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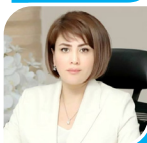
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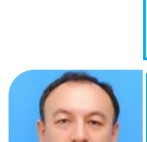
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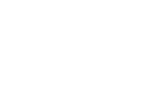
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ASSESSMENT OF AGRARIAN SECTOR EFFICIENCY THROUGH THE SFA MODEL

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Abstract: This article utilizes the parametric Stochastic Frontier Analysis (SFA) method to evaluate the efficiency of Uzbekistan's agricultural sector. The study is based on panel data from 2010 to 2025, which identifies the boundary state of the agricultural production function and resource elasticity. The results of the SFA model showed that the average technical efficiency in the republic is 73%. The article compiled regional performance profiles, analyzing Samarkand and Navoi regions as the leading regions.

Key words: agrarian sector, SFA model, technical efficiency, stochastic boundary analysis, production function, gamma coefficient, resource elasticity, agriculture of Uzbekistan.

Аннотация: В данной статье с использованием параметрического метода стохастического пограничного анализа (SFA) оценивается эффективность аграрного сектора Узбекистана. Исследование основано на панельных данных за 2010–2025-годы, что позволило определить граничное состояние сельскохозяйственной производственной функции и эластичность ресурсов. Результаты модели SFA показали, что средняя техническая эффективность по республике составляет 73%. В статье также были сформированы региональные профили эффективности, в рамках которых Самаркандская и Навоийская области определены как лидирующие регионы.

Ключевые слова: аграрный сектор, модель SFA, техническая эффективность, стохастический пограничный анализ, производственная функция, гамма-коэффициент, эластичность ресурсов, сельское хозяйство Узбекистана.

INTRODUCTION

In the context of global economic changes and the need to ensure food security, the quantitative assessment of agricultural sector efficiency remains one of the most important areas of economic research. In this regard, two main methodological approaches prevail in the world scientific literature: parametric and non-parametric methods within the framework of the concept of the efficiency threshold, founded by M. Farrell.

At the stage of modernizing our country's economy, transitioning the agricultural sector from extensive development to intensive development based on a cluster system and innovative technologies has been identified as one of the primary tasks. In the process of this transformation, it is important to determine the real potential of regional agricultural production and assess the level of utilization of available resources.

In this scientific article, the stochastic boundary analysis (hereinafter referred to as SFA) model, one of the two internationally recognized methods mentioned above, was used to evaluate the efficiency of the agricultural sector. The main advantage of the SFA method is that it allows for the separation of random errors from systemic inefficiencies in areas highly dependent on natural factors (e.g., weather), such as agriculture. Its main goal is to form a regional efficiency profile of the agricultural sector of Uzbekistan based on panel data covering 2010-2025, determine the threshold state of the production function, and assess resource elasticity.

The study also provides for a scientific analysis of the pace of technical progress and modernization in the field, taking into account the trend of the times. The results obtained on the basis of a comprehensive approach serve as a scientific basis for identifying latent (hidden) opportunities in the agricultural sector and forming regional economic policy.

REVIEW OF LITERATURE ON THE SUBJECT

Parametric orientation has scientifically proven the advantages of the method using the stochastic efficiency estimation (SFA) method, proposed almost simultaneously by D. Aigner, C. Lovell, and P. Schmidt, as well as W. Meeusen and J. van den Broeck. As a result, it became possible to study random errors in areas related to natural factors, such as agriculture, separately from systemic inefficiency. Subsequently, the development of variants of this model adapted to panel data by G. Battese and T. Coelli [3] paved the way for the study of technical efficiency and technological changes in the agricultural sector in dynamics. In this study, a regional efficiency profile of the agricultural sector of Uzbekistan was formed based on the synthesis of these internationally recognized methodologies.

The study transitioned to the stochastic performance estimation (SFA) model. The elasticity coefficients obtained as a result of regression analysis show which resource is of priority importance in agricultural production growth, while the next stage of efficiency analysis determines how much these resources are used. This makes it possible to scientifically forecast the directions of the transition from quantitative production growth to qualitative changes.

RESEARCH METHODOLOGY

In this study, the Stochastic Frontier Analysis (SFA) model, which is parametric from two complementary approaches, was used methodologically based on the principles of multidimensional statistical analysis. Additionally, statistical observation, grouping, indexing, and correlation-regression analysis methods were widely used in data collection.

ANALYSIS AND RESULTS

This analytical period, covering 2010-2025, includes two important stages of agrarian reforms in the republic: the transition from extensive development to intensive development based on a cluster system and innovative technologies. This served to reflect not only quantitative changes in the models, but also qualitative transformation processes in numbers (Table 1).

Table 1. SFA Model Results of Agricultural Indicators in Uzbekistan¹

Metrics (Variables)	Estimate	Standard error (Std. Error)	z-statistics (z value)	P-value (Pr (> z))
Constant (Intercept)	1.5761	0.8256	1.9090	0.0562
Investments (log)	-0.0286	0.0565	-0.5062	0.6127
Land area (log)	0.1552	0.0482	3.2214	0.0013
Number of items (logs)	0.9765	0.0499	19.5601	0.0001
Total dispersion	0.1670	0.0428	3.9013	0.0001
Gamma coefficient	0.9551	0.1576	6.0590	0.0001
Log-likelihood value	-5.0539			

The results of the stochastic boundary analysis in the table above made it possible to determine the production function in the country's agricultural sector and its deviation from the boundary. The maximum plausibility estimates of the model show that the gamma coefficient is 0.955, which is extremely significant at a level of $p < 0.001$. This indicator scientifically proves that the main obstacle to the use of production reserves in the industry is not a technological shortage, but inefficiency in the management of available resources [4].

The resource elasticity determined within the SFA model provided interesting results that differ from traditional OLS models. Specifically, the elasticity coefficient of the labor factor (lnbands) was 0.976 ($p < 0.001$), indicating that it is the most strategic resource for establishing production boundaries. The statistical significance of the land area coefficient (lnler) at a level of 0.155 ($p < 0.01$) indicates that intensive land resource use still has potential for growth in terms of marginal efficiency [5].

¹ Source: Developed by the author.

According to the model results, the average technical efficiency (mean efficiency) of the republic's agricultural sector was 0.743 (or 74.3%). This means that under current technological conditions and the amount of available resources, agricultural enterprises in Uzbekistan have the opportunity to increase production volumes by an average of 25.7% without additional resource expenditures, solely through the optimization of management and technical processes. This situation indicates that the next stage of agrarian reforms should be aimed not only at attracting investment but also at introducing innovative management methods that bring production processes closer to the efficiency threshold.

The average technical efficiency for the model was 0.723 (or 72.3%). This indicator means that in the agricultural sector, there is an opportunity to increase production by an additional 27.7% with available resources and current technology. The extremely high gamma coefficient provides a scientific justification for the possibility of utilizing these reserves only by improving management quality, enhancing personnel qualifications, and optimizing agrotechnical measures. This conclusion serves as a starting point for the strategic directions developed to increase regional efficiency in the practical part of the dissertation (Table 2).

Table 2. Parametric SFA Results of Agricultural Indicators in Uzbekistan²

#	Territory	For 1 model	according to model 2	Average
1.	Republic of Uzbekistan	0.74	0.72	0.73
including				
1.1.	Republic of Karakalpakstan	0.40	0.36	0.38
1.2.	Andijan region	0.90	0.92	0.91
1.3.	Bukhara region	0.72	0.68	0.70
1.4.	Jizzakh region	0.71	0.65	0.68
1.5.	Kashkadarya region	0.64	0.57	0.60
1.6.	Navoi region	0.91	0.92	0.91
1.7.	Namangan region	0.84	0.87	0.85
1.8.	Samarkand region	0.94	0.93	0.93
1.9.	Surkhandarya region	0.55	0.50	0.52
1.10.	Syrdarya region	0.72	0.74	0.73
1.11.	Tashkent region	0.84	0.78	0.81
1.12.	Fergana region	0.66	0.63	0.64
1.13.	Khorezm region	0.78	0.81	0.79

The results of the two different SFA models used in the study showed that the efficiency of agricultural production in the regions of the Republic of Uzbekistan demonstrates significant regional diversity. Although the average efficiency coefficient of the republic has stabilized at 0.73 (73%), in the context of regions, this indicator varies within a broad range from 0.38 to 0.93. Such differences empirically highlight the importance of considering the territorial characteristics of agrarian reforms and identifying region-specific development opportunities to further strengthen agricultural efficiency across all territories.

Samarkand (0.93), Navoi (0.91), and Andijan (0.91) regions lead the performance ranking. The proximity of these territories to the "production frontier" means that the system for using their available resources (land, water, labor) has been optimized to the maximum extent. In particular, the widespread introduction of intensive technologies in the conditions of limited land resources in the Samarkand and Andijan regions, and a high level of cluster system and agro-industrial integration in the Navoi region serve as the main factors of this efficiency.

Conversely, in the Republic of Karakalpakstan (0.38), Surkhandarya (0.52), and Kashkadarya (0.60) regions, efficiency indicators were significantly lower than the national average. In particular, the efficiency reserve in the Republic of Karakalpakstan is 62%. This means that there is an opportunity to almost double production by improving the reclamation status of existing lands, modernizing irrigation systems, and increasing management efficiency rather than attracting new resources to increase production volumes in this region.

CONCLUSIONS AND SUGGESTIONS

The results of the conducted research allowed for important scientific conclusions to be drawn regarding the improvement of production efficiency in our country's agrarian sector. According to the results of the

² Source: Developed by the author.

stochastic boundary analysis (SFA), the average technical efficiency coefficient of the republic's agriculture was 0.73 (or 73%). This means that under current technological conditions and the amount of available resources, agricultural enterprises have the opportunity to increase production volumes by an average of 27% without additional resource expenditures, solely through the optimization of management and technical processes.

It was found that the gamma coefficient, which is one of the most important indicators of the model, is equal to 0.99 and has very high statistical significance. This result scientifically proves that almost the entire gap between real and potential production in the agricultural sector is directly related to technical inefficiency.

Analysis of resource elasticity showed that the labor factor is the most strategic resource in determining the production threshold. At the same time, the results of the model with a time trend (T) confirmed that technical progress in the republic's agricultural sector occurs at an average rate of 3.4% annually, and the production frontier is shifting upward due to innovative methods.

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