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Econometric methods for solving problems of analysis and forecasting dynamics of yield of agricultural crops

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Abstract: This article is devoted to the use of limited resources in agricultural production, forecasting profitability and productivity, improving the integration of agricultural enterprises, analyzing the results of factors-dependent, using economic-mathematical and econometric (additive, multiplicative and multiple (proportional)) models, econometric studies based on the application of econometric methods for planning and forecasting agro-economic development of agriculture, and also search for new scientific approaches to agroeconomic forecasting.
The range of key objectives of agro-economic forecasting is defined, that is, determining the level of satisfaction of demand for agricultural products in the near future, as well as creating an effective production management system and ensuring sustainable economic development, and its relationship with industry and other sectors in the region. The optimal solutions are achieved due to higher economic identification of factors and sources of economic growth, systematic analysis of conditions in the implementation of an integrated approach in economic processes.

1. Introduction

In five priority areas of the development strategy of the Republic of Uzbekistan for 2017 - 2021, the issues of further development and liberalization of the economy in the direction of a certain macroeconomic stability and high rates of economic growth are fully covered, to maintain the competitiveness of the national economy, the rapid development and modernization of agriculture, balanced socio-economic development the country's economy by improving the investment climate and attracting foreign investment.
In the modernization of the agro-industrial complex, one of the priority tasks is the economic development of agricultural sectors [1]. To accomplish this task, first of all, econometric studies based on the use of modern information and communication technologies, methods of mathematical statistics and econometrics for analysis, planning and forecasting of agricultural economic development are required.
Currently, globalization and modernization of agriculture have created a sense of ownership of property, the ability to more efficiently use property and experience in managing farm enterprises. Planning and forecasting the development of agriculture and innovation require careful qualitative and quantitative analysis, which requires research and development in the use of advanced innovations, the rational use of limited resources, and the improvement of integration of agricultural enterprises. The main condition

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for the sustainable development of agricultural enterprises is the introduction of advanced agricultural and scientific achievements, the effective use of all material, natural, capital and labor resources. For this reason, the optimality of the proposed solutions is achieved through a higher economic identification of factors and sources of economic growth, a systematic analysis of the conditions and the implementation of an integrated approach to economic processes.

2. Research Methods

The main tasks of analysis and agroeconomic forecasting are to determine the level of satisfaction of demand for agricultural products and production potential, as well as the needs of the sector, create an effective enterprise production management system and, thus, ensure sustainable economic development, and its relationship with industry and other industries in the region, sustainable growth, optimal combination of limited resources and improved agricultural production capabilities Twa.

When analyzing and forecasting the development of agriculture, much attention is paid to the level and structure of agricultural production, the scientific basis of the quantity and quality of land resources, crop productivity, livestock productivity and improving product quality and other tasks. Prediction of production in agricultural enterprises is associated with climatic conditions and increased economic productivity of agricultural land with a number of specific features compared to other sectors [2-4].

In the current market economy, the factors affecting economic development and assessing their impact on agricultural production processes, analysis and forecasts are increasing. First of all, researchers have achieved significant results in the theory and practice of agricultural use of their production functions.

As you know, mathematical modeling of economic phenomena and processes is a key and important tool for economic analysis and forecasting. Mathematical modeling gives a clear idea of the object being studied, the quantitative expression of nature and the influence of its internal structure and external relations. High rates of intensification of agricultural production and the widespread use of extrapolation methods in increasing crop yields and livestock productivity.

An important aspect of economic research is the analysis and forecasting of the demand for food products and their value. The republic's agricultural policy is urgently needed to develop alternative options for future agricultural policy using econometric models supported by farmers and subsidizing food production and consistent changes in the domestic food market.

Econometric models can be expressed as a system of equations, inequalities and equations in the mathematical form of the laws of change in economic indicators.

The general view of econometric models is as follows:

$$Y = f(x_1, x_2, \ldots, x_n) \qquad (1)$$

In the econometric model Y - the main endogenous indicator, the laws of change in the model Y, $(x_1, x_2, ..., x_n)$ can be investigated using $(x_1, x_2, ..., x_n)$ - influencing exogenous indicators.

The creation or modeling of the final factor model for the analysis of indicators of economic efficiency of an enterprise based on a qualitative analysis of the essence of an economic phenomenon expressed in this indicator is formal and intuitive. The modeling of the indicator model is based on the following economic criteria when choosing factors that are elements of a factorized system: its relevance, own originality, accessibility and accountability. Generally speaking, factorized input factors should be quantitative [5-6].

In the modeling of sensitive systems, a large number of similar factors can be identified for the analysis of economic activity:

1) additive models

$$y = \sum_{i=1}^{n} x_i = x_1 + x_2 + ... + x_n; \qquad (2)$$

2) multiplicative models

$$y = \prod_{i=1}^{n} x_i = x_1 x_2 ..... x_n; \qquad (3)$$

3) multiple (proportional) models

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$$y = \frac{x_1}{x_2};.....y = \frac{\sum_{i=1}^{n} x_i}{x_{i+1}};....y = \frac{x_1}{\sum_{i=1}^{n} x_i};....y = \frac{\sum_{i=1}^{n} x_i}{\sum_{i=1}^{m} x_i}; \quad (4)$$

Where **y -** is the final indicator (initial coefficient); $\mathbf{x_i}$ **-** factors.

As is known, the analysis and forecast of production is considered as the first stage of planning the national economy. Extensive financing is provided as part of a comprehensive program of scientific and technological development and a general scheme for the development and deployment of production forces.

Currently, radical changes in the economy of our republic create new problems in production. This, in turn, requires a search for new approaches to the analysis and forecasting of the scale of the used economic and mathematical models [6-8].

It is necessary to pay attention to the most important issues of economic analysis and forecasting, without pretending to make a complete list of agricultural and food problems in the country.

The first question is the problem of satisfying the needs of the population for food. The solution to this problem is now limited by demand in the food market, if it was previously considered necessary and offered by the assortment of food products. The decline in total income and a sharp increase in social stratification, despite the fact that most of the main elasticity of demand for food is relatively small, the scale of profit and level of profit led to a sharp decline in demand. In such cases, predictable changes in food demand are determined by the choice of promising socio-economic strategies that involve the use of demand models that are more sensitive to changes in income in various policy areas.

The financial condition of some agricultural enterprises is considered inefficient because many enterprises in different types of agriculture are considered backward in the application of innovative technologies and have no prospects for full development.

3. Results and Discussion

The solution to this problem is related to the elimination of intersectoral inequality in price. As a result of the lack of effective natural monopoly control over high reseller prices and low purchase prices, local enterprises experience difficulties in the local market and access to most markets. The reduction in the share of value added in agriculture cannot be changed without targeted government intervention. Changes in commodity prices and transportation tariffs should be reflected in forecasting templates in one way or another. As for the liquidation of local monopolistic enterprises of agricultural raw materials, world practice has clearly demonstrated the important role of sales in this work. Therefore, in our opinion, it is wise to use agro-industrial associations to recall the experience of mathematical modeling and create other forms of cooperative ones.

In the problem of efficient use of production resources, production factors should allow to evaluate the value (position) of these factors from the models used in the market. At the same time, this leads to the choice of a development path, which leads to the full use of resources and inefficient use of production factors by assessing its consequences. Assessment of factors in a significant part of the non-productive sphere requires the creation of original mathematical models and new approaches to it.

Using the example of three crops, using the methods of analysis and forecasting of econometric modeling, we investigated the trend in the dynamics of crop yields of the republic on the basis of experimental data.

As you know, the study of agricultural processes in the form of a dynamic algebraic series and forecasting crop yields on the basis of experimental data from previous years, plays an important role with limited agricultural resources and determining the economic efficiency of farming, the agricultural sector and indicates the main ways of their development.

The study carries out processing and econometric analysis of the productivity of agricultural crops (cotton, wheat, potatoes) in the Republic of Uzbekistan for the observation period 2003-2018, as a time series (Table 1).

Table 1. The productivity of agricultural crops (cotton, wheat, potatoes) in the Republic of Uzbekistan for the observation period 2003-2018

№	Years	crop yields (productivity)		
		cotton	wheat	potato
1	2003	20.5	36.4	152.5
2	2004	24.5	37	157.5
3	2005	25.3	41.5	170.3
4	2006	25	42.7	175.2
5	2007	25.5	44.1	184.1
6	2008	24	44.4	194.1
7	2009	25.3	48.2	198.4
8	2010	25.4	45.9	194.9
9	2011	26.3	47.2	195.7
10	2012	26.4	47.3	203.7
11	2013	25.7	47.4	210.7
12	2014	26.1	47.9	213.6
13	2015	25.9	48.2	219.1
14	2016	23.4	47.9	225.1
15	2017	24	42.2	217.9
16	2018	20.9	41	224.8

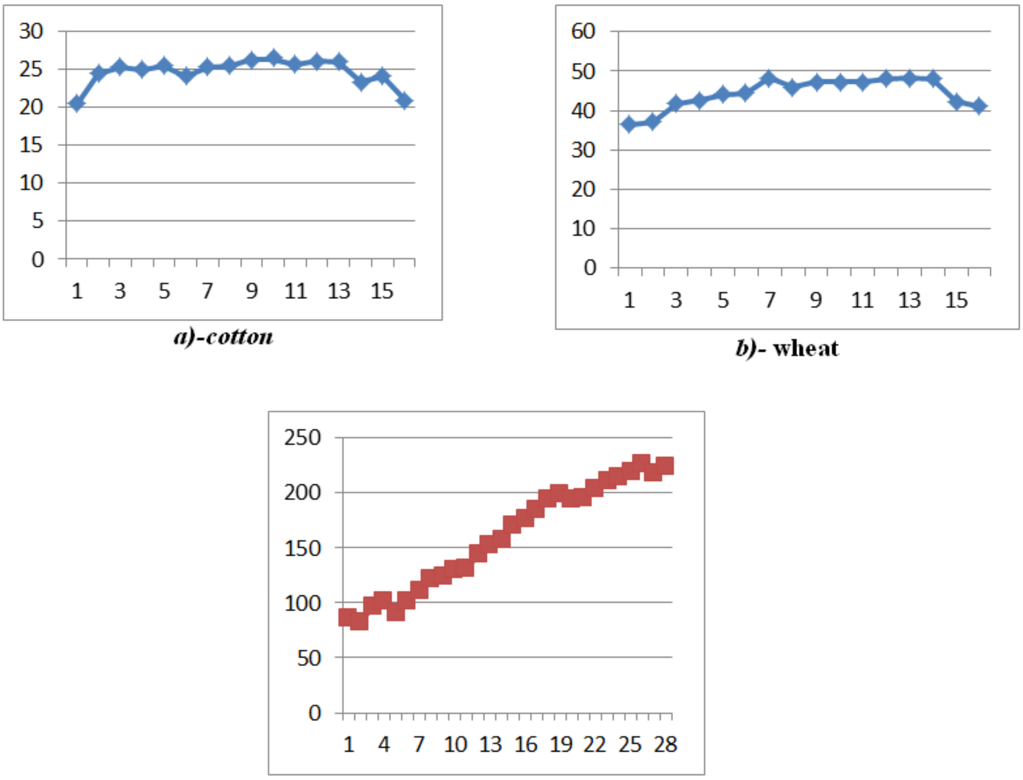
The annual re-cultivation of crops gives grounds to consider this process as a discrete $\{y_t,\ t \in T\}$ time series (for example: where t-years, $y_t -$ crop yields in the t-th year, T- observation volume).
We know that in the general case, the time series $\{y_t,\ t \in T\}$ consists of four components: trend, fluctuations relative to the trend, seasonality effect and random component [10, 11].
Based on the statistical data given in table No. 1, we carry out processing and analysis of crop yields as a discrete time series. A graphical representation of the observations of crop yields (cotton, wheat, potatoes) in a rectangular coordinate system gives rise to a first approximation, suggesting the hypothesis that the trend part of the process under study has a linear relationship (see polygon of the distribution of crop yields, Figure1), $\mathbf{y_i(t) = a_1 + a_0}$, where the parameters a_1, a_2 are determined by the least squares method, i.e. based on experimental observation data, solving the following system of normal equations (5):

$$\begin{cases} a_0 T + a_1 \sum t = \sum y_t \\ a_0 \sum t + a_1 \sum t^2 = \sum y_t t \end{cases} \tag{5}$$

Now, compiling worksheets based on the statistical data of table No. 1, we solve equation (5) using the least squares methods and find the value of the parameters of the linear regression equation.
Then we get the equation of the linear trend (trend) of crop productivity: cotton - $y_1(t)$, wheat - $y_2(t)$, potato - $y_3(t)$

$$y_1(t) = 0{,}58t + 24{,}64$$
$$y_2(t) = 1{,}46t + 44{,}33 \tag{6}$$
$$y_3(t) = 6{,}99t + 159{,}33$$

Using statistical criteria, it can be established that in the equations $y_i(t) = a_1 t_i + a_0$, the main hypothesis $H_0: a_1 = 0$ is rejected and the alternative hypothesis $H_1: a_1 \neq 0$ with the same significance level $\alpha = 0{,}05$ is accepted.



a)-cotton *b)- wheat* *c)-potato*

Figure 1. Crop yield distribution: (*a*)*-cotton, б)-wheat, c)-potato*

Putting the value t=3,7,12 in all equations (6) we find the expected forecast of crop yields on average for the republics of 2021 cotton: $\boldsymbol{y_1}(3) = 26{,}38$ cwt / ha, $y_2(3) = 48{,}71$ cwt / ha, $y_3(3) = 180{,}3$ cwt / ha, and in 2025 year $y_1(7) = 28{,}7$ cwt / ha, $y_2(7) = 54{,}55$ cwt / ha, $y_3(7) = 208{,}26$ cwt / ha with a guarantee of 95 percent.

Now we calculate the coefficients of variation of the order differences and establish that $V_1 \approx V_2 \approx V_3$. Therefore, finite first-order differences eliminate the linear tendency.

$$V_k = \frac{\sum_{t=k}^{T} \left(\Delta^k y_t\right)^2}{(T-k)C_{2k}^k}$$

To check for the presence of autocorrelation in the series of dynamics of crop yields (cotton, wheat, potatoes), we use the Darbin - Watson criteria

$$d = \sum_{t=1}^{T-1} (Y_{t+1} - Y_t)^2 / \sum_{t=1}^{T} Y_t^2 \; . \qquad (7)$$

We calculate the values of d_{nab} by the formula (7), $d_{nab} = 0{,}012 - cotton, d_{nab} = 0{,}001 - wheat, d_{nab} = 0{,}042 - potatoes,$ and compare them with the value $d_{crit} = 1{,}08$. Since all $d_{nab} < d_{crit} = 1{,}08,$ therefore, crop yields have an autocorrelation dependence $Y_t = \rho Y_{t-1} + \varepsilon_t$, where ρ = *COV*(Y_t,Y_{t+1}), that is, the crop yield in the current year depends on the crop of the previous year.

Based on sample data, we calculate the numerical characteristics of the regression equations - $y_i(t)$ - crop yields (table No. 2).

Table 2. The numerical characteristics of the regression equations - $y_i(t)$ - crop yields

Selective specifications	Estimates of sample characteristics		
	cotton	wheat	potato
Average yield $\bar{y}_t$ (cwt/ha):	24.64	44.33	159.33
Dispersion:	3.10	15.15	2319.299
Standarddeviation, σ_T:	1.76	3.89	48.159
The coefficient of variation v (%):	7.14%	8.78%	30.23 %
Asymmetry, A_ς :	-1.49	-0.87	-0.159
Excess, $E_{K\varsigma}$:	1.65	-0.21	-1.481
Mean Error $\bar{y}_t, m_y$	0.44	0.97	9.104
Marginalerrorm'_y:	0.94	2.07	19.392
Standard deviation error σ_T:	0.31	0.69	6.436
Interval estimates (95%) $\bar{y}_t \pm tm_y$:	24.64±0.94	44.33±2.07	159.33±19.392
Testing the statistical hypothesisH_0: $P(\bar{y}_t < x) = \Phi_{a,\sigma}(x)$:	with a 95% guarantee, hypothesis H_0 is accepted		

As you know, the normal distribution in mathematical statistics has a special place, and the main conclusions are based on it. The normality check $\bar{y}_t \sim$ average crop yields can be established, i.e. if the following inequalities hold true [15]:

$$|A_\varsigma| < 1{,}5\sigma_1 \quad , \quad |E_\varsigma + 6/(p+1)| < 1{,}5\sigma_2$$

Then, with a 95% guarantee, we can assume that the average crop yield $\bar{y}_i(t)$ has a normal distribution.

In the general case, a statistical test of hypotheses:

$$H_0 : P(X < x) = F_{a,b}(x), H_1 : P(X < x) \neq F_{a,b}(x)$$

about the normal distribution of a random variable (average crop yield, with parameters:

cotton – $\bar{y}_i(t) \sim$ N (24,64; 1,76); wheat - $\bar{y}_i(t)$ ~N(42,26; 3.89); potatoes - $\bar{y}_i(t)$ ~N(140,018;48,159) using the χ^2-Pearson criterion and other criteria is taken with a significance level of α = 0.05.

Now, it is possible to construct interval estimates for the average crop yield by the ratio:

$$\bar{Y}_{T+i} - t(T-2;\alpha)\bar{\sigma}_y \leq a_0 + a_1(T+i) \leq \bar{Y}_{T+i} + t(T-2;\alpha)\bar{\sigma}_y$$

where, the value of $\pm(T\text{-}2 ; \alpha)$ is determined by the student distribution table.

Hence, crop yields in 2020 with a probability of 0.95 are expected in the limit: yields - cotton (23.70; 25.58) *cwt* / ha, wheat - (42.26; 46.40) *cwt* / ha, potatoes - (140.018; 178.722) *cwt* / ha.

4. Conclusions

Thus, based on the above statistical and econometric analyzes of the dynamics of crop yields $y(t)$ as a time series with a reliability of γ = 0.95, we can draw the following conclusions: based on an econometric analysis and forecasting cotton yield, we can construct point and interval statistical estimates for their selective characteristics, to determine the explicit types of trends and establish its linearity, as well as the Darbin - Watson criterion, it can be established that the autocorrelation in the considered series of dynamics, have linear trends. In addition, using statistical criteria, it can be established that the agricultural processes in question are generally unsteady time series.

In addition, based on the foregoing, it should be noted that analysis and agro-economic forecasting is the basis for scientifically based decisions, which is one way to increase the scientific level of planning and support the concept of medium and long-term planning, structural analysis and optimal decision making. In practice, the use of scientifically based models of analysis and forecasting and methods of product planning involves the development of prospects for agricultural enterprises, the most effective ways of productive programming, targeted development. Detecting bad economic growth trends using analysis and forecasting methods and assisting them in timely prevention and stimulation of positive growth in product development.

In general, the urgent need to solve pressing problems in agriculture requires the expansion of intellectual research and the effective use of economic, mathematical and econometric methods and models.

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