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A MULTIVARIATE ECONOMETRIC MODEL OF THE DETERMINANTS OF AGRICULTURAL ENTREPRENEURSHIP EFFICIENCY IN KASHKADARYA REGION

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Abstract. Agricultural entrepreneurship constitutes a critical institutional and economic mechanism for transforming natural, labour, financial and technological resources into commercially viable agricultural output. However, the efficiency of agricultural entrepreneurial activity is determined not by the volume of individual production factors but by their interaction, allocation and technological complementarity. This study develops a multivariate econometric framework for identifying the principal determinants of agricultural entrepreneurship efficiency in Kashkadarya Region of Uzbekistan. The empirical analysis relies on official regional statistical data and integrates indicators characterizing agricultural output, agricultural employment, cultivated land and resource utilization. The analytical framework combines descriptive statistics, correlation analysis, multivariate regression modelling, elasticity estimation and econometric diagnostics. The empirical evidence demonstrates a substantial divergence between the dynamics of agricultural output and primary production resources. Agricultural production increased from 2,753.7 billion UZS in 2010 to 43,586.9 billion UZS in 2024, while cultivated agricultural land decreased by 12.57%. Agricultural employment increased by only 14.1% between 2010 and 2025, despite a pronounced expansion of agricultural output. The Pearson correlation coefficient between agricultural output and cultivated area over 2010–2024 was approximately −0.906, indicating a strong inverse association. These results suggest that agricultural development in Kashkadarya is increasingly associated with intensification, capital deepening, technological modernization and improvements in resource-use efficiency rather than extensive expansion of land and labour resources. The proposed econometric specification provides an analytical basis for estimating the marginal and elasticity effects of investment, credit, labour, fixed capital, land and technological provision on agricultural entrepreneurship efficiency.

Keywords: agricultural entrepreneurship, econometric modelling, agricultural efficiency, multivariate regression, elasticity, technical efficiency, resource allocation, Kashkadarya Region, Uzbekistan.

1. INTRODUCTION

Agriculture remains one of the structurally significant components of the regional economy of Uzbekistan, particularly in territories characterized by a high concentration of agricultural production, extensive rural employment and differentiated natural-resource conditions. Within this context, agricultural entrepreneurship should not be interpreted exclusively as the establishment or expansion of individual farm enterprises[1] Rather, it represents a complex economic process involving the mobilization and transformation of land, labour, financial capital, technological resources, managerial competencies and market opportunities into economically valuable agricultural output[2]

The contemporary paradigm of agricultural development increasingly emphasizes productivity, technical efficiency and resource-use optimization rather than merely increasing the physical volume of production. International empirical studies demonstrate that technical efficiency can be

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substantially influenced by irrigation infrastructure, technological adoption, agricultural extension, mechanization, institutional arrangements and access to financial resources. Recent research has also demonstrated that agricultural productivity is multidimensional, incorporating technical change, technical efficiency change and scale effects[3]

The relevance of these findings to Uzbekistan is particularly high[4] Evidence from Uzbek wheat production demonstrates that agricultural extension services can significantly affect technical efficiency, confirming the importance of institutional and knowledge-related factors in addition to conventional production inputs[5] At the same time, agricultural entrepreneurship has a broader behavioural and institutional dimension. Digital technologies, entrepreneurial capabilities, institutional conditions and access to markets increasingly shape farmers' entrepreneurial behaviour and performance. Kashkadarya Region provides an appropriate empirical setting for analysing these relationships. The region has substantial agricultural potential, but the dynamics of its agricultural sector indicate that production growth cannot be explained simply by expansion of cultivated land or labour resources[6,7]

The principal research question of this study is: Which economic, resource and technological factors exert the greatest influence on agricultural entrepreneurship efficiency in Kashkadarya Region?

The research objectives are to: (1) identify the structural dynamics of agricultural production and resource utilization; (2) quantify the statistical relationship between agricultural output and principal production factors; (3) develop a multivariate econometric specification of agricultural entrepreneurship efficiency; (4) determine the expected marginal and elasticity effects of major explanatory variables; and (5) formulate evidence-based policy implications for increasing agricultural entrepreneurial efficiency.

The scientific novelty of the study lies in the integration of regional agricultural statistics with an econometric determinant framework, allowing the transition from descriptive statistical assessment toward quantitative modelling.

2. MATERIALS AND METHODS

2.1. Data Sources and Analytical Framework

The study is based on official statistical data for Kashkadarya Region, including agricultural production, agricultural employment and cultivated land. During 2010–2024, agricultural production increased from 2,753.7 billion UZS to 43,586.9 billion UZS, while cultivated land decreased from 493,003.0 to 431,038.9 hectares. Agricultural employment increased from 259.5 thousand persons in 2010 to 296.1 thousand persons in 2025, reaching a maximum of 342.3 thousand persons in 2017. The research applies descriptive statistics, productivity analysis, correlation analysis and multivariate econometric modelling to assess the transformation and efficiency of agricultural entrepreneurship.

2.2. Measurement of Agricultural Entrepreneurship Efficiency

Agricultural efficiency is assessed using labour and land productivity indicators. Labour productivity represents agricultural output per agricultural worker, while land productivity reflects agricultural output generated per hectare of cultivated land. These indicators enable the assessment of agricultural performance in relation to the utilization of key production resources.

2.3. Econometric Specification

The study considers investment, agricultural credit, labour, fixed capital, cultivated land and technological provision as the principal determinants of agricultural entrepreneurship efficiency. Investment, credit, fixed capital and technology are expected to contribute positively to efficiency, while the effects of labour and land may vary depending on their marginal productivity and utilization intensity. A log-linear specification is additionally considered to evaluate the elasticity of agricultural efficiency with respect to the selected determinants.

2.4. Correlation and Model Diagnostics

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Pearson correlation analysis is used to identify the direction and strength of relationships among the main variables. Since correlation does not establish causality, the results are interpreted as preliminary evidence and complemented by multivariate analysis. Model reliability is assessed using R^2, adjusted R^2, the F-test and Student's t-test. Potential multicollinearity, heteroskedasticity, autocorrelation and specification errors are also considered to ensure the statistical robustness of the econometric results.

3. RESULTS

3.1. Structural Transformation of Agricultural Production

The empirical analysis reveals a substantial structural transformation of agricultural production in Kashkadarya Region during the period under consideration. Between 2010 and 2024, the nominal value of agricultural production increased from 2,753.7 billion UZS to 43,586.9 billion UZS. This represents an absolute increase of 40,833.2 billion UZS and a relative increase of 1,483.1%, indicating that the nominal volume of agricultural production expanded approximately 15.83-fold over the study period. At the same time, the area of cultivated agricultural land declined from 493,003.0 hectares in 2010 to 431,038.9 hectares in 2024. The reduction amounted to 61,964.1 hectares, equivalent to 12.57% of the initial cultivated area. Thus, agricultural output increased substantially despite a considerable contraction in cultivated land.

This divergence between output growth and land-use dynamics provides important preliminary evidence of an intensification process in the regional agricultural economy. The observed transformation may be associated with improvements in production technology, irrigation efficiency, capital intensity, crop structure, mechanization and the adoption of modern agricultural practices.

Table 1.

Dynamics of agricultural production and cultivated land in Kashkadarya Region.

Year	Agricultural production, billion UZS	Cultivated land, ha
2010	2,753.7	493,003.0
2015	9,089.0	493,918.0
2020	23,777.8	454,629.0
2022	32,240.7	418,465.0
2023	38,462.6	422,456.1
2024	43,586.9	431,038.9

3.2. Correlation between Agricultural Production and Cultivated Land

The correlation analysis for 2010–2024 indicates a strong inverse relationship between agricultural production and cultivated land in Kashkadarya Region. The Pearson correlation coefficient was approximately −0.906, indicating a very strong negative linear association between the two variables.

The corresponding coefficient of determination was approximately 0.821, meaning that around 82.1% of the variation in one variable is statistically associated with the linear movement of the other within the observed sample. Nevertheless, this result should not be interpreted as evidence of a direct causal relationship. The negative association may simultaneously reflect technological modernization, changes in irrigation practices, capital accumulation, crop specialization, agricultural prices, climatic conditions and institutional reforms.

The correlation result nevertheless provides an important empirical indication that the recent development of agriculture in Kashkadarya has not been primarily driven by expansion of cultivated

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land. Instead, intensive utilization of existing productive resources appears to have become increasingly important.

3.3. Dynamics of Agricultural Employment

Agricultural employment in Kashkadarya Region increased from 259.5 thousand persons in 2010 to 296.1 thousand persons in 2025. The absolute increase was 36.6 thousand persons, corresponding to a relative increase of 14.1%.

However, agricultural employment reached its highest observed level in 2017, at 342.3 thousand persons. Subsequently, employment declined to 296.1 thousand persons by 2025, representing a reduction of 46.2 thousand persons, or approximately 13.5%.

The divergence between agricultural output and employment is particularly significant. While employment declined by 13.5% from its 2017 peak, agricultural production continued to increase. This pattern is consistent with a potential transition toward mechanization, capital deepening, technological substitution and improvements in labour productivity.

The results therefore suggest that the expansion of agricultural production is increasingly becoming less dependent on proportional growth in labour inputs. Nevertheless, establishing the causal contribution of mechanization and technology requires a multivariate econometric assessment.

Table 2.

Agricultural employment dynamics in Kashkadarya Region.

Indicator	2010	2017	2025
Agricultural employment, thousand persons	259.5	342.3	296.1
Change relative to 2010, %	100.0	131.9	114.1
Change relative to 2017, %	75.8	100.0	86.5

3.4. Nominal Labour Productivity

The dynamics of nominal labour productivity provide additional evidence of structural changes in the agricultural sector.

In 2010, agricultural production per agricultural worker was approximately 10.61 million UZS per worker, based on agricultural production of 2,753.7 billion UZS and employment of 259.5 thousand persons. By 2025, agricultural production had reached 49,950.0 billion UZS, while agricultural employment amounted to 296.1 thousand persons. Consequently, nominal agricultural output per worker increased to approximately 168.69 million UZS per worker.

The resulting increase represents approximately 15.90 times the 2010 level.

This substantial increase indicates that the nominal value of agricultural production has grown considerably faster than agricultural employment. From an entrepreneurial-efficiency perspective, this pattern is consistent with increasing capital intensity, technological modernization and improved utilization of production resources.

Nevertheless, because both the numerator and denominator are based on aggregate nominal indicators, the result should be interpreted as a nominal labour productivity indicator rather than a pure measure of physical labour productivity.

3.5. Structural Composition of Agricultural Production

The structure of agricultural production in 2025 demonstrates a relatively concentrated production profile. Kashkadarya Region produced approximately 954.6 thousand tonnes of grain and

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leguminous crops, 286.3 thousand tonnes of melons, 215.2 thousand tonnes of fruits and berries, and 131.7 thousand tonnes of grapes. The combined production volume of these four product groups reached approximately 1,587.8 thousand tonnes.

Grain and leguminous crops accounted for the largest share, approximately 60.1% of the selected production volume. Melons represented 18.0%, fruits and berries 13.6%, while grapes accounted for 8.3%. The predominance of grain and leguminous production indicates a relatively concentrated agricultural structure. From an agricultural entrepreneurship perspective, greater diversification toward higher-value crops, horticulture, viticulture and agricultural processing could potentially increase value added per hectare and strengthen farm-level profitability.

Such a conclusion, however, requires additional evidence concerning production costs, market prices, profitability and value-added generation.

Table 3.

Structure of selected agricultural production in Kashkadarya Region, 2025.

Agricultural product	Production, thousand tonnes	Share, %
Grain and legumes	954.6	60.1
Melons	286.3	18.0
Fruits and berries	215.2	13.6
Grapes	131.7	8.3
Total	1,587.8	100.0

3.6. Determinants of Agricultural Efficiency

The empirical findings provide a basis for identifying the principal factors that may determine agricultural efficiency in Kashkadarya Region. Six major explanatory variables are considered particularly relevant: investment, credit availability, agricultural labour, fixed capital, cultivated land and technological development.

Investment is expected to have a positive effect because capital expenditure can expand production capacity, improve infrastructure and facilitate technological modernization. Credit availability may similarly contribute to efficiency by reducing financial constraints faced by agricultural enterprises and farmers. The effect of labour is theoretically ambiguous. Additional labour can increase production when labour is a binding production factor; however, under conditions of increasing mechanization, excessive labour intensity may reduce productivity.

Fixed capital and technological development are expected to have positive effects because modern machinery, irrigation equipment, energy-efficient technologies and digital agricultural solutions can improve the utilization of land, water, labour and other productive resources.

Table 4.

Theoretical direction of the determinants of agricultural efficiency.

Variable	Expected effect	Economic interpretation
Investment (INV)	+	Expands productive capacity and technological potential
Credit (CRED)	+	Relaxes financial constraints
Labour (LAB)	±	Depends on marginal

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		labour productivity
Fixed capital (CAP)	+	Increases capital intensity
Land (LAND)	±	Depends on marginal land productivity
Technology (TECH)	+	Improves technical and production efficiency

The role of cultivated land is also theoretically ambiguous. An increase in land resources does not necessarily result in proportional growth in output if land productivity is low. Conversely, efficient utilization of limited land resources can generate higher economic returns through intensification.

3.7. Econometric Assessment of Agricultural Efficiency

The descriptive and correlation results indicate that agricultural development in Kashkadarya Region should be examined through a multidimensional econometric framework rather than through a single resource indicator.

The proposed empirical framework considers agricultural efficiency as a function of investment, credit, labour, fixed capital, land resources and technological development. The purpose of the model is to determine which factors exert statistically significant influence on agricultural efficiency and to quantify the relative contribution of each determinant.

The econometric assessment should include several stages. First, the statistical significance of individual explanatory variables should be evaluated using Student's t-test. Second, the joint explanatory power of the determinants should be assessed using the F-test. Third, the explanatory capacity of the model should be evaluated through the coefficient of determination and adjusted coefficient of determination.

Additional diagnostic procedures are also necessary to ensure econometric reliability. These should include testing for multicollinearity, heteroskedasticity, autocorrelation and model specification errors.

The available empirical evidence already demonstrates several important structural tendencies. Agricultural production increased by 1,483.1% between 2010 and 2024, while cultivated land decreased by 12.57%. Agricultural employment declined by 13.5% from its 2017 peak, while nominal output per worker increased approximately 15.9 times between 2010 and 2025.

Taken together, these findings indicate a gradual transformation of Kashkadarya's agricultural economy toward a more intensive, capital-dependent and technologically oriented production structure. Investment, technological modernization, access to credit and efficient utilization of existing land and labour resources therefore represent potentially important mechanisms for improving the efficiency of agricultural entrepreneurship in the region.

At the same time, the reported relationships should be interpreted as empirical associations rather than causal effects until the complete annual dataset and multivariate econometric estimation are implemented. This approach ensures statistical validity, methodological transparency and reproducibility of the research findings.

4. DISCUSSION

The empirical findings reveal a fundamental transformation in the production architecture of Kashkadarya agriculture. The simultaneous increase in agricultural production and decrease in cultivated land provides a strong empirical basis for hypothesizing an intensification process. Such a pattern suggests increasing importance of technological progress, capital accumulation, irrigation efficiency, mechanization and productivity enhancement.

The labour dynamics provide complementary evidence. Employment declined by 13.5% from its 2017 peak, while agricultural production continued to expand. This may indicate a gradual transition

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from labour-intensive production toward relatively more capital- and technology-intensive production. Nevertheless, the use of current-price output means that the productivity interpretation must be treated cautiously until a deflated real-output series is introduced.

The coefficient r = −0.906 between agricultural output and cultivated land is particularly informative. It does not imply that land has become economically irrelevant; rather, it suggests that changes in land area alone cannot account for the observed development trajectory. Therefore, the econometric model should focus on the interaction of land with capital, technology, finance and labour productivity.

From the perspective of agricultural entrepreneurship, efficiency is determined by the entrepreneur's ability to combine production factors under institutional and market constraints. Consequently, policy interventions should prioritize access to productive finance, technology diffusion, mechanization, managerial capability, value-chain integration and evidence-based resource allocation.

5. CONCLUSION

The study developed a multivariate econometric framework for analysing the determinants of agricultural entrepreneurship efficiency in Kashkadarya Region. The empirical assessment produced several principal findings. First, agricultural production increased from 2,753.7 billion UZS in 2010 to 43,586.9 billion UZS in 2024, representing a 1,483.1% increase or approximately 15.83-fold expansion in nominal terms. Second, cultivated agricultural land decreased from 493,003.0 hectares to 431,038.9 hectares, corresponding to a 12.57% reduction. Third, the Pearson correlation coefficient between agricultural production and cultivated land was approximately −0.906, indicating a very strong inverse statistical association. Fourth, agricultural employment increased by 14.1% between 2010 and 2025 but declined by 13.5% from its 2017 peak. Fifth, nominal agricultural output per worker increased from approximately 10.61 million UZS to 168.69 million UZS, corresponding to an approximately 15.9-fold increase.

These findings collectively suggest that the future efficiency of agricultural entrepreneurship in Kashkadarya should be analysed through capital deepening, technological modernization, financial accessibility, labour productivity and resource-allocation efficiency rather than through expansion of land and labour alone. The proposed econometric model provides the methodological basis for estimating the marginal effects and elasticities of investment, credit, fixed capital, labour, land and technological factors once the complete annual regional dataset is assembled.

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