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Technical Efficiency of Organic and Conventional Rice Farming in Central Vietnam: A Meta-frontier DEA Analysis

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This study evaluates the technical efficiency (TE) of organic and conventional rice farming systems in Thua Thien Hue Province, Vietnam, using Meta-frontier Data Envelopment Analysis (DEA). Based on data from 111 conventional and 74 organic rice farms, the results show that conventional farming operates closer to the meta-frontier. TE in conventional farms (88.8%-90.6%) slightly exceeds that of organic farms (87.0%–88.8%), indicating modest input-saving potential for both systems. A Bootstrapped truncated regression reveals that a higher number of plots enhances efficiency through risk diversification, while higher rice price and organic-related complexities negatively influence TE. These findings highlight the need for targeted interventions to improve resource use in organic farming, thereby balancing sustainability with productivity goals.

Keywords: Organic rice, conventional rice, DEA, technical efficiency, Thua Thien Hue.

INTRODUCTION

The growing demand for sustainable agricultural practices, driven by concerns over environmental degradation, food safety, and climate change, has positioned organic agriculture as a viable alternative to conventional farming systems (World Bank, 2022; Willer *et al.*, 2024). In rice production, organic farming offers the dual benefits of minimizing synthetic input use and promoting ecological balance and biodiversity conservation (Hokazono *et al.*, 2009; Komatsuzaki and Syuaib, 2010; Arunrat *et al.*, 2022). However, transitioning to organic farming is fraught with challenges, particularly in regions where conventional practices have long dominated. Vietnam, as one of the world's leading rice producers, exemplifies this struggle (World Bank, 2022; Dinh *et al.*, 2023). Efforts to promote organic rice farming have intensified in recent years (Willer *et al.*, 2024), including in Thua Thien Hue Province (Department of Agriculture and Rural Development, 2023), a region with a rich agricultural tradition and favorable climatic conditions. While not among Vietnam's primary rice-producing areas like the Mekong and Red River Deltas, Thua Thien Hue holds potential for advancing sustainable farming practices, particularly in organic rice production (People's Committee of Thua Thien Hue Province, 2022). Despite these efforts, adoption of organic farming in this province remains limited due to persistent concerns over productivity, technical efficiency, and market access (Department of Agriculture and Rural Development, 2023).

A critical factor influencing the adoption and viability of organic farming is technical efficiency (TE), which quantifies how effectively farmers utilize inputs to produce outputs. TE provides insights into the productivity trade-offs inherent in organic systems, particularly under resource constraints. Analytical approaches such as Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) have been widely used to assess TE in agriculture. Global and regional studies reveal that TE in organic rice farming varies significantly due to differences in experience, institutional support, and local context. In China, DEA-based analyses revealed that early adopters of organic farming initially exhibited high efficiency, but scores declined as farmers faced challenges in fully transitioning to organic methods. In contrast, later adopters showed improvement over the same period, reflecting the benefits of knowledge transfer and gradual adaptation (Chen *et al.*, 2012). In Indonesia, DEA analyses reported relatively high TE (88.4%) but still indicated potential for improvement (Wibowo *et al.*, 2019). In contrast, Northeast Thailand showed significantly low efficiency, with most farms operating below 40% (Panpluem

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et al., 2019). In Eastern Thailand, SFA analyses demonstrated that farmers affiliated with the Alternative Agriculture Network (AAN) achieved higher TE (0.733) compared to conventional organic farmers (0.688) and chemical rice farmers (0.669) (Kerdsriserm *et al.*, 2018). These studies across Asia highlight significant variability in TE. However, few have focused on Vietnam, where organic farming remains under-researched despite growing interest.

In Vietnam, research on rice farming has primarily focused on conventional production systems. Although the national agenda has increasingly promoted sustainable agriculture, systematic evaluation of TE in organic farming remains scarce. In Thua Thien Hue Province, recent efforts have sought to expand organic practices (People's Committee of Thua Thien Hue Province, 2022), yet empirical studies have largely emphasized contract farming (Nguyễn *et al.*, 2020b), economic efficiency analyses (Nguyễn *et al.*, 2020a; Châu *et al.*, 2024), and the roles of agricultural cooperatives (Nguyễn *et al.*, 2021). Little is known about how efficient inputs are being used in organic systems or what factors influence their performance. This gap limits the ability of policymakers and stakeholders to support efficient and scalable transitions to organic farming in the region.

This study addresses the identified gap by employing Meta-frontier Data Envelopment Analysis (DEA) to evaluate and compare the technical efficiency of organic and conventional rice farming systems in Thua Thien Hue Province. This approach allows comparison across heterogeneous technologies, making it particularly suited for contrasting farming systems with distinct input structures and technical environments. Specifically, the research seeks to assess TE levels, identify key factors influencing efficiency, and provide empirical evidence to support the strategic development of organic farming as a sustainable agricultural model. The findings aim to contribute to the growing discourse on sustainable agriculture, offering practical insights to enhance efficiency and foster the adoption of organic practices in Vietnam's rice sector.

MATERIALS AND METHODS

***Data collection*:** The research was conducted in Huong Thuy town, which has a large rice growing in Thua Thien Hue province. Thuy Phu commune was selected because the organic rice growing model has been implemented in this commune since 2016. 111 farmers applying conventional rice models and 74 organic rice farmers were interviewed face-to-face through questionnaires using simple random sampling. They contain detailed information on cultivation patterns, mainly focusing on production costs and income of rice production. Economic performance from two rice production models is calculated in the winter-spring crop 2023 (3 months from January to April - around 100 days).

Data Envelopment Analysis (DEA): Meta-frontier data envelopment analysis: To measure and assess variations in efficiency scores across organic and conventional rice groups in Vietnam, this study applies meta-frontier data envelopment analysis. Unlike traditional data envelopment analysis (DEA) introduced by Farrel (1957), the meta-frontier approach accounts for technological heterogeneity among farms. Conventional DEA assumes that all farms operate under a uniform technology set (Ton Nu Hai et al., 2020), which may not be valid for rice farming in Vietnam due to differences in production technologies.

Meta-frontier data envelopment analysis (meta-frontier DEA), as introduced by O'Donnell *et al.* (2008), provides a non-parametric framework for comparing efficiency across groups with varying technologies or production environments. This method is built based on the foundation of traditional DEA by constructing production frontiers that represent the most efficient input-output combinations observed within the data. For groups of farms with similar production conditions or sub-technologies, individual group frontiers are established, while the meta-frontier represents the overall boundary of unrestricted technological possibilities (O'Donnell *et al.*, 2008).

Consider a group of farms producing M outputs $y \in R_+^M$ using N inputs $x \in R_+^N$. The production set is defined as:

$$T = \{(xy) \in R_+^{N+M} | x \; can \; produce \; y\}$$

The DEA model under variable return to scale (VRS) is specified:

$$\min_{\theta,\lambda_j} \theta$$

$$\text{Subject to}$$

$$Y\lambda \geq y$$

$$\theta x_i \geq X\lambda$$

$$\sum_{i=1}^{N} \lambda_i = 1$$

$$\lambda_i \geq 0$$

While DEA model under constant return to scale (CRS) is as below:

$$\min_{\theta,\lambda_j} \theta$$

$$\text{Subject to}$$

$$Y\lambda \geq y$$

$$\theta x_i \geq X\lambda$$

$$\lambda_i \geq 0$$

Where, θ represents the technical efficiency (TE) score, which ranges between zero and one (0 ≤ θ ≤ 1). A farm achieves technical efficiency and lies on the frontier when θ equals one. The vector λ is an Nx1 matrix of weights (constants) that forms the linear combination of peer farms for the i-th farm. Y denotes the output quantities, while X represents the observed inputs. The vector –yi corresponds to the output of the i-th farm compared to the output vector of a theoretically efficient farm (Yλ). Xλ refers to the minimum input required by the theoretically efficient farm to produce the same output level as the i-th farm. Conversely, xi represents the actual input level of the i-th farm.

The difference between VRS-TE and CRS-TE is due to scale inefficiency. Scale efficiency is calculated by the ratio between technical efficiency under CRS and VRS.

When θ equals one, the farm is considered technically efficient because its input level matches the minimal input needed by the theoretically efficient farm to produce the same output. However, when θ is less than one, the farm is technically inefficient, indicating potential to further reduce its input usage to match Xλ while maintaining the same output level.

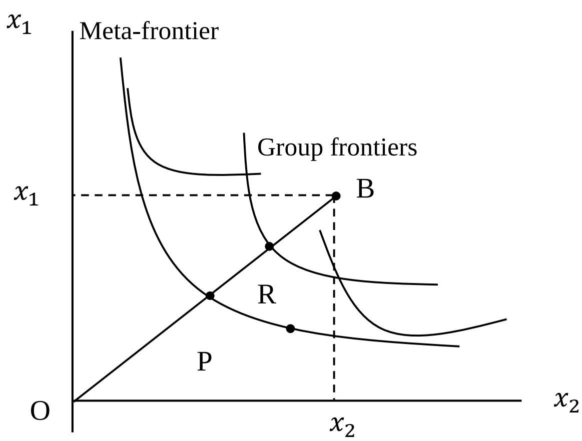

Figure 1. The group frontiers and meta-frontier in estimating technical efficiency.

Figure 1 illustrates the group frontiers and meta-frontier used to evaluate technical efficiency. In this illustration, farm R is technical-efficient under the group frontier but technical-inefficient under meta-frontier. The meta-frontier inefficiency is measured by the distance PR. This inefficiency is due to the difference in technology. Moreover, to address potential bias in efficiency estimates caused by the deterministic nature of non-parametric methods, this study employs meta-frontier data envelopment analysis combined with the smoothed bootstrap procedure, as introduced by Simar and Wilson (1998).

Determinants of technical efficiency: To examine the factors influencing efficiency, this study applied a bootstrapped truncated regression approach, as outlined by Simar and Wilson (2007). This method is essential because the DEA efficiency scores derived in the first stage are unobserved, influenced by all observations, and exhibit serial correlation (Simar & Wilson, 2007). Additionally, the environmental variables (Zi) in the second stage are correlated with the error term (ei) due to their association with xi and yi in the first stage (Simar & Wilson, 2007). The inverse of the bias-corrected efficiency scores was then regressed on a set of explanatory variables, expressed as follows:

The reciprocal of the meta-frontier efficiency scores is regressed on a set of explanatory variables as follows:

$$\overline{\overline{\delta_i}} = \alpha + Z_i\beta + \varepsilon_i, i = 1, \dots, n$$

Where $\overline{\overline{\delta_i}}$ represents the reciprocal of the meta-frontier technical efficiency scores. A negative coefficient for an independent variable indicates a positive influence on technical efficiency, while positive coefficient implies a negative impact. α denotes a constant term, β is a vector of parameters, Z_i represents a vector of specific variables and ε_i is the statistical noise, $\varepsilon_i \sim N(0, \sigma_\varepsilon^2)$ with left truncation at $1 - Z_i\beta$.

RESULTS AND DISCUSSION

***Inputs and outputs comparison between organic and conventional systems*:** The inputs, outputs, and price information per farm per production cycle, as summarized in Table 1, reveal significant differences between the two farming systems. First, in terms of outputs, conventional farms achieved an average yield of 2,457 kg per production cycle, with a wide range from 647 kg to 6,150 kg, indicating substantial variability in production levels. In contrast, organic farms produced a lower average yield of 1,141 kg per cycle, with outputs ranging from 443 kg to 2,542 kg. However, organic farms demonstrated greater consistency, as evidenced by a smaller standard deviation of 479 kg compared to 1,148 kg for conventional farms.

Next, regarding inputs, conventional farms exhibited higher input usage in certain areas. For instance, they used an average of 36 kg of seedlings per cycle, more than double the 16 kg used by organic farms. Conventional farms also applied 193 kg of fertilizer per cycle, whereas organic farms relied more heavily on natural fertilizers, averaging 269 kg per cycle. Labor usage showed a slight difference, with conventional farms requiring 21 man-days per cycle compared to 16 man-days in organic farms. Additionally, conventional farms operated on a larger scale, cultivating an average area of 7 sào (3,500 m²) per cycle compared to 4 sào (2,000 m²) in organic systems.

Finally, in terms of price information, the two systems displayed notable cost differences. Conventional farms incurred higher pesticide costs, averaging 106,000 VND per 500 m², compared to 55,000 VND in organic systems. Similarly, fertilizer costs were higher in conventional farms, averaging 18,000 VND/kg, while organic farms reported significantly lower costs of 10,000 VND/kg. These findings highlight the reduced reliance on chemical inputs in organic farming systems, reflecting their ecological orientation and cost-saving potential.

Table 1. Description of rice production and inputs used across farming systems and seasons in DEA (per farm per production cycle).

Variables	Conventional (n = 111)				Organic (n = 74)			
	Mean	Min	Max	SD	Mean	Min	Max	SD
Technical efficiency model								
Output								
Rice quantity (kg)	2,457	647	6150	1,148	1.141	443	2,542	479
Inputs								
Seedling (kg)	36	9	86	16.8	16	6	35	6.5
Labor (man-days)	21	6	53	9.8	16	6	33	7.0
Fertilizer (kg)	193	53	508	91.5	269	107	579	110.2
Area (500 m^2)	7	2	18	3.2	4	1	8	1.5
Price information for cost efficiency model								
Seedling (1000 VND/kg)	26	17	27	2.1	27	27	27	0
Labor (1000 VND/man-days)	150	150	150	0	150	150	150	0
Fertilizer (1000 VND/kg)	18	15	20	1.0	5	4	6	0.3
Pesticide cost (1000 VND/500 m^2)	106	53	561	46.6	55	40	76	7.6

***Technical efficiency comparison between farming systems*:** Table 2 provides a comparative analysis of technical efficiency (TE) across conventional and organic farming systems, evaluated using three measures: CRS_TE (Technical Efficiency under constant returns to scale), VRS_TE (Technical Efficiency under variable returns to scale), and SE (Scale Efficiency). The findings underscore key differences in efficiency levels and variability between the two systems, offering insights into their respective performance and areas for improvement.

Table 2. TE scores across farming systems and seasons.

TE scores	Conventional (n = 111)	Organic (n = 74)
CRS_TE: Mean (SD)	0.888 (0.034)	0.870 (0.50)
CRS_ TE min	0.822	0.740
CRS_TE max	0.966	0.974
VRS_TE: Mean (SD)	0.906 (0.031)	0.888 (0.50)
VRS_TE min	0.745	0.745
VRS_TE max	0.973	0.973
Scale Efficiency SE: Mean (SD)	0.980 (0.024)	0.980 (0.021)
SE min	0.914	0.923
SE max	1.000	1.00

* Note: CRS_TE (Technical Efficiency under constant return to scale), VRS_TE (Technical efficiency under variable return to scale), SE (Scale Efficiency) = CRS_TE/VRS_TE.

Under the CRS assumption, conventional farming achieves a mean TE score of 0.888 (SD = 0.034), suggesting that input usage could be reduced by approximately 11.2% without compromising output levels. In comparison, organic farming exhibits a mean CRS_TE of 0.870 (SD = 0.050), indicating that inputs could potentially be reduced by 13% to achieve optimal efficiency. These results highlight that while both systems operate below full technical efficiency, conventional farming demonstrates a slight advantage in achieving closer alignment to the production frontier. The narrower standard deviation for conventional farming reflects greater consistency across farms, whereas organic farming shows more variability (CRS_TE ranging from 0.740 to 0.974), likely influenced by differences in resource availability, management practices, and levels of expertise among farmers. For VRS_TE, conventional farming again outperforms organic farming, with mean scores of 0.906 (SD = 0.031) and 0.888 (SD = 0.050), respectively. This result indicates that conventional farms are more adaptable to variable operating conditions, such as fluctuations in input levels or environmental changes. Organic farming, while achieving slightly lower VRS_TE scores, demonstrates comparable efficiency with scores ranging from 0.745 to 0.973. The higher variability in organic farming efficiency suggests additional constraints, such as reliance on natural inputs (biological pest and weed control and natural fertilizers) and the complexities of organic certification, which may limit its ability to optimize resources under variable returns to scale. This TE level aligns closely with that reported by Mazhar *et al.* (2022) for export-oriented organic rice farmers in Pakistan, who achieved a TE score of 89.7%. Similarly, Nuraini *et al.* (2016) found a mean technical efficiency score of 0.89 among organic rice farmers in Indonesia.

These findings, which indicate slightly higher TE scores for conventional rice farmers across both CRS and VRS models, are partially consistent with existing literature. Ngo *et al.* (2025), who analyzed organic and conventional rice production in the Red River Delta, Vietnam using a meta-frontier DEA approach, found that conventional farms slightly outperformed organic ones in the autumn crop. However, higher TE scores among organic farmers were observed during the spring season, suggesting that seasonal factors may influence relative efficiency. A similar pattern emerges in the study by Kerdsriserm *et al.* (2018), where chemical rice farmers demonstrated slightly higher TE than conventional organic farmers - those not participating in any support network. In contrast, organic rice farmers affiliated with the Alternative Agriculture Network (AAN) achieved the highest TE scores among all groups. This reinforces the notion that institutional support, training, and organized input access play a critical role in enhancing the technical efficiency of organic farming systems.

Scale Efficiency (SE) scores are identical for both systems, with a mean value of 0.980. This indicates that most farms, regardless of farming system, operate close to their optimal scale. The minimal efficiency gap (approximately 2%) between observed SE scores and the theoretical maximum (1.0) suggests that adjustments to scale are unlikely to yield significant improvements. Similar findings were reported by Ngo et al. (2025), whose results showed that SE was also equal between the two systems across seasons and model specifications. The consistency of this result across two distinct agroecological regions implies that scale inefficiency is not a major concern in smallholder rice production, regardless of farming system. Instead, policy attention should be directed toward addressing technical inefficiencies, such as access to technology, training, or management capacity, especially among organic producers.

The disparities in TE scores between conventional and organic systems reflect differences in production technologies. Conventional farming operates closer to the meta-frontier, which represents the theoretical efficiency boundary achievable by the best-performing systems. This suggests that conventional farming technologies, characterized by established practices and extensive use of synthetic inputs, are more efficient in resource utilization. In contrast, organic farming systems, constrained by reliance on natural inputs and stricter compliance requirements, operate further from the meta-frontier, indicating greater inefficiencies.

Overall, the findings emphasize the importance of targeted interventions to address inefficiencies in organic farming. Policies aimed at providing technical training, improving resource accessibility, and standardizing organic practices could significantly enhance the efficiency of underperforming farms. At the same time, the environmental benefits of organic farming should be considered, highlighting the importance of balancing efficiency improvements with sustainability goals.

***Analysis of technical efficiency determinants*:** The descriptive statistics presented in Table 3 provide a comparative analysis of key variables influencing the efficiency of conventional and organic farming systems, including rice price, number of plots, service costs, and other costs. The findings reveal distinctions between the two systems in terms of variability and uniformity, reflecting the operational and market dynamics inherent to each farming method.

Rice price remains consistent across both systems, with a mean value of 8 for both conventional and organic farming. However, while the organic system exhibits no variation (SD = 0), the conventional system shows a slight variability (SD = 0.29) with prices ranging from 7 to 9. The absence of variability in the organic system's rice price can be attributed to fixed purchase prices agreed upon in advance through contractual arrangements between Que Lam Company and the Phu Bai Agricultural Cooperative. These contracts, signed before each production season, ensure price stability and effectively minimize the market fluctuations commonly observed in conventional farming systems.

The number of plots differs slightly between the systems. Conventional farms average 2.37 plots (SD = 1.07) with a range of 1 to 6, while organic farms average 2.58 plots (SD = 1.02) with a range of 1 to 5. The marginally higher number of plots in organic farming may reflect differences in land management practices between the systems.

Service costs for soil preparation and harvesting reveal critical differences. The mean cost for soil preparation services is similar in both systems (100.98 for conventional, 100.13 for organic), but variability differs significantly (SD = 9.86 in conventional versus SD = 0.80 in organic). Likewise, harvesting service costs in conventional farming exhibit a slight variation (mean = 115.98, SD = 1.85), whereas costs are uniform in organic farming (mean = 115, SD = 0). While the pricing for these services is consistent across both systems, the slight cost differences arise due to varying local conditions. Organic rice production areas benefit from favorable factors such as better road access and higher-quality

Table 3. Descriptive statistics for variables used in the bootstrapped truncated regression .

	Conventional				Organic			
	Mean	**Min**	**Max**	**SD**	**Mean**	**Min**	**Max**	**SD**
Rice price	8	7	9	0.29	8	8	8	0
Number of plots	2.37	1.00	6.00	1.07	2.58	1.00	5.00	1.02
Tillage machine	100.98	40.36	127.53	9.86	100.13	100.00	105.03	0.80
Harvesting machine	115.98	115.00	125.00	1.85	115.00	115.00	115.00	0.00
Organic	111				74			
Other costs	104.43	60.00	150.00	13.16	102.84	60.00	150.00	17.67

soil, which minimize additional surcharges. In contrast, conventional farming areas experience slightly more variability due to differing field conditions and less favorable logistics.

Lastly, other costs show variability across both systems, with organic farming exhibiting a higher standard deviation (17.67 compared to 13.16 in conventional farming), despite similar mean values (102.84 for organic and 104.43 for conventional). The greater variability in organic farming likely reflects a wider range of expenditures on specific inputs and services, including organic fertilizers, biological products, herbs, pest and weed control, packaging materials, and communication expenses. These costs are often influenced by factors such as geographic accessibility, individual farm requirements, and the stricter compliance standards associated with organic certification. In contrast, conventional farming benefits from more uniform and readily available inputs, resulting in greater cost standardization. This highlights the inherent complexity of organic farming systems, which must navigate additional logistical and regulatory challenges that contribute to cost variability.

These results underline the uniformity in organic farming practices, driven by stricter regulatory frameworks, and the variability in conventional farming, which reflects operational flexibility. Policymakers and practitioners should focus on optimizing cost structures in organic farming, particularly addressing variability in "other costs" through better resource accessibility and streamlined certification processes. Conversely, efforts in conventional farming could aim at standardizing practices to improve efficiency and minimize disparities.

Table 4 outlines the determinants of technical efficiency (TE) in rice farming under constant returns to scale (CRS) and variable returns to scale (VRS) models, using a truncated regression approach. The coefficients presented reflect the direction and magnitude of influence for each variable, with negative coefficients indicating a positive influence on TE and positive coefficients indicating a negative influence on TE.

Most existing literature focuses primarily on total land size when examining its relationship with technical efficiency. For example, Istiyanti *et al.* (2018) found that medium-sized landholdings (500–1000 m²) were positively associated with higher technical efficiency, while farms with less than 500 m² or more than 1000 m² tended to be less efficient in Indonesia. Similarly, Ngo *et al.* (2025) reported a positive relationship between farm size and TE. However, few studies have explicitly considered the role of land fragmentation (i.e., the number of plots per farm). Interestingly, this study finds that the number of plots is consistently and significantly associated with higher TE under both the CRS (-6.86e-03, significant at the 10% level) and VRS (-8.52e-03, significant at the 5% level) models. This contrasts with Chanmony Sok *et al.* (2023), who found that land fragmentation reduced productivity among organic rice farmers in Cambodia. While land fragmentation is often perceived as a barrier to efficiency, in the context of Thua Thien Hue province, it may facilitate more attentive and adaptive management across diverse micro-environments, benefiting both organic and conventional farming systems. For organic farmers in particular, where the model remains relatively new and is typically applied on a small scale, land fragmentation may represent an adaptive strategy rather than a constraint. It allows for production risk diversification and enables farmers to optimize input use and tailor farming practices to the specific conditions of each plot. These adaptations help sustain efficiency without relying on synthetic inputs.

Rice price demonstrates a positive coefficient under both CRS (3.76e-02, significant at the 5% level) and VRS (3.42e-02, significant at the 10% level), suggesting a negative relationship with TE in both models. This finding indicates that higher rice prices may impose additional challenges on farmers, such as meeting market expectations for quality, which can complicate efficient resource allocation and operational decision-making. Moreover, premium pricing often correlates with higher input costs, particularly in organic systems, where farmers may need to invest in certified organic fertilizers, pest control measures, quality assurance processes and compliance with organic standards. These added costs create financial pressure and operational complexities, which can negatively affect efficiency. This underscores the dual challenge of achieving both high market value and optimal resource utilization in organic farming systems.

Table 4. Determinants of technical efficiency with α = 10% .

	CRS		VRS	
	Coefficient	**Confident interval**	**Coefficient**	**Confident interval**
Intercept	9.07e-01**	(2.26e-01 1.55021)	7.27e-01*	(0.09858 1.36095)
Rice price	3.76e-02**	(8.08e-03 0.06731)	3.42e-02*	(0.00257 0.06383)
Number of plots	-6.86e-03*	(-1.30e-02 -0.00056)	-8.52e-03**	(-0.01530 -0.00164)
Tillage machine	1.05e-03	(-8.32e-05 0.00196)	1.11e-03	(-0.00024 0.00215)
Harvesting machine	-1.41e-03	(-6.23e-03 0.00405)	3.47e-06	(-0.00503 0.00528)
Organic	2.78e-02***	(1.09e-02 0.04402)	3.20e-02***	(0.01471 0.04942)
Other costs	-8.72e-06	(-4.44e-04 0.00045)	6.88e-05	(-0.00039 0.00053)

*, **, *** indicate 10%, 5% and 1%

The organic farming system variable shows a strong positive and statistically significant coefficient under both CRS (2.78e-02, significant at the 1% level) and VRS (3.20e-02, significant at the 1% level), implying a negative impact on TE. The challenges of organic farming, including higher labor requirements, reliance on natural inputs, and the complexities of organic certification, likely contribute to reduced efficiency. The consistency of this finding across both models highlights the need for targeted interventions, such as technical training, subsidized inputs, and improved support systems, to help farmers overcome the constraints of organic production and achieve greater efficiency.

These results emphasize the critical role of structural and market-related factors in shaping technical efficiency in rice farming systems. While variables such as the number of plots enhance efficiency through risk diversification and production stability, others, such as rice price and organic practices, present significant challenges. Policymakers must address these issues by promoting interventions that stabilize market conditions, reduce financial burdens, and provide technical support. By doing so, farmers can better optimize resource use and enhance the long-term sustainability of their farming practices.

***Conclusion*:** This study provides a comprehensive analysis of the technical efficiency (TE) of organic and conventional rice farming systems in Thua Thien Hue Province, Vietnam, using Data Envelopment Analysis (DEA) and bootstrapped truncated regression. The findings reveal notable differences in productivity, input use, and efficiency between the two farming systems. Conventional farming systems demonstrate higher average productivity and efficiency under constant returns to scale (CRS), reflecting economies of scale and established practices. However, they exhibit greater variability in performance, indicating potential inefficiencies in resource allocation among farms. Conversely, organic farming systems, despite lower overall productivity, show greater consistency in output and efficiency under variable returns to scale (VRS). This highlights the ecological and regulatory strengths of organic farming but also underscores challenges related to fragmented landholdings and variable input costs. Key determinants of technical efficiency include rice price, land fragmentation, and farming practices, with organic farming emerging as a significant driver of efficiency and a promising model for sustainable agricultural development.

To address persistent challenges and improve technical efficiency in both systems, targeted interventions are essential. Consolidating fragmented landholdings could enable economies of scale and streamline resource allocation, while improving market structures, particularly for organic rice, through stable pricing mechanisms and expanded distribution networks, would incentivize farmers to adopt sustainable practices. Capacity-building programs focusing on modern farming techniques, efficient input use, and organic certification processes could bridge efficiency gaps and enhance overall farm performance. Furthermore, subsidizing organic inputs, such as fertilizers and pest control products, could alleviate financial burdens on organic farmers, and strengthening cooperatives to provide centralized services like irrigation and soil preparation could reduce operational inefficiencies. Finally, investing in research and innovation tailored to local farming conditions could advance productivity and sustainability across both organic and conventional systems. Overall, this study highlights the trade-offs between sustainability and productivity in rice production, providing valuable insights for policymakers and practitioners. Implementing these recommendations can pave the way for a more sustainable and resilient agricultural sector in Vietnam.

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***Availability of data*:** The dataset is not publicly available due to ongoing PhD research.

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***Policy referred*:** This study refers to Vietnam's National Organic Agriculture Policy.

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