i	i	x_i	y_i	$\hat{y}$	$x_i - \bar{x}$	$(x_i - \bar{x})^2$	ε_i	ε_i^2	A_i	$\Delta\varepsilon_i$
1	169	1634	1537,1459	401,9	161523,61	96,8541	9380,7184	0,0593	—	—
2	142	1686	1438,6649	453,9	206025,21	247,3351	61174,6556	0,1467	150,481	22644,5311
3	191	1754	1805,1483	521,9	272379,61	-51,1483	2616,1534	0,0292	-298,4835	89092,3731
4	136	1108	1435,1257	-124,1	15400,81	-327,1257	107011,2395	0,2952	-275,9774	76163,5126
5	45	558	577,0035	-674,1	454410,81	-19,0035	361,134	0,0341	308,1222	94939,2894
6	62	820	1001,1246	-412,1	169826,41	-181,1246	32806,1039	0,2209	-162,121	26283,2277
7	59	850	939,8807	-382,1	146000,41	-89,8807	8078,5441	0,1057	91,2438	8325,4369
8	59	1136	939,8807	-96,1	9235,21	196,1193	38462,7714	0,1726	286	81796
9	105	1369	1414,3114	136,9	18741,61	-45,3114	2053,1184	0,0331	-241,4306	58288,7484
10	77	1406	1232,7143	173,9	30241,21	173,2857	30027,9431	0,1232	218,5971	47784,682
∑	—	—	—	—	1483784,9	—	291972,382	1,22	—	505317,8012

Source: calculated by the authors

The correlation coefficient:

$$R = \sqrt{1 - \frac{\sum (y_i - y_i)^2}{\sum (y_i - \bar{y})^2}} = \sqrt{1 - \frac{291972,382}{1483784,9}} \approx 0,8962.$$

The determination coefficient:

$$R^2 = 0,8962^2 \approx 0,8032.$$

Fisher's F-test:

– critical (tabular)
$F_{tabl} = F(a, k_1, k_2) = F(0,05, 3, 6) \approx 4,7571.$

– factual
$$F_{fact} = \frac{R^2}{1-R^2} \cdot \frac{k_2}{k_1} = \frac{0,8032}{1-0,8032} \cdot \frac{6}{3} \approx 8,1639.$$

where k_1 = m = 3, k_2 = n – m – 1 = 12– 3 – 1 = 8, (a=0.05)
m – the number of parameters in the variables of the regression equation.

The analysis of the impact of the volume of agricultural products sold on the gross regional product for the Transcarpathian region is carried out as follows. The value of the auxiliary values necessary for calculations is presented in Table 6.

Table 6.
Results of calculations of auxiliary values (Transcarpathian region)

i	x_i	y_i	x_i^2	x_i^3	x_i^4	x_i^5	x_i^6	x_iy_i	$x_i^2y_i$	$x_i^3y_i$
1	330	2656	108900	35937000	11859210000	3913539300000	1291467969000000	876480	289238400	95448672000
2	321	2623	103041	33076161	10617447681	3408200705601	1094032426497921	841983	270276543	86758770303
3	328	2811	107584	35287552	11574317056	3796375994368	1245211326152704	922008	302418624	99193308672
4	104	1733	10816	1124864	116985856	12166529024	1265319018496	180232	18744128	1949389312
5	22	851	484	10648	234256	5153632	113379904	18722	411884	9061448
6	35	1235	1225	42875	1500625	52521875	1838265625	43225	1512875	52950625
7	33	1315	1089	35937	1185921	39135393	1291467969	43395	1432035	47257155
8	46	1671	2116	97336	4477456	205962976	9474296896	76866	3535836	162648456
9	57	1885	3249	185193	10556001	601692057	34296447249	107445	6124365	349088805
10	50	1949	2500	125000	6250000	312500000	15625000000	97450	4872500	243625000
$\sum$	1326	18729	341004	105922566	34192164852	11131499494926	3632039679526764	3207806	898567190	284214771776

Source: calculated by the authors

$$\begin{cases} a\sum x_i^3 + b\sum x_i^2 + c\sum x_i + nd = \sum y_i; \\ a\sum x_i^4 + b\sum x_i^3 + c\sum x_i^2 + d\sum x_i = \sum x_i y_i; \\ a\sum x_i^5 + b\sum x_i^4 + c\sum x_i^3 + d\sum x_i^2 = \sum x_i^2 y_i; \\ a\sum x_i^6 + b\sum x_i^5 + c\sum x_i^4 + d\sum x_i^3 = \sum x_i^3 y_i. \end{cases} \Leftrightarrow$$

$$\Leftrightarrow \begin{cases} 105922566a + 341004b + 1326c + 10d = 18729, \\ 34192164852a + 105922566b + 341004c + 1326d = 3207806, \\ 11131499494926a + 34192164852b + 105922566c + 341004d = 898567190, \\ 13632039679526764a + 11131499494926b + 34192164852c + 105922566d = 284214771776 \end{cases}$$

Solving the system of linear equations by Kramer's method:

$$\Delta = \begin{vmatrix} 105922566 & 341004 & 1326 & 10 \\ 34192164852 & 105922566 & 341004 & 1326 \\ 11131499494926 & 34192164852 & 105922566 & 341004 \\ 3632039679526764 & 11131499494926 & 34192164852 & 105922566 \end{vmatrix} = 1,6997378314774298e + 26;$$

$$\Delta a = \begin{vmatrix} 18729 & 341004 & 1326 & 10 \\ 3207806 & 105922566 & 341004 & 1326 \\ 898567190 & 34192164852 & 105922566 & 341004 \\ 284214771776 & 11131499494926 & 34192164852 & 105922566 \end{vmatrix} = 1,465169819909349e + 23 \Rightarrow$$

$$\Rightarrow a = \frac{\Delta a}{\Delta} = \frac{1,465169819909349e + 23}{1,6997378314774298e + 26} \approx 0,0009;$$

$$\Delta b = \begin{vmatrix} 105922566 & 18729 & 1326 & 10 \\ 34192164852 & 3207806 & 341004 & 1326 \\ 11131499494926 & 898567190 & 105922566 & 341004 \\ 3632039679526764 & 284214771776 & 34192164852 & 105922566 \end{vmatrix} = -7,081523586277719e + 25 \Rightarrow$$

$$\Rightarrow b = \frac{\Delta b}{\Delta} = \frac{-7,081523586277719e + 25}{1,6997378314774298e + 26} \approx -0,4166;$$

$$\Delta c = \begin{vmatrix} 105922566 & 341004 & 18729 & 10 \\ 34192164852 & 105922566 & 3207806 & 1326 \\ 11131499494926 & 34192164852 & 898567190 & 341004 \\ 3632039679526764 & 11131499494926 & 284214771776 & 105922566 \end{vmatrix} = 8,90039704793933e + 27 \Rightarrow$$

$$\Rightarrow c = \frac{\Delta c}{\Delta} = \frac{8,90039704793933e + 27}{1,6997378314774298e + 26} \approx 52,3634;$$

$$\Delta d = \begin{vmatrix} 105922566 & 341004 & 1326 & 18729 \\ 34192164852 & 105922566 & 341004 & 3207806 \\ 11131499494926 & 34192164852 & 105922566 & 898567190 \\ 3632039679526764 & 11131499494926 & 34192164852 & 284214771776 \end{vmatrix} = 1,0336494102946565e + 27 \Rightarrow$$

$$\Rightarrow d = \frac{\Delta d}{\Delta} = \frac{1,0336494102946565e + 27}{1,6997378314774298e + 26} \approx 6,0812.$$

So, the cubic one-factor regression equation, which describes the impact of the amount of agricultural products sold on the gross regional product (GRP) of the Transcarpathian region, will be:

GRP= 0.0009AP3– 0.4166AP 2 + 52.3634AP + 6.0812.

GRP – gross regional product of yhe Transcarpathian region;
AP – the volume of agricultural products sold in Transcarpathian region.

Fig. 5 shows the dependence between two indicators, namely the impact of the volume of agricultural products sold on the gross regional product of the Transcarpathian region.

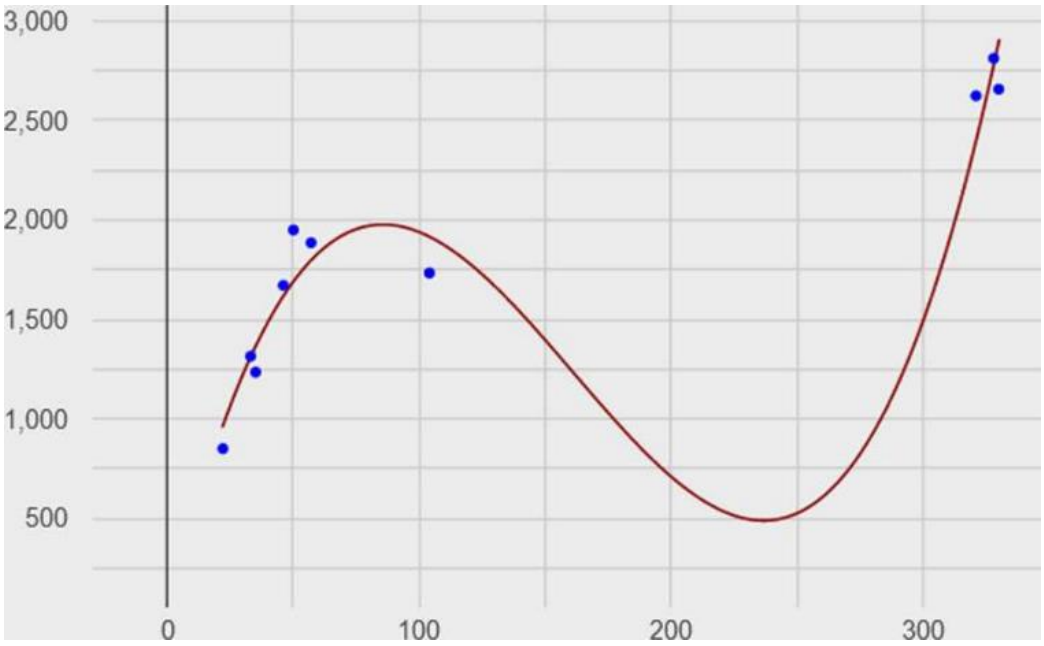

Figure 5. Graphic representation of the influence of the amount of agricultural products sold on the gross regional product of the Transcarpathian region.
Source: developed by the authors

Table 7 provides supporting data for evaluating the significance of the correlation parameters.

Table 7.
The value of auxiliary values for evaluating the significance of correlation parameters (Transcarpathian region)

i	i	x_i	y_i	$\hat{y}$	$x_i - \bar{x}$	$(x_i - \bar{x})^2$	ε_i	ε_i^2	A_i	$\Delta\varepsilon_i$
1	330	2656	2893.189	783.1	613245.61	-237.189	56258.5991	0.0893	—	—
2	321	2623	2396.8853	750.1	562650.01	226.1147	51127.84	0.0862	463.3036	214650.2382
3	328	2811	2776.9175	938.1	880031.61	34.0825	1161.6192	0.0121	-192.0321	36876.3373
4	104	1733	1915.2897	-139.9	19572.01	-182.2897	33229.521	0.1052	-216.3722	46816.9279
5	22	851	965.6073	-1021.9	1044279.61	-114.6073	13134.8296	0.1347	67.6824	4580.9043
6	35	1235	1365.3917	-637.9	406916.41	-130.3917	17002.0031	0.1056	-15.7844	249.1487
7	33	1315	1311.3454	-557.9	311252.41	3.6546	13.356	0.0028	134.0463	17968.4149
8	46	1671	1617.1215	-201.9	40763.61	53.8785	2902.8976	0.0322	50.224	2522.446
9	57	1885	1796.8153	12.1	146.41	88.1847	7776.536	0.0468	34.3061	1176.9102
10	50	1949	1690.4374	76.1	5791.21	258.5626	66854.6338	0.1327	170.378	29028.6494
∑	—	—	—	—	3884648.9	—	249461.8354	0.7475	—	353869.9769

Source: calculated by the authors

The correlation coefficient:

$$R = \sqrt{1 - \frac{\sum (y_i - y_i)^2}{\sum (y_i - \bar{y})^2}} = \sqrt{1 - \frac{249461,8354}{3884648,9}} \approx 0,9674.$$

The determination coefficient:

$$R^2 = 0,9674^2 \approx 0,9358.$$

Fisher's F-test:

– critical (tabl)
$F_{tabl} = F(a, k_1, k_2) = F(0,05; 3; 6) \approx 4,7571.$

– factual
$$F_{fakt} = \frac{R^2}{1-R^2} \cdot \frac{k_2}{k_1} = \frac{0,9358}{1-0,9358} \cdot \frac{6}{3} \approx 29,1442.$$

where k_1 = m = 3, k_2 = n – m – 1 = 12– 3 – 1 = 8, (a=0.05)
m – the number of parameters in the variables of the regression equation.

The fourth region of the Carpathian Economic Region is Ivano-Frankivsk. Let's analyze the impact of the volume of agricultural products sold on the gross regional product of the Ivano-Frankivsk region. The value of the auxiliary values necessary for calculations is presented in Table 8.

Table 8.
Results of calculations of auxiliary values (Ivano-Frankivsk region)

i	x_i	y_i	x_i^2	x_i^3	x_i^4	x_i^5	x_i^6	$x_i y_i$	$x_i^2 y_i$	$x_i^3 y_i$
1	251	4006	63001	15813251	3969126001	996250626251	250058907189001	1005506	252382006	63347883506
2	267	4068	71289	19034163	5082121521	1356926446107	362299361110569	1086156	290003652	77430975084
3	400	4387	160000	64000000	25600000000	10240000000000	4096000000000000	1754800	701920000	280768000000
4	264	2744	69696	18399744	4857532416	1282388557824	338550579265536	724416	191245824	50488897536
5	101	1351	10201	1030301	104060401	10510100501	1061520150601	136451	13781551	1391936651
6	160	1831	25600	4096000	655360000	104857600000	16777216000000	292960	46873600	7499776000
7	150	1966	22500	3375000	506250000	75937500000	11390625000000	294900	44235000	6635250000
8	171	2363	29241	5000211	855036081	146211169851	25002110044521	404073	69096483	11815498593
9	223	2748	49729	11089567	2472973441	551473077343	122978496247489	612804	136655292	30474130116
10	180	3084	32400	5832000	1049760000	188956800000	34012224000000	555120	99921600	17985888000
∑	2167	28548	533657	147670237	45152219861	14953511877876,998	5258131039007717	6867186	1846115008	547838235486

Source: calculated by the authors

$$\begin{cases} a\sum x_i^3 + b\sum x_i^2 + c\sum x_i + nd = \sum y_i; \\ a\sum x_i^4 + b\sum x_i^3 + c\sum x_i^2 + d\sum x_i = \sum x_i y_i; \\ a\sum x_i^5 + b\sum x_i^4 + c\sum x_i^3 + d\sum x_i^2 = \sum x_i^2 y_i; \\ a\sum x_i^6 + b\sum x_i^5 + c\sum x_i^4 + d\sum x_i^3 = \sum x_i^3 y_i. \end{cases} \Leftrightarrow$$

$$\Leftrightarrow \begin{cases} 147670237a + 533657b + 2167c + 10d = 28548, \\ 45152219861a + 147670237b + 533657c + 2167d = 6867186, \\ 14953511877876,998a + 45152219861b + 147670237c + 533657d = 1846115008, \\ 15258131039007717a + 14953511877876,998b + 45152219861c + 147670237d = 547838235486. \end{cases}$$

Solving the system of linear equations by Kramer's method:

$$\Delta = \begin{vmatrix} 147670237 & 533657 & 2167 & 10 \\ 45152219861 & 147670237 & 533657 & 2167 \\ 14953511877876,998 & 45152219861 & 147670237 & 533657 \\ 5258131039007717 & 14953511877876,998 & 45152219861 & 147670237 \end{vmatrix} = 1,3347003245641903e + 27;$$

$$\Delta a = \begin{vmatrix} 28548 & 533657 & 2167 & 10 \\ 6867186 & 147670237 & 533657 & 2167 \\ 1846115008 & 45152219861 & 147670237 & 533657 \\ 547838235486 & 14953511877876,998 & 45152219861 & 147670237 \end{vmatrix} = -8,117299831574964e + 22 \Rightarrow$$

$$\Rightarrow a = \frac{\Delta a}{\Delta} = \frac{-8,117299831574964e + 22}{1,3347003245641903e + 27} \approx -0,0001;$$

$$\Delta b = \begin{vmatrix} 147670237 & 28548 & 2167 & 10 \\ 45152219861 & 6867186 & 533657 & 2167 \\ 14953511877876,998 & 1846115008 & 147670237 & 533657 \\ 5258131039007717 & 547838235486 & 45152219861 & 147670237 \end{vmatrix} = 2,535663738503598c + 25 \Rightarrow$$

$$\Rightarrow b = \frac{\Delta b}{\Delta} = \frac{2,535663738503598c + 25}{1,3347003245641903e + 27} \approx 0,019;$$

$$\Delta c = \begin{vmatrix} 147670237 & 533657 & 2167 & 10 \\ 45152219861 & 147670237 & 6867186 & 2167 \\ 14953511877876,998 & 45152219861 & 1846115008 & 533657 \\ 5258131039007717 & 14953511877876,998 & 547838235486 & 147670237 \end{vmatrix} = 1,8171485540403015e + 28 \Rightarrow$$

$$\Rightarrow c = \frac{\Delta c}{\Delta} = \frac{1,8171485540403015e + 28}{1,3347003245641903e + 27} \approx 13,6147;$$

$$\Delta d = \begin{vmatrix} 147670237 & 533657 & 2167 & 28548 \\ 45152219861 & 147670237 & 533657 & 6867186 \\ 14953511877876,998 & 45152219861 & 147670237 & 1846115008 \\ 5258131039007717 & 14953511877876,998 & 45152219861 & 547838235486 \end{vmatrix} = -2,8194954381027008e + 29 \Rightarrow$$

$$\Rightarrow d = \frac{\Delta d}{\Delta} = \frac{-2,8194954381027008e + 29}{1,3347003245641903e + 27} \approx -211,2456.$$

The cubic one-factor regression equation, which describes the influence of the volume of agricultural products sold on the gross regional product (GRP) of the Ivano-Frankivsk region will be:

GRP= -0.0001AP3+ 0.019AP 2 + 13.6147AP – 211.2456

GRP – gross regional product of the Ivano-Frankivsk region;
AP – the volume of agricultural products sold in Ivano-Frankivsk region.

Fig. 6 shows the dependence between two indicators, namely the influence of the volume of agricultural products sold on the gross regional product of the Ivano-Frankivsk region.

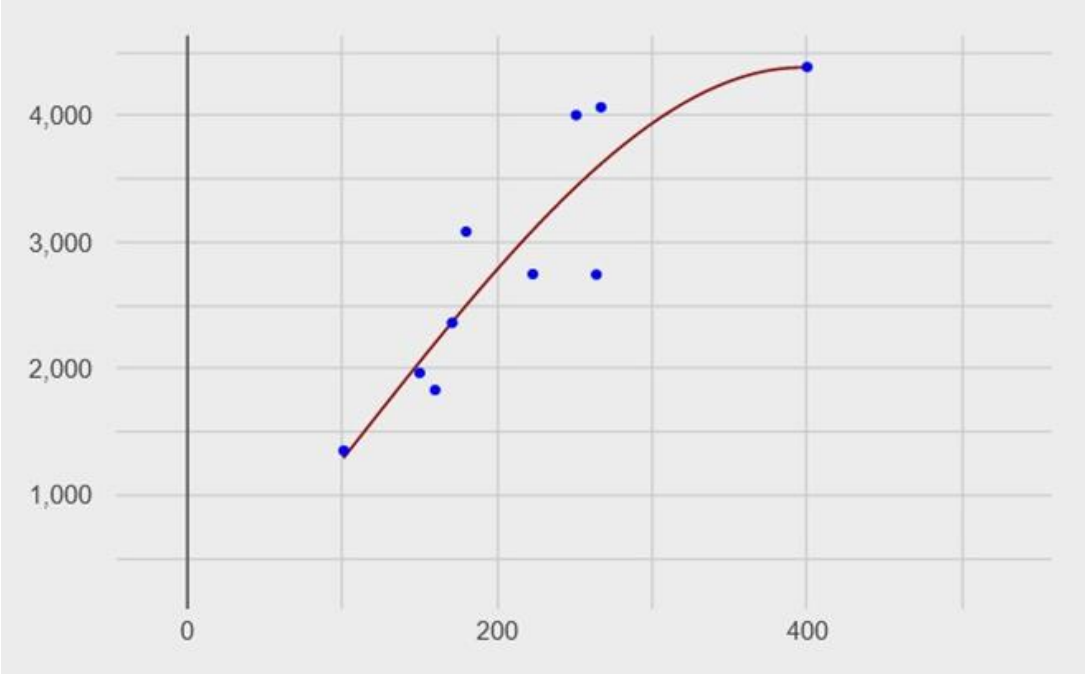

Figure 6. Graphic representation of the impact of the volume of agricultural products sold on the gross regional product of the Ivano-Frankivsk region
Source: developed by the authors

Table 9 provides supporting data for evaluating the significance of the correlation parameters.

Table 9.
The value of auxiliary values for evaluating the significance of correlation parameters (Ivano-Frankivsk region)

i	i	x_i	y_i	$\hat{y}$	$x_i - \bar{x}$	$(x_i - \bar{x})^2$	ε_i	ε_i^2	A_i	$\Delta\varepsilon_i$
1	251	4006	3441,2053	1151,2	1325261,44	564,7947	318993,0437	0,141	—	—
2	267	4068	3620,6077	1213,2	1471854,24	447,3923	200159,8268	0,11	-117,4024	13783,3329
3	400	4387	4381,9835	1532,2	2347636,84	5,0165	25,1656	0,0011	-442,3757	195696,2805
4	264	2744	3588,0837	-110,8	12276,64	-844,0837	712477,2551	0,3076	-849,1002	720971,1602
5	101	1351	1294,973	-1503,8	2261414,44	56,027	3139,0206	0,0415	900,1106	810199,1662
6	160	1831	2204,3401	-1023,8	1048166,44	-373,3401	139382,8368	0,2039	-429,3671	184356,0826
7	150	1966	2053,1491	-888,8	789965,44	-87,1491	7594,9642	0,0443	286,191	81905,2982
8	171	2363	2368,2813	-491,8	241867,24	-5,2813	27,892	0,0022	81,8678	6702,338
9	223	2748	3095,1356	-106,8	11406,24	-347,1356	120503,1554	0,1263	-341,8544	116864,4036
10	180	3084	2500,2406	229,2	52532,64	583,7594	340775,0036	0,1893	930,895	866565,5299
∑	—	—	—	—	9562381,6	—	1843078,1639	1,1673	—	2997043,592

Source: calculated by the authors

The correlation coefficient:

$$R = \sqrt{1 - \frac{\sum (y_i - y_i)^2}{\sum (y_i - \bar{y})^2}} = \sqrt{1 - \frac{1843078,1639}{9562381,6}} \approx 0,8985.$$

The determination coefficient:

$$R^2 = 0,8985^2 \approx 0,8073.$$

Fisher's F-test:

– critical (tabular)
$$F_{tabl} = F(a, k_1, k_2) = F(0,05, 3, 6) \approx 4,7571.$$

– factual
$$F_{\text{fact}} = \frac{R^2}{1 - R^2} \cdot \frac{k_2}{k_1} = \frac{0,8073}{1 - 0,8073} \cdot \frac{6}{3} \approx 8,3765.$$

Where k_1 = m = 3, k_2 = n – m – 1 = 12– 3 – 1 = 8, (a=0.05)
m – the number of parameters in the variables of the regression equation.

The correlation coefficient should be in the range from -1 to 1, and when it approaches 1, the closeness of the interaction is stronger. With a value of 1, the equation is generally functional rather than correlational. So, it can be stated that the dependence between the two parameters in the Lviv (0.8801), Chernivtsi (0.8962), Transcarpathian (0.9674) and Ivano-Frankivsk (0.8985) regions is significant, according to the model, the change in the volume of agricultural products sold in the region leads to the change in gross regional product. Taking into account the rapid development of the agricultural sector before the start of hostilities on the territory of Ukraine, the above is quite real and justified.

Also, the results of calculations demonstrate a situation when $F_{fact} > F_{tabl}$, which suggests that the determined regression model is significant and corresponds as closely as possible to the real functioning model for all four regions.

Conclusions

The conducted analysis proved the significant role of agriculture in the development of the economy of Ukraine's regions. Ukraine is an agrarian country with a rich agricultural history, but in today's extremely difficult conditions of war, it faces extreme challenges, including: worker safety, limited access to resources, significant economic losses, destruction of agricultural facilities, insufficient funding and support, environmental risks and natural resources, etc.

The following should be noted among the promising directions that should be aimed at the restoration of the agricultural sector and the formation of branding of agricultural regions. Implementation of the latest technologies, digital solutions, modern methods of soil cultivation and plant cultivation, will contribute to increasing the productivity and quality of agricultural products. Stimulating young farmers and agro-entrepreneurs, providing financial and consulting support, training and providing access to modern technologies helps young specialists develop their agricultural businesses. Attracting investments in the agricultural sector, which optimizes the processes of introducing innovative technologies, will contribute to the development of infrastructure and the creation of jobs. The development of organic production in the agricultural sector aimed at protecting the health of the population and the environment. It is also extremely important to establish cooperation with international partners, which will facilitate the exchange of experience and technologies, and financial support. Support is effective through the creation of state programs

aimed at financial assistance, consultations, ensuring access to markets and exports, encouraging start-ups in the field of agricultural entrepreneurship development.

However, in the conditions of war, for the recovery and further development of the agricultural sector, it is necessary to create a favorable investment climate, ensure transparency and stability in legislation, which is currently a significant problem for Ukraine.

Bibliographic references

Aidat, T., Benziouche, S.E., Cei, L., Giampietri, E., & Berti, A. (2023). Impact of Agricultural Policies on the Sustainable Greenhouse Development in Biskra Region (Algeria). *Sustainability*, 15(19), 14396. https://doi.org/10.3390/su151914396

Bansah, K. J., Arthur-Holmes, F., & Assan, E. (2023). Climate induced transformation of agriculture to artisanal mining economy in dry regions. *Journal of Rural Studies*, *99*, 11-19.

Butko, M, Popelo, O., & Pishenin, I. (2019). Innovations in Human Resources Management in Eurointegration Conditions: Case for Ukrainian Agro-industrial Complex. *Marketing and management of innovations*, 2, 74-82.

Cervelli, E., Recchi, P. F., Scotto di Perta, E., & Pindozzi, S. (2023). Land Use Change Scenario Building Combining Agricultural Development Policies, Landscape-Planning Approaches, and Ecosystem Service Assessment: A Case Study from the Campania Region (Italy). *Land*, 12(10), 1-24.

Flury, C., Giuliani, G., & Buchli, S. (2008). The importance of agriculture within the regional economy. *Swiss Agricultural Review*, 40(1), 63-68.

Loizou, E., Karelakis, C., Galanopoulos, K., & Mattas, K. (2019). The role of agriculture as a development tool for a regional economy. *Agricultural Systems*, 173, 482-490. https://doi.org/10.1016/j.agsy.2019.04.002

Muhammedov, M., Nizamov, A., Mustafoev, G., Babakulov, B., & Yuldashev, S. (2023). The role of agriculture in shaping the prospects of socio-economic development of Uzbekistan. *Scientific Horizons*, 26(11), 155-165. http://ir.polissiauniver.edu.ua/handle/123456789/14624

Pradeleix, L., Roux, P., Bouarfa, S., & Bellon-Maurel, V. (2023). Multilevel life cycle assessment to evaluate prospective agricultural development scenarios in a semi-arid irrigated region of Tunisia. *Agricultural Systems*, *212*, 103766. https://doi.org/10.1016/j.agsy.2023.103766

State Statistics Committee (n/f). Official site. URL: https://ukrstat.gov.ua

Sutradhar, A., & Daspattanayak, P. (2023). A regional model for the variability of Agricultural development: evidence from a drought-prone region of Rarh Bengal, Eastern India. *Model. Earth Syst. Environ.*, *9*, 3663-3691. https://doi.org/10.1007/s40808-023-01721-6

Verma, K., Sharma, P., Bhardwaj, D. R., Kumar, R., Kumar, N. M., & Singh, A. K. (2023). Land and environmental management through agriculture, forestry and other land use (AFOLU) system. *Land and Environmental Management through Forestry*, 247-271.

Wanghai, T., Mingjiang, D., Quanjiu, W., Lijun, S., Changkun, M., & Songrui, N. (2023). Ecological agriculture connotation and pathway of high-quality agricultural development system in Northwest arid region. *Transactions of the Chinese Society of Agricultural Engineering (Transactions of the CSAE)*, *39*(20), 221-232. http://www.tcsae.org/en/article/doi/10.11975/j.issn.1002-6819.202305240

Zafeiriou, E., Karelakis, C., Martínez-Zarzoso, I., Galanopoulos, K., & Gkika, D. (2023). Economic Development and Pesticide Use in EU Agriculture: A Nonlinear Panel Data Autoregressive Distributed Lag Approach. *Agriculture*, *13*(9), 1693.

Zhang, Q., Qu, Y., & Zhan, L. (2023). Great transition and new pattern: Agriculture and rural area green development and its coordinated relationship with economic growth in China. *Journal of Environmental Management*, *344*, 118563.