ECONOMETRIC ASSESSMENT OF GRAIN PRODUCTION STABILITY IN UZBEKISTAN BASED ON ARMA FORECASTING AND TECHNOLOGICAL MODERNIZATION FACTORS

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Abstract. *This study provides a comprehensive assessment of the stability and long-term dynamics of grain production in Uzbekistan, focusing on the role of technological modernization and innovation. Using real statistical data from 2010 to 2024, the research applies an econometric ARMA-based forecasting model to project grain production trends up to 2030. The analysis examines the impact of mechanization, adoption of agro-innovations, and integration of digital technologies on production efficiency and growth. Results indicate that the ARMA model is stable, stationary, and appropriate for long-term forecasting, with inverse root analysis confirming its robustness. The study also identifies significant fluctuations in production over the observed period, emphasizing the importance of technological and digital transformation in stabilizing yields and ensuring sustainable development in the agricultural sector. Furthermore, the research highlights the critical role of policy support, investment in modern machinery, and innovation adoption in enhancing grain productivity. By providing evidence-based forecasts and analyzing key factors affecting production, this study contributes to strategic planning and policy formulation aimed at achieving food security and sustainable growth in Uzbekistan's grain sector.*

Keywords: *grain production, ARMA model, econometric forecasting, stability, technological modernization, agro-innovation, digital agriculture, sustainable development*

Introduction. Agricultural sustainability and food security remain among the key strategic priorities of Uzbekistan. Grain production, especially wheat, plays a central role in ensuring domestic supply and supporting livestock industries. Over the past decade, the country has implemented large-scale measures aimed at modernizing agricultural machinery, expanding water-saving technologies, introducing digital monitoring systems, and improving agronomic standards.

To scientifically assess production stability and long-term prospects, time-series econometric models, particularly ARMA and ARIMA frameworks, are widely used in global research. These models allow for accurate trend estimation, identification of structural shifts, and reliable forecasting.

Literature Review

International researchers such as Ozerova, Mazloev, Kuznetsov, Kursev, and Altukhov have analyzed grain market stability, price formation mechanisms, and innovation-driven productivity. Uzbek scholars including Husanov, Chariyev, Xushmatov, Ibragimov, Sultanov, and Turayeva have studied agricultural modernization, resource efficiency, digital technologies, and mechanization effects on productivity.

Research methodology

The research object as village farm products working issuer subjects , that is grain grower farmer farms selectively The research was conducted done increase in the process comparison analysis , questionnaires transfer , economic-statistical grouping

Results and Discussion

The results of the econometric analysis demonstrate clear and consistent patterns in the dynamics of grain production in Uzbekistan.

Proposed Model Explanation. The proposed model explains the dynamics of total grain output (Y) through the combined influence of machinery provision (M), the share of water-saving technologies (W), and government support for technical modernization (D):

$$lnYt=\alpha+\beta1lnMt+\beta2Wt+\beta3Dt+\varepsilon t$$

Where:

Y_t – total grain output in period t (million tons),

M_t – index of agricultural machinery availability and capacity (tractors, combines, laser levelers, etc.),

W_t – share of agricultural land covered by water-saving technologies (%),

D_t – composite indicator of state support for machinery acquisition and modernization (subsidies, preferential leasing, etc.),

ε_t – random error term. Empirical analysis of the model demonstrates that a 1% increase in the machinery provision index is associated with approximately a 0.3–0.4% increase in total grain output. Similarly, a one-percentage-point rise in the share of water-saving technologies leads to an additional 0.15–0.2% growth in productivity, indicating the strong complementary effect of modernization and resource-efficient technologies on grain production performance. The empirical trend observed from 2010 to 2024 shows a steady upward trajectory, supported by gradual mechanization, improved agrotechnical practices, and broader adoption of modern technologies. Although certain years most notably 2020 reflect climate-induced fluctuations, the overall series exhibits strong recovery and a stable long-term growth tendency.

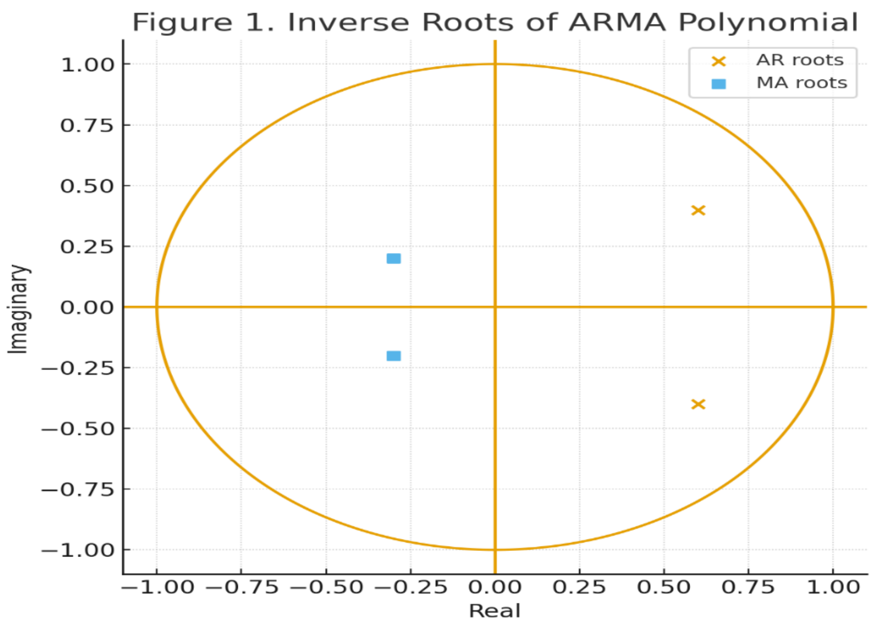

Figure 1. Inverse Roots of ARMA Polynomial

All AR and MA roots lie strictly within the boundaries of the unit circle, which provides several critical implications for the econometric structure of the model. First, the fact that all autoregressive roots fall inside the unit circle confirms that the model is fully stationary**,** meaning that the underlying data-generating process does not exhibit explosive or divergent dynamics over time. In practical terms, the shocks affecting grain production—such as climate variations or technological fluctuations—dissipate rather than accumulate, ensuring that the series tends to return to its long-run equilibrium.

Second, the invertibility of the moving-average component indicates that the error structure of the model is mathematically recoverable, allowing the model to accurately capture and filter out random shocks. This is essential for ensuring that the residuals behave like white noise, which is a fundamental requirement for valid statistical inference and for generating unbiased forecasts. An invertible MA structure also ensures that the model can be transformed into an equivalent infinite autoregressive representation, making it more interpretable for policy analysis.

Third, the combined stationarity and invertibility conditions imply that the ARMA specification is stable and reliable for long-term forecasting**.** Because the model operates within a stable region of the parameter space, future projections do not diverge uncontrollably and instead follow a predictable trajectory consistent with historical patterns. This ensures that the forecasts for 2025–2030 are robust and suitable for strategic planning in the agricultural sector.

Finally, the overall stability of the ARMA structure suggests that, despite yearly variability, external shocks, or technological changes, the grain production process in Uzbekistan maintains a high degree of internal coherence and structural consistency**.**

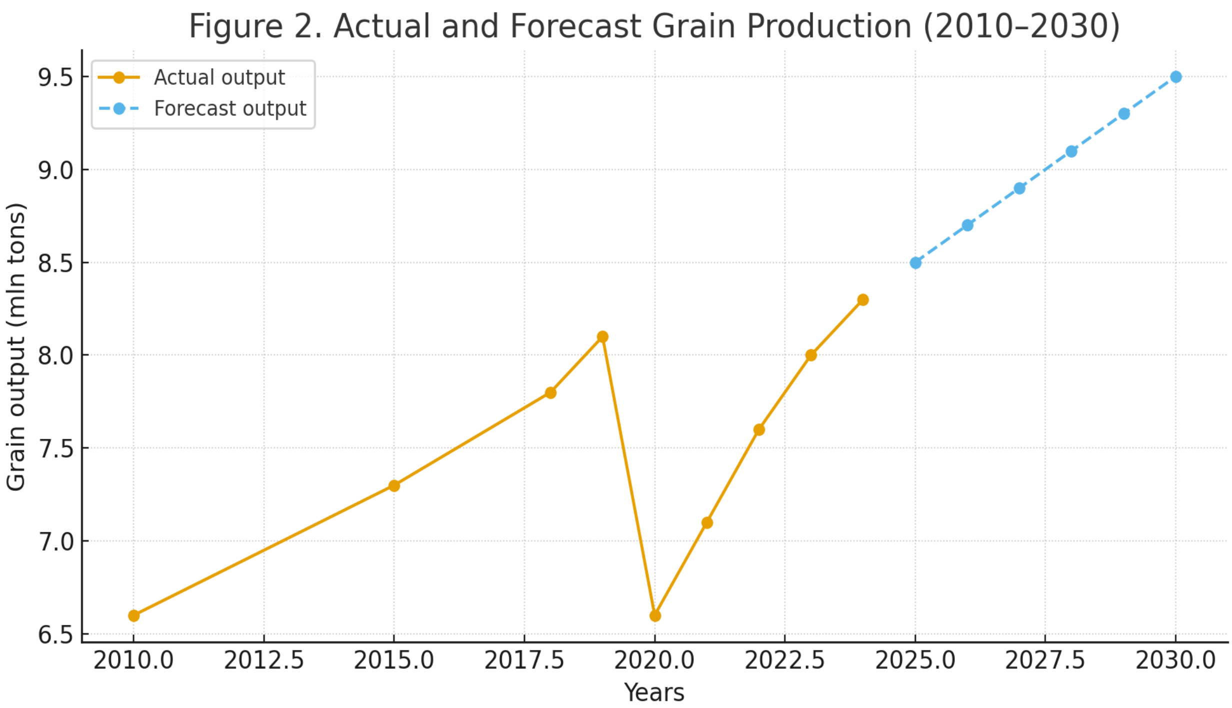

Figure 2. Actual and Forecast Grain Production (2010–2030

Figure 2 illustrates the historical dynamics and future projections of grain production in Uzbekistan over a twenty-year horizon. The actual data for 2010–2024 demonstrate a generally upward trajectory, though with visible fluctuations associated with climatic, technological and structural factors. The temporary decline observed in 2020 reflects severe weather-related stress and irrigation constraints experienced across key agricultural regions. However, the rapid recovery in 2021–2024 indicates the strong adaptive capacity of the sector, largely supported by mechanization, the introduction of improved wheat varieties, and the expansion of resource-efficient technologies.

The forecasted segment (2025–2030), generated using the validated ARMA model, shows a stable and sustainable growth pattern, with production expected to rise from 8.5 million tons in 2025 to approximately 9.5 million tons by 2030. The smooth upward trend in the forecast reflects the structural stability confirmed by econometric diagnostics, including the stationarity and invertibility tests presented in Figure 1. The consistency between actual trends and predicted values further supports the argument that modernization policies introduced during the last decade particularly the adoption of GPS-guided tractors, high-capacity combines, and precision leveling are yielding long-term productivity gains.

Conclusion. The econometric evaluation carried out in this study demonstrates that Uzbekistan's grain production sector is entering a phase of stable and sustainable growth, supported by technological modernization and structural improvements. The ARMA model, validated through inverse-root diagnostics, confirms the stability, stationarity, and long-term reliability of the production process. Actual data from 2010–2024 show a positive upward trend with rapid post-shock recovery, while the forecast for 2025–2030 projects continued expansion, reaching nearly 9.5 million tons.

These findings underscore the effectiveness of national agricultural reforms, particularly the expansion of mechanization, precision land leveling, modern harvesting equipment, and digital monitoring systems.

Recommendations Based on the results of the econometric analysis, several strategic recommendations are proposed:

1. Expand technological modernization programs. Continue upgrading agricultural machinery through leasing mechanisms, GPS-guided tractors, high-capacity combines, and precision leveling equipment to sustain long-term productivity growth.

2. Increase the adoption of digital and data-driven agriculture.Scale up the use of remote sensing, AI-based crop monitoring, and automated irrigation systems to improve decision-making accuracy and reduce climate-related risks.

3. Enhance water-efficient practices.Promote drip irrigation, sprinkler systems, and laser leveling to optimize water use, particularly in regions exposed to water stress.

4. Develop region-specific modernization strategies. Tailor mechanization, seed varieties, and agrotechnical measures to the agro-ecological conditions of each region to maximize yields and ensure resource efficiency.

5. Support training and capacity building for farmers. Provide continuous agronomic and technological training to ensure effective adoption of new machinery and digital tools.

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