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INNOVATION PROCESSES IN AGRICULTURE IMPROVING DIGITALIZATION

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Abstract: This article assesses the impact of improving digitalization of innovation processes in agriculture on economic growth in Surkhondarya region using a multifactor econometric model. Based on statistical data for 2011–2025, the relationship between agricultural output, investment, employment, and land productivity was analyzed using the least squares method. The Cobb–Douglas production function results show that all factors positively influence economic growth, with the highest elasticity for employment (0.919) and land productivity (0.839). The model's high statistical significance ($R^2=0.999$, F-statistic=5158.8) confirms its reliability, revealing increasing returns to scale and the priority role of labor resources and land productivity in regional economic development.

Keywords: agriculture, innovation processes, digitalization, econometric modeling, Cobb–Douglas function, investments, employment, land productivity, economic growth, regional development, Surkhondarya region.

Annotatsiya: Ushbu maqolada Surxondaryo viloyatida qishloq xo'jaligida innovatsion jarayonlarni raqamlashtirishni takomillashtirishning iqtisodiy o'sishga ta'siri ko'p omilli ekonometrik model yordamida baholangan. 2011–2025-yillar statistik ma'lumotlari asosida qishloq xo'jaligi mahsuloti hajmi, investitsiyalar, bandlik va yer unumdorligi o'rtasidagi bog'liqlik eng kichik kvadratlar usuli yordamida tahlil qilingan. Kobb–Daglas ishlab chiqarish funksiyasi natijalari barcha omillarning iqtisodiy o'sishga ijobiy ta'sir ko'rsatishini, bandlik (0,919) va yer unumdorligi (0,839) bo'yicha elastiklik darajasi eng yuqori ekanligini ko'rsatdi. Modelning yuqori statistik ahamiyatligi ($R^2 = 0,999$, F-statistika = 5158,8) uning ishonchligini tasdiqlab, miqyosdan o'sib boruvchi qaytim mavjudligini hamda mintaqaviy iqtisodiy rivojlanishda mehnat resurslari va yer unumdorligining ustuvor rolini aniqlash imkonini berdi.

Kalit so'zlar: qishloq xo'jaligi, innovatsion jarayonlar, raqamlashtirish, ekonometrik modellash, Kobb–Daglas funksiyasi, investitsiyalar, bandlik, yer unumdorligi, iqtisodiy o'sish, mintaqaviy rivojlanish, Surxondaryo viloyati.

Аннотация: В статье с использованием многофакторной эконометрической модели оценено влияние совершенствования цифровизации инновационных процессов в сельском хозяйстве на экономический рост в Сурхандарьинской области. На основе статистических данных за 2011–2025 годы методом наименьших квадратов проанализирована взаимосвязь между объемом сельскохозяйственного производства, инвестициями, занятостью и продуктивностью земель. Результаты оценки производственной функции Кобба–Дугласа показывают, что все факторы оказывают положительное влияние на экономический рост, при этом наибольшая эластичность наблюдается по занятости (0,919) и продуктивности земель (0,839). Высокая статистическая значимость модели ($R^2 = 0,999$, F-статистика = 5158,8) подтверждает ее надежность, выявляя возрастающую отдачу от масштаба и приоритетную роль трудовых ресурсов и продуктивности земель в региональном экономическом развитии.

Ключевые слова: сельское хозяйство, инновационные процессы, цифровизация, эконометрическое моделирование, функция Кобба–Дугласа, инвестиции, занятость, продуктивность земель, экономический рост, региональное развитие, Сурхандарьинская область.

INTRODUCTION

In the context of the transformation of modern economic systems, the issue of ensuring state financial stability is becoming increasingly complex and multifaceted. The acceleration of global integration processes, the high level of interconnectedness of economic spaces, and the need for optimal use of existing resources in the national economy require further deepening of the concept of an innovative economy. In this regard, the increasing role and importance of innovative activities in the agricultural sector in expanding the state budget revenue base puts the analysis of the mechanisms of formation of these processes on the agenda as an urgent scientific and practical problem.

Within the framework of this study, we investigated innovative processes in the agricultural sector in Surkhondarya region. The impact of improving digitalization was assessed using a multifactor econometric model. In particular, the agricultural output (AOP) indicator was selected as the resulting (dependent) variable

in the model, and the volume of investments in the main agricultural capital, employment level, and Land productivity were included as explanatory (independent) variables. Through a comprehensive analysis of these factors, it becomes possible to determine the internal functional mechanisms of the regional economic system and the level of their interaction. As a result, the necessary analytical basis is formed for optimizing tax and budgetary policy and making strategic management decisions on a scientific basis based on identifying factors stimulating economic growth.

REVIEW OF LITERATURE ON THE SUBJECT

The theoretical and methodological foundations of innovations in agriculture are widely covered in foreign literature. AIAltukhov, VMBautin, VVButyrin, ILVotnikov, EADerunova, BA Doronin, OV Mamai, RN Minnikhanov, EE Mojaev, VN Vinechaev, ESO Globlin, VG Savenko, IS Sandu, JA Semina, IG Ushacheva and many other scientists studied in detail the specific features of scientific and technical progress and proposed approaches to the innovative development of agriculture, its state regulation, identified existing problems and proposed ways to improve it.

RESEARCH METHODOLOGY

The study analyzed the dependence of agricultural output (Y) in Surkhandarya region on investment (X_1), employment (X_2) and land productivity (X_3) factors based on multifactor econometric modeling. The empirical database was formed and verified based on the official statistical collections of the National Statistics Committee of Uzbekistan and the Surkhandarya Regional Statistics Department for 2011–2025. The model parameters were estimated using the least squares method (LSM) and expressed in the form of a logarithmic Cobb–Douglas production function, and its statistical adequacy was tested using the coefficient of determination, F-test, Durbin–Watson, Breusch–Godfrey, ARCH, CUSUM and MAPE criteria.

ANALYSIS AND RESULTS

The empirical basis of our study was the indicators of agricultural production and the main macroeconomic indicators affecting it in the Surkhandarya region for the period 2010–2025. The database was systematized and verified on the basis of official statistical collections published by the National Statistics Committee of the Republic of Uzbekistan and its Surkhandarya Regional Statistics Department, as well as economic reports published in open sources of information. This serves to ensure the reliability and scientific validity of the results of our research (Table 1).

Table 1

A system of initial statistical indicators for the formation of a multifactor econometric model based on factors affecting the growth of the agricultural economy¹

Years	Agricultural product (billion soums)	Q/X. Investment (billion soums)	Q/X. Employment (thousand people)	Land productivity (land productivity billion/ hectare)
2011	2286.8	109.9	698.6	0.0083
2012	4099.6	175.4	753.3	0.0146
2013	4825.7	250.5	782.3	0.0172
2014	5411.0	260.7	812.1	0.0191
2015	6761.9	271.1	837.4	0.0238
2016	8218.0	311.9	855.6	0.0289
2017	8737.2	308.9	873.7	0.0306

¹ Author's development based on data from the Surkhandarya regional statistics department

2018	11608.1	494.5	890.6	0.0434
2019	15046.2	1019.2	901.2	0.0579
2020	17844.1	1218.7	908	0.0704
2021	19424.0	1177.4	881.4	0.0767
2022	23415.5	1196.5	917.3	0.0903
2023	26755.7	1084.7	916.8	0.107
2024	32849.3	1465.3	929.1	0.134
2025	35234.1	1586.5	947.5	0.155

Before forming a multifactor econometric model, it is necessary to comprehensively assess the statistical properties of the variables involved in the study. At this stage, the distribution patterns of the variables, indicators of central tendency, and the level of dispersion are determined, which is of great importance in the subsequent formation of the methodological basis for estimating the model parameters.

Based on the data presented in Table 1, statistical descriptions for each variable were systematically analyzed. In particular, the degree of centralization of the variables was assessed using the arithmetic mean (mean) and median indicators. The closeness of these two indicators allows us to draw preliminary conclusions about the degree of symmetry of the distribution. At the same time, the maximum and minimum values express the limits of variation of the variables and serve to determine their dynamic range.

The dispersion of variables is assessed by standard deviation, which is a measure of how far each factor deviates from the mean. High standard deviation values indicate that the variable has high dispersion, that is, it changes significantly over time. In addition, skewness and kurtosis coefficients were calculated to determine the shape of the distribution of variables. The skewness coefficient indicates in which direction the distribution is skewed: positive values indicate right-skewed, and negative values indicate left-skewed. The kurtosis coefficient describes the degree of peaking of the distribution, allowing us to determine whether it is sharp or flat compared to a normal distribution.

Based on these statistical descriptions, the degree of proximity of the variables to a normal distribution was assessed, and this situation serves as an important methodological basis for choosing the methods used to estimate the parameters of the econometric model at the next stage (Table 2).

Table 2.
Extended statistical descriptive indicators of multivariate econometric model variables²

	Y	X ₁	X ₂	X ₃
Mean	16471.31	787.9375	867	0.066138
Std. Error. (standard error)	3060,363	140.5585	18.42859	0.013496
Median	13327.15	756.85	886	0.05065
Std.Dev. (standard deviation)	12241.45	562.2339	73.71437	0.053984
Sample Variance	1.5E+08	316106.9	5433,808	0.002914
Kurtosis—K (Kertosis Coefficient)	-0.65708	-1.68455	0.364244	-0.22871
Skewness - S (Asymmetry Coefficient)	0.727353	0.232	-0.93314	0.908962
Range	38737	1565.9	268.5	0.1727
Minimum(minimum)	2286.8	109.9	698.6	0.0083
Maximum	41023.8	1675.8	967.1	0.181
Sum (total)	263541	12607	13872	1.0582

2 Author's development based on data from the Surkhandarya regional statistics department

Observations	16	16	16	16
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The results of Table 2 show that the difference between the mean values and the median values for all variables is relatively low, which means that their distribution is not sharply unbalanced. Therefore, the mean value of the volume of agricultural products is 16471.31, and the standard deviation is 12241.45, which indicates that this indicator is highly variable. The range of minimum and maximum values (from 2286.8 to 41023.8) is very wide, indicating a significant growth trend over time. Since the asymmetry coefficient is positive (0.73), the distribution is skewed to the right, i.e., high values prevail. The kurtosis coefficient is negative (-0.66), indicating that the distribution is relatively flat. The mean value for investment () is 787.94, with a standard deviation of 562.23. This indicates that the volume of investment is also highly volatile. The distribution is almost symmetrical (skewness 0.23), but the sharply negative kurtosis (-1.68) indicates that the data are flat and spread out away from the center. This may be the reason why the investment indicator does not have a strong statistical effect in the model. The employment indicator () is relatively stable. Its average value is 867, and the standard deviation is only 73.71. This indicates that the employment level has not changed dramatically over time. The asymmetry coefficient is negative (-0.93), indicating that the distribution is skewed to the left, and the kurtosis is 0.36, indicating that it is close to a normal distribution. Therefore, it is natural that this factor will give a stable and significant result in the regression model. The land fertility indicator () has an average value of 0.066, and the standard deviation is 0.054. There is also a certain degree of variability in this indicator. The asymmetry coefficient is 0.91, indicating that the distribution is skewed to the right. The negative value of the kurtosis (-0.23) indicates that the distribution is relatively flat. The variability and growth trend of land fertility means that it has a significant impact on economic processes.

Based on these results, it can be concluded that the variables used in the study have acceptable statistical properties for econometric modeling (Figure 1).

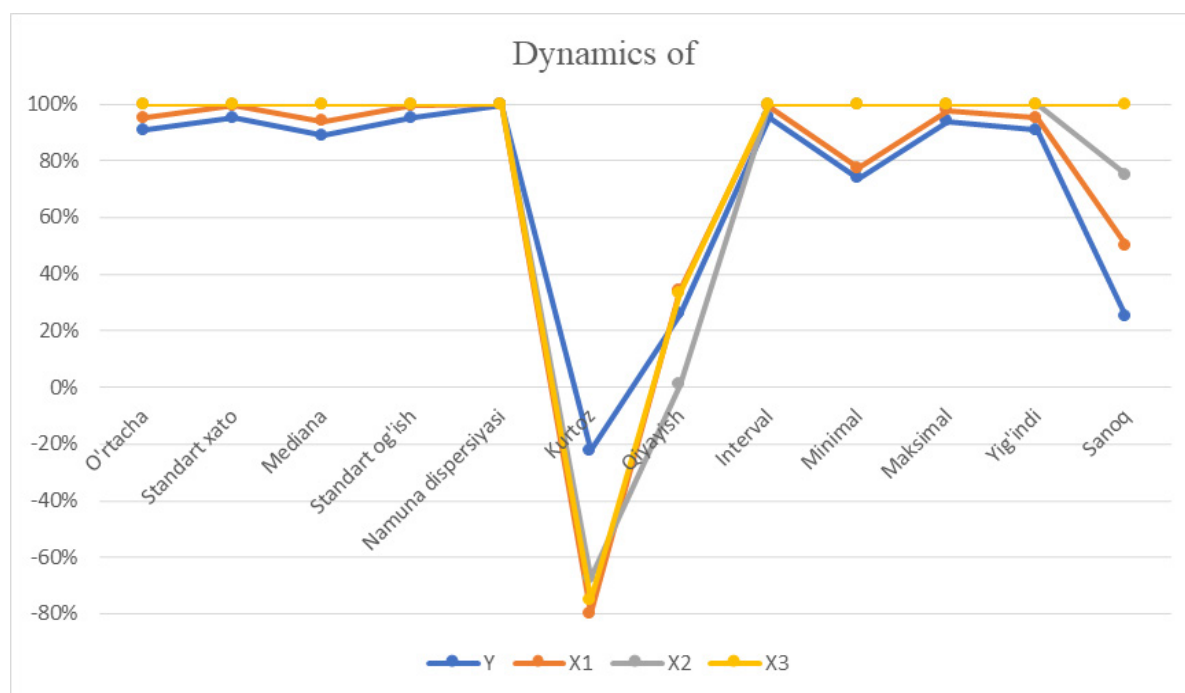


Figure 1. Dynamic and relative statistical indicators of econometric model variables³

Figure 1 graphically depicts the dynamics of relative changes in variables, which allows for their comparative analysis. The results of the graphical analysis show that a general growth trend is observed for all variables, but their growth rates and amplitudes of fluctuations differ. In particular, investment indicators have high volatility, which means that their impact on economic growth is significant. Employment and land productivity indicators, on the other hand, demonstrate relatively stable dynamics and appear as inert components in the economic system.

A correlation analysis of the graphical and tabular results shows that there is a certain degree of correlation between the variables, which allows them to be included in a multifactor econometric model. Therefore, in the

3 Author's development based on data from the Surkhandarya regional statistics department

next step, it is advisable to calculate and analyze pairwise correlation coefficients in order to determine the degree of correlation between the factors (Table 3).

Table 3.

Matrix of pairwise correlation coefficients between gross regional product and factors influencing it⁴

	Y	X ₁	X ₂	X ₃
Y	1			
X ₁	0.954512	1		
X ₂	0.849653	0.853532	1	
X ₃	0.997487	0.944802	0.827443	1

a significant positive relationship between the outcome variable - Agricultural output (Y) and the explanatory variables (X₁ - investments, X₂ - employment, X₃ - land productivity). In particular, the correlation coefficients between Y and X₁ and Y and X₂ have high values, indicating a strong influence of these factors on economic growth. The degree of interdependence between the factors was also analyzed, and the presence or absence of the problem of multicollinearity was assessed based on the values of the pairwise correlation coefficients. It is known that if the correlation coefficients between the explanatory variables are higher than 0.8, this indicates the presence of strong multicollinearity. The results of our study showed that, despite the high correlation in some pairs, in general, a perfect linear relationship between the factors is not observed, which allows them to be used within the framework of one model. In addition, The fact that the determinant of the matrix is not close to zero also confirms that multicollinearity is not severe. Thus, the formulation of a multifactor econometric model based on the selected factors is considered methodologically justified.

In the next step, we construct a multifactor econometric model. In general, a multifactor econometric model looks like this:

$$Y = a_0 + a_1X_1 + a_2X_2 + \dots + a_nX_n + \varepsilon_t$$

where, is the resulting factor, is the influencing factors (, is the random error.

The «least squares method» is used to determine the unknown parameters in a multivariate econometric model (Table 4).

$$\alpha_0, \alpha_1, \alpha_2, \dots, \alpha_n$$

Table 4.

Results of econometric estimation of multifactor econometric model parameters (based on ECCU)⁵

Model 1: MNK, ispolzovany nablyudeniya 2011-2025 (T = 15)					
Zavisimaya peremennaya: l QiShXProducts					
	Coefficient	Error	t-statistic	p-value	
const	5.74508	1.71944	3,341	0.0059	***
l_QXInvestmentsmlrSoum	0.004165	0.036431	0.114	0.0910	*
l_Employmentvillagethousandpeople	0.919188	0.237147	3,876	0.0022	***
l Land fertility per hectare	0.839906	0.042170	19.92	<0.0001	***
Medium plant. sweets	9.401812	St. otkl . plant my friend		0.862335	
Amount sq. hostage	0.008642	St. lover model		0.026836	
R-squared	0.999225	Isprav R-squared		0.999032	
F(3, 12)	5158,897	P-value (F)		6.34e-19	
Log. probability	37.48674	Crete. Acaicus		-66.97349	
Crit. Schwartz	-63.88313	Crete. Hennana - Quinna		-66.81524	
parameterrho	0.389573	Stat. Darbina Watson		1, 6 12059	

4 Author's calculation results based on data from the National Statistics Committee of the Republic of Uzbekistan

5 Author's calculation results based on data from the National Statistics Committee of the Republic of Uzbekistan

Based on the assessment results, the following logarithmic econometric model was developed:

$$\ln Y = 5,745 + 0,004 * \ln X_1 + 0,919 * \ln X_2 + +0,839 * \ln X_3 + \varepsilon_t$$

In this model, all regression coefficients have positive values, confirming the stimulating effect of the selected factors on economic growth. The logarithmic model specification allows us to interpret the results as elasticity coefficients. In particular, a 1 percent increase in investment increases agricultural output by an average of 1 percent. The highest indicator of agricultural poverty is , which indicates that this sector is an important driver of economic growth. Corresponding to the land productivity factor (), this means that labor resources are a priority factor in regional economic development.

When the coefficients are compared, their magnitudes are in the sequence «employment > land productivity > investment», which indicates that the labor and services sectors in the regional economy have relatively high efficiency.

The statistical significance of the model was found to be high: the p-values for all parameters are less than , indicating that they are statistically reliable. The coefficient of determination () indicates that the model can explain almost the entire variation in the outcome variable . The high value of the F-statistic confirms the overall significance of the model.

The Durbin–Watson statistic is , which indicates that there is no strong autocorrelation in the model residuals, but does not rule out the possibility of some degree of positive correlation. Therefore, it is advisable to perform additional diagnostic tests when working with time series.

The model corresponds to a production function of the Cobb–Douglas production function type according to its functional form and is expressed as follows:

$$Y = e^{5,745} X_1^{0,004} * X_2^{0,919} * X_3^{0,839}$$

The sum of the coefficients is approximately equal to , which is greater than unity. This situation indicates the presence of increasing returns to scale in the production process. That is, if all factors are increased by 1 percent at the same time, agricultural output increases by more than 1 percent. This indicates the existence of the effect of efficient use of resources in the regional economy (Table 5).

Table 5.

Quality indicators and overall adequacy assessment of a multifactor econometric model⁶

Indicators	Values
	0.999
F-statistic	5158.8
Probe(F)	6.34e-19
Durbin-Watson	1.61

Table 5 presents the main statistical criteria that characterize the overall quality of the econometric model, which allow for a comprehensive assessment of the level of reliability of the model and the degree of correspondence to empirical data. The very high value of the coefficient of determination ($R^2 = 0.999$) means that almost the entire part of the variation in the outcome variable is explained by the model. This indicates that the selected regression specification is highly adequate. The large value of the F-statistic and the proximity of the corresponding probability level ($\text{Prob}(F) \approx 0.000$) to zero confirm the overall statistical significance of the model. That is, all the explanatory variables included in the model together have a significant impact on the outcome indicator. The Durbin–Watson statistic is 1.61, which indicates that there is no strong autocorrelation in the residuals. Since this value is not close to the ideal 2, the possibility of some degree of positive autocorrelation cannot be ruled out. Therefore, there is a need for an in-depth diagnostic analysis of the model (Table 6).

Table 6.

Results of diagnostic tests on econometric model residuals⁷

Tesatname	Result	p-value	Conclusion
CUSUM	Not out of bounds	-	Stable
CUSUMSQ	Partially crossed the border	-	Stable
ARCH test	LM = 9.24	0.04	No heteroscedasticity

⁶ Author's calculation results based on data from the National Statistics Committee of the Republic of Uzbekistan

⁷ Author's calculation results based on data from the National Statistics Committee of the Republic of Uzbekistan

Breusch-Godfrey	LM = 2.73	0.02	Weak autocorrelation
MAPE	0.20 (20%)	-	High predictability

Diagnostic tests are important in checking the compliance of the model with the classical regression assumptions. According to the results obtained, the CUSUM and CUSUMSQ tests confirm the stability of the parameters over time, that is, there are no structural breaks in the model structure. This means that the model parameters have been consistently maintained throughout the observation period. The results of the ARCH test ($p\text{-value} > 0.05$) indicate that there is no heteroscedasticity problem in the residuals. This confirms the fulfillment of the classical assumption of constant variance and increases the efficiency of the estimated parameters. The results of the Breusch–Godfrey test indicate the possibility of a weak degree of autocorrelation in the residuals. However, the statistical significance of this condition is low and does not significantly affect the overall reliability of the model results.

A relatively high MAPE value indicates that the model has moderate forecast accuracy. This indicates that caution is needed when using the model for forecasting purposes (Figure 2).

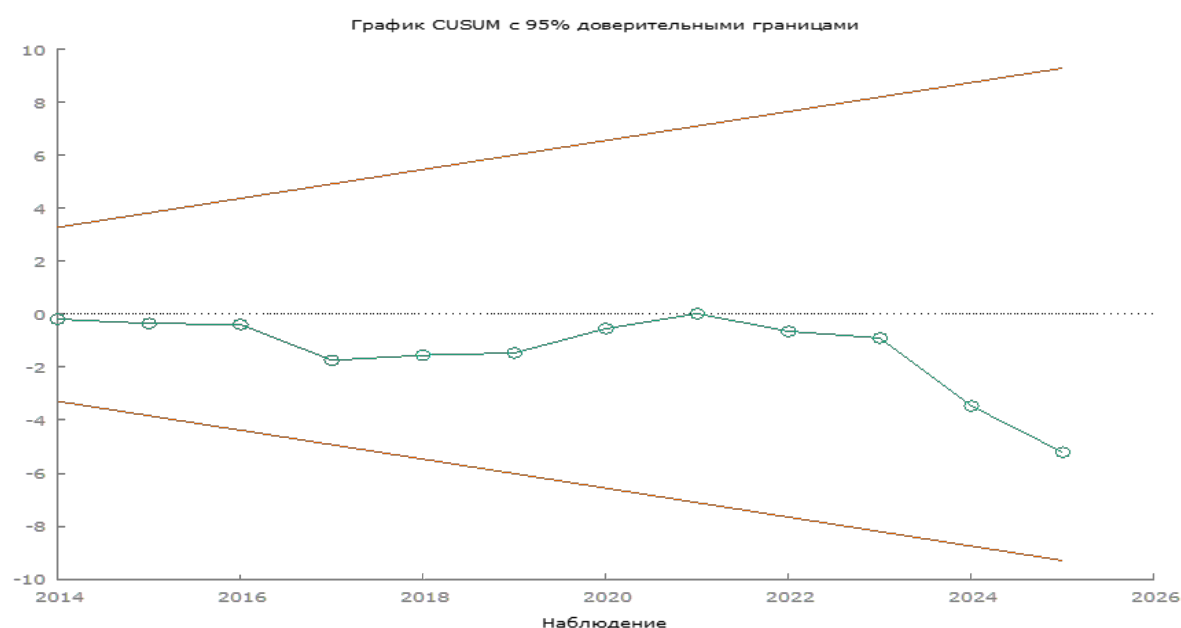


Figure 2. Stability analysis of model parameters based on CUSUM tests⁸

The graphical results show that the CUSUM and CUSUMSQ lines do not exceed the confidence interval. This confirms the stability of the model parameters throughout the observation period. This result indicates that the model is structurally well specified and that the parameters do not undergo abrupt changes over time (Figure 3).

⁸ Author's calculation results based on data from the National Statistics Committee of the Republic of Uzbekistan

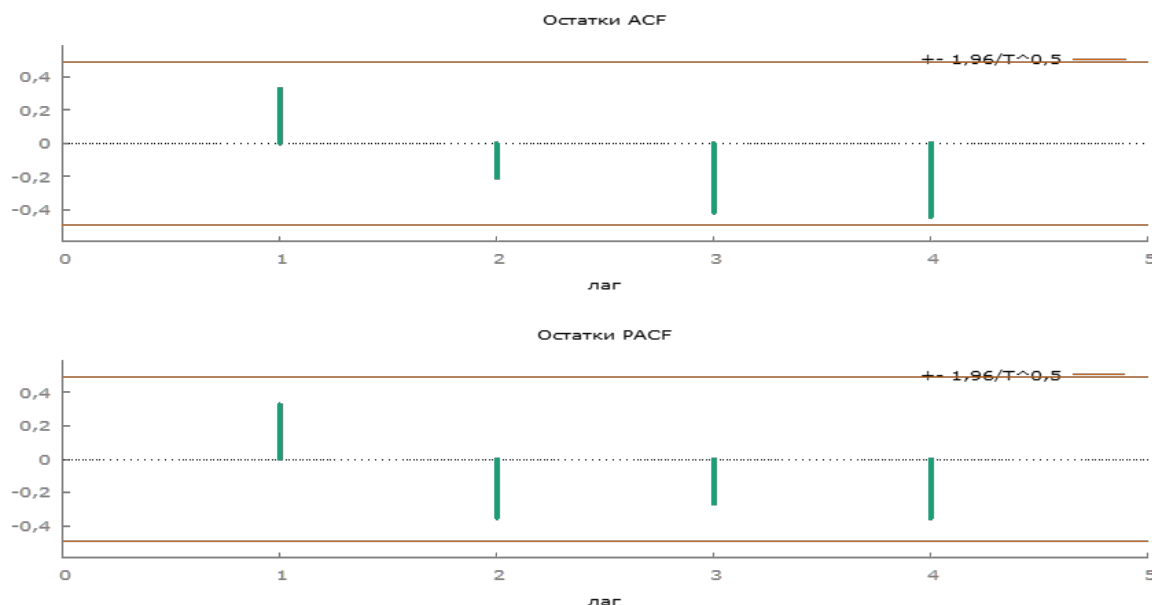


Figure 3. Diagnostic analysis based on autocorrelation (ACF) and partial autocorrelation (PACF) functions of model residuals⁹

To further assess the adequacy of the econometric model, the time dependence properties of the residuals were analyzed using the autocorrelation function (ACF) and partial autocorrelation function (PACF). This step serves to visually and statistically confirm the results of the Durbin–Watson and Breusch–Godfrey tests conducted above.

CONCLUSIONS AND SUGGESTIONS

Within the framework of this study, the impact of innovative development factors on economic growth in the agricultural sector in the Surkhandarya region was comprehensively assessed based on a multifactor econometric model. The results of our study showed that investments, poverty level, and land fertility have a significant positive impact on the dynamics of agricultural output.

Based on the results of the analysis, the following scientific conclusions were formulated:

The highest impact on regional economic growth falls on the employment factor in the agricultural sector, which indicates the crucial role of labor resources;

Land fertility is an important driver of economic development, and its increase significantly stimulates economic growth;

Investments in agriculture have a positive impact on economic growth, but with relatively lower elasticity;

The results of the production function analysis confirm the existence of increasing returns to scale in the regional economy.

In general, the developed econometric model is of significant scientific and practical importance in the in-depth analysis and forecasting of regional economic processes, as well as the development of effective economic policy measures. This model can be used to improve regional development strategies, effectively use resources, and determine directions for the development of an innovative economy.

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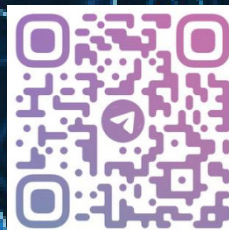
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