The role of economic and structural factors in the development of agriculture: regional approach

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ORIGINAL ARTICLE

Abstract. The article analyses the impact of various economic and structural factors on the development of agriculture in Russian regions based on statistical data and a variety of economic and mathematical methods. The research uses calculation of relative and average values, multivariate grouping, and regression analysis. The cluster analysis revealed two groups of regions in terms of gross value added. The first group includes regions with highly developed agriculture significantly exceeding the indicators of the second one. This is confirmed by the results of regression analysis. Investments in fixed assets turned out to be the most significant factor affecting gross value added. Additionally, research forecasts a variable with fluctuations in independent characteristics by simulation modelling. It demonstrates the resilience or vulnerability of the agricultural sector to changes in the economic environment. The research results have practical significance for development of state support measures and increase the efficiency of the agrarian sector in Russian regions, providing food security and sustainable economic development.

Keywords: agriculture, clusters, cluster analysis, regression model, economic model, simulation modelling

JEL codes: Q19

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Introduction

Agriculture plays a key role in the Russian economy. It ensures the country's food security and makes a significant contribution to the gross domestic product. However, this sector has repeatedly faced serious challenges during periods of large-scale economic reforms. In the 1990s, the country radically transformed its economic system. It resulted in the emergence of private ownership of the means of production. It also caused the disruption of inter-industry relations, inflation, reduction of governmental support, and price disparity. Hence, the economy was significantly weakened. Recently, Russian agriculture has been gradually recovering. However, many challenges exist as a result of previous crises and reforms.

Therefore, the research is extremely relevant and concerns with the impact of economic factors affecting agricultural development.

Indeed, we decided to consider the impact of various economic indicators on the dynamics of agricultural production using statistical data and applying multidimensional analysis and regression modelling.

The research results contribute to understanding of the economic factors determining the sustainability and development of agriculture in Russia. It allows ones to develop more effective governmental support measures to strengthen the agricultural sector, provide sustainable conditions for its development, and improve the country's food security.

Methods

The study assessed the relationship of key indicators characterising agriculture in the regions of Russia. The following indicators of gross added value (GVA) were selected as initial data. They are taken from open sources, primarily from data from the Federal State Statistics Service[1] (Rosstat) and the Unified Interdepartmental Information and Statistical System[2] (UIISS):

Y – GVA by the agricultural activity, forestry, hunting, fishing and fish farming, thousand RUB;

X1 – agricultural products (mln, RUB);

X2 – the average annual number of people employed in the economy since 2016 (people, values of the indicator for the year, calculated on the basis of data integration);

X3 – the cost of fixed assets for «Agriculture, forestry, hunting, fishing, and fish farming» (mln, RUB);

X4 – investments in fixed assets in «Agriculture, forestry, hunting, fishing, and fish farming» (mln, RUB);

X5 – gross yield of grain (thousand tons);

X6 – production of livestock and poultry for slaughter (thousand tons);

X7 – milk production (thousand tons);

X8 – crop acreage (thousand hectares);

X9 – feed consumption per conventional head of cattle in agricultural organizations (hundredweight of feed units);

The indicators do not include Khanty-Mansiysk Autonomous Okrug – Yugra, Yamalo-Nenets Autonomous Okrug (their data are insignificant and are included in the indicators of the Tyumen region; similar for Nenets Autonomous Okrug – the data are included in the indicators of the Arkhangelsk region). We do not consider Moscow, St. Petersburg, and Sevastopol due to their low rates.

Main part

Indeed, we consider the variation of agricultural gross value added (GVA) of the Russian Federation regions. Therefore, we construct a box-and-whiskers diagram. It allows us to visualise the distribution of GVA by federal districts, 2016, 2019, 2022 (Figure 1).

To construct the diagram, the tools of the Python Plotly library were used. It allows us to create interactive visualisations.

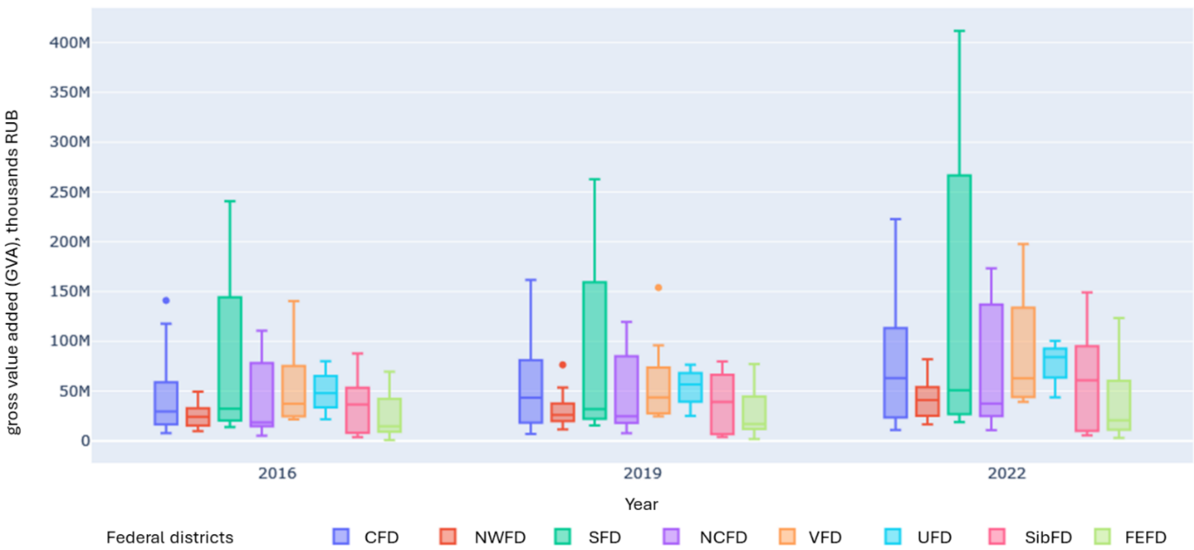

Figure 1. Variation of the GVA by type of activity «Agriculture, forestry, hunting, fishing and fish farming», 2016, 2019, 2022, mln RUB

Source: composed by the authors

The data in Figure 1 cover a period of three years and show significant differences in median values among federal districts. The highest variation is observed in the Central, Southern, North Caucasian, and

[1] *Russian Statistical Yearbook: Federal State Statistics Service. URL: https://rosstat.gov.ru/folder/210/document/12993 (Assessed 10.09.2024).*

[2] *A unified interdepartmental information and statistical system. URL: https://fedstat.ru / (Assessed 10.09.2024).*

Volga districts. It is primarily due to natural and climatic features [1]. Russia has only a limited number of regions appropriate for crop cultivation. They are Central Black Earth region, southern regions such as Kuban and Stavropol, and southern parts of Siberia, especially Altai Krai. However, livestock farming may be developed in most parts of the country, but its costs and profitability vary considerably by region.

In addition, the data for the three studied years demonstrate a gradual increase in agricultural GVA in all districts and especially in the Southern Federal District (SFD). It indicates a positive trend in the agricultural sector, despite differences in environmental conditions and costs.

Consequently, it would be incorrect to assess the level of development and efficiency of agriculture equally across the country without considering regional specifics.

The next research stage is clustering the Russian Federation regions by a set of independent variables for 2022. For this purpose, we apply cluster analysis as a methods of multidimensional statistical analysis. It allows us to identify structures in data and cluster them by similarity [2]. We apply the union method as the clustering algorithm; the distance measure is the Euclidean distance. To form clusters, we use the Ward method. It optimises the total intra-group distance and effectively organises regions into groups. The implementation of this cluster procedure was performed using the Python programming language and the Plotly library. The results of the clustering algorithm are visualised (Figure 2).

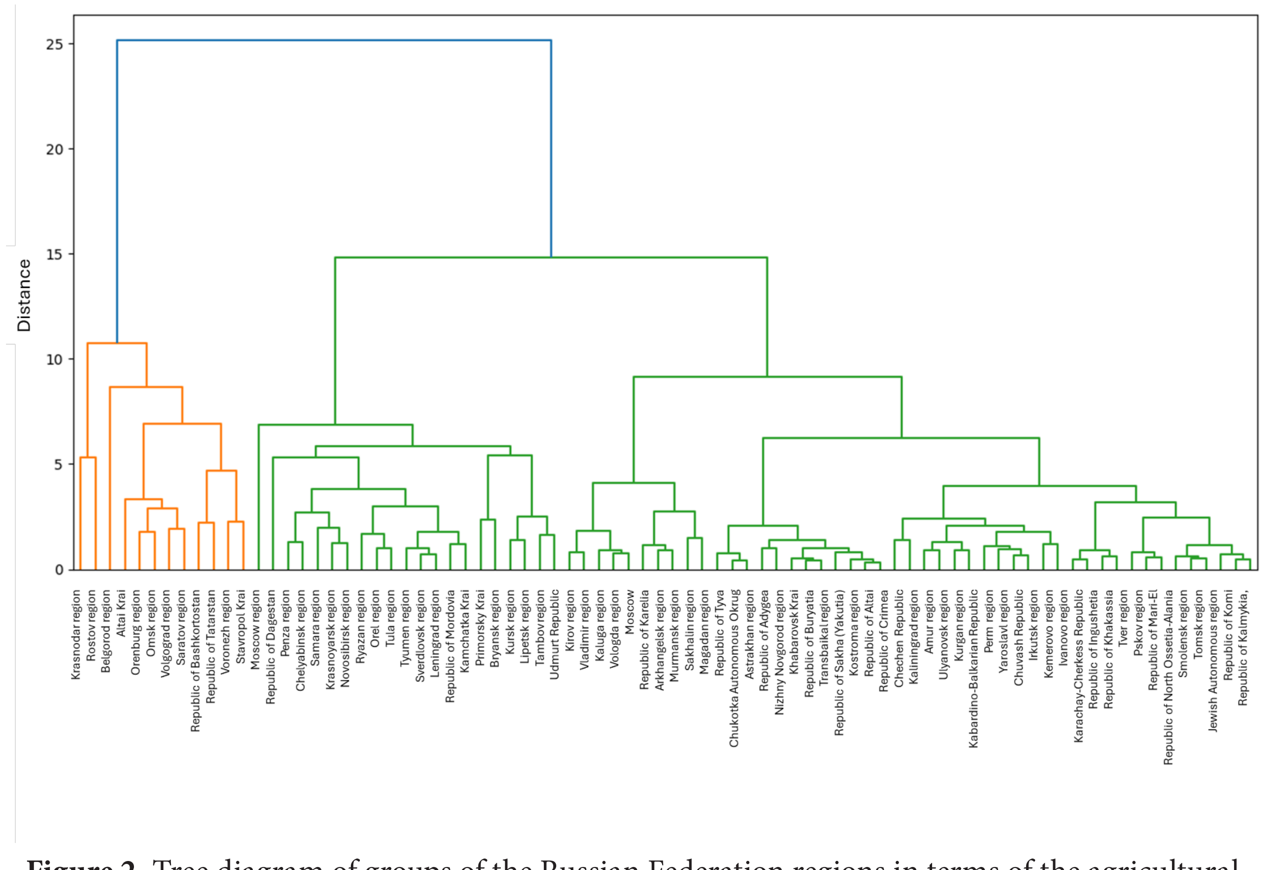

Figure 2. Tree diagram of groups of the Russian Federation regions in terms of the agricultural development

Source: composed by the authors

The Russian Federation regions are located on the OX axis, and on the OY axis is the value of an integral indicator formed on the basis of factors affecting the development of regional agriculture. This indicator does not have the units of measurement; it is a multidimensional statistical estimation.

The first cluster is located between Krasnodar and Stavropol Krai. It includes 12 regions of the Russian Federation. The average value of gross value added (GVA) for this group is 198,825,839 thousand RUB; the coefficient of variation is 40.98%. It indicates high indicators of economic activity and development of the agricultural sector in these regions.

The second cluster is located between the Moscow region and the Republic of Kalmykia. It includes 68 regions of the Russian Federation. The average value of gross value added (GVA) for this group is 52,572,615 thousand RUB; the coefficient of variation is 71.49%. Therefore, this group includes subjects with low values of the effective variable. It indicates limited opportunities for farming.

Indeed, the initial set of subjects was divided into two groups. It confirms the hypothesis of the existing regional differentiation in terms of resource provision and the possibilities of agricultural activity [3]. According to the identified patterns, we construct a regressive model with a fictitious variable D. It will assume the value 1 if the subject belongs to the first cluster and 0 if it belongs to the second one. It allows us to assess the stratification in the aggregate of regions.

The Python programming language and the Plotly library were used to build the regression model. The simulation result for the first (Figure 3) and second clusters (Figure 4).

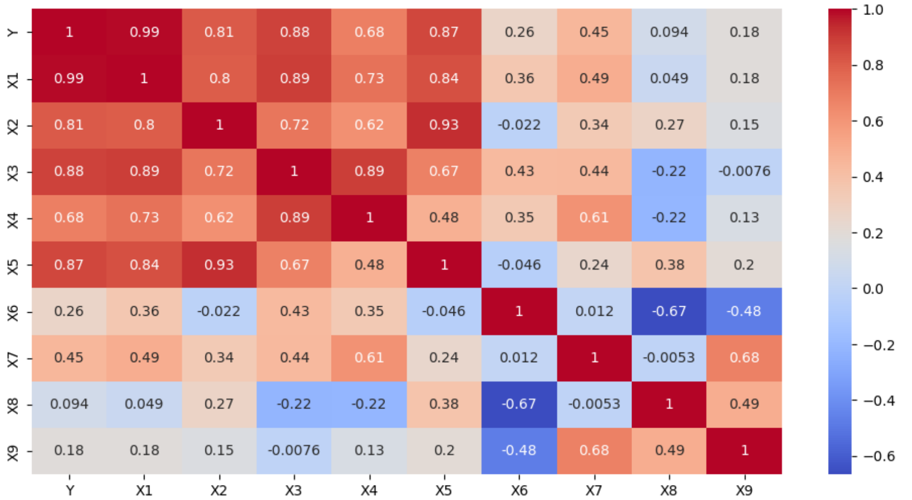

Figure 3. The value of the correlation coefficients for the first cluster

Source: composed by the authors

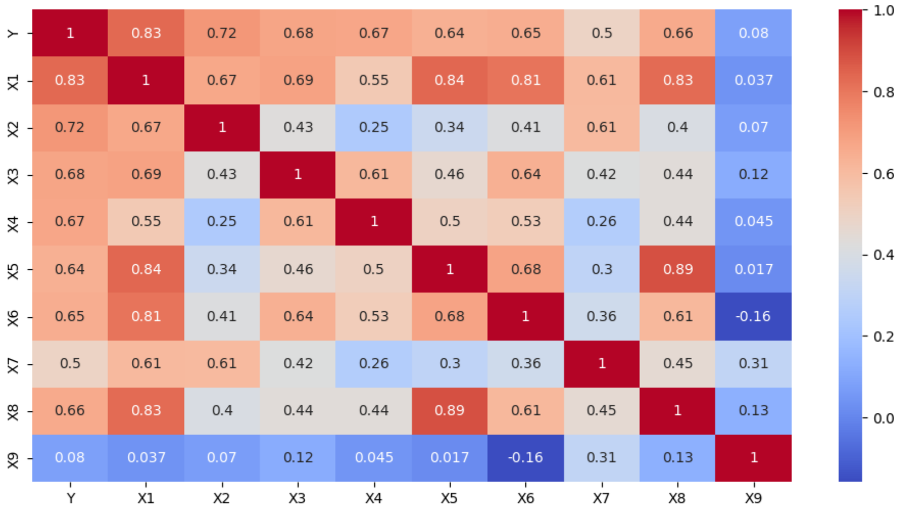

Figure 4. The value of the correlation coefficients for the second cluster

Source: composed by the authors

According to the data on the correlation coefficients for both clusters, not all selected factors have a significant impact on the gross value added (GVA) in agriculture. Moreover, the significant factors vary in different subgroups of the Russian Federation regions. It additionally confirms the hypothesis on a significant differentiation between regions in terms of their resource provision [3].

Furthermore, there is a significant relationship between the independent variables. It indicates the presence of a multicollinearity problem. Multicollinearity complicates the separation of the specific variable's contribution to the final outcome. It may provide the distorted estimates of the regression model coefficients. In such conditions, application of all factors in one model may result in incorrect conclusions on the significance of individual variables and their influence on the outcome variable.

Therefore, it is necessary to adjust the structure of the regression model. Hence, we use only the most significant factors in the model and include the variable D. The X4 indicator was chosen as one of the key factors. It shows the impact of investments on agricultural GVA. The results of estimating the values of the economic model are presented in Table 1.

Table 1 – The results of estimating the values of the economic model of D and X4 impact on agricultural GVA in the Russian Federation regions (calculated using the Python programming language and the Plotly library)

Model Elements	Regression coefficients b_j	The standard error of b_j	The actual values of t(71) - Student statistics	p-significance level
Intercept term	127,202,088.92	13,654,520.48	9.32	0.0
D	-102,486,714.89	12,398,849.71	-8.27	0.0
X4	4,033.01	508.98	7.92	0.0

Source: composed by the authors

The regression equation is characterized by a high value of determination coefficient $R^2 = 0.75$. It explains 75% of dependent variable variation of the independent variables.

The statistical significance of the equation is confirmed by the high value of Fisher's F-statistics F (3.4) = 118.19 with a significance level of p ≈ 3.4 × 10-24. It indicates the general significance of the entire regression model. The actual value of the Student's t-statistics indicates the statistical significance of the equation parameters.

The interpretation of the parameter at X4 is as follows: an increase in investments in fixed assets by 1 min RUB increases agricultural GVA by 508.98 thousand RUB.

The value of the dummy variable D shows a gap between the groups of the Russian Federation regions. The local regression line for the second cluster runs lower by 10,286714.89 RUB. It highlights the differences in the level of agricultural development between these regional groups. The simulation is visualised in Figure 5.

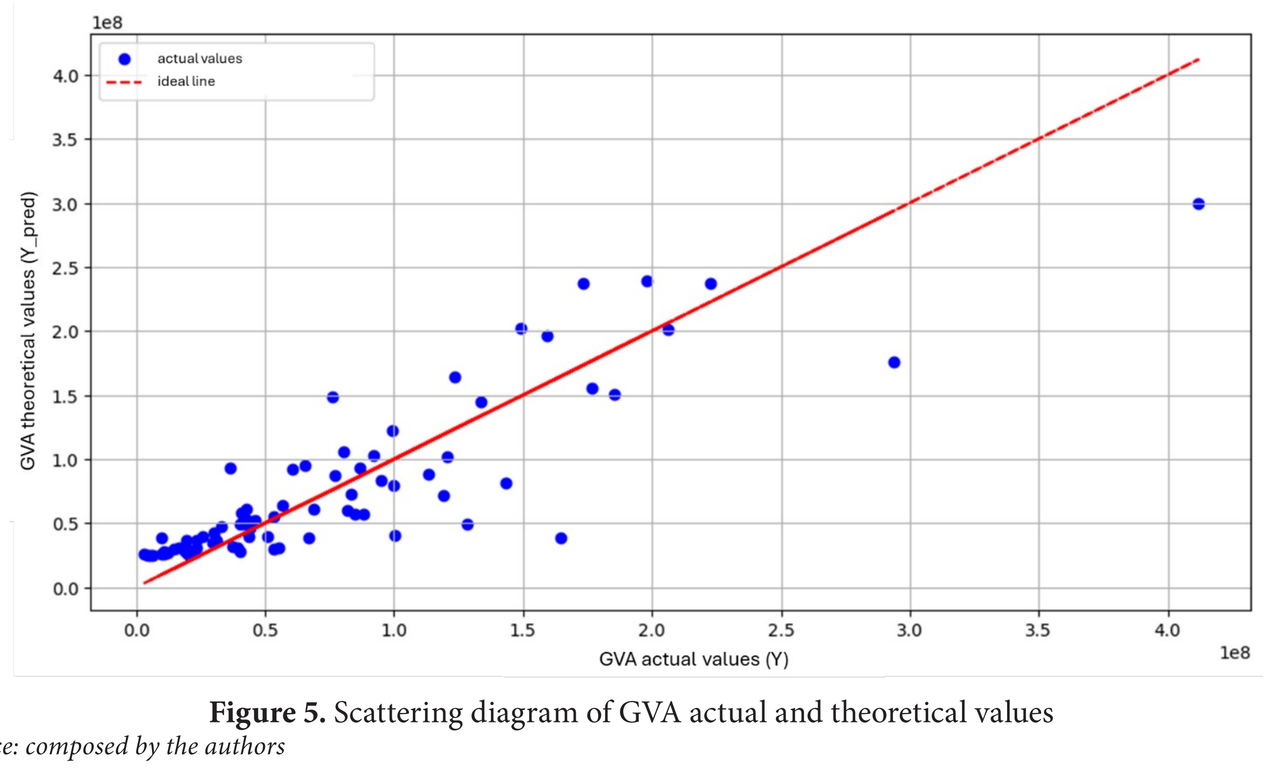

Figure 5. Scattering diagram of GVA actual and theoretical values
Source: composed by the authors

The differentiation of the Russian regions in terms of the agricultural development is clearly visible. It is confirmed by various points of intersection of local regression lines with the OY axis. Hence, it confirms the hypothesis put forward earlier.

After confirming the statistical significance of the constructed model, simulation modeling was performed. It provides two scenarios: an optimistic one – the values of the independent variable X4 were increased by 25%, and a pessimistic one – the same value was underestimated by 25%, reflecting possible positive and unfavorable economic conditions (Table 2).

Table 2 – Simulation results of the dependent variable with underestimated and overestimated values of the X4 variable (calculated using the Python programming language and the Plotly library)

Variables	Optimistic forecast		Pessimistic forecast	
	1st cluster	2nd cluster	1st cluster	2nd cluster
D	1	0	1	0
X4	8,634	22,199	5,180	13,320
Point forecast Y	59,536,925	216,731,776	45,608,305	180,919,901
-0,95%CL	47,989,160	192,042,692	35,520,883	158,441,739
+0,95%CL	71,084,691	241,420,860	55,695,727	203,398,063

Source: composed by the authors

According to both scenarios, even with optimal forecasts, the regions included in cluster 1 are significantly advance the regions of cluster 2. This indicates the existence of systemic problems with ensuring food security at the regional level. In particular, regions with low agricultural development indicators experience significant challenges. They are exacerbated by logistical difficulties and the high cost of food transportation, especially in the remote regions of Siberia, the Far East and the Arctic zone. Redistribution of resources from more developed regions of the 1st cluster may help to address the problem. However, such measures are associated with increasing the cost of food products for the consumers. It is particularly acute in regions remote from major traffic routes. Therefore, an integrated approach is needed to address the problem. This approach should include improving the efficiency of agriculture in the regions of the 2nd cluster, developing transport infrastructure and programmes to support the agricultural sector.

Conclusion

Indeed, the Russian Federation regions are significantly differentiated in terms of the agricultural development. The cluster analysis revealed two groups of regions in terms of gross value added (GVA). The first group includes regions with highly developed agriculture significantly exceeding the indicators of the second one. This is confirmed by the results of regression analysis. Investments in fixed assets turned out to be the most significant factor affecting GVA.

Simultaneously, a multicollinearity problem was recognized. It requires a revision of the model and the exclusion of variables with a negligible effect. The results of simulation modelling based on optimistic and pessimistic scenarios demonstrated higher GVA values in the regions of the first cluster even under unfavorable economic conditions. It indicates a sustained superiority of agricultural economic development in some regions. Moreover, it requires the design of support measures and development strategies to improve the situation in underdeveloped regions.

Hence, the results emphasize the importance of targeted actions at the level of public policy aimed at improving the efficiency of agriculture, transport infrastructure, and ensuring favorable conditions for the agricultural sector with low development indicators.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR'S CONTRIBUTIONS

Sergey N. Kosnikov – writing – original draft; formal analysis
Alexander P. Berus – data curation; visualization;

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