HONG KONG JOURNAL OF SOCIAL SCIENCES

香港社會科學學報

第一的第63期 (2024春/夏) Vol. 63 Spring/Summer 2024

Open Access Article https://doi.org/10.55463/hkjss.issn.1021-3619.63.20

Technical Efficiency and Returns to Scale in Vietnam's Agriculture: Stochastic Output Distance Function Approach

Duc-Tri Tran[1], Nguyen To-The[2], Viet-Anh Dao[2], Tuan Nguyen-Anh[2], Linh Nguyen-Thi-Thuy[2], Ashfaq Ahmad Shah[3], Huong Nguyen-Thi-Lan[2]*

[1] *Vietnam National University of Agriculture, Hanoi, Vietnam*

[2] *VNU University of Economics and Business, Hanoi, Vietnam*

[3] *College of Humanities and Development Studies (COHD), China Agricultural University, Beijing, 100193.*

Received: May 29, 2024 ▪ Reviewed: June 20, 2024

▪ Accepted: June 28, 2024 ▪ Published: July 15, 2024

Abstract:
The purpose of this study is to analyze the effects of technical efficiency (TE) and return to scale on Vietnamese agriculture using panel data. This study employs a stochastic output distance function technique applied to panel data collected from 487 households over five surveys. This approach is used to investigate TE, its determinants, technical change, and return to scale in Vietnamese agriculture. The overall technical efficiency is 89.29%, with variations in efficiency observed across provinces. Household and plot sizes positively and significantly affect efficiency, whereas ethnicity of household heads negatively impacts efficiency, with the average rate of technical change decreasing by 4.43%. The returns to scale are currently at 0.78, indicating an increase. TE growth has been declining, with an average annual decline of 2.71%. The findings suggest that to boost agricultural productivity, there is a need for collaboration between farmers and the government to improve technical efficiency, adapt agricultural practices, and achieve a more efficient scale of operation. This study provides a detailed analysis of the determinants of TE and return to scale in Vietnamese agriculture using panel data, highlighting the significant impact of household characteristics and offering insights into the decline in annual TE growth.

Keywords: technical efficiency, stochastic output distance function, Vietnamese agriculture.

越南农业的技术效率和规模收益：随机产出距离函数方法

Corresponding Author: Huong Nguyen-Thi-Lan, VNU University of Economics and Business, Hanoi, Vietnam; email: huongkthb@gmail.com

摘要:
本研究的目的是利用面板数据分析技术效率(泰克)和规模收益对越南农业的影响。本研究采用随机输出距离函数技术，应用于五次调查中从487个家庭收集的面板数据。这种方法用于研究越南农业的泰克、其决定因素、技术变革和规模收益。总体技术效率为89. 29%，各省的效率各不相同。家庭和地块规模对效率有显著的正向影响，而户主的种族对效率有负面影响，平均技术变革率下降了4. 43%。规模收益目前为0. 78，表明有所增加。泰克增长率一直在下降，年均下降2. 71%。研究结果表明，为了提高农业生产力，农民和政府需要合作，以提高技术效率，调整农业实践，实现更高效的经营规模。本研究利用面板数据对越南农业泰克和规模回报的决定因素进行了详细分析，强调了家庭特征的显著影响，并对年度泰克增长下降提供了见解。

关键词：技术效率，随机产出距离函数，越南农业。

1. Introduction

Economic growth in Vietnam in general and in the agricultural sector in particular has been remarkable since the "Doi-Moi" institutional reforms of 1986. In 2020, the agricultural sector accounted for 14.85% of Vietnam's gross domestic product (GDP) (General Statistic Office, 2020). Institutional reforms and the implementation of trade liberalization policies jointly contributed to structural transformation across various sectors of the economy, leading to further industrialization. As a result, factors of production (labor and capital) were able to flow freely across different productive sectors, facilitating the movement of labor from farm to non-farm (industrial) sectors. The proportion of the labor force engaged in agricultural activities declined from 63% in 2000 to 42% by 2016 (General Statistic Office, 2000, 2016). Urban residential land increased sharply from 75,128 hectares in 2000 to 156,500 hectares by 2016. The agricultural sector has to adapt to meet the rising demand for food and feed the growing population. Crop and livestock production require significant investments in advanced technology to increase efficiency and productivity.

Many studies have explored the impacts of different technologies employed in diverse farming systems in Vietnam due to the heterogeneity of agroecology. These studies focus on how efficient the various production regimes are in terms of technology (Pedroso et al., 2018; Ho & Shimada, 2019; Lampach et al., 2021; Thach et al., 2021; Umetsu, 2022; Nguyen et al., 2022). Most of these studies used traditional methods for measuring technical efficiency (TE), such as data envelopment analysis (DEA) (non-parametric approach) and stochastic frontier analysis (SFA).

Traditional methods of measuring TE had two shortcomings. These techniques could not account for objective behaviors, such as profit maximization and cost minimization, in multi-output technology settings because they lacked price information. While describing the TE and productivity of a technology, these two drawbacks can be avoided using a distance function. However, not all firms achieve TE, and the distance function can be estimated using both econometrics and mathematical programing methods. DEA is one of the most important methods to measure nonparametricity. There is no requirement for production technology because the DEA uses linear programing. However, SFA necessitates the use of production technology to specify distance function parameters (O'Donlell & Coelli, 2005).

It is relatively easy to quantify production components in non-agricultural industries such as manufacturing and trading. However, due to the multiplicity of output parameters for agricultural and livestock enterprises, the process in the agriculture sector is challenging. Brummer et al. (2006) used a stochastic output distance function with panel data to analyze policy reform and changes in productivity in Chinese agriculture. Research indicated that in the first sub-sample, the TE was relatively low and changed at a small rate. In the second sub-sample, the TE was higher and tended to increase.

Despite the extensive literature on TE, technical change, and returns to scale in both agricultural and non-agricultural sectors in many developing countries, empirical research in Vietnam, particularly that utilizing distance functions, remains limited. We address this gap by applying distance functions to panel farm household data to quantify TE and its determinants in Vietnamese agriculture, including technical change and return to scale. We used the Tobit model to analyze the TE drivers. Our findings have significant implications for enhancing technological change to ensure sustainable growth in Vietnam's agricultural sector. These insights are also relevant for other developing countries in which agricultural sector growth is crucial for livelihood enhancement.

2. Methodologies and Data

2.1. Data and Sources

This study used the VARHS data according to the flowchart of the research methodology (Figure 1). The VARHS survey began in 2002 with a small sample (932 households in 3 provinces). In 2010, the sample size was increased to 2,324 households across 12 provinces, up from 3,223 households in round 2008. In round 2012, the sample size was 3,202 households, of which 2,200 were panel households. In round 2014, the sample size was 3,700 households, while in round 2016, it was 3,648 households. In round 2018, the sample size was 3,582 households. We used a balanced panel of 487 farm households interviewed during the five survey rounds between 2010 and 2018, giving 2,435 observations from the three provinces of Vietnam (Table 1).

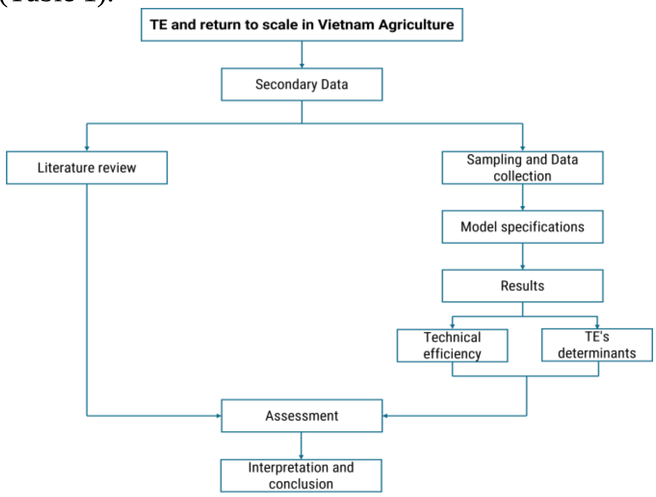

Figure 1. Flowchart of research methodology (Developed by the authors)

Table 2. Observations by region (Developed by the authors)

Detail	Phu Tho Province	Lao Cai Province	Lai Chau Province
Number of households	112	230	145
Observation	560	1150	725

This study chooses to select a sample based on the primary criteria of representativeness, which include crop and livestock production, for several reasons. First, crops and livestock are collectively the primary components of agricultural production. By analyzing both, this study gains a holistic view of agricultural productivity. Production processes for crops and livestock differ significantly, involving varied techniques, resources, and management practices. Therefore, the results obtained allow for a more comprehensive understanding of how different agricultural practices impact TE. Additionally, there is often considerable variability in efficiency levels between crop production and livestock farming. It is possible to identify sector-specific challenges and opportunities for improvement. Both crops and livestock are crucial to the economy, especially in an agricultural-intensive focus country like Vietnam.

Moreover, the descriptive statistics reveal that households with 2 output elements in the agricultural sector (crop and livestock) are concentrated mainly in northern Vietnam. This is plausible for the following reasons: (i). agro-ecological diversity in the north; (ii). large fragmentation of land, making it easy to produce a variety of agricultural products; (iii). greater farm diversification that limits the scale of crop and livestock production, marketable surpluses, and farm incomes. As implied in these areas, farmers frequently should decide how to allocate resources between crop production and livestock farming. Therefore, it is essential to analyze the insights from two major agricultural factors to optimize resource allocation and maximize overall farm efficiency.

2.2. Model Specification

In this study, the Battese and Coelli (1992) model was employed to run a series of models based on varying assumptions for the analysis: (i) Model-1 entails the estimation of all parameters; this is a time-varying decay model, and u_i is independent and identically distributed (i.i.d), non-negative, and has a truncated normal distribution (u_i ~ i.i.d $N(\mu, \sigma_u^2)$); (ii) Model-2 assumes that $\mu = 0$; this is a time-varying decay model, and u_{it} has a half-normal distribution (u_i ~ i.i.d $N(0,\sigma_u^2)$); (iii) Model-3 assumes that $\eta = 0$; this is time-invariant, and u_{it} distribution is non-negative truncations of the $N(\mu, \sigma_u^2)$ distribution; (iv) Model-4 assumes that $\mu = \eta = 0$; this is time-invariant, and u_i is non-negative and has a half-normal distribution (u_i~i.i.d $N(0,\sigma_u^2)$); (v) Model-5 assumes that $\mu = \eta = \gamma = 0$; this is a time-invariant model, u_i has a half-normal distribution (u_i~i.i.d $N(0,\sigma_u^2)$), and u_{it} is absent from the model (the observation variables are fully technically efficient.).

The stochastic production frontier with the translog form is as follows:

$$Livestock = \alpha_0 + \alpha_1 Crop + \alpha_{11} Crop^2 + \beta_1 Land + \beta_2 Labor + \beta_3 Inter + \beta_{11} Land^2 + \beta_{22} Labor^2 + \beta_{33} Inter^2 + \beta_{12} Land*Labor + \beta_{13} Land*Inter + \beta_{23} Labor*Inter + \gamma_{11} Crop*Land + \gamma_{12} Crop*Labor + \gamma_{13} Crop*Inter + \delta_1 Yr + \delta_{11} Yr^2 + \delta_{12} Yr*Crop + \delta_{13} Yr*Land + \delta_{13} Yr*Labor + \delta_{14} Yr*Inter + u_{it} + v_{it},$$

where *l* denotes the natural logarithm of variables, *Yr* denotes a time trend, v_{it} is i.i.d. $N(0, \sigma^2_v)$, u_{it} i.i.d. $N(\mu, \sigma^2)$. The output variables include the total turnover of crop production (*Crop*) and the total turnover of livestock (*Livestock*). The input variables include total area used for cultivation and livestock (*Land*), total labor used for cultivation and livestock (*Labor*), and intermediate input costs (*Inter*).

The log-likelihood ratio (LR) test was used to determine the appropriate model for the data. Based on this model, the TE, output elasticity, and returns to scale are estimated. The Tobit model is used to determine TE drivers as follows:

$$TE = \psi_0 + \psi_1 Gender + \psi_2 Fami + \psi_3 Ethnic + \psi_4 Frag,$$

where *Gender* represents the gender of the household head (1 - male; 0 - female), *Fami* represents the number of family members, *Ethnic* represents ethnicity of the household head (1 if Kinh or Hoa; 0 - otherwise), *Frag* represents the number of the plot of the household. The following section discusses the findings of the study, starting with the descriptive statistics and then the model results.

3. Results and Discussion

3.1. Descriptive Statistics

Table 2 provides a summary of the statistics for the variables used in the estimation of the distance function. The total value of crops produced represents a high proportion of the value of agricultural production. The intermediate production cost is relatively high, resulting in lower profits in Northern Vietnam. Most households are headed by men. Few of them are Kinh or Hoa, and the rest constitute a few ethnic groups.

Table 3. Descriptive statistics of the samples (The authors)

Variables	Mean	Std. Err.	Min.	Max.
Crop (1000 VND)	13,307.00	9,563.00	250.00	101,023.00
Livestock (1000 VND)	3,782.00	7,028.00	31.25	176,572.00
Land (m^2)	10,940.00	24,962.00	0	836,710.00
Labor (man-days)	338.50	212.70	0	1,943.00
Inter (1000 VND)	13,832.00	31,367.00	335.00	1.048e+06
Gender (1 - male; 0 - female)	1.08	0.27	1	2
Fami (number)	5.43	1.94	1	16
Ethnic (1 if Kinh or Hoa; 0 - otherwise)	0.20	0.40	0	1
Frag (number)	6.10	2.50	1	19

3.2. Results

3.2.1. Parameter Estimates

Four models were fitted, and the hypotheses were tested for suitability, as outlined in Table 3. Maximum likelihood estimation (MLE) was used to estimate the parameters. Model-1 was taken as the root for comparison with other models with different assumptions to find the most suitable model.

Table 3. Hypothesis test for model specification and statistical assumptions (Developed by the authors)

Null hypothesis	Model	LR test	Prob > chi2	Decision
1) H_0: $\mu = 0$	Model-1 vs. Model-2	8.66	0.0032	Reject H_0
2) H_0: $\eta = 0$	Model-1 vs. Model-3	15.22	0.0001	Reject H_0
3) H_0: $\mu = \eta = 0$	Model-1 vs. Model-4	15.61	0.0004	Reject H_0
4) H_0: $\mu = \eta = \gamma = 0$	Model-1 vs. Model-5	76047	0.0000	Reject H_0
5) H_0: $\psi_0 = ... = \psi_4 = 0$	Tobit model	56.57	0.0000	Reject H_0

In conclusion, after testing the models under different assumptions, Model-1 was considered the best. As a result, Model-1 was selected for further analysis. Results of using MLE to estimate the parameters of the stochastic frontier production function are presented in Table 4. The coefficients of *lnLand* and *lnLabor* are positive and statistically significant at the 95% confidence interval, which explains that the land and labor used by households in agricultural production in the study area are appropriate and have a positive impact on the value of agricultural production.

Table 4. Maximum likelihood estimates of the stochastic frontier model (Developed by the authors)

Variables	Coef.	Std. Err.	[95% Conf. Interval]	
lnCrop	1.3986^{***}	0.1248	1.1539	1.6432
$lnCrop^2$	-0.0815^{***}	0.0139	-0.1089	-0.0541
lnLand	0.1388^{**}	0.0705	0.0005	0.2771
lnLabor	0.5657^{***}	0.1816	0.2097	0.9218
lnInter	-0.1133	0.1308	-0.3698	0.1432
$lnLand^2$	-0.0755^{***}	0.0031	-0.0814	-0.0695
$lnLabor^2$	-0.0805^{***}	0.0241	-0.1279	-0.0331
$lnInter^2$	0.0241^{*}	0.0145	-0.0043	0.0525
lnLand*lnLabor	0.0539^{***}	0.0104	0.0334	0.0743
lnLand*lnInter	-0.0062	0.0066	-0.0192	0.0068
lnLabor*lnInter	-0.0611^{***}	0.0156	-0.0916	-0.0304
lnCrop*lnLand	0.0007	0.0067	-0.0126	0.0142
lnCrop*lnLabor	-0.0698^{***}	0.0173	-0.1039	-0.0358
lnCrop*lnInter	0.0212^{*}	0.0118	-0.0018	0.0444
Yr	0.4296^{***}	0.0879	0.2572	0.6022
Yr^2	-0.0128	0.0104	-0.0333	0.0075
Yr*lnCrop	0.0027	0.0082	-0.0134	0.0189
Yr*lnLand	-0.0201^{***}	0.0059	-0.0318	-0.0084
Yr*lnLabor	-0.0342^{***}	0.0132	-0.0598	-0.0085
Yr*lnInter	0.0023	0.0079	-0.0133	0.0179
Constant	-8.9774^{***}	0.8346	-10.6133	-7.3414

*** p<0.01, ** p<0.05, * p<0.1

Variable *Yr* in the production function measures neutral technical change. Similarly, the interaction terms between time and other stochastic frontier functions are intended to measure the error rate of technical change. *Yr*'s coefficient is statistically significant and positive, which explains that neutral technical change occurs over the period and that technical change increases at an increasing rate.

The interaction terms between year and *lnLand* (*Yr*lnLand*) is positive and statistically significant at the 99% confidence interval. This shows a technical change in Vietnam's agriculture with land deceleration at a small rate of 2.01% during the study period. Analogously, the periodic interaction coefficient between *Yr* and *lnLabor* is positive and statistically significant at the 99% confidence interval, which explains the technical change in agriculture with labor deceleration of only 3.42% during the study period. The coefficient estimates for the interaction terms between *Yr* and *lnInter* are not statistically significant.

3.2.2. Technical Efficiency

The results indicate that the TE of agriculture in Vietnam is in the range of 21.41% to 98.25%. The average TE of the agricultural sector in Vietnam is 89.29% (Table 5). It shows that 10.71% is lost due to: (i) inefficiencies in agricultural production (either crop or livestock or both) and (ii) inefficiencies among households. Concurrently, the results indicate that farmers can increase their production by about 9.23% by improving TE. A review of the TE for each province reveals that Lao Cai exhibits the highest average TE for agricultural production (90.51%), followed by Lai Chau (89.09%). Conversely, Phu Tho exhibits the lowest average TE for agricultural production (87.07%). However, the average TE does not vary significantly across the provinces.

Table 5. Technical efficiency by province (Developed by the authors)

Province	Obs.	Mean	Std. Dev.	Min.	Max.
Phu Tho	560	0.8707	0.1137	0.2141	0.9825
Lao Cai	1150	0.9051	0.0659	0.4703	0.9837
Lai Chau	725	0.8909	0.0617	0.5261	0.9834
Total	2435	0.8929	0.0796	0.2143	0.9837

The average TE decreased over the years, from 94.02% in 2010 to 83.35% in 2018 (Table 6). It can be explained by the following: (i) the country's industrialization and modernization drive has resulted in industry restructuring. The proportion of industry and trade tends to increase while the agriculture's share of the economy shrinks and growers lose interest in agricultural production; (ii) input factors in agricultural production still have a positive impact on agricultural output, but the opportunity cost of agricultural production is smaller than the opportunity cost of other industries. This has led to input factors such as labor and other costs of farmer households gradually shifting to other occupations; (iii) some typical rural households have undergone a significant transformation in agricultural production, achieving considerable success in this domain. In contrast, other farmers have retained the same traditional production methods. This creates a widening gap between rural households in the study areas; 1 ≥ TE ≥ 0.9 accounted for 60.16%, 0.9 > TE ≥ 0.8 accounted for 30.10%, 0.8 > TE ≥ 0.7 accounted for 6.41%, 0.7 > TE ≥ 0.6 accounted for 2.05%, 0.6 > TE ≥ 0.5 accounted for 0.78%, and 0.9 > TE accounted for only 0.49%. Thus, the allocation density of TE in the range greater than 0.8 and less than 1 accounted for a large proportion (over 90%) (Figure 2).

Table 6. Technical efficiency by year (Developed by the authors)

Year	Obs.	Mean	Std. Dev.	Min.	Max.
2010	487	0.9401	0.0411	0.6025	0.9837
2012	487	0.9221	0.0521	0.5121	0.9785
2014	487	0.8991	0.0651	0.4132	0.9717
2016	487	0.8699	0.0803	0.3112	0.9628
2018	487	0.8335	0.0972	0.2140	0.9512

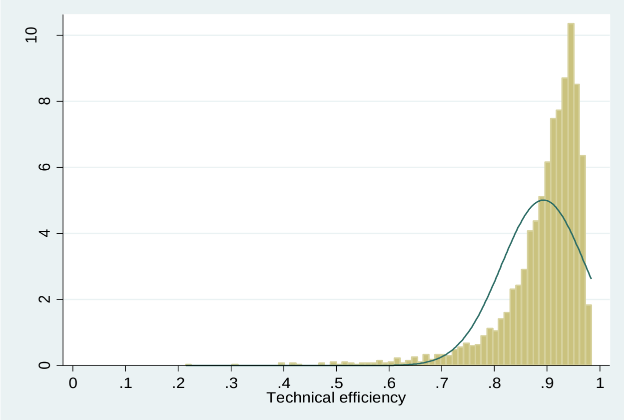

Figure 2. Distribution of technical efficiency in Vietnam's agriculture (Developed by the authors)

Table 7. Factors affecting technical efficiency (Developed by the authors)

Variables	Coef.	Std. Err.	[95% Conf. Interval]	
Gender	0.0006	0.0066	-0.0112	0.0136
Fami	0.0022***	0.0008	0.0006	0.0039
Ethnic	-0.0348***	0.0071	-0.0486	-0.0209
Frag	0.0038***	0.0008	0.0021	0.0054
Constant	0.8635***	0.0104	0.8431	0.8839

*** p<0.01, ** p<0.05, * p<0.1

The Wald test result showed that the gender of the household head, the number of family members, the ethnicity of the household head, and the number of plots in the household improved model fit. The coefficient of *Fami* is positive, indicating that households with more family workers realize higher TE than family labor-constrained households. Furthermore, in Vietnam, farming systems are labor-intensive, and the contribution of family labor is of particular importance for resource-poor farmers seeking to enhance TE in production. The coefficient of the *Ethnic* variable is negative, explaining that Kinh- or Hoa-headed households have lower TE than other ethnic groups. These results are inconsistent with the findings by Ali and Jan (2017) and To The and Nguyen Tuan (2019), who posited that being a member of a minority has no impact on production efficiency. This discrepancy can be attributed to the fact that the Kinh and Hoa groups are frequently situated in the delta region, whereas the study area is mountainous. Additionally, the Kinh ethnic group constitutes a minor proportion and possesses fewer advantages than the ethnic minorities. *Frag*'s coefficient is positive, which is consistent with Kompas et al. (2012) and Nguyen-Van and To-The (2016). This indicates that households with more plots have higher TE than those with fewer plots. This is particularly evident in Vietnam, particularly in the northern mountains, where there is a pronounced fragmentation of land. A large number of plots often means that the land area is larger; the greater the number of plots, the more straightforward it is to allocate cultivation and husbandry production structures than in households with fewer plots of land.

3.2.3. Elasticity Output and Returns to Scale

The results of the elasticity estimation are presented in Table 8. All the three inputs affected TE in agricultural production. The most important factor was land area, followed by intermediate costs and the number of laborers. Specifically, if other inputs were kept constant, a 1% increase in cultivated land, labor, or intermediate costs increased the value of production by 0.337, 0.201, and 0.246%, respectively.

Table 8. Estimating the input distance elasticity (Developed by the authors)

Input	Elasticity	Std. Dev.	Min.	Max.
lnLand	0.337	0.012	-0.404	0.714
lnLabor	0.201	0.016	-0.154	0.941
lnInter	0.246	0.011	-0.119	0.377

The RTS estimates are presented in Table 9. When all input factors increased by 1%, agricultural output increased from 0.712% to 0.850% between 2008 and 2016. This suggests that farmers in Northern Vietnam were implementing appropriate adjustments to their agricultural practices, namely, the combination of inputs and the balancing of crop and livestock production.

Table 9. Returns to scale by year (Developed by the authors)

Year	Obs.	Mean	Std. Dev.	Min.	Max.
2008	487	0.712	0.089	0.289	0.941
2010	487	0.736	0.121	0.291	1.046
2012	487	0.801	0.103	0.354	1.074
2014	487	0.819	0.103	0.479	1.081
2016	487	0.850	0.104	0.371	1.132

4. Conclusion and Policy Implications

We employed the distance function approach to study TE, technical change, and return to scale in Vietnamese agriculture, as well as the Tobit estimator to examine the causes of TE in crop and livestock production. The first finding of this study is that the level of TE in Vietnamese agriculture remained constant at 89.29% during the study period despite fluctuations across the provinces of Phu Tho, Lao Cai, and Lai Chau. The second discovery is that all selected inputs positively and significantly influenced the value of agricultural production. Among these inputs, land was ranked first in terms of impact, followed by intermediate and labor costs. The next one is a negative shift in the output distance function inwards. However, this rate of change has decreased over time, suggesting that farmers in Northern Vietnam have been making appropriate decisions by effectively adjusting and combining their inputs. Additionally, the average TE growth rate for the period was 2.71%, though it displayed a decreasing trend.

Our findings align with previous research indicating that land and intermediate costs are critical factors in agricultural production, surpassing labor costs in terms of their impact on output elasticity. Similar studies have also noted fluctuations in TE across regions and the importance of adjusting inputs to maintain productivity. However, our observed rate of technical change and TE growth provide new insights into the temporal dynamics of agricultural efficiency in Vietnam, highlighting a more pronounced negative shift and decreasing productivity trend than in earlier studies.

The results of this study have significant policy implications for TE and return to scale in Vietnamese crop and livestock production. To increase TE, higher investments in agricultural extension services are necessary to better equip farm households to embrace productivity-boosting technology, thereby enhancing market accessibility and labor efficiency. The findings also suggest that adopting practices such as crop rotation, intercropping, and multi-cropping can improve soil quality in intensive agricultural settings like Vietnam. In addition, optimizing the use of inputs to maximize crop and livestock yields and earnings is crucial. Increasing the number of cycles per year for livestock production can further increase productivity. From the perspective of the off-farm sector, it is of paramount importance for farm households to diversify their income sources by engaging in off-farm activities, including domestic or foreign labor, home crafts, trading, and services. The Vietnamese government should invest in workforce skill enhancement through on-the-job and vocational training and address disguised employment in the agriculture sector. It is imperative to enhance labor efficiency in agriculture, as evidenced by the observation that high-TE groups demonstrate a greater revenue or profit per labor unit than their low-TE counterparts. Nevertheless, the overall labor efficiency remains low. Future research should focus on the impact of fiscal and monetary policies on agricultural productivity and explore innovative strategies to reduce the effects of inflation on the agricultural sector.

References

[1] ALI, A., & JAN, A.U. (2017). Analysis of Technical Efficiency of Sugarcane Crop in Khyber Pakhtunkhwa: A Stochastic Frontier Approach. *Sarhad Journal of Agriculture,* 33(1), 69–79. https://doi.org/10.17582/journal.sja/2017.33.1.69.79

[2] BATTESE, G.E., & COELLI, T.J. (1992). Frontier production functions, technical efficiency and panel data: With application to paddy farmers in India. *Journal of Productivity Analysis*, 3(1-2), 153-169. https://doi.org/10.1007/BF00158774

[3] BRUMMER, B., GLAUBEN, T., & LU, W. (2006). Policy reform and productivity change in Chinese agriculture: A distance function approach. *Journal of Development Economics,* 81(1), 61-79. https://doi.org/10.1016/j.jdeveco.2005.04.009

[4] GENERAL STATISTIC OFFICE. (2000). *Statistic Yearbook of Vietnam.* Retrieved from https://www.gso.gov.vn/en/data-and-statistics/2020/02/statistical-yearbook-2000/

[5] GENERAL STATISTIC OFFICE. (2016). *Statistic Yearbook of Vietnam.* Retrieved from https://www.gso.gov.vn/en/data-and-statistics/2019/10/statistical-yearbook-of-vietnam-2016/

[6] GENERAL STATISTIC OFFICE. (2020). *Statistic Yearbook of Vietnam.* Retrieved from https://www.gso.gov.vn/en/data-and-statistics/2021/07/statistical-yearbook-of-2020/

[7] HO, T., & SHIMADA, K. (2019). Technical efficiency of rice farming in the Vietnamese Mekong Delta: A stochastic frontier approach. *Ritsumeikan Economic Review,* 67(5-6), 130-144. Retrieved from https://www.researchgate.net/profile/Ho-Thanh-Tam/publication/331971603_Technical_Efficiency_of_Rice_Farming_in_the_Vietnamese_Mekong_Delta_A_Stochastic_Frontier_Approach/links/6010dd7892851c2d4df6d70d/Technical-Efficiency-of-Rice-Farming-in-the-Vietnamese-Mekong-Delta-A-Stochastic-Frontier-Approach.pdf

[8] KOMPAS, T., CHE, T.N., NGUYEN, H.T.M., & NGUYEN, H.Q. (2012). Productivity, Net Returns, and Efficiency: Land and Market Reform in Vietnamese Rice Production. *Land Economics,* 88(3), 478–495. https://doi.org/10.3368/le.88.3.478

[9] LAMPACH, N., TO-THE, N., & NGUYEN-ANH, T. (2021). Technical efficiency and the adoption of multiple agricultural technologies in the mountainous areas of Northern Vietnam. *Land Use Policy,* 103, 105289. https://doi.org/10.1016/j.landusepol.2021.105289

[10] NGUYEN-VAN, P., & TO-THE, N. (2016). Technical efficiency and agricultural policy: evidence from the tea production in Vietnam. *Review of Agricultural, Food and Environmental Studies,* 97(3), 173–184. https://doi.org/10.1007/s41130-016-0026-1

[11] NGUYEN, T.V., SIMIONI, M., LE QUYEN, C., & VALTYSSON, H.P. (2022). Productivity, technical efficiency, and technological change in Vietnamese oceanic tuna fisheries. *Fisheries Research*, 248, 106202. https://doi.org/10.1016/j.fishres.2021.106202

[12] O'DONLELL, C.J., & COELLI, T.J. (2005). A Bayesian approach to imposing curvature on distance functions. *Journal of Econometrics*, 126(2), 493-523. https://doi.org/10.1016/j.jeconom.2004.05.011

[13] PEDROSO, R., TRAN, D.H., VIET, T.Q., LE, A.V., DANG, K.T., & LE, K.P. (2018). Technical efficiency of rice production in the delta of the Vu Gia Thu Bon river basin, Central Vietnam. *World Development Perspectives,* 9, 18-26. https://doi.org/10.1016/j.wdp.2017.12.001

[14] THACH, K.S.R., VO, H.T., & LEE, J.Y. (2021). Technical efficiency and output losses in shrimp farming: a case in Mekong Delta, Vietnam. *Fishes,* 6(4), 59. https://doi.org/10.3390/fishes6040059

[15] TO THE, N., & NGUYEN TUAN, A. (2019). Efficiency and adoption of organic tea production: Evidence from Vi Xuyen district, Ha Giang province, Vietnam. *Asia-Pacific Journal of Regional Science*, 3, 201–217. https://doi.org/10.1007/s41685-018-0092-2

[16] UMETSU, C. (2022). Sustainable farming techniques and farm size for rice smallholders in the Vietnamese Mekong Delta: A slack-based technical efficiency approach. *Agriculture, Ecosystems & Environment,* 326, 107775. https://doi.org/10.1016/j.agee.2021.107775

参考文:

[1] ALI, A., & JAN, A.U. (2017)。开伯尔-普什图省甘蔗作物技术效率分析：随机前沿方法。萨哈德农业杂志，33(1)，69–79。https://doi.org/10.17582/journal.sja/2017.33.1.69.79

[2] BATTESE, G.E., & COELLI, T.J. (1992)。前沿生产函数、技术效率和面板数据：应用于印度稻农。生产力分析杂志，3(1-2)，153-169。https://doi.org/10.1007/BF00158774

[3] BRUMMER, B.、GLAUBEN, T.、& LU, W. (2006)。中国农业的政策改革与生产力变化：距离函数方法。发展经济学杂志，81(1)，61-79。https://doi.org/10.1016/j.jdeveco.2005.04.009

[4] 国家统计局。（2000年）。越南统计年鉴。取自 https://www.gso.gov.vn/en/data-and-statistics/2020/02/statistical-yearbook-2000/

[5] 国家统计局。（2016年）。越南统计年鉴。取自 https://www.gso.gov.vn/en/data-and-statistics/2019/10/statistical-yearbook-of-vietnam-2016/

[6] 国家统计局。(2020)。越南统计年鉴。取自 https://www.gso.gov.vn/en/data-and-statistics/2021/07/statistical-yearbook-of-2020/

[7] HO, T., & SHIMADA, K. (2019)。越南湄公河三角洲水稻种植技术效率：随机前沿方法。立命馆经济评论，67(5-6)，130-144。摘自 https://www.researchgate.net/profile/Ho-Thanh-Tam/publication/331971603_Technical_Efficiency_of_Rice_Farming_in_the_Vietnamese_Mekong_Delta_A_Stochastic_Frontier_Approach/links/6010dd7892851c2d4df6d70d/Technical-Efficiency-of-Rice-Farming-in-the-Vietnamese-Mekong-Delta-A-Stochastic-Frontier-Approach.pdf

[8] KOMPAS, T., CHE, T.N., NGUYEN, H.T.M., & NGUYEN, H.Q. (2012).

生产力、净回报和效率：越南稻米生产的土地和市场改革。土地经济学，88(3)，478–495。https://doi.org/10.3368/le.88.3.478

[9] LAMPACH, N.、TO-THE, N. 和 NGUYEN-ANH, T. (2021)。越南北部山区技术效率和多种农业技术的采用。土地利用政策，103，105289。https://doi.org/10.1016/j.landusepol.2021.105289

[10] NGUYEN-VAN, P. 和 TO-THE, N. (2016)。技术效率和农业政策：来自越南茶叶生产的证据。农业、食品和环境研究评论，97(3)，173–184。https://doi.org/10.1007/s41130-016-0026-1

[11] NGUYEN, T.V.、SIMIONI, M.、LE QUYEN, C. 和 VALTYSSON, H.P. (2022)。越南远洋金枪鱼渔业的生产力、技术效率和技术变革。渔业研究，248，106202。https://doi.org/10.1016/j.fishres.2021.106202

[12] O'DONLELL, C.J. 和 COELLI, T.J. (2005)。一种对距离函数施加曲率的贝叶斯方法。计量经济学杂志，126(2)，493-523。https://doi.org/10.1016/j.jeconom.2004.05.011

[13] PEDROSO, R.、TRAN, D.H.、VIET, T.Q.、LE, A.V.、DANG, K.T. 和 LE, K.P. (2018)。越南中部武嘉秋盆河流域三角洲水稻生产的技术效率。世界发展展望，第9卷，第18-26页。https://doi.org/10.1016/j.wdp.2017.12.001

[14] THACH, K.S.R.、VO, H.T. 和 LEE, J.Y. (2021)。对虾养殖的技术效率和产量损失：以越南湄公河三角洲为例。鱼类，6(4)，59。https://doi.org/10.3390/fishes6040059

[15] TO THE，N.，& NGUYEN TUAN，A.（2019年）。有机茶生产的效率和采用：来自越南河江省毗川区的证据。亚太区域科学杂志，3，201-217。https://doi.org/10.1007/s41685-018-0092-2

[16]UMETSU，C.（2022年）。越南湄公河三角洲稻米小农的可持续农业技术和农场规模：基于松弛的技术效率方法。农业、生态系统与环境，326，107775。https://doi.org/10.1016/j.agee.2021.107775