Analysis of the Gross Agricultural Product in the Northwestern Federal District

E S Minina, I L Minin and D L Minin

Yaroslav-the-Wise Novgorod State University, ul. B. St. Petersburgskaya, 41, Veliky Novgorod, Russia Federation

E-mail: elena.minina@novsu.ru

Abstract. The article discusses the main aspects of the development of trends in the regional agro-industrial complex of the Northwestern Federal District, the peculiarities of their change in the context of the globalization of the world economy and uneven development of the industry in certain areas of the region. The main features of the functioning of agricultural sectors are highlighted, the main development trends are predetermined, and their main characteristics are investigated in relation to the time indicator. The results of the study of the structure of the gross regional agricultural product of the district in the context of the constituent entities of the Federation are presented. The main recommendations related to the peculiarities of the development of the branches of the district agriculture are formulated and the general trend of the development of the agricultural economy of the district for the medium term is determined. The transitional nature of development has been identified, requiring additional support measures from both civil society and public authorities.

1. Introduction

The development of branches of the agro-industrial sector is fundamental for the functioning of many branches of the national economy and is one of the resource bases, ensuring the sustainable development of the territory. The actualization of the development of our own agriculture is due to the unstable situation in the product markets, which provides a significant part of the needs of labor resources for the reproduction of the population, the introduction of strict customs rules in the field of trade in rural products. Formation of products with low added value necessitates constant monitoring of the development of agricultural production [1].

2. Problem statement

Changes in the development of the national economy during the implementation of its restructuring ensures the formation of an optimal structure of homogeneous industries. In a developing economy, nonlinear dynamics is observed, which predetermines an increase in the risks of changing the direction of development of both a separate industry and the entire region [2]. The fundamental problem of the development of the agrarian industry is the uneven development of the marketability of production and the provision of sustainable growth of the gross product, which significantly depends on the possibility of selling products in the local, regional and the market of the customs union [3]. Determining the time and value of the gross product in crisis (peak) periods will allow distributing the financial burden on supporting agriculture and administrative decisions of public authorities related to compulsory price regulation of the agricultural market [4].
3. Research questions
It is necessary to investigate the issues related to the dynamics of agricultural development in the subjects of the Northwestern Federal District to solve this problem [5]:

– determination of the trend in the development of agricultural production and the likelihood of the trend implementation;
– disclosing the nature of the dynamics of the agrarian complex of each subject of the Northwestern Federal District and determining (if any) critical points of development;
– creation of a forecast for the development of the industry in the constituent entities of the Northwestern Federal District for the medium term (2021–2026);
– creation and determination of the general probability of the development trend of the district as a set of trends in the regions, subjects of the Russian Federation.

4. Purpose of the study
The main purpose of the study will be to determine the nature of the development of agriculture in the subjects of the Northwestern Federal District in the medium term and to create a set of development trends for each region to form and ensure progressive development in the medium and long term.

5. Research methods
The study used the methods of trend analysis to determine development trends, methods of mathematical statistics and mathematical analysis to define the coefficients of determination of trends and the nature of the development of agriculture in the corresponding regions of the Northwestern Federal District.

6. Findings
We study the indicators of agricultural development in the subjects of the Northwestern Federal District (the Republic of Karelia and Komi, the Nenets Autonomous Okrug, Arkhangelsk, Vologda, Kaliningrad, Leningrad, Novgorod, Pskov regions, the federal city of St. Petersburg) [6], through trend analysis (1.1–1.11), based on data from the Federal Statistics Service of the Russian Federation for the respective regions for the period from 2004 to 2020 to achieve this goal:

\[
\begin{align*}
Y_{ka} &= 68.747x^2 - 334.89 + 5975, \quad R^2 = 0.9443 \\
Y_{ko} &= 3.8718x^2 + 448.74x + 4410, \quad R^2 = 0.9158 \\
Y_{nao} &= 355x^{0.6289}, \quad R^2 = 0.8156 \\
Y_{ao} &= 1675.2x + 4523.2, \quad R^2 = 0.9603 \\
Y_{vo} &= 69.173x^2 - 452.19x + 14942, \quad R^2 = 0.8127 \\
Y_{ko} &= 59.519x^2 + 712.84x + 14942, \quad R^2 = 0.9716 \\
Y_{lo} &= 12021x^{0.5296}, \quad R^2 = 0.9135 \\
Y_{no} &= 392.94x^2 - 2531.3x + 16377, \quad R^2 = 0.9135 \\
Y_{lo} &= 1120.4x + 2870.4, \quad R^2 = 0.8879 \\
Y_{no} &= 127.9x^2 - 1005.8x + 6130.4, \quad R^2 = 0.9828 \\
Y_{spb} &= 5.1098x^{2.582}, \quad R^2 = 0.9084
\end{align*}
\]

\(Y_{ko}, Y_{nao}, Y_{ao}, Y_{vo}, Y_{ko}, Y_{lo}, Y_{no}, Y_{g}, Y_{spb}\) – are the estimated value of the gross agricultural product of the constituent entities of the Federation of the Northwestern Federal District, calculated on the basis of data from the Federal Statistics Service, million rubles [6].
x – is a temporary variable used to describe the period from 2004 to 2026 and taking integer values in the interval [0;23].

When calculating trends, it is possible to visually determine the nature of the development of the phenomenon, based on the characteristics of the functions themselves, which form the trends in the development of the regional industry [7]. For a more accurate characterization, it is important to perform a mathematical analysis of the functions and determine the critical points of the functions, which will indicate either a change in the direction of the trend (extrema), or the acceleration of the development of the phenomenon (inflection points) while maintaining the trend [8]. Let us calculate the first derivatives of the functions obtained above to determine the rate of development of the phenomenon (2.1–2.11):

\[ Y_{ka}' = 137.494x - 334.89 \]  
\[ Y_{ko}' = (-7.7436)x + 448.74 \]  
\[ Y_{nao} = 223.3853/x^{0.3711} \]  
\[ Y_{ao}' = 1675.2 \]  
\[ Y_{vo}' = 138.346x - 452.19 \]  
\[ Y_{lo}' = 119.038x + 712.84 \]  
\[ Y_{m} = 6366.3216/x^{0.4704} \]  
\[ Y_{m}' = 785.88x - 2531.3 \]  
\[ Y_{m}' = 1120.4 \]  
\[ Y_{po}' = 255.8x - 1005.8 \]  
\[ Y_{spb}' = 13.1935x^{1.582} \]  

We will equate derivatives (2.1–2.11) to 0 and determine the value of \( x \), as well as the value of the second derivative to determine the key characteristics of the extremum points and inflection points and the use of this variable in the initial trend (1.1–1.11) to accurately describe not only the time of occurrence of the event, but also the calculation of the value of the gross product in these periods. As a result of calculations, trends were obtained with a different nature and direction of development, depending on each specific situation. Using the values of the indicators of a specific variable, we will create a forecast for a five-year period of development of the region (table 2).

**Table 1.** Mathematical analysis of the development of regional trends in agriculture in the Northwestern Federal District (calculated based on data [6]), million rubles.

| Region               | First derivative of the equation with the value \( Y_i = 0 \) | \( x \) | Second derivative of the equation | \( Y'' \) at \( x \) | \( Y \) at \( x \) | Indicator development status |
|----------------------|-------------------------------------------------------------|------|----------------------------------|------------------|----------------|-----------------------------|
| Republic of Karelia  | 137.494x – 334.89 = 0                                        | 2.436| 137.494                          | 137.494          | 5567.559       | Crisis, June 2005           |
| Komi Republic        | (-7.7436)x + 448.74 = 0                                      | 57.95| 57.95                            | -7.7436          | -7.7436        | Peak, December 2060         |
Table 2. Calculation of the gross agricultural product of the regions of the Northwestern Federal District for the period 2021–2026, based on indicators [6], million rubles.

| Region/Year | 2021  | 2022  | 2023  | 2024  | 2025  | 2026  |
|-------------|-------|-------|-------|-------|-------|-------|
| X           | 18    | 19    | 20    | 21    | 22    | 23    |
| Republic of Karelia | 22221.41 | 24430.16 | 26776.4 | 29260.14 | 31881.37 | 34640.09 |
| Komi Republic | 11233.46 | 11538.94 | 11836.6 | 12126.68 | 12408.93 | 12683.44 |
| Nenets Autonomous Okrug | 2187.328 | 2262.982 | 2337.172 | 2409.998 | 2481.547 | 2551.9 |
| Arkhangelsk Region (except for the Nenets Autonomous Okrug) | 34676.8 | 36352.0 | 38027.2 | 39702.4 | 41377.6 | 43052.8 |
| Vologda Region | 29214.63 | 31321.84 | 33567.4 | 35951.3 | 38473.55 | 41134.15 |
| Kaliningrad region | 37330.08 | 40245.12 | 43279.2 | 46432.32 | 49704.48 | 53095.67 |
| Leningrad region | 55556.25 | 57170.04 | 58744.35 | 60282.04 | 61785.65 | 63257.45 |
| Murmansk region | 98126.16 | 110133.6 | 122927.0 | 136506.2 | 150871.4 | 166022.4 |
| Novgorod region | 23037.6 | 24158.0 | 25278.4 | 26398.8 | 27519.2 | 28639.6 |
| Pskov region | 29465.6 | 33192.1 | 37174.4 | 41412.5 | 45906.4 | 50656.1 |
The city of Saint Petersburg, a city of federal significance.

Northwestern Federal District

Proceeding from the fact that the parts of the phenomenon form a single whole, therefore, it is possible to determine the probability of the general trend model as the sum of the sets of determination coefficients for the average share of regions (Table 3) and to determine the development trend itself as a simple sum of trends (3).

| Region                          | Average | Share    | Determination coefficient | Contribution to the overall probability of a function |
|--------------------------------|---------|----------|---------------------------|-----------------------------------------------------|
| Republic of Karelia             | 28201.59 | 6.563041 | 0.9443                   | 6.19748                                             |
| Komi Republic                   | 11971.35 | 2.785959 | 0.9158                   | 2.551381                                            |
| Nenets Autonomous Okrug         | 2371.821 | 0.551967 | 0.8156                   | 0.450185                                            |
| Arkhangelsk Region (except for the Nenets Autonomous Okrug ) | 38864.8  | 9.044569 | 0.9603                   | 8.6855                                              |
| Vologda Region                  | 34943.81 | 8.132082 | 0.8127                   | 6.608943                                            |
| Kaliningrad region              | 45014.48 | 10.47571 | 0.9716                   | 10.1782                                             |
| Leningrad region                | 59465.96 | 13.83885 | 0.9135                   | 12.64179                                            |
| Murmansk region                 | 130764.5 | 30.43135 | 0.9816                   | 29.87141                                            |
| Novgorod region                 | 25838.6  | 6.013128 | 0.8879                   | 5.339056                                            |
| Pskov region                    | 39634.52 | 9.223697 | 0.9828                   | 9.065049                                            |
| The city of Saint Petersburg, a city of federal significance | 12631.75 | 2.939646 | 0.9084                   | 2.670375                                            |
| Northwestern Federal District   | 429703.2 | 100      | 94.25937                 |                                                     |

We present the basic equation of the agricultural development trend in the key areas under study to ensure the possibility of applying the presented calculations and recommendations. Having determined the probability of the district agricultural trend, we calculate the trend by adding the functions (3):

\[ Y_{\text{nmfr}} = 5.1098x^{2.582} + 714.4072x^2 - 1792.68x + 355x^{0.6289} + 12021x^{0.5296} + 66881.3, \ R^2=0.9426 \]  

(3)

The presented equation can be used to calculate the predicted GRP values for agriculture to make strategic and tactical management decisions to ensure the progressive development of industries in the medium and long term, considering the changing conditions of doing business in the respective territories.
7. Conclusion
The development of agriculture in the district has a characteristic feature of the transitional period of economic development of the country with the formation of various trends depending on the level of development of agriculture in the region [9].

As a result of the study, the following trends in the development of the regions of the Northwestern Federal District were identified:

1) Uniform progressive development, characteristic of the stable economy of developed countries (Arkhangelsk and Novgorod regions) [10]. The optimal structure of agriculture has been formed and the territory is the standard for the sustainability of the development of the industry, the probability of crises is infinitely small [11].

2) Uneven progressive development is typical for developing countries, it is extremely unstable and has a high probability of a trend change in the long term when macroeconomic conditions change [12]:
   - a sharp polynomial growth after the passage of the industry crisis of 1997-2006 (Kaliningrad (1997), Republic of Karelia (2005), Murmansk, Pskov and Vologda regions (2006)), growth is also observed in the Komi Republic until 2060, which will be replaced by a protracted crisis of agricultural production;
   - constant fading growth, characteristic of implicit crisis trends, is associated with stagnation of industry production, which requires immediate intervention of public authorities and civil society participants to adopt and implement measures of public-private support (Nenets Autonomous Okrug, Leningrad Region and the city of Saint Petersburg (before 2003, after that the power function passed the inflection point and the economy began to develop at an accelerated pace).

The level of reliability of the forecast is quite high and the probability of events being realized is 94.27%, which indicates the quality of the analysis carried out and considering the main direction of the development of agriculture in the federal district in the medium term.

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