

Article

Modeling and Forecasting the Impact of Investment and Innovation Activity on Regional Economic Development

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Abstract: This study assesses the impact of investment volume and research and development (R&D) expenditure on the growth of the Gross Regional Product (GRP) of Surkhandarya region, based on statistical data for 2011–2025, using ARIMA and ARIMAX econometric models, and develops forecast indicators for 2026–2031. The analysis results revealed that a 1-unit increase in investment volume leads to a 0.16-unit increase in GRP, and investment volume is forecasted to grow from 21,721.7 billion soums in 2026 to 30,211.0 billion soums in 2031 (a 39.1% increase). Under the influence of innovation factors, the region's GRP is expected to amount to 63,032.9 billion soums in 2026 and reach 95,963.3 billion soums in 2031. The statistical reliability and high accuracy of the developed models were fully confirmed by the Dickey–Fuller and Ljung–Box tests, as well as by the approximation error (MAPE of 4.89% and 6.86%).

Keywords: Gross Regional Product (GRP), Surkhandarya region, investment volume, innovation activity, research and development, ARIMAX model, ARIMA model, econometric modeling, time series forecasting, MAPE error, Dickey-Fuller test, Ljung-Box test.

1. Introduction

In today's economy, ensuring sustainable development of regions and increasing their competitiveness are inseparably linked to investments directed toward capital assets, as well as scientific research and development (R&D) expenditures. International economic practice and scientific research indicate that forecasting macroeconomic indicators using only a single-factor approach is insufficient; multifactorial econometric models that also account for external factors (exogenous variables) ensure a higher level of accuracy. In particular, the ARIMAX (Autoregressive Integrated Moving Average with Exogenous Variables) model, based on the Box-Jenkins methodology and incorporating external factors, is recognized as one of the most effective tools worldwide for assessing and forecasting the dynamics of growth of national and regional Gross Domestic Product and Gross Regional Product [1].

In the Republic of Uzbekistan, comprehensive reforms aimed at strengthening the investment attractiveness of regions, improving the investment climate, and stimulating innovation activity have been carried out in recent years. Ensuring the macroeconomic stability of our country's regions and increasing the Gross Regional Product (GRP) requires identifying, both scientifically and practically, the key drivers influencing them. Econometric modeling of the impact of investment and innovation activity at the regional

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level is of significant importance in developing strategic regional programs and rationally allocating resources, and serves as a reliable mechanism for decision-making by relevant authorities [2].

This article is based on time series data of Surkhandarya region for 2010–2023, examining the relationship between the dynamics of the Gross Regional Product (Y_t) and investments directed toward capital assets (X_{1t}) as well as research and development expenditures (X_{2t}) through empirical modeling. The main objective of the study is to compare the ARIMA model, which produces forecasts based solely on internal dynamics, with the ARIMAX model, which incorporates investment and innovation factors, for Surkhandarya region's GRP volume, to assess the stationarity of the time series (ADF test) and model parameters (AIC, BIC, MAPE, RMSE), and to develop short- and medium-term econometric forecasts of the region's growth trajectory [3].

Nobel laureate, American economist R. M. Solow, in his fundamental research, theoretically and empirically substantiated the decisive role of capital investments and technological progress in shaping macroeconomic growth and the volume of gross output [4]. According to the neoclassical growth model developed by the author, along with production factors (capital and labor), exogenous technological changes (the Solow residual) are considered the main driver of long-term economic growth. Furthermore, P. M. Romer, developing endogenous growth theory, demonstrated that research and development (R&D), innovation activity, and investments directed toward human capital, as internal factors of the economic system, ensure sustainable growth [5].

The methodological foundations of time series modeling and forecasting were established by G. E. P. Box and G. M. Jenkins, whose Autoregressive Integrated Moving Average (ARIMA) methodology is widely applied in assessing the internal dynamics of economic indicators [6]. With the aim of further refining this approach and incorporating the influence of exogenous variables (such as the volume of investments and innovations), C. W. J. Granger developed methods for modeling causal relationships between time series (Granger causality) and exogenous factors [7]. These scientific perspectives today enable, through ARIMAX models, a highly accurate assessment of the influence of external economic factors on the dynamics of regional GRP.

Among scholars of the Commonwealth of Independent States (CIS), A. G. Granberg has created a significant scientific school in modeling regional economics and formulating interregional economic relations and regional production functions. In his research, the scholar substantiated, through econometric models, the role of local investments and regional infrastructure development in increasing the volume of regional gross output. Similarly, the Russian economist-statistician S. A. Ayvazyan, in the field of applied econometrics and time series analysis, developed complex statistical models and proposed a multifactorial modeling methodology for assessing the level of socio-economic development of regions [8].

Uzbek scholars have also comprehensively studied the issues of econometric modeling of regional economics and investment-innovation processes. In particular, Sh. I. Mustafaqulov has developed the theoretical and methodological foundations for assessing the investment climate attractiveness of regions and conducting a quantitative analysis of the impact of investment flows on regional economic growth. The author has empirically proven that the rational allocation of investment resources is a key factor in the sustainable growth of regional GRP volume. T. Sh. Shodiyev, in turn, has conducted profound scientific research in the field of econometric modeling of national and regional economies, formulating production functions and forecasting economic indicators, and has proposed a methodology for enhancing the reliability of statistical modeling in time series analysis [9].

2. Materials and Methods

The research data were compiled from the official indicators of the National Statistics Committee of the Republic of Uzbekistan and the Statistics Department of Surkhandarya Region for the years 2011–2025. As the endogenous variable, the region's Gross Regional Product volume (Y_t , billion soums) was used, while investments directed toward fixed capital (X_{1t} , billion soums) and research and development (R&D) expenditures (X_{2t} , billion soums) were used as exogenous factors.

The empirical analysis was conducted based on the Box–Jenkins methodology, using ARIMA(1,2,0), ARIMAX(1,1,0), and ARIMAX(1,2,0) specifications. The stationarity of the time series was determined through the ADF and KPSS tests, and the model parameters were estimated using the Maximum Likelihood Estimation (MLE) method. The optimality and forecast accuracy of the models were verified in the Gretl software package using the AIC, BIC, and HQIC information criteria, R^2 , the Ljung–Box Q' test (for diagnosing residual autocorrelation), as well as the MAPE and RMSE indicators.[10]

3. Results

In accordance with the econometric modeling methodology proposed in this study, based on time series data of Surkhandarya region for 2011–2025, the impact of investments directed toward fixed capital and research and development (R&D) expenditures on the volume of Gross Regional Product was assessed, and forecast indicators for 2026–2031 were developed. The stationarity of the time series and the reliability of the model parameters were verified using the Box–Jenkins methodology, the ADF and Ljung–Box tests, and information criteria (AIC, BIC, HQIC).

3.1 Modeling and Forecasting the Impact of Investments on GRP

To assess the impact of investments directed toward fixed capital on the volume of Gross Regional Product of Surkhandarya region, the ARIMAX(1,1,0) model was estimated. According to the model parameters determined based on the Shannon and Maximum Likelihood Estimation (MLE) method, the existence of a high degree of statistical relationship between the variables was confirmed.

According to the results of Model 1, the coefficient of determination was $R^2 = 0.9948$ (adjusted $R^2_{adj} = 0.9944$), the Akaike criterion $AIC = 249.5634$, the Schwarz criterion $BIC = 252.1197$, and the Hannan–Quinn criterion $HQIC = 249.3268$. In the model equation, the investment input coefficient ($\beta_1 = 0.272681$, $p = 0.0064$) and the autoregressive parameter ($\phi_1 = 0.857752$, $p < 0.0001$) proved to be highly significant. According to the model results, it was determined that a 1-unit increase in investment volume directed toward the economy leads, on average, to a 0.16-unit increase in the GRP volume of Surkhandarya region.

In the diagnostic analysis of the model, the approximation error was $MAPE = 4.8948\%$, which is noticeably below the 10% threshold, indicating a high level of forecast accuracy. When tested for autocorrelation in the residuals using the Ljung–Box test, a value of $Q' = 2.65234$ ($p = 0.4484 > 0.05$) was recorded, confirming the absence of autocorrelation in the residuals (the "white noise" property).

To determine the future dynamics of investment volume, forecast parameters for 2026–2031 were formulated based on the estimated ARIMA(1,2,0) model ($\phi_1 = -0.809563$, $R^2 = 0.829886$, $AIC = 246.3008$). According to this, investment volume in the region is expected to grow from 21,721.7 billion soums in 2026 to 30,211.0 billion soums in 2031, representing an absolute increase of 8,489.3 billion soums.

3.2 Modeling the Impact of Research and Development (R&D) Expenditures on GRP

To assess the impact of the volume of research and development (R&D) activities carried out by organizations of Surkhandarya region on the growth of GRP, the specifications of the ARIMAX(1,2,0) and ARIMAX(1,1,0) models were applied.[11]

According to the empirical estimation results, the ARIMAX(1,2,0) model specification demonstrated a coefficient of determination of $R^2 = 0.990037$ (adjusted $R^2_{adj} = 0.989041$), with AIC = 215.8174 and BIC = 217.7570. The input coefficient of scientific and innovation factors ($\beta_2 = 48.9564$, $p = 0.0421$) and the autoregressive parameter ($\phi_1 = -0.724726$, $p = 0.0002$) were found to be statistically significant.

The approximation error of this model amounted to MAPE = 6.86%, indicating an acceptable level of forecast accuracy. In the autocorrelation analysis, the Ljung–Box test result was $Q' = 0.788795$ ($p = 0.3745 > 0.05$), confirming the absence of serial correlation in the model residuals.

Based on the ARIMAX(1,1,0) model, constructed taking into account innovation and scientific-technical drivers, the GRP volume of Surkhandarya region is forecasted to reach 63,032.9 billion soums in 2026 (95% confidence interval: 60,508.5–65,557.2 billion soums) and 95,963.3 billion soums by 2031 (95% confidence interval: 77,473.4–114,453 billion soums). This indicator demonstrates a trend of increasing 28.3-fold relative to the 2011 baseline level.

3.3 Model Accuracy and Economic Interpretation

The practical reliability of the obtained time series and forecast model results was confirmed through the correspondence graphs between actual and forecasted values, as well as error criteria.

The fact that the approximation errors for both models are below 10% attests to the high accuracy of the developed ARIMAX econometric models. The results indicate that, in ensuring long-term sustainable economic growth in Surkhandarya region, enhancing the efficiency of resources directed toward research and development and technological innovation, alongside traditional capital investments, serves as a decisive institutional and econometric driver. [12]

4. Discussion

The role of innovation economics in ensuring the safety of the modern economy is significant. The development of innovation activity, the mastery of new technologies, and the efficient utilization of scientific-technical supply are closely linked to investment flows. For this reason, the volume and structure of investments occupy a particularly important place among the key aspects of innovative development.

Investments directed toward regional economics serve not only the process of upgrading financial production but also accelerate the creation of new industries and the process of technological renewal within the infrastructure development sphere. Investments based on high-technology projects are considered one of the factors determining the innovation strategy of regions. At the same time, the relationship between investment and innovation production is complex and multifactorial in nature, necessitating its in-depth examination through econometric analysis.

Taking the above into account, in our research we decided to use the ARIMAX (Auto Regressive Integrated Moving Average with Exogenous Variables) model, which represents an advanced methodological approach in the field of time series analysis. It significantly expands the capabilities of the traditional ARIMA (AutoRegressive Integrated Moving Average) modeling. The ARIMAX model is formed by integrating the core components of ARIMA modeling — the autoregressive, differencing, and moving average elements — with external (exogenous) variables. As a result, a complex model

emerges that provides forecasting capability while accounting for the external factors influencing it. This integration, in particular, creates the opportunity to obtain more accurate and meaningful forecasts in complex systems where the analyzed indicator is significantly affected by external factors.[13]

From a statistical point of view, the ARIMA model consists of three main components. The first is the autoregressive (AR) component, which models the relationship between the current observation and its lagged values. The second is the integration (I) component, which involves the process of differencing the time series in order to render it stationary. The third component is the moving average (MA) component, which expresses the relationship between the current observation and random errors (residuals) from previous periods. Although ARIMA models are effective in many cases, they are based on the assumption that the time series is shaped solely under the influence of its own past values. In practice, this assumption does not always hold fully valid, since in many processes external variables exert a significant influence on the time series. The ARIMAX model has been developed precisely to overcome these limitations, providing the capability to directly incorporate external variables into the model structure. As a result, the dynamics of the time series can be explained not only by internal lags but also through the influence of economic or natural factors.

Mathematically, the ARIMAX(p,d,q) model is expressed in the following form:

$$\Delta^d Y_t = c + \sum_{i=1}^p \varphi_i \Delta^d Y_{t-i} + \sum_{j=1}^q \theta_j \varepsilon_{t-j} + \sum_{k=1}^K \beta_k X_{k,t} + \varepsilon(t) \quad (1)$$

The Table 1. practical application of the ARIMAX model involves several important stages. First and foremost, the data preparation process is of significant importance, which entails identifying and filling in missing values, eliminating outliers, and ensuring the relevance of external variables and their temporal alignment with the dependent variable. In the next stage, the stationarity of the time series is checked, and if necessary, differencing is performed. To test for stationarity, the Augmented Dickey–Fuller (ADF) test and the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test are commonly used.

Figure 1. For the period from 2011 to 2025, an ARIMAX model is constructed based on the time series of Surkhandarya region's GRP indicator (Y_t). Initially, using this model, the impact of investment volume on the GRP volume of Surkhandarya region was examined. [14]

Table 1. Indicators of GRP and Investment Volume for Surkhandarya Region

Years	Gross Regional Product volume of Surkhandarya region (billion soms)	Investment volume of Surkhandarya region (billion soms)
2011	3,394.70	655.3
2012	5,217.10	802.9
2013	6,436.40	980.3
2014	7,436.40	1,371
2015	9,213.20	1,509.1
2016	11,114.40	1,843.6
2017	12,179.60	2,142.4
2018	16,354.40	3,551
2019	21,229.40	7,240.6
2020	25,473.10	11,835.1
2021	27,571.60	10,068.2
2022	33,591.10	12,037.8

2023	39,201.80	11,569.4
2024	46,999.20	18,307.7
2025	54,354.10	16,593.1

Using the given data, we will analyze the change (dynamics) of GRP and investment volume of Surkhandarya region over time.

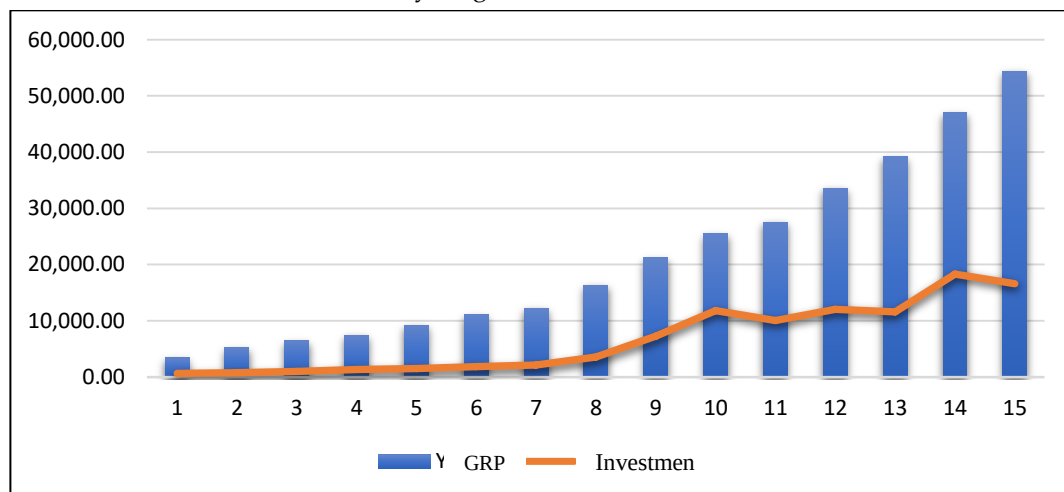


Figure 1. Dynamics of GRP and investment volume for Surkhandarya region

Based on the statistical data presented above, the GRP volume of Surkhandarya region amounted to 3,394.70 billion soums in 2011, and this indicator reached 54,354.10 billion soums by 2025. It can be observed that the GRP volume has increased approximately 16-fold compared to the previous period.

The GRP volume of Surkhandarya region exhibited an upward trend over the 2011–2025 period, with an average annual growth rate exceeding 20%. The investment volume of Surkhandarya region amounted to 655.3 billion soums in 2011, and this indicator reached 16,593.1 billion soums by 2025, representing an approximately 25-fold increase. In the ARIMAX model, parameters are typically estimated using the Maximum Likelihood Estimation (MLE) method or other optimization methods that best fit the model to the data. After the parameters are estimated, the adequacy and validity of the underlying assumptions of the model are checked. This diagnostic process includes analyzing the residuals, verifying whether they possess the "white noise" property. Additionally, the absence of autocorrelation in the residuals is confirmed using the Ljung–Box test. If the model is found to be sufficiently adequate, it is used for forecasting future values, taking into account the anticipated changes in the external variables.

To Table 2. determine whether a given time series is stationary or non-stationary, the Augmented Dickey–Fuller (ADF) test is applied. The ADF test is a statistical test used to verify the stationarity property of time series data. For a time series to be stationary, its mean, variance, and autocorrelation structure must not change over time. This is particularly important when working with models such as ARIMAX, since most time series models require stationarity.

For the purpose of forecasting the impact of investments on the GRP volume of Surkhandarya region, the available statistical data were analyzed, and based on them, the ARIMAX(1,1,0) model was developed (Table 2).

Table 2. Results of the ARIMAX(1,1,0) Model Based on Forecasting the Impact of Investments on GRP Volume for Surkhandarya Region

Model: ARIMAX, using observations 2012–2025 (T = 14); Dependent variable: (1-L) Gross Regional Product volume; Standard errors computed based on the Hessian

Indicator	Coefficient	Std. Error	z-statistic	p-value
const	4011.09	1823.64	2.199	0.0278**
phi_1	0.857752	0.141458	6.064	<0.0001***
d_Investment volume_bln soums	0.272681	0.100000	2.727	0.0064***

Model Statistics	Value	Model Statistics	Value
Mean of dependent variable	3639.957	S.D. of dependent variable	2392.933
Mean of innovations	213.9288	S.D. of innovations	1287.938
R-squared	0.994801	Adjusted R-squared	0.994368
Log-likelihood	-120.7817	Akaike criterion	249.5634
Schwarz criterion	252.1197	Hannan–Quinn criterion	249.3268
AR Root (Modulus)	1.1658	Frequency	0.0000

Note: *** and ** denote statistical significance at the 1% and 5% levels, respectively.

The mathematical equation form of the ARIMAX(1,1,0) model, based on forecasting the impact of investment volume on the GRP volume of Surkhandarya region, is expressed as follows:

$$(1 - L)YaHM_t = 4011,09 + 0,973253 * (1 - L)YaHM_{t-1} + 0,165658 * X_{1t} + \varepsilon_t \quad (2)$$

Here: GRP_t — GRP volume of Surkhandarya region (billion soums); X_{1t} — investment volume of Surkhandarya region (billion soums)

The coefficient of determination, standard errors, F-Fisher, t-Student, as well as the Akaike and Schwarz criteria presented in Table 2 confirm the statistical reliability and adequacy of the model. This particular model provides the capability to develop forecast parameters for the future impact of investment volume on the GRP volume of Surkhandarya region.

The significance of the model was tested using the approximation error (MAPE), and its value was found to be $MAPE = \frac{1}{n} \sum \left| \frac{y_i - \hat{y}_i}{y_i} \right| * 100\% = 4,8948\%$, which turns out to be considerably smaller than 10%, indicating that the forecast possesses a high degree of accuracy.

Furthermore, the model was tested for autocorrelation using the Ljung–Box test. As a result, the p-value was found to be 0.4484, which is sufficiently greater than the 0.05 threshold, confirming the absence of autocorrelation (Table 3).[15]

Table 3. Ljung–Box Test Result for Autocorrelation Testing

Ljung–Box Test for Autocorrelation
Test for the presence of autocorrelation up to order 4
Ljung–Box Q' = 2.65234
p-value = P(Chi-square(3) > 2.65234) = 0.4484
Furthermore, the correlogram of the model residuals was also analyzed (Figure 2).

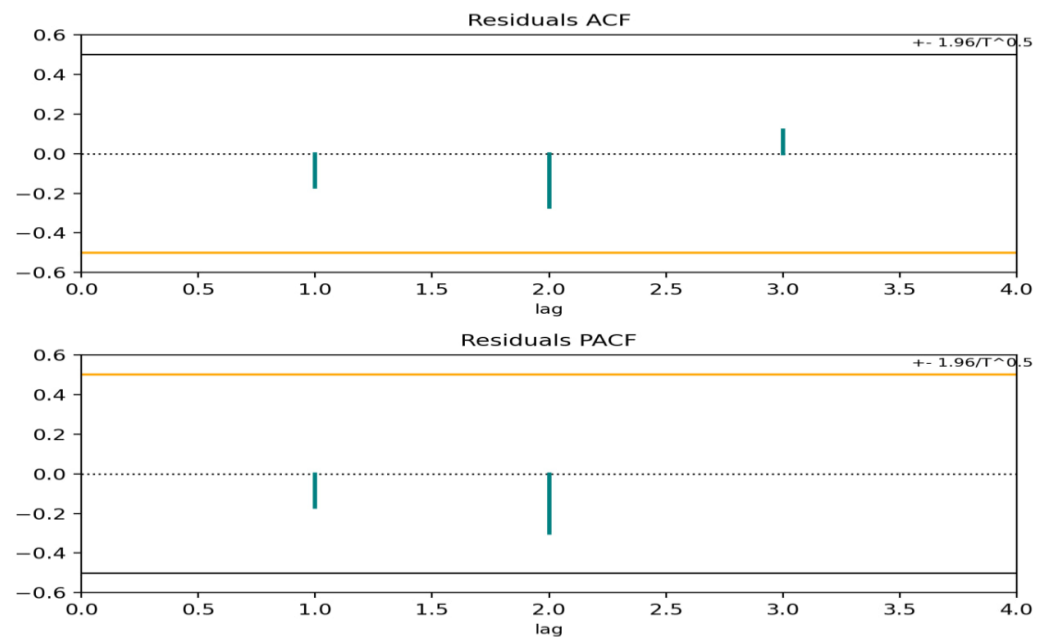


Figure 2. Correlogram of the residuals of the GRP volume forecast model for Surkhandarya region

In this manner, the results of the econometric model based on forecasting the impact of investments on the GRP volume of Surkhandarya region were developed. According to the model results, a 1-unit increase in the volume of investments directed toward the economy leads to a 0.16-unit increase in the GRP volume of Surkhandarya region. Based on the results obtained above, we constructed the ARIMAX model based on modeling the impact of investments on the GRP volume of Surkhandarya region, and forecast values were developed on the basis of this model.

Before forecasting the impact of investments on the GRP volume of Surkhandarya region, we first calculate the forecast values of investment volume using the ARIMA model. Utilizing the investment volume indicators of Surkhandarya region presented in Table 1 above, we developed the following ARIMA(1,2,0) model (Table 4).

Table 4. Results of the ARIMA(1,2,0) Model Based on Forecasting Investment Volume for Surkhandarya Region

Model 1: ARIMA(1,0,0) Results (for Investments)

Model: ARIMA, using observations 2013–2025 ($T = 13$); Dependent variable: $(1 - L)^2$ Investments; Standard errors computed based on the Hessian

Indicator	Coefficient	Std. Error	z-statistic	p-value
phi_1	-0.809563	0.179783	-4.503	<0.0001***

Model Statistics	Value	Model Statistics	Value
Mean of dependent variable	-143.2462	S.D. of dependent variable	3988.499
Mean of innovations	266.2370	S.D. of innovations	2589.829
R-squared	0.829886	Adjusted R-squared	0.829886
Log-likelihood	-121.1504	Akaike criterion	246.3008
Schwarz criterion	247.4307	Hannan–Quinn criterion	246.0685
AR Root (Modulus)	1.2352	Frequency	0.5000

*Note: *** denotes statistical significance at the 1% level.*

The mathematical equation form of the ARIMA(1,2,0) model constructed for the purpose of forecasting the investment volume of Surkhandarya region is expressed as follows:

$$(1 - L)^2 I_t = -0,809563 * (1 - L)^2 I_{t-1} + \varepsilon_t \quad (3)$$

Here: I_t – investment volume of Surkhandarya region (billion soums).

In this way, the results of the econometric model based on forecasting the investment volume indicators of Surkhandarya region were formulated. The forecast values of the investment volume indicators of Surkhandarya region were calculated. The forecast values of the investment volume indicators of Surkhandarya region, according to the above econometric model, are presented in Table 5.

Table 5. Results of the Econometric Modeling Based on Forecasting Investment Indicator Volumes (billion soums) for Surkhandarya Region

Year	Forecast Value	Standard Error	95% Confidence Interval
2026	21,721.7	2,589.83	16,645.7–26,797.6
2027	21,310.2	4,026.45	13,418.6–29,201.9
2028	25,383.8	6,634.98	12,379.5–38,388.1
2029	25,826.5	9,006.18	8,174.69–43,478.3
2030	29,208.6	12,058.8	5,573.82–52,843.3
2031	30,211	15,075.32	663.9–59,758.1

The analysis of the forecast results carried out for the years 2026–2031 indicates that the indicator under forecast is expected to exhibit an overall upward trend in the future. In particular, the forecast value is expected to increase from 21,721.7 units in 2026 to 30,211.0 units in 2031. Over this period, the absolute growth of the indicator amounts to 8,489.3 units, that is, approximately 39.1%.

In this study, the dynamics of the investment volume of Surkhandarya region over the period 2011–2025 were analyzed using the ARIMA model, an econometric instrument for time series analysis. The main objective of the analysis consisted of calculating its statistical characteristics and forecast values for subsequent periods.

The volume of research and development (R&D) activities carried out by organizations in Surkhandarya region is one of the key economic indicators reflecting the region's scientific-technical potential and the level of its innovative development. This indicator is directly related to the demand for scientific research in the region, the activity of scientific institutions and higher education establishments, and the processes of creating and implementing new technologies. Growth in the volume of research and development signifies the activation of innovation activity within the regional economy. Such a process can positively influence increased labor productivity, improved production efficiency, and the development of economic activity types that generate high added value through the introduction of new technologies. For this reason, this indicator can be regarded as an important factor in assessing the long-term economic development trends of the region.

By examining the dynamics of the volume of research and development activities in Surkhandarya region over the years, it is possible to identify the changing trends of scientific-innovation activity. If a steady increase in the indicator is observed, this may indicate that the economic importance of resources directed toward scientific activity and scientific research in the region is growing. Conversely, a decline or sharp fluctuation in the indicator is unlikely to indicate the absence of problems related to financing scientific activity, the potential of scientific personnel, or the implementation of scientific research into practice.

In the econometric modeling of this indicator, the use of the ARIMAX model, alongside its dynamics over time, provides the capability to also account for the external economic factors influencing the volume of research and development activities carried out by organizations on GRP. In this case, the volume of research and development is taken as the influencing variable.

For the period from 2011 to 2024, an ARIMAX model was constructed based on the time series of GRP indicators (Y_t) of Surkhandarya region. Using this model, the impact of the volume of research and development activities carried out by organizations on the GRP of Surkhandarya region was examined (Table 6).

Table 6. Indicators of GRP and the Volume of Research and Development Activities Carried Out by Organizations for Surkhandarya Region

Years	Gross Regional Product volume of Surkhandarya region (billion soums)	Volume of research and development activities carried out by organizations of Surkhandarya region (billion soums)
2011	3,394.70	0.3
2012	5,217.10	0.8
2013	6,436.40	0.5
2014	7,436.40	0.9
2015	9,213.20	1.8
2016	11,114.40	2.2
2017	12,179.60	2.8
2018	16,354.40	4.3
2019	21,229.40	36.2
2020	25,473.10	1
2021	27,571.60	2.9
2022	33,591.10	6.4
2023	39,201.80	7.4
2024	46,999.20	11.0

For the purpose of forecasting the impact of the volume of research and development activities carried out by organizations on the GRP volume of Surkhandarya region, the available statistical data were analyzed, and based on them, the ARIMAX(1,2,0) model was developed (Table 7).

The mathematical equation form of the ARIMAX(1,2,0) model, based on forecasting the impact of the volume of research and development activities carried out by organizations on the GRP volume of Surkhandarya region, is as follows:

$$(1 - L)GRP_t = 465,504 - 0,724726 * (1 - L)GRP_{t-1} + 48,9564 * X_{2t} + \varepsilon_t \quad (4)$$

Here: GRP_t — GRP volume of Surkhandarya region (billion soums); X_{2t} — volume of research and development activities carried out by organizations (billion soums)

Table 7. Results of the ARIMAX(1,2,0) Model for Analyzing the Impact of the Volume of Research and Development Activities Carried Out by Organizations on GRP Volume for Surkhandarya Region

Model 1: ARIMAX(1,0,0) Results (for Volume of Innovations)

Model: ARIMAX, using observations 2013–2024 ($T = 12$); Dependent variable: $(1 - L)^2 GRP$; Standard errors computed based on the Hessian

Indicator	Coefficient	Std. Error	z-statistic	p-value
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const	465.504	234.707	1.983	0.0473**
phi_1	-0.724726	0.197331	-3.673	0.0002***
Volume of innovations implemented by organizations	48.9564	24.0865	2.033	0.0421**

Model Statistics	Value	Model Statistics	Value
Mean of dependent variable	497.9167	S.D. of dependent variable	1764.238
Mean of innovations	-35.49532	S.D. of innovations	1351.650
R-squared	0.990037	Adjusted R-squared	0.989041
Log-likelihood	-103.9087	Akaike criterion	215.8174
Schwarz criterion	217.7570	Hannan–Quinn criterion	215.0993
AR Root (Modulus)	1.3798	Frequency	0.5000

Note: *** and ** denote statistical significance at the 1% and 5% levels, respectively.

The coefficient of determination, standard errors, F-Fisher, t-Student, as well as the Akaike and Schwarz criteria presented in this table confirm the statistical reliability and adequacy of the model (1). This, in turn, provides the capability to develop future forecasts of the impact of investment volume on the GRP volume of Surkhandarya region.

The significance of the model was tested using the approximation error (MAPE), and its value was found to be $MAPE = \frac{1}{n} \sum \left| \frac{y_i - \hat{y}_i}{y_i} \right| * 100\% = 6,86\%$, which is considerably smaller than 10%, confirming that the forecast possesses an acceptable level of accuracy.

Furthermore, the model was tested for autocorrelation using the Ljung–Box test. As a result, the p-value was found to be 0.3745, which is sufficiently greater than the 0.05 threshold, confirming the absence of autocorrelation (Table 8).

Table 8. Result of the Ljung–Box Test for Autocorrelation Testing
Test for Autocorrelation up to Order 2

Indicator	Value
Ljung-Box Q'	0.788795
p-value = P(Chi-square(1) > 0.788795)	0.3745

Note: Since the p-value exceeds 0.05, the null hypothesis of no autocorrelation in the residuals is not rejected, meaning the model residuals show no autocorrelation.

As a result, using the ARIMAX(1,1,0) model, we forecast the volume of research and development activities carried out by organizations of Surkhandarya region. As is known, in the ARIMA model only an endogenous variable exists. However, in the ARIMAX model, both endogenous and exogenous variables can be present simultaneously. For this reason, using the forecast values from the ARIMA(1,2,0) model, the forecast results of the ARIMAX(1,1,0) modeling are presented in Table 9 below.

Table 9. Forecasting Results of the ARIMAX(1,1,0) Modeling, Reflecting the Impact of the Volume of Research and Development Activities Carried Out by Organizations on the GRP (billion soums) of Surkhandarya Region

Year	GRP Forecast Values (billion soums)	Standard Error	95% Confidence Interval
2026	63,032.9	1,287.94	60,508.5–65,557.2
2027	69,735.9	2,717.29	64,410.1–75,061.7

2028	77,263.1	4,305.92	68,823.6–85,702.5
2029	83,458.0	5,982.37	71,732.8–95,183.2
2030	90,161.0	7,701.52	75,066.3–105,256
2031	95,963.3	9,433.80	77,473.4–114,453

Based on the above, we will examine the correspondence graph of the observed and forecasted values regarding the impact of the volume of research and development activities carried out by organizations on the GRP of Surkhandarya region (Figure 3).

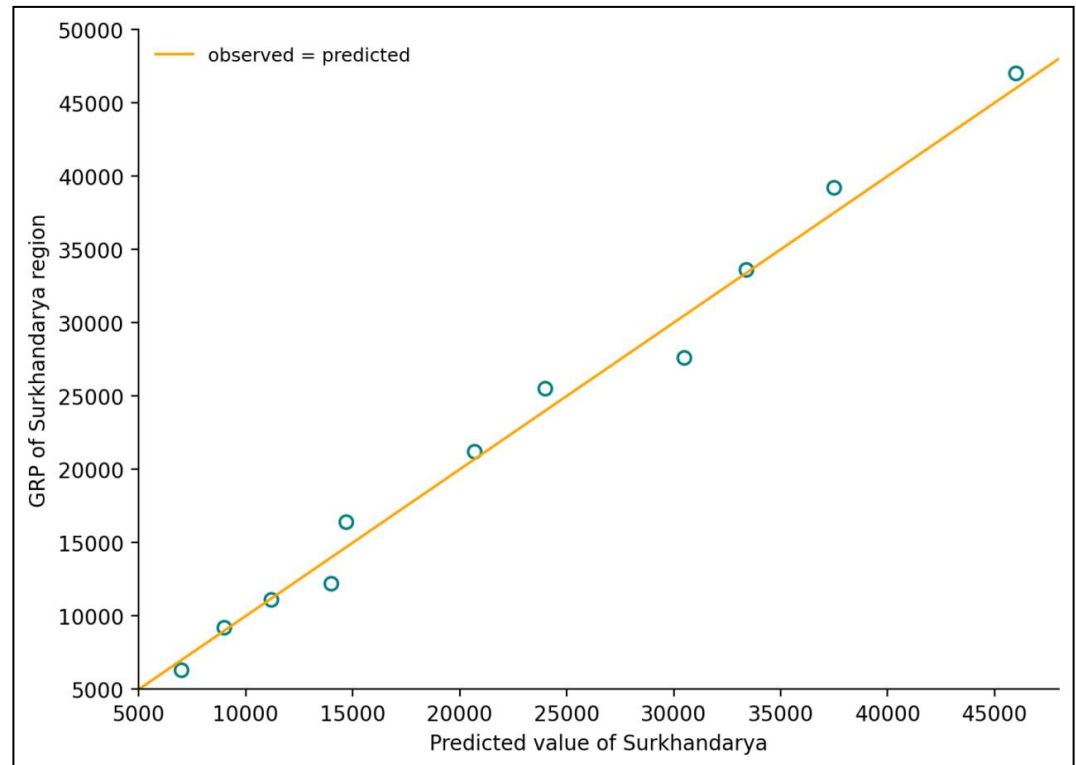


Figure 3. Graph of the high degree of correspondence between the observed and forecasted values presented

The graphical results presented in this figure indicate the existence of a high degree of correspondence between the observed and forecasted values. The model adequately reflects the fundamental dynamics of the indicator under study over time. Despite deviations in certain periods, the overall trend has been preserved. This, in turn, demonstrates the practical applicability of the model in modeling and forecasting the process under study.

We will now present the depiction of the forecast values calculated based on the ARIMAX model, which reflects the impact of the volume of research and development activities carried out by organizations on the GRP of Surkhandarya region (Figure 4).

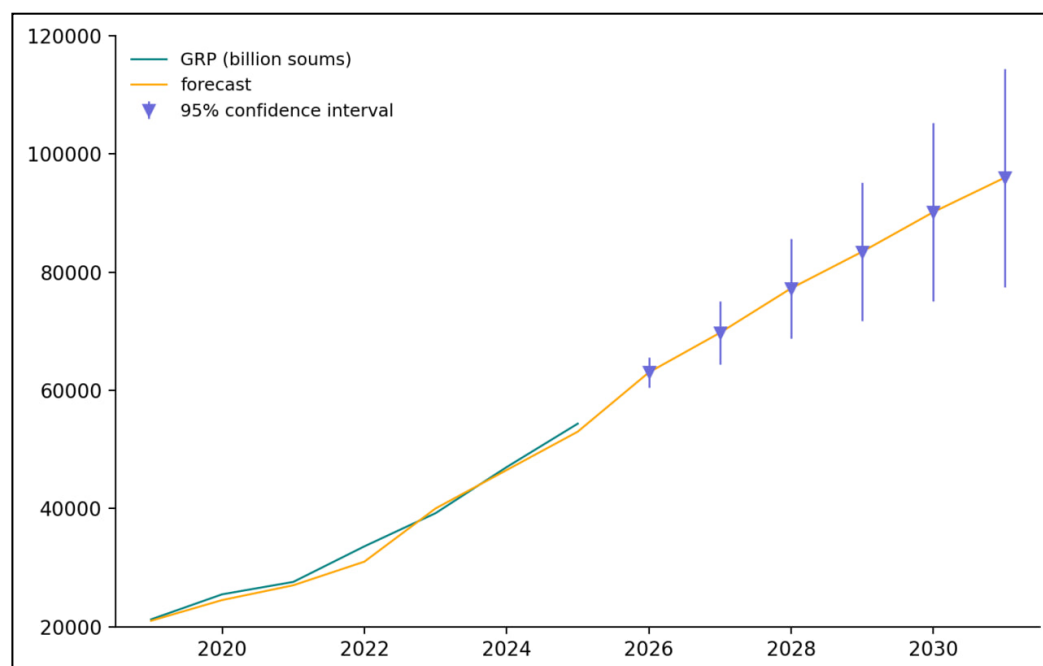


Figure 4. Depiction of the forecast values of the impact of investment volume on the GRP volume of Surkhandarya region

Based on the ARIMAX(1,1,0) model, forecast indicators of the Gross Regional Product (in billion soums) volume for the years 2026–2031 are expressed. According to the model results, the forecast process exhibits an upward trend. While the GRP volume of Surkhandarya region in 2026 is expected to amount to 63,032.9 billion soums, by 2031 it may reach 95,963.3 billion soums. This means that a 28.3-fold increase relative to the 2011 level will be achieved.

5. Conclusion

The empirical econometric analysis conducted based on time series data of Surkhandarya region for 2011–2025 confirmed that investments directed toward fixed capital, as well as research and development (R&D) expenditures, exert a significant and statistically important influence on the growth of the Gross Regional Product. The estimated ARIMAX(1,1,0) and ARIMAX(1,2,0) models demonstrated a high level of model specification reliability, distinguished by high coefficients of determination, approximation errors below 10%, and the absence of autocorrelation in the residuals according to the Ljung–Box test results. According to the obtained econometric forecast results, the investment volume in the region is expected to grow from 21,721.7 billion soums in 2026 to 30,211.0 billion soums in 2031, while the GRP volume is forecasted to increase from 63,032.9 billion soums in 2026 to 95,963.3 billion soums in 2031, demonstrating an economic growth trend of 28.3-fold relative to the 2011 baseline level.

The research results indicated that, alongside traditional capital investments, innovation and scientific-technical drivers play a decisive role in ensuring the long-term sustainability of regional economic growth. The growth parameter of research and development expenditures and its high multiplicative effect on GRP empirically substantiate the necessity of transitioning Surkhandarya region's economy toward a knowledge- and high-technology-based economic model, moving away from a resource-intensive one. In this regard, in the coming period, regional investment policy should focus not only on expanding traditional infrastructure investments but also on prioritizing capital allocation toward commercializing research and development outcomes and toward sectors with high potential for technological modernization and innovation.

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