SECTION III. MATHEMATICS

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Mathematical methods and their application in the sectors of the national economy (case study of agribusiness)

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Abstract

Agribusiness is one of the most important areas in the economic structure of the Russian Federation, and its research is significant because of the country's dependence on food supplies. At the same time, manufacturing is characterized by a rather complex technological cycle and has many economic entities involved in the sale of products. Under these conditions, the construction of an optimal management system of an agricultural enterprise cannot be carried out without formed practical analysis models that help to identify the patterns of their operation. At the same time, it is the agrarian sector that seems to be the standard for the application of mathematical methods, making it possible to account for the laws and trends that have formed during forecasting the development of this and other sectors. The mathematical analysis of statistical data in the agricultural sector is based on various models and methods, among which the preference is given to economic and mathematical or simulation modeling. Using traditional mathematical models during static observation, trends and forecasts of the development of the sector have been built, the study of which is the objective of this paper.

Keywords: agricultural industry, trends, dynamics, growth, mathematical methods, trend.

Аннотация

Агробизнес является одной из важнейших областей в экономической структуре Российской Федерации и значимость его исследования обусловлена зависимостью страны от продовольственных запасов. В тоже время промышленное производство характеризуется довольно сложным технологическим циклом и имеет множество субъектов экономики, участвующих в реализации продукции. В этих условиях построение оптимальной управленческой системы аграрного предприятия не может производиться без наличия сформированных практических моделей анализа, способствующих выявлению закономерностей их функционирования. В то же время именно аграрная сфера представляется эталонной для применения в ней математических методов, которые позволяют учитывать законы и сформировавшиеся тенденции при разработке прогнозов развития этой и других отраслей. Математический анализ статистических данных аграрной сферы строится на различных моделях и методах, среди которых преимущество отдается экономико-математическому или имитационному моделированию. Посредством традиционных математических моделей при проведении статического наблюдения строятся тренды и прогнозы развития отрасли, на изучение которых нацелена данная статья.

Ключевые слова: аграрная промышленность, тенденции, динамика, рост, математические методы, тренд.

Basic part.

Mathematical methods in the field of the agricultural sector are used quite often. In this case, the research database can be agribusiness enterprises of separate regions,

municipalities, and the entire country. The analysis is carried out using the methods of absolute and relative differences, as well as by identifying the average annual growth rates of sectoral indicators and their growth [1]. The purpose of this analysis is to identify factors and trends that contribute to the development of management decisions aimed at improving the efficiency of the sector in the future. In this case, the series of dynamics of the number of employees in the sector compared to similar sectors, as well as the volume of industrial output, are the paramount parameters of assessment. Thus, Figure 1 shows the dynamics of the number of sector employees for the period of 2003–2020.

Figure 1. Dynamics of the number of employees in the industry for the period of 2003–2020, million people

Source: compiled by the author based on [2]

Figure 1 shows that in 2020, due to the crisis, there was a decrease in the number of sector employees. In general, the number of employees in the sector during 2003–2019 steadily increased, despite the decline in other industries in some periods. However, 2020 negatively affected all industrial enterprises, which cut the number of employees, some of whom lost their jobs due to bankruptcy of companies or layoffs. The indicator of the share of the food sector employees in the total number of people employed in the economy and in manufacturing as a whole is of interest.

The share of employees in the food sector is about 10% of all employed in manufacturing, which indicates the importance of this sector. Gradually, there is a positive trend in the number of employees in the sector, which indicates the expansion of the food sector in Russia.

The share of people employed in the food sector has not significantly increased in relation to the entire economic structure of the country, while in manufacturing, there has been a rather tangible increase in this indicator, which allows concluding that the development of the sector is stable. Most of the staff cuts in 2020 affected manufacturing as a whole; in the food sector, they were not so significant.

Next, a comparative analysis of the number of enterprises in manufacturing general and in the food sector in particular has been made (Figure 2).

Figure 2. Dynamics of the number of enterprises in manufacturing as a whole and in the agricultural sector
Source: compiled by the author based on [2]

Compared to 2016, the number of enterprises in manufacturing decreased, as well as in the food sector. However, this does not indicate a deterioration in the sectoral performance. These trends are associated with an increase in the integration movements towards mergers of small companies into large holdings, since it is becoming more and more difficult for small businesses to withstand difficult market conditions.

An important indicator in statistical analysis, which makes it possible to identify sectoral trends more clearly, is the dynamics of the production output in physical and value terms.

Next, it is necessary to compare the dynamics of industrial and food production in comparison by types of products (Figure 3).

Figure 3. Dynamics of production of the entire manufacturing industry and the agricultural sector in comparison by types of products, million rubles
Source: compiled by the author based on [2]

Figure 3 shows that, despite the crisis, in 2020 there was an increase in the total volume of food production. This is due to the increase in food prices, which was observed in 2020, as well as in the demand for food in view of the economic crisis. Most of the sales are dairy products and meat. The share of vegetable fats and oils is also high.

Next, an analysis of the ratio of the growth rates of the volume of production in the entire manufacturing industry and in the food sector should be carried out. The data for analysis are shown in Figure 4.

Figure 4. Ratio of output growth rates in manufacturing and the agricultural sector, million rubles

Source: compiled by the author based on [2]

This graph proves the above conclusion that despite the economic crisis in 2020, the food sector has developed quite steadily. There was an increase in the volume of production output, despite the fact that there was a significant decline in manufacturing.

In conclusion, it is logical to present the dynamics of financial results obtained in the entire manufacturing and the food sector in particular, which is shown in Figure 5.

Figure 5. Ratio of growth rates in financial performance in manufacturing and agribusiness, million rubles

Source: compiled by the author based on [2]

It can be concluded that, despite the general decline in profits due to the crisis in the economy, there is a slight increase in the financial performance of the food sector. To confirm the indicated data, it is worth presenting an analysis of the indicators of the profitability of enterprises.

The main indicator of corporate efficiency is profitability, the analysis of which is shown in Figure 6.

Figure 6. Dynamics of efficiency indicators of industrial and agribusiness enterprises, %

Source: compiled by the author based on [2]

Figure 6 proves that, while the average level of profitability in manufacturing as a whole decreases, in the food sector, on the contrary, there is a slight increase in 2020, which is associated with an increase in sales and in prices in the reporting year in comparison with the baseline in the food sector in Russia as a whole.

The use of mathematical models in statistics allows identifying clearer trends and determining the degree of influence on an industry of particular factors [3]. A factor analysis of changes in the volume of production in 2020 compared to 2019 has been carried out as follows.

The volume of production output was:

2019 $y = 2,398$ billion rubles.

2020 $y = 2,564$ billion rubles.

Thus, the volume of production in 2020 increased compared to 2019 by 166 billion rubles ($2,564 - 2,398$) or by 21.3% ($2,564 : 2,398 = 1.069$).

Now, one can find the influence of factors on the overall change in the volume of production output by the food sector. The factor model has the form [4]:

$$Y = N \times d \times T,$$

where N is the total number of manufacturing staff;

D is the proportion of workers in the total number of manufacturing staff;

T is the labor productivity of workers.

Now, it is possible to calculate labor productivity in 2019 and 2020.

2019 $T_0 = 2,398 : 68.5 = 35$ million rubles per person

2020 $T_1 = 2,564 : 67.3 = 38.1$ million rubles per person

1. Due to the increase in the number of manufacturing staff, the volume of production increased by 33.9 billion rubles.

$$\Delta Y (N) = \Delta N \times d_0 \times T_0 = (68.5 - 67.3) \times 0.807 \times 35 = 33.9 \text{ billion rubles}$$

2. Due to the decrease in the share of workers in the total number of manufacturing staff, the volume of production output decreased by 32.9 billion rubles.

$$\Delta Y (d) = N_1 \times \Delta d \times T_0 = 67.3 \times (0.793 - 0.807) \times 35 = -32.9 \text{ billion rubles}$$

3. Due to the increase in labor productivity, the volume of production output increased by 183,106.0 million rubles.

$$\Delta Y(T) = N1 \times d1 \times \Delta T = 67.3 \times 0.793 \times (38.1 - 35) = 165.4 \text{ billion rubles}$$

$$\Delta Y = \Delta Y(N) + \Delta Y(d) + \Delta Y(T) = 33.9 - 32.9 + 165.4 = 166.4 \text{ billion rubles}$$

Thus, the greatest share in the increase in sales proceeds belongs to the influence of increased labor productivity.

So, through the use of a mathematical model, it was revealed that the main factor that influenced the volume of sectoral output was productivity growth.

In order to make a forecast for the sector development, one can smooth the considered time series using the 3-year moving average method [5]. The calculation results are presented in Table 1.

Table 1

Smoothing time series using the 3-year moving average method

Year	Production volume in 2017 prices, billion rubles	Moving total $y1 + y2 + y3$	Moving average $(y1 + y2 + y3) : 3$, billion rubles
2016	1,674	-	-
2017	1,885	-	-
2018	1,932	5,491	1,830.3
2019	2,392	6,209	2,069.6
2020	2,565	6,889	2,296.3

Source: compiled by the author based on [2]

According to Table 1, it can be concluded that there is a trend towards an increase in the level of food production since 2018.

In the authors' opinion, analytical alignment is a more perfect technique for revealing a general tendency in the time series [6]. When analyzing the general trend by analytical alignment, it is worth taking into account the levels of the time series, which can be with a certain degree of approximation to certain mathematical functions. Thus, on the basis of theoretical analysis, it is possible to identify the nature of the sector's development over time.

Next, this series of dynamics can be aligned according to the equation of a straight line:

$$Y_t = a_0 + a_1 \times t,$$

where a_0, a_1 – parameters of the straight line equation;

t – year legend.

The parameters of the equation of the straight line are found by the least-squares method using a system of linear equations.

$$\begin{aligned} a_0 \times n + a_1 \times \sum t &= \sum y \\ a_0 \sum t + a_1 \sum t^2 &= \sum ty \end{aligned}$$

The calculated parameters of the straight line equation are displayed in Table 2.

Table 2

Calculation of the parameters of the straight line equation

Year	Year legend, t	Production volume, billion rubles, y	t^2	$T \times y$	Yp	$(y - yp)^2$
2016	- 2	1,674	4	4	-3,348	5,022
2017	- 1	1,885	1	1	-1,885	3,770
2018	0	1,932	0	0	0	1,932
2019	1	2,392	1	1	2,392	0
2020	2	2,565	4	4	5,130	-2,565
$\sum$	0		10			

Source: compiled by the author based on [2]

The straight line equation has the form $Y_t = 520.96 + 72.91t$.

According to the straight line equation, the conclusion can be drawn that with each subsequent year, the output of the food sector enterprises will increase.

So, the case study of an analysis of the main indicators of the development of the agricultural sector allows concluding on the importance of mathematical methods in doing such analysis. At the same time, it is possible to calculate predicted values, as well as identify factors that have become key in certain trends.

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