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STATISTICAL APPROACHES TO STUDYING ECONOMIC GROWTH IN AGRICULTURAL SECTOR OF THE REGION

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Abstract

Agriculture is a complex dynamic economic system characterized by the interaction of biological, natural, economic and social processes. This determines the stochastic nature of the functioning of this industry and justifies the expediency of a statistical approach to its analysis, including the study of economic growth. The article presents methodological approaches that allow identifying and measuring economic growth in agriculture in the region by comparing the results of statistical modeling of the relationship between the costs of basic resources and the output of agricultural products in different groups of production units. Kinetic production functions in the clusters of agricultural organizations in the region are constructed taking into account the nonlinear nature of the functioning of agriculture as a production economic system. Possibilities of probable statistical models for determining the factors limiting economic growth are reflected. The effect of expanding the scale of agricultural production has been determined and the situation has been predicted, which ensures that production is located in the economic area and an additional economic effect is obtained, which is expressed in increased output. The issues of determining statistically significant discrepancies between cluster groups, substantiating the legitimacy of comparing the results of their activities, are considered. The article proposes to extend the regularities of the functioning of clusters of production units with higher performance results to other clusters as an alternative to the territorial management principle and the scenario-based planning approach when elaborating measures for the development of agricultural production at the regional level.

Keywords: Agriculture, clusters, economic growth, production elasticity, production function

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1. Introduction

Reproduction processes in agriculture in modern conditions are positioned with an integrated approach in state policy to the digitalization of the industry (Ivanova & Merkulova, 2018). Agricultural activity is considered as one of the strategic directions for the development of the economy of agricultural regions, ensuring food security and the implementation of the import substitution policy (Kulikov & Minakov, 2018; Nikitin & Smykov, 2019). One of the key aspects of this process is the achievement of economic growth in the industry, a generally recognized quantitative indicator of which is the increase in agricultural output over a certain period of time (Nikitin et al., 2020). The definition and analysis of this indicator is provided by statistical calculations and is carried out depending on the set of initial data based on the study of time series or modeling of regression dependencies.

2. Problem Statement

Official statistics measure economic growth in the industry in the context of three categories of farms using indices of the physical volume of agricultural production. Their analytical capabilities allow characterizing the change in the volume of production for a year and longer periods of time, reflecting the degree of reaction of various categories of agricultural producers to the factors of the external environment of the industry and, on the basis of this, identifying their adaptive capabilities. The identity of the methodology for calculating indices at the federal and regional levels allow comparing the growth trends in agricultural production in the corresponding categories of farms in various constituent entities of the Russian Federation and with the all-Russian indicators.

The indices of the physical volume of agricultural production in the Tambov region, which has a historically established agricultural specialization of the regional economy, for 2015-2019 are presented in Table 1.

Table 1. Volume indices of agricultural production in the region, %

Farm categories	2015	2016	2017	2018	2019	Average over 2014-2018
Agricultural organizations	110.6	97.8	118.6	102.9	109.3	107.6
Households of the population	106.5	81.6	99.0	89.2	95.7	94.0
Peasant (farming) households	111.7	92.3	109.5	107.4	104.9	104.9

Source: authors' calculations using data of ROSSTAT (https://rosstat.gov.ru/)

The positive growth rates of agricultural production in the analyzed period in the region were characteristic of agricultural organizations and peasant (farming) households (Winkler et al., 2021). The households of the population had a regressive character of agricultural production. The higher average rate of increase in production in agricultural organizations compared to other commodity producers indicates their better adaptation to negative climatic and economic conditions, which is largely due to the large volumes of investment of these agricultural formations in the region.

The use of indices of the physical volume of agricultural production implements only the dynamic aspects of the study of economic growth in the industry, reflecting the trends and prospects of the agricultural market (Palei et al., 2020). Therefore, in the presence of static data sets, another approach is

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relevant, which is based on the specificity of the relationship between resource inputs and agricultural output, which has been repeatedly confirmed in applied statistical studies. The authors compare the results of modeling this relationship in different groups of the same type of production units in the region according to the data of the reporting year. The nonlinearity and probabilistic nature of the models is predetermined by the stochasticity of the agricultural production process. The fulfillment of the requirement of the materiality of differences between groups of economic entities is achieved using cluster analysis as a method of multidimensional classification, the implementation of which is adequately provided by the functionality of modern statistical software products (Popova, 2015).

3. Research Questions

The aspects this work is devoted to reflect the feasibility of using statistical tools in the study of agricultural production in the region taking into account the stochastic nature of the industry's functioning and allowing to identify economic growth and predict its characteristics with static data sets for production units.

In accordance with this, the following issues are considered in the work:

- selecting, based on the cluster analysis procedures, homogeneous groups of the same type of economic entities of the agrarian regional economy which appreciably differ in the values of resource availability and gross production indicators;
- constructing statistical models in the form of production functions, reflecting the dependence of the volume of agricultural production on the amount of resources spent;
- determining additional agricultural output based on linear interpolation of elasticity coefficients and indicators of resource availability in clusters with statistically significant differences in performance.

4. Purpose of the Study

The aim of the work is to substantiate methodological approaches to identifying and measuring economic growth in agriculture based on the results of statistical modeling of the relationship between resource inputs and agricultural output.

5. Research Methods

The research materials were the data of the consolidated annual report on 285 agricultural organizations of the Tambov region in 2019, on the basis of which the cluster analysis was carried out by the hierarchical agglomerative method Ward's in the Statistica software package. During the research, the method of statistical modeling was also used.

6. Findings

In the modern strategic management of agriculture in the region, a scenario approach is implemented, based on the construction of different scenarios based on the determination of a quantitatively limited set of dominant goals (Antsiferova et al., 2019). Determination of the prospects for the development of agricultural production based on statistical approaches is considered as an alternative.

The cluster analysis of agricultural organizations in the region using the Ward's method was justified by the relatively small volume of the initial data set and the high robustness of the procedures in relation to noise and emissions. The classification was made by the volume of fixed resources (land area (x_1), the number of workers (x_2), the amount of fixed assets (x_3) and the amount of working capital (x4)), which act as factor indicators for the output of agricultural products. In the process of agglomeration, four representative clusters were identified, the content characteristics of which are presented in Table 2.

Table 2. Indicators of resource availability and agricultural production in clusters of agricultural organizations in the region

Indicator (average per organization)	1 cluster	2 cluster	3 cluster	4 cluster
Number of agricultural organizations	131	99	32	23
Agricultural land area [ha]	6876	5655	6943	7898
Average annual number of workers [people]	55	73	115	186
Average annual cost of fixed assets [ths. RUB]	208742	168084	201722	200728
Average annual cost of circulating assets [ths. RUB]	113653	83190	119447	226807
Cost of agricultural products [ths. RUB]	321414	281048	376056	398543
Falls on 100 hectares of agricultural land:				
- workers [people]	0.8	1.3	1.7	2.3
- fixed assets [ths. RUB]	3035.8	2972.3	2905.4	2541.5
- working capital [ths. RUB]	1652.9	1471.1	1720.4	2871.7

At the next stage, in the selected clusters of agricultural organizations in the region, statistical modeling of the relationship between the amount of resources expended (x_j) and the volume of output (Y) was performed. For this purpose, the production kinetic function $Y = a_0 x_1^{\alpha_1} x_2^{\alpha_2} \cdot \ldots \cdot x_n^{\alpha_n} \cdot e^{a_1 x_1 + a_2 x_2 + \ldots + a_n x_n} = \prod_{j=1}^{n} x_j^{\alpha_j} \cdot e^{a_j x_j}$ was used. The description of production and technological dependencies in agriculture based on this function allows assessing the influence of the size of the basic resources on the output through the parameters of elasticity. The coefficients of elasticity of the production kinetic function for each factor are calculated using the formula $E_j = \alpha_j + a_j x_j$ using the average size of the corresponding type of resource in the studied economic entities of each cluster. They reflect the relative change in the effective output indicator *Y* with a one percent change in the *j*-th factor (Popova & Fetskovich, 2015).

It is methodologically important that cluster analysis precedes the construction of production functions, since the relationship between the studied characteristics has significant differences in different clusters of production units (Smagin, 2015). That is, the model makes sense only in the area covered by the actual data used in its construction.

The kinetic production functions constructed in the four identified clusters of agricultural organizations describing the dependence of gross agricultural output on the size of resources are as follows:

in the 1st cluster: $Y = 18.122 \cdot x_1^{0.133} x_2^{0.158} x_3^{-0.106} x_4^{0.424} e^{0.0131 x_2 + 0.000001 x_4}$;

in the 2nd cluster: $Y = 0.042 \cdot x_1^{0.208} x_2^{0.761} x_4^{1.678} e^{-0.00007x_1 - 0.0048x_2 - 0.0000012x_4}$;

in the 3 cluster: $Y = 3.023 \cdot x_1^{-0.317} x_2^{1.079} x_3^{1.742} x_4^{0.694} e^{0.00018x_1 - 0.0122x_2 - 0.000021x_3}$;

in the 4 cluster: $Y = 2284.48 \cdot x_1^{-0.098} x_4^{0.377} e^{0.00018x_2}$.

From the values of the elasticity coefficients calculated by the parameters of these functions, it follows that in the 1st cluster of agricultural organizations:

– expansion of the area of agricultural land by 1% leads to an increase in the volume of agricultural production by an average of 0.133%;

– an increase in the average annual number of workers by 1% causes an increase in the cost of gross agricultural production by an average of 0.158 + 0.0131 x_2%, which for organizations in this cluster is 0.630%;

– an increase in the average annual value of fixed assets by 1% is accompanied by a decrease in gross production by an average of 0.106%;

– an increase in the size of working capital by 1% leads to an increase in the volume of agricultural products by an average of 0.424 + 0.000001 x_4%, which for organizations of this cluster is equal to 0.734%.

The calculation of elasticity coefficients in other clusters is carried out in a similar way. The calculation results are presented in Table 3.

Table 3. Influence of the size of resources on the change in agricultural output in the clusters of agricultural organizations in the region

Resource change by 1%	Elasticity coefficient			
	1 cluster	2 cluster	3 cluster	4 cluster
Expansion of agricultural land	+0.133	-0.022	+0.303	-0.098
Increase in the average annual number of employees	+0.630	+0.411	-0.324	+0.335
Growth in the average annual value of fixed assets	-0.106	0.000	+0.498	0.000
Growth of the average annual value of working capital	+0.734	+0.726	+0.694	0.377

The different nature and degree of influence of the size of basic resources on the change in gross agricultural production in the selected groups of production units of the region are obvious, which makes it possible to identify the factors limiting economic growth and predetermines the options for predicting the situation that ensures economic growth.

The reliability of the obtained statistical characteristics and conclusions on them is provided by a critical assessment of the initial data and the significance of the constructed production functions, confirmed by the values of the statistical and mathematical criteria of adequacy.

The use of coefficients of elasticity of production functions allows characterizing the economic growth in agriculture in the region from three perspectives:

1) identifying the location of production in the economic area;

2) determining the achieved positive effect of expanding the scale of production;

3) calculating the obtained additional economic effect expressed in an increase in output.

The peculiarity of the kinetic production function with variable elasticity is that persistence in the economic area is possible even with a negative value of either the parameter α_j or the parameter a_j, provided

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that the limits of change x_j in a given population lead to a positive value of E_j . That is, an increase in the costs of each resource must be accompanied by a certain increase in the volume of production.

This condition is not met in any cluster of production units in the region.

The positive effect of expanding the scale of production is determined on the basis of the elasticity of production calculated as the sum of the partial coefficients of elasticity. The production elasticity for agricultural organizations of the clusters is as follows.

In the 1st cluster, E =0.133+0.630–0.106 +0.734=1.391;

in the 2nd cluster, E = –0.022+0.411+0.726=1.115;

in the 3rd cluster, E =0.303–0.324+0.498+0.894=1.171;

in the 4th cluster, E = –0.098+0.335+0.377=0.614.

The value of this indicator is more than one in the first three clusters testifies to the positive effect of expanding the scale of production, when with an increase in resource costs by 1%, the output of agricultural products increases on average by 1.391%, 1.115% and 1.171%, respectively.

The third position of economic growth—obtaining an additional economic effect—is expressed in an increase in output. Within the framework of the methodology under consideration, this can be ensured by extending the regularities of the functioning of clusters with higher performance results to other clusters. This makes sense only if there are statistically significant discrepancies between the cluster groups of production units in the region, not only in the size of resources (which is provided by the cluster analysis algorithm), but also in the level of indicators of the efficiency of agricultural production. This procedure can be performed using the nonparametric Kruskal-Wallis test, which is used to compare several samples of different sizes (Popova, 2015).

Further calculations are related to linear interpolation between the elasticity coefficients of resources, from the use of which a negative or zero return was obtained, and indicators of resource availability, in the levels of which there is a significant difference. Based on this, an equation is constructed, into which the recommended value of the resource availability indicator is substituted, and thereby a new value of the corresponding elasticity coefficient is calculated. The production elasticity indicator for the problem cluster is recalculated. It is compared with its previous value, the resulting difference is multiplied by the output for the given cluster, and thus an additional economic effect is determined.

The situation in clusters 1 and 4 is indicative, in which, respectively, the highest and lowest returns on the use of resources are observed. Agricultural organizations of the 4th cluster are characterized by a negative return on the use of land resources (E_1 = -0.098) and a lower provision of fixed assets. Based on a comparison of organizations in the 1st and 4th clusters in terms of the elasticity of land use (E_1) and the cost of fixed assets per 100 hectares of agricultural land (x), linear interpolation was carried out, which resulted in the following equation: E_1 = 0.000174x-0.458. The real thing is to increase the capital supply in the organizations of the 4th cluster to the regional average level of 2865 thousand rubles. In this case, the coefficient of elasticity of the use of land resources will be 0.040%.

Comparing organizations of 1 and 4 clusters in terms of the elasticity of the use of fixed assets (E_3) and their value per 100 hectares of agricultural land (x), linear interpolation was carried out, which resulted in an equation of the form: E_3 = 0.000354x-0.702. At the recommended level of capital provision, the elasticity coefficient will be 0.312% instead of zero.

An increase in the level of provision of fixed assets ensures the transition of production units of the 4th cluster to the economic area. In this case, the elasticity of production will be 1.064% (= 0.040 + 0.335 + 0.312 + 0.377), that is, there is a positive effect of expanding the scale of production. An increase in the elasticity of production in cluster 4 by 0.450% (1.064 – 0.614) leads to an increase in the volume of production by 1793.44 thousand rubles per organization, which for all agricultural organizations of 4 clusters is expressed in obtaining an additional economic effect in the amount of 41 million 249 thousand rubles.

7. Conclusion

Thus, the presented statistical approaches to the study of economic growth in agriculture in the region, based on the use of cluster analysis procedures and the results of statistical modeling and linear interpolation, provide adequate characteristics of economic growth in static aggregates of production units of the industry under study.

It was found that in different clusters there are significantly different relationships between the analyzed features, which indicates the advisability of developing proposals and recommendations not for the entire set of economic entities in the region, but within a group of production units included in a particular cluster.

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