Southeast Asian Journal of Economics Vol.13(1), April 2025: 200-234
Received: January 9, 2024
Revision: February 26, 2023
Accepted: June 19, 2024

Productivity Dynamics and Determinants in Agricultural Enterprises: Implications for Technology-Oriented Development in the Mekong Delta

Nguyen Thuy Trang
Department of Rural Socio-Economics, College of Rural Development, Can Tho University, Vietnam.
Vo Hong Tu
Department of Rural Socio-Economics, College of Rural Development, Can Tho University, Vietnam.
Corresponding author: vhtu@ctu.edu.vn
Tran Van Khoa
College of Rural Development, Can Tho University, Vietnam.

Abstract

Agricultural enterprises are vital for rural socio-economic development yet face productivity and technology adoption challenges amid global economic integration. This study examines total factor productivity dynamics, technical efficiency, and technological progress for 87 agricultural enterprises from 2016 to 2021. Utilizing firm-level data from the Annual Survey on Enterprises, data envelopment analysis reveals a 6.5% increase in average technical efficiency but a concerning 12.7% annual decline in technological change. Mean total factor productivity also drops by 7.1% annually, indicating significant obstacles to overall productivity growth. The random effect regression results suggest that agricultural cooperatives experience slower technological advancements. Furthermore, being situated near a port and engaging in export activities help enterprises improve productivity. Investments in research and development positively impact total factor productivity changes, suggesting a crucial avenue for enhancing agricultural enterprise performance amidst evolving economic landscapes.

Keywords: agricultural enterprise, technical efficiency, technological change, total factor productivity.

1. Introduction

The Mekong Delta significantly contributes to Vietnam's agricultural production (Tu et al., 2018; GSO, 2023), yet there remains a gap in knowledge regarding the factors that enable its enterprises to thrive and succeed economically. While past endeavors have mainly focused on boosting production, less emphasis has been placed on economic and business aspects (Trinh & Lee, 2023). This paper seeks to address this oversight by delving into the efficiency and productivity dynamics of agricultural enterprises (AEs) operating in the Mekong Delta.

AEs are crucial for Vietnam and the Mekong Delta's economic growth and poverty reduction, but they face challenges like resource constraints and technological backwardness (Cuong et al., 2007; Thanh et al., 2011; World Bank, 2016). Despite favorable conditions, their development has been slow. By understanding factors influencing efficiency and productivity changes, policymakers can devise targeted interventions to bolster the development of AEs.

Amidst international integration and the fourth industrial revolution, the adoption of new technology plays a pivotal role in the overall development of enterprises, including those in the agricultural sector. It significantly contributes to enhancing competitive advantages at both the enterprise and national levels (Asiedu et al., 2023). However, the uptake of technology in agricultural enterprises has been relatively low (Gallardo & Sauer, 2018; Tu et al., 2018; Tran et al., 2020). Vietnamese agricultural firms' technology was reported to be out-updated and lagging behind the global average (Nhut, 2018; Giang et al., 2019). Thus, investigating the technological change of AEs is crucial for policymakers, particularly in Vietnam in general and the Mekong Delta in particular.

This study contributes to the literature by examining the technical efficiency, technological change, and total factor productivity (TFP) of AEs in the Mekong Delta. The current study employed Malmquist Total Factor Productivity (hereafter referred to as Malmquist TFP or MTFP) analysis to assess productivity changes over time, shedding light on the performance of individual enterprises and the sector as a whole (Felipe, 1999; Coelli & Rao, 2005). The growth rate of Malmquist TFP serves as a vital tool for assessing sustainable development, resource use efficiency, and technological progress (Coelli et al., 2005; Coomes et al., 2019; Song et al., 2022).

In Vietnam and the Mekong Delta, several studies have been conducted regarding TFP for enterprises. Duong et al. (2013) explored the factors influencing TFP in six industries in Ho Chi Minh City. Giang et al. (2019) analyzed total factor productivity and its determining factors among 420 AEs during the period 2000–2009. This study employed the production function to capture the total factor productivity and did not consider the technological, technical changes or TFP changes. Luong and Danh (2020) employed the Malmquist TFP to assess the total factor productivity growth in the agricultural sector of the Mekong Delta region from 1990 to 2015. Unlike these previous studies focusing on aggregate data or specific sectors, this current study analyzes firm-level data, providing insights into the nuances of AEs' performance. By identifying factors affecting efficiency and productivity, our findings offer policymakers actionable insights to foster sustainable agricultural development in the Mekong Delta. Furthermore, our study fills a gap in the literature by providing a comprehensive analysis of technological changes and efficiency dynamics specific to agricultural enterprises in the region.

2. Literature Review

The rapid growth of the global population presents a significant challenge for the agricultural sector, as the demand for food is expected to increase in the coming decades (Cohen, 2006; Christoplos, 2014). However, increasing production solely by increasing inputs, e.g., capital and labor, is not a sustainable solution due to various constraints faced by both developed and developing countries. Factors such as scarcity of agricultural land, labor force limitations in developed countries, capital shortage in developing countries, and environmental requirements imposed by agricultural policies further emphasize the importance of productivity change, technology-based development, and resource use efficiency in the agricultural sector (Baráth et al., 2020; Han & Lee, 2020; Liu et al., 2021). Resource use efficiency refers to the effectiveness with which available resources are utilized to produce outputs. It is a measure of how well inputs such as labor, capital, and materials are employed to generate desirable outputs. Efficient resource use implies maximizing output with the given inputs or minimizing inputs for a given level of output, ultimately leading to improved productivity.

Malmquist TFP measures offer a comprehensive approach that overcomes the limitations of partial indicators such as land, labor, and capital productivity. Malmquist TFP takes into account the ratio of output to aggregate and weighted inputs, making it more suitable for comparisons across entities and over time (Coelli, 1996; Coelli & Rao, 2005; Coelli et al., 2005). The concept of Malmquist TFP and its estimation methods have been widely discussed in the literature, leading to a growing popularity in measuring TFP and exploring its drivers (Coelli, 1996; Coelli & Rao, 2005).

Over the years, numerous studies have utilized data envelopment analysis (DEA) to estimate the common production frontier and examine variations in agricultural productivity across different regions. Coelli and Rao (2005) employed the DEA model to analyze agricultural productivity differences among 93 countries, categorizing them into four distinct groups. Notably, their findings highlighted America as the region with the highest technical efficiency, while Africa demonstrated the lowest. In contrast, Asia emerged as a leading player in agricultural production technology. Krishnasamy and Ahmed (2009) adopted a similar approach to analyze productivity growth and assess the gap between 26 OECD countries. At a micro-data level, Breustedt et al. (2011) scrutinized the technical efficiency and technology gap of 1,239 traditional farms and 102 organic farms in Bavaria, Germany. In general, these studies suggested that the TFP plays an important role in the sustainable development of economies. Other previous studies considered resource use efficiency for the agricultural sector and farmers (Umetsu et al., 2003; Parry & Hawkesford, 2010; Tu, 2017). Studies relating to technological, TFP changes, resource use efficiency, and its determinants at the firm level, particularly AEs, are quite limited, especially in developing countries like Vietnam.

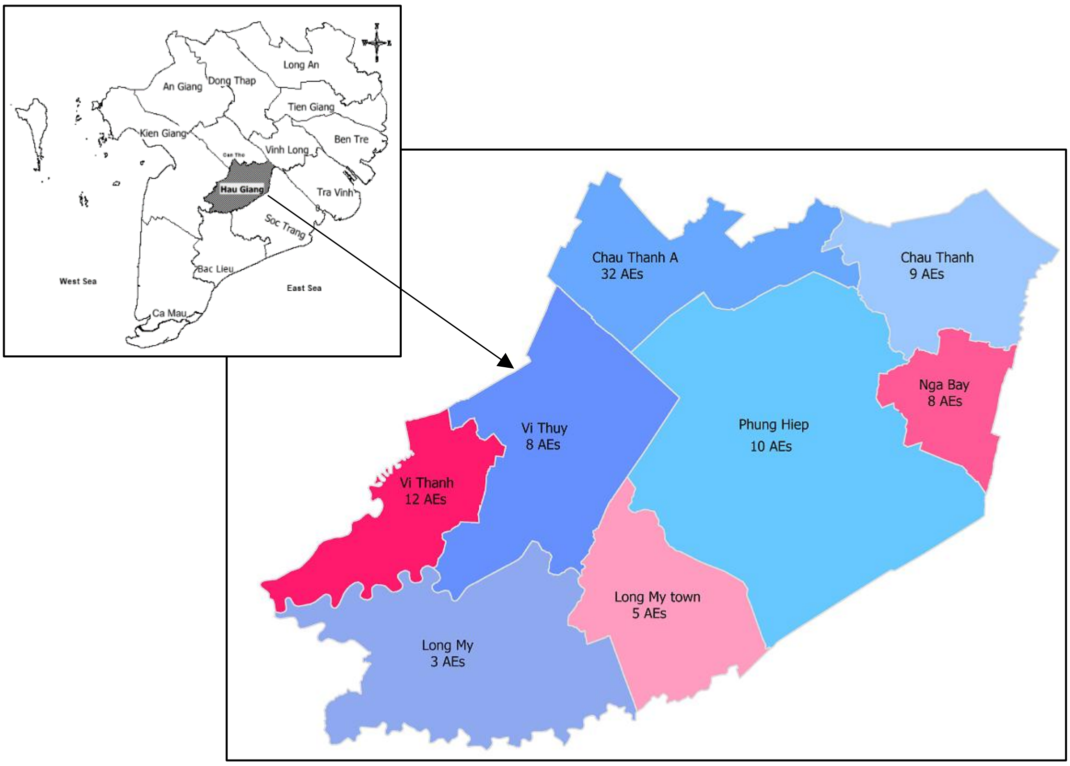
3. Methodology

3.1 Study Sites

Hau Giang is a province known for its agricultural focus, with more than 70% of the population residing in rural areas and depending mainly on agriculture for their livelihoods. This province is considered the newest province in the Mekong Delta and was separated from Can Tho City in 2004.

Therefore, promoting the development of agricultural businesses in the area plays a crucial role in the overall development of the Mekong Delta region. Another notable feature of the province is its agricultural nature combined with a port system catering to agricultural product exports, which has attracted many large processing businesses, such as Minh Phu Corporation and Cafatex. In addition, the province has been actively promoting entrepreneurship and rural economic development through initiatives like the establishment of new rural areas and the One Village One Product (OCOP) program. As a result, the province has experienced a notable increase in enterprises, from 1,701 in 2017 to 2,425 in 2020, including approximately 300 AEs (Hau Giang Statistical Office, HGSO, 2022). Thus, this current study considers the case of Hau Giang AEs to investigate resource use efficiency and its determinants. The map of the Vietnamese Mekong Delta and the study site is illustrated below.

Figure 1. Map of the Mekong Delta and sample size by study sites in Hau Giang province



3.2 Data Collection

To analyze the resource use efficiency or technical efficiency and technological and total factor productivity changes and its determinants, we utilized firm-level data from the Annual Survey on Enterprises conducted by the Hau Giang Statistical Office. The survey covered approximately 200–250 AEs for each year within the period 2016–2021. During the analysis, we encountered several challenges. Some firms were not consistently available for every year. Additionally, there were cases of firms changing their main business activities, which were not covered by the survey. To address these issues, we cleaned the data by constructing a balanced panel dataset of 87 agricultural firms. Each firm in the survey was assigned a unique special tax code that remained unchanged over the years, enabling the creation of a panel dataset for individual firms. Moreover, the survey provided industry codes based on the Vietnamese Standard Industrial Classification 1993 (VSIC 1993), which allowed us to filter firms operating in the agricultural sector. The dataset from this survey included information on enterprise type, ownership status, employees, assets and liabilities, sales, capital stock, and government obligations.

3.3 Data Analysis

The Malmquist TFP measure is employed in economic analysis to evaluate changes in the efficiency and technological progress of a firm over time. This index can be broken down into two primary components: technical efficiency change and technological change. The present study adopted the Malmquist TFP index as proposed by Färe et al. (1994), and the estimation was conducted using DEAP software.

Assumed that for each period $t = 1, ..., T$, there exists a production technology d_t that represents all possible combinations of outputs y_t that can be produced using input x_t. In this study, total revenue represents the output of AEs, while labor and capital are considered as the two inputs. These variables are fundamental in productivity measurement studies. Furthermore, the surveyed AEs encompass agricultural cooperatives with profit-sharing mechanisms that differ significantly from other types of AEs, as they are obligated to establish funds (such as financial risk reserve fund and development investment fund) as per regulations. Therefore, in the study, revenue is utilized instead of profit to represent the output variable. Färe et al. (1994) provided the following formula for calculating the Malmquist TFP index:

$$MTFP_0(y_{t+1}, x_{t+1}, y_t, x_t) = \left[\frac{d_0^t(x_{t+1}, y_{t+1})}{d_0^t(x_t, y_t)} \times \frac{d_0^{t+1}(x_{t+1}, y_{t+1})}{d_0^{t+1}(x_t, y_t)}\right]^{1/2} \quad (1)$$

The Malmquist TFP index represents the change in productivity from one period to another. It compares the production point (x_{t+1}, y_{t+1}) with the previous production point (x_t, y_t). An MTFP value greater than 1 indicates an improvement in TFP from period t to t+1. The formula demonstrates that the MTFP is calculated as the average of the two productivity indices corresponding to the technology levels of period t and period t+1, respectively.

Based on Equation (1), the calculation of the MTFP index requires determining the efficiency index for four component distance functions $d_0^t(x_t, y_t)$, $d_0^t(x_{t+1}, y_{t+1})$, $d_0^{t+1}(x_{t+1}, y_{t+1})$, and $d_0^{t+1}(x_t, y_t)$. To obtain the MTFP value, it is necessary to assume constant returns to scale (CRS). Moreover, input-oriented estimation appears to be more suitable for AEs due to market fluctuations, rendering AEs incapable of accurately determining market prices. Consequently, AEs have greater control over reducing inputs, making input-oriented estimation more appropriate in this context.

$$[d_0^t(x_t, y_t)]^{-1} = max_{\phi,\lambda}\, \phi, \tag{2}$$

$$\text{St } -\phi y_{it} + Y_t\lambda \geq 0,$$

$$x_{it} - X_t\lambda \geq 0\ ,$$

$$\lambda \geq 0$$

$$[d_0^{t+1}(x_{t+1}, y_{t+1})]^{-1} = max_{\phi,\lambda}\, \phi, \tag{3}$$

$$\text{St } -\phi y_{i,t+1} + Y_{t+1}\lambda \geq 0,$$

$$x_{i,t+1} - X_{t+1}\lambda \geq 0,$$

$$\lambda \geq 0$$

Similarly, we calculate the index for the distance function $d_0^t(x_{t+1}, y_{t+1})$ and $d_0^{t+1}(x_t, y_t)$ as follows:

$$[d_0^t(x_{t+1}, y_{t+1})]^{-1} = max_{\phi,\lambda}\, \phi, \tag{4}$$

$$\text{St } -\phi y_{i,t+1} + Y_t\lambda \geq 0,$$

$$x_{i,t+1} - X_t\lambda \geq 0,$$

$$\lambda \geq 0$$

$$[d_0^{t+1}(x_t, y_t)]^{-1} = max_{\phi,\lambda}\, \phi, \tag{5}$$

$$\text{St } -\phi y_{it} + Y_{t+1}\lambda \geq 0,$$

$$x_{it} - X_{t+1}\lambda \geq 0,$$

$$\lambda \geq 0$$

Therefore, once the distance efficiency index and MTFP are calculated, we can proceed to calculate the technological change (TC) index and the technical efficiency change (TEC) index using the following Equations (6) and (7) as presented by Coelli (1996) and Luong and Danh (2020).

$$TC = \left[\frac{d_0^t(x_{t+1}, y_{t+1})}{d_0^{t+1}(x_{t+1}, y_{t+1})} \times \frac{d_0^t(x_t, y_t)}{d_0^{t+1}(x_t, y_t)}\right]^{1/2} \tag{6}$$

$$TEC = \frac{d_0^{t+1}(x_{t+1}, y_{t+1})}{d_0^t(x_t, y_t)} \tag{7}$$

Note that If the MTFP index is greater than 1, it indicates improvement in productivity, reflecting advancements in technology or efficiency gains (better resource use efficiency). Conversely, an index less than 1 suggests a decline in productivity.

Within this scope of study, the main emphasis lies in comprehending the correlation between MTFP, TEC, and TC, and time-varying factors like R&D. There are no compelling reasons to account for individual-specific effects. Furthermore, random effects regression is suitable when unobservable time-invariant characteristics influence productivity changes. Thus, to explore the factors driving fluctuations in MTFP, TEC, and TC, the study opted for random effects regression on panel data. As outlined, the study's dataset extended from 2016 to 2021, encompassing a six-year period. However, due to efficiency changes being assessed against the base year, the data on MTFP, TEC, and TC changes spanned five years, totaling 435 observations (87 x 5). The random effects regression model is depicted in formula (8) below:

$$Y_{it} = \alpha_0 + \alpha_{1t}X_{1t} + \alpha_{2t}X_{2t} + \cdots + \alpha_{kt}X_{kt} + \eta_i + \varepsilon_{it} \tag{8}$$

where Y_{it} is the dependent variables, representing for TFP change, TC, and TEC of each AE in year *t;* X_{it} is independent variables (*i*=1…k), representing for firm characteristics in year *t*; α_{it} is the parameters to be estimated; η_i is the fixed effect for AE *i,* indicating the time-invariant unobserved heterogeneity that varies across AEs, and in the random effect model, η_i is uncorrelated with the explanatory variables, enabling the inclusion of time-invariant variables such as an individual's gender or education level; and ε_{it} is the error term, which includes all other unobserved factors that affect productivity changes but are not accounted for by the independent variables or the fixed effects.

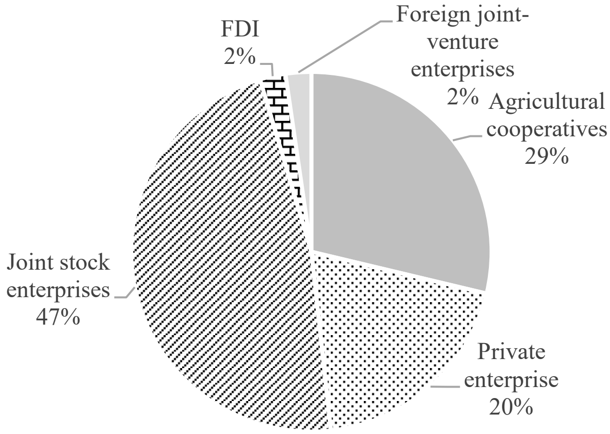
4. Results and Discussion

4.1 Characteristics of Agricultural Enterprises

The survey results provide valuable insights into the types of AEs in the province. The data reveals that AEs engage in five main types of operations, i.e., joint stock companies, private enterprises, cooperatives, FDI enterprises, and foreign joint-venture enterprises (Figure 1). Among the surveyed AEs, the largest proportion, accounting for 47% of the total sample, consists of joint stock companies. The second most common type of enterprise is agricultural cooperatives, which make up 29% of the surveyed AEs, equivalent to 25 enterprises. Agricultural cooperatives are characterized by a group of farmers pooling their resources and efforts to achieve common goals.

The survey also reveals that FDI enterprises and foreign joint-venture enterprises make up a smaller proportion of AEs in the province, each accounting for 2% of the sample. This translates to two enterprises each.

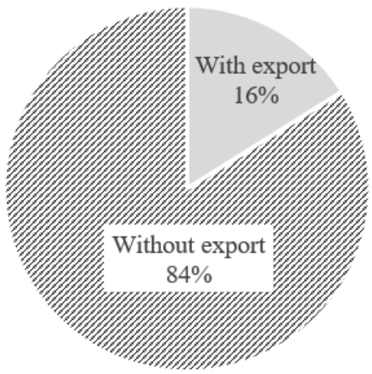
Figure 1. Types of agricultural enterprises in Hau Giang province



Source: Enterprise survey data in Hau Giang province, n=87

Export activities have emerged as a popular and significant aspect of enterprise performance, aligning with the prevailing economic trends, especially in the agricultural sector (Figure 2).

Figure 2. Percentage of agricultural enterprises engaged in exporting



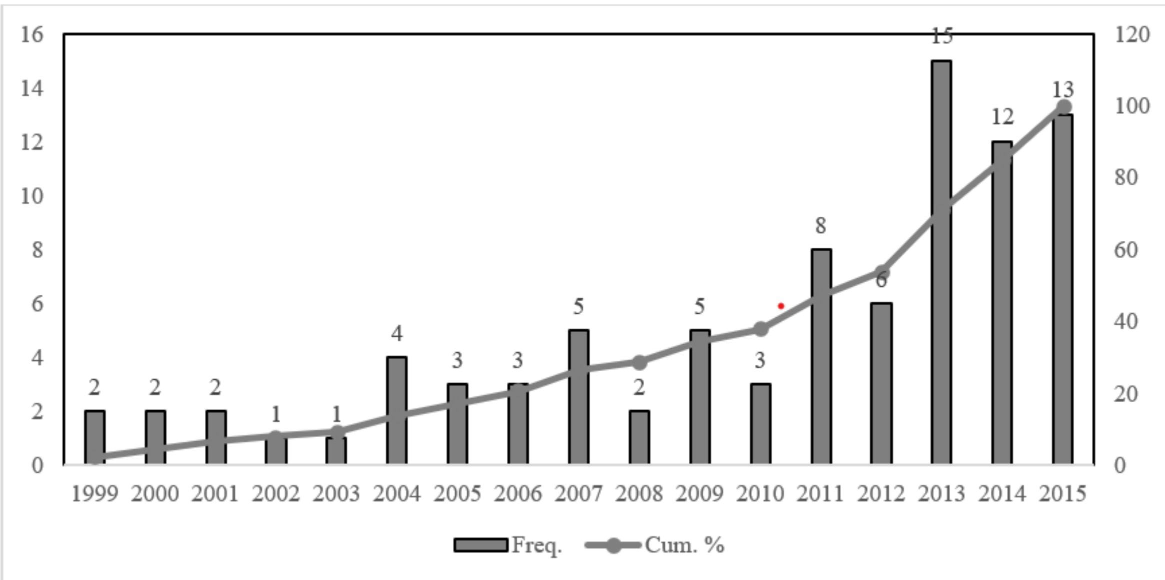
Source: Enterprise survey data in Hau Giang province, n=87

According to the data, 16% of the surveyed enterprises have an established export market, while the majority of enterprises do not engage in exporting their goods.

These exporting businesses are primarily located in the two districts of Chau Thanh and Chau Thanh A, which share administrative boundaries with or located near the port.

Figure 3 provides valuable insights into the establishment profiles of the AEs surveyed. The data indicates that out of the 87 AEs surveyed, their year of establishment ranged from 1999 to 2015. The number of enterprises established varied across different years, with the highest number established in 2013, totaling 15 enterprises, while the lowest numbers were recorded in 2002 and 2003, with only one enterprise established in each year. The cumulative rate of established enterprises demonstrates a gradual increase over the years from 1999 to 2015. The presence of supportive policies plays a crucial role in encouraging investment and fostering the growth of AEs. Governments often implement measures to promote the agricultural sector, such as providing financial incentives, tax breaks, streamlined regulations, and infrastructure development. These policies create an enabling environment that attracts businesses and facilitates their establishment and growth within the agricultural sector.

Figure 3: Year of establishment of agricultural enterprises in Hau Giang province



Source: Enterprise survey data in Hau Giang province, n=87

The age of the legal representative of the enterprise is considered a factor that can affect the performance of the enterprise. The results in Table 1 show that the average age of legal representatives is approximately 54 years, with the youngest representative being 36 years old and the oldest reaching 73. By embracing both youth and experience, enterprises can tap into the advantages offered by different age groups. Younger legal representatives can infuse energy, innovation, and technological acumen into the enterprise, while older legal representatives can provide mentorship, industry expertise, and valuable relationships (Cheung & Chow, 2006; Harniati & Anwarudin, 2018).

Table 1. Age of the legal representative of the agricultural enterprise

Age group	**Frequency**	**Ratio**	**Accumulative**
From 36-50	38	43.68	43.68
From 51-60	21	24.14	67.82
> 60	28	32.18	100.00
Medium		54.28	
Max		73	
Min		36	

Source: Enterprise survey data in Hau Giang province, n=87

4.2 Performance of Agricultural Enterprises

In this study, we consider the total revenue of AEs as the output variable, along with labor and capital as the input variables. Our analysis focuses on these three variables. Subsequently, we employ the MTFP approach to estimate technological change, efficiency, and TFP changes.

Bartlett's test results show that the value $\chi^2(7)$= 1.76, which is much smaller than the critical value, so we prove that there is no difference or variation in labor over the years.

Table 2 provides insights into the average number of employees in the surveyed enterprises over the years. While there are some fluctuations in the data, the average number of employees has not changed significantly. However, it is important to note that the standard deviation is considerably high compared to the average, indicating a large dispersion in the annual labor size among the enterprises. This indicates that there is a substantial difference in the number of employees between individual enterprises each year. The data shows that in 2016 and 2017, the number of employees remained relatively stable. In 2018, there was a slight decrease in the number of employees, but it increased again in 2019. However, from 2020 onward, there is a decreasing trend in the average number of employees. These fluctuations could be attributed to various factors, such as changes in market conditions, economic fluctuations, or industry-specific dynamics.

Table 2. Labor force of agricultural enterprises in the period 2016–2021

Year	Mean	SD	Min	Max
2016	119.46[a]	654.46	2	5.973
2017	119.46[a]	654.46	2	5.973
2018	109.96[a]	596.52	3	5.462
2019	117.18[a]	635.47	2	5,788
2020	106.94[a]	598.78	2	5,500
2021	106.94[a]	598.78	2	5,500
Bartlett's test		$\chi^2(7) = 1.76$		

Source: Enterprise survey data in Hau Giang province, n=522

Note: The letter [a] in the same column indicates no significant difference at $\alpha = 5\%$

Now we turn to consider the capital of AEs, where Bartlett's test results show that the value $\chi^2(7)$= 18.58, which is greater than the critical value, so we do not prove that there is a difference or fluctuation in the capital of the enterprise over the years.

Table 3. Capital movements of agricultural enterprises in the period 2016–2021

Unit: Million VND

Year	Medium	SD	Min	Max
2016	101,364.30	473,589.90	64	3,735,063
2017	115.787.60	509,425.70	64	3,366,806
2018	114.403.30	508,445.40	64	3,768,361
2019	88,167.33	378,318.30	93	3,006,573
2020	87,495.04	382,584.10	0	3,085,857
2021	87,499.56	382,583.10	0	3,085,857
Bartlett's test		$\chi^2(7) = 18.58$		

Source: Enterprise survey data in Hau Giang province, n=522
Note: The letter [a] in the same rows indicates no significant difference at $\alpha = 5\%$

The survey data presented in Table 3 highlights the fluctuations in the average capital of enterprises over the years. Specifically, there was an increase in the average capital source in 2017 compared to 2016. However, from 2018 to 2021, a downward trend was observed. The fluctuations in average capital can be influenced by various factors, including economic conditions (COVID-19), market dynamics, and the specific circumstances of the surveyed enterprises.

Table 3 also demonstrates the considerable differences between enterprises with the highest and lowest capital over the years. For instance, enterprises with the highest capital had an impressive capital of 3,085,857 million dong, while enterprises with the lowest capital in 2020 and 2021 had no capital (which may be attributed to the dissolution of the enterprise).

In conclusion, Table 3 reveals fluctuations in the average capital of enterprises over the years, with a general downward trend from 2016 to 2021. The data also highlights the significant differences between enterprises with the highest and lowest capital. These findings underscore the financial challenges faced by enterprises, including the lack of capital and the instability of capital sources. Addressing these challenges requires comprehensive strategies and supportive measures to foster financial stability, facilitate access to capital, and promote sustainable growth for enterprises.

Now, we proceed to estimate the financial performance, specifically focusing on the output variable revenue used for the MTFP calculation for AEs in the study sites from 2016 to 2021.

Table 4. Performance of AEs during the period 2016–2021

Unit: Billion VND

Year	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**Growth (%)**
Revenue	165.525 (820.55)	158.53 (714.52)	170.73 (1.053.48)	176.22 (1.134.61)	157.21 (951.71)	157.23 (949.88)	-0.85
Cost	159.65 (806.79)	148.30 (680.78)	161.50 (991.17)	161.68 (1.047.85)	146.71 (906.80)	144.79 (904.80)	-1.62
Profit	5.86 (24.01)	10.22 (37.79)	1.59 (35.09)	5.27 (39.77)	2.25 (12.85)	2.20 (12.85)	-15.06
No. of AEs with negative profit	3	1	16	17	19	19	-
Profit/Cost	0.04	0.07	0.01	0.03	0.02	0.02	-
Profit/Revenue	0.04	0.06	0.01	0.03	0.01	0.01	-
Revenue/Cost	1.04	1.07	1.06	1.09	1.07	1.09	-

Note: The figures in (.) represents the standard deviation

Table 4 illustrates fluctuations in enterprises' average revenue over the years. Starting at 165.525 billion VND in 2016, it dropped to 158.53 billion VND in 2017, then peaked at 170.73 trillion VND in 2018 and 2019. However, a decline followed in 2020 and 2021, with revenue falling to 157.21 trillion VND. Overall, from 2016 to 2021, there was a decreasing trend in enterprise revenue, averaging a 0.85% decline annually. Moreover, the standard deviation values were significantly higher than the average annual revenue, indicating substantial revenue dispersion among enterprises. As for average profits, they varied inconsistently over the years. Overall, average profits experienced a downward trend from 2016 to 2021, with an average annual decrease rate of approximately 15.06%.

The study also reveals that profitability ratios, including revenue on cost, profit on revenue, and revenue on cost, are notably low, indicating suboptimal efficiency in enterprise production and operations. Despite extensive agricultural development support policies in the province between 2016 and 2021, such as initiatives for agricultural restructuring and cooperative development, alongside favorable conditions for agricultural sector growth, enterprises encounter significant challenges. These challenges include a competitive business landscape, obstacles in accessing capital from financial institutions and governmental bodies, adverse natural conditions, and heightened business risks for agricultural goods. Particularly impactful was the COVID-19 pandemic in 2020 and 2021, which significantly disrupted AEs' operations, leading to revenue declines, profit reductions, and a surge in loss-making enterprises. This trend peaked during these two years, with up to 19 enterprises reporting negative profits annually.

4.3 Measurement of Resource Use Efficiency and Malmquist TFP

Utilizing the data summarized in Tables 2, 3, and 4 on output (revenue) and inputs (labor and capital), the study has assessed various performance indicators. Employing the MTFP approach, the analysis encompasses technical efficiency, technological change, TFP change, and technical efficiency change over the specified period. Technical efficiency, technological change, and TFP are three distinct concepts used to assess the performance and productivity of operations. By analyzing technical efficiency, AEs can identify inefficiencies in resource allocation and production processes, enabling them to adjust and optimize their operations. Technological change analysis helps AEs understand how the adoption of new technologies or production methods can enhance productivity and competitiveness. TFP analysis provides a comprehensive measure of overall productivity growth, guiding AEs in identifying areas for improvement and benchmarking their performance against industry standards.

Table 5 illustrates the fluctuating average level of technical efficiency among AEs over the years. In 2016, the average technical efficiency was 0.5284, indicating the inefficient use of resources among AEs. By 2018, there was a slight increase to 0.5759, reflecting an improvement in resource use efficiency. However, in 2019–2020, it decreased slightly to 0.5722 and 0.5607, respectively.

Table 5 also reveals that some enterprises achieved very high technical efficiency each year, with the highest level reaching 100%. However, there were significant differences between enterprises with the highest and lowest efficiency levels, highlighting unequal performance. Overall, the data indicates that technical efficiency among enterprises has very slightly changed over the years. The large disparity between the highest and lowest efficiency levels suggests insufficient optimization of input resources and limited technical application.

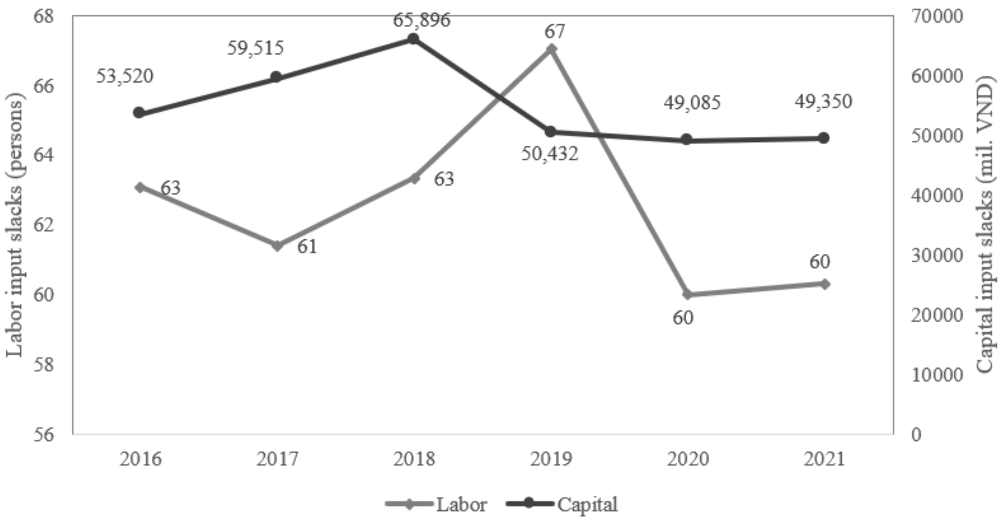
Table 5. Technical efficiency of agricultural enterprises in the period 2016–2021

Year	Medium	SD	Min	Max
2016	0.5284	0.2950	0.047	1
2017	0.5136	0.3068	0.013	1
2018	0.5759	0.3215	0.006	1
2019	0.5722	0.3183	0.004	1
2020	0.5607	0.3067	0.009	1
2021	0.5637	0.3060	0.009	1

Source: Enterprise survey data in Hau Giang province, n=522

Based on the estimated results of input-oriented technical efficiency, the study proceeded to estimate the average input slacks for AEs spanning the period from 2016 to 2021, as illustrated in Figure 4. The analysis reveals a trend of decreasing input slacks over the years, particularly notable in the case of capital input. Interestingly, labor input exhibited the highest slack in 2019, the year before the disruptive effects of the COVID-19 pandemic. Nonetheless, the AEs promptly adapted to those circumstances, leading to subsequent reductions in labor input slacks in the ensuing years. Such findings underscore the resilience and adaptability of these enterprises in responding to external challenges and optimizing resource utilization for improved efficiency.

Figure 4. Input slacks among AEs during 2016–2021



Source: Enterprise survey data in Hau Giang province, n=522

Now, we turn to estimate the changes in TE, TC, and MTFP among AEs in Hau Giang province.

Table 6. TEC, TC, and MTFP changes of AEs in the period 2016–2021

Year	**TE change**		**Technological change**		**MTFP change**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
2016	-	-	-	-	-	-
2017	0.752	5.472	1.511	0.514	1.136	9.422
2018	0.794	74.692	0.880	0.160	0.699	86.012
2019	0.614	350.369	0.864	0.063	0.530	76.889
2020	3.511	53.609	0.440	0.315	1.545	31.283
2021	1.065	0.307	1.000	0.025	1.065	0.307
Medium	1.065	0.537	0.873	0.095	0.929	0.453

Source: Enterprise survey data in Hau Giang province, n=522

The research findings presented in Table 6 reveal important insights regarding the performance of AEs in Hau Giang province during the period of 2016–2021. The results indicate that the technical efficiency of these enterprises witnessed a positive growth of 6.5%. However, there was a notable decrease in technological change, with a reduction of 12.7%. Consequently, the MTFP experienced a decline of 7.1%. Comparisons with previous studies by Nghiem and Coelli (2002), Kompas (2004), and Che et al. (2006) for rice farming suggest that the MTFP change in this current study as a whole is lower. This implies that the MTFP growth is relatively higher in the rice sector compared to other agricultural sectors.

These findings suggest that the AEs in Hau Giang province did not prioritize substantial investments in scientific and technological advancements over the examined period. Instead, they predominantly relied on outdated technologies that have been in use since their establishment. This reliance on outdated practices/technologies has had detrimental effects on efficiency and performance, as well as the optimal utilization of available resources.

To address these challenges and foster growth and competitiveness, it is crucial for AEs to recognize the significance of investing in scientific research, technological advancements, and innovation. It is imperative for stakeholders to promote and support initiatives that encourage the AEs to adopt new technologies, thereby driving sustainable development and progress in the agricultural sector of Hau Giang province.

Table 7. Distribution of changes in MTFP of agricultural enterprises

Distribution level	**Frequency**	**Percent**	**Accumulative**
<0.3	5	5.75	5.74
0.3-0.4	2	2.30	8.04
>0.4-0.5	4	4.60	12.64
>0.5-0.6	2	2.30	14.94
>0.6-0.7	3	3.45	18.38
>0.7-0.8	4	4.60	22.98
>0.8-0.9	14	16.09	39.07
>0.9-1.0	16	18.39	57.46
>1.0-1.1	7	8.05	65.51
>1.1-1.2	4	4.60	70.11
>1.2	26	29.89	100.00
Mean		**0.929**	
Standard deviation		**0.453**	

Based on the data presented in Table 7, it is observed that 37 enterprises exhibited an increase in the TFP index, representing 42.54% of the total. The majority of these enterprises (26 out of 37) had an MTFP index above 1.2. On the other hand, there were 50 enterprises with a reduction in MTFP, accounting for 57.46% of the total. Among these, 39 enterprises had an MTFP index below 1.0, and 30 of them showed a relatively low level of MTFP change (above 0.8).

These findings underscore the importance of focusing on strategies and initiatives that support AEs in enhancing their productivity and efficiency. By investing in technology and innovation and adopting best practices, enterprises can optimize their MTFP, leading to improved overall performance. The results suggest that enterprises close to the threshold of MTFP increase should seize the opportunity to invest in technological advancements and innovation, enabling them to move toward higher levels of productivity and competitiveness.

To understand the factors contributing to the differences in efficiency among AEs, the study conducted a regression analysis between the TEC, TC, and MTFP change indices and the characteristics of the enterprises. The descriptive statistics of the variables used in the regression model are presented in Table 8.

Table 8. Descriptive statistics of variables affecting the efficiency gaps

Variable	Notation	Description of variables	Mean	SD
X_1	*COOP*	Cooperative (dummy variable, 1=cooperative and 0=Other)	0.287	0.455
X_2	*EXPO*	Export (dummy variable, 1=Yes and 0=No)	0.160	0.369
X_3	*FORE*	Foreign joint venture (dummy variable, 1=Yes and 0=No)	0.045	0.210
X_4	*YEAR*	Years of establishment (years)	5.678	4,468
X_5	*AGE*	Age of the AE owner (years)	53.287	10.853
X_6	*GEN*	Dummy variable, 1=Male, 0=Female	0.747	0.437
X_7	*EDU*	Educational level of the AE's owner (schooling year)	13.551	2.640
X_8	*R&D*	Investment of R&D within the past 5 years (dummy variable, 1=yes, 0=no)	0.609	0.490
X_9	*PORT*	Near the port (dummy variable, 1=yes, 0=no)	0.471	0.502
X_{10}	*CITY*	Located in the city (dummy variable, 1=yes, 0=no)	0.287	0.455

The descriptive statistics in Table 8 reveal that within the observed sample, 28.7% of AEs were cooperatives, and 4.5% were foreign joint ventures. Lately, numerous programs and projects have concentrated on investing in and offering technical support, along with providing machinery and equipment for agricultural cooperatives (Cox & Le, 2017). Consequently, the study seeks to assess the impact of these investments on efficiency indicators in resource utilization. Many previous studies have also demonstrated that foreign joint ventures positively influence efficiency and technological change (Ge & Chen, 2008; Liu et al., 2020). Among the surveyed enterprises, 16% engaged in export activities. Despite numerous studies suggesting that AEs in China involved in exports witness lower TFP growth compared to AEs without exports (Bao et al., 2003; Ge & Chen, 2008; Li, 2010), this study anticipates that exporting enterprises will demonstrate a more efficient use of resources compared to their non-exporting counterparts (Pham, 2015; Hien, 2021). Given that a significant portion of the enterprises in Chau Thanh and Chau Thanh A were large-scale AEs situated in proximity to the port, the study sought to explore potential distinctions between these enterprises and those situated at a greater distance from the port. Additionally, the analysis results indicate that most enterprises relied on outdated technologies, prompting an investigation into whether the hypothesis regarding the year of establishment leading to a decline in the TEC, TC, and MTFP indices holds true. The descriptive statistics also indicate that, on average, AEs in Hau Giang province were established approximately 5.7 years ago, and the majority of enterprise owners were male, accounting for 74.7%. Moreover, the study aims to explore the impact of R&D investment on the resource use efficiency in AEs.

Now, we turn to investigate the factors affecting the TEC, TC, and MTFP gaps of the AEs. The regression results are summarized in Table 9.

Prior to executing the random effects regression for panel data, the study conducted a multicollinearity test using a Variance Inflation Factor (VIF) with case- and time-specific dummies in Ordinary Least Squares (OLS). The findings revealed that all variables exhibited VIF values below 1.76, with the overall VIF value standing at 1.51, signifying the lack of multicollinearity within the regression model. The regression results in Table 9 indicate that the variable "COOP" has a negative relationship with technological change. This can be easily explained in practice as agricultural cooperatives are often small in scale and lack capital, which hinders their investment in scientific and technological activities. Although the influence is not statistically significant, the results indicate that the variable "year of establishment" is inversely related to all productivity changes (MTFP, TEC, and TC). This result once again confirms that AEs in the study sites have not been prioritizing investment in scientific and technological advancements in recent times, leading to a decrease in the efficiency of their production and business operations.

Table 9. Random effect regression results of factors affecting the efficiency gaps

Variable	**Notation**	**TEC**		**Technological change**		**MTFP change**	
		Coeff.	**SE**	**Coeff.**	**SE**	**Coeff.**	**SE**
X_1	*COOP*	-4.892	21.321	-0.147^{***}	0.042	-4.537	6.923
X_2	*EXPO*	56.199^{**}	26.899	0.014	0.053	-9.661	8.685
X_3	*FORE*	-53.603	40.987	-0.006	0.080	-0.256	13.307
X_4	*YEAR*	-2.398	2.450	-0.007	0.004	-0.913	0.770
X_5	*AGE*	-0.405	0.840	0.001	0.001	0.163	0.273
X_6	*GEN*	-0.293	19.687	-0.021	0.038	-15.228^{**}	6.395
X_7	*EDU*	-0.196	3.252	-0.0002	0.006	0.476	1.054
X_7	*R&D*	19.581	21.794	0.054	0.042	20.762^{***}	7.061
X_9	*PORT*	11.600	20.641	0.030	0.040	11.064^{*}	6.707
X_{10}	*CITY*	-7.032	22.450	0.042	0.044	-1.543	7.297
Constant		38.631	64.649	0.963^{***}	0.135	2.482	20.543

R^2 (overall)	0.018	0.041	0.052
δ_e	162.314	0.108	52.697
δ_u	25.582	0.304	0.000
Wald χ^2 prob	0.608	0.017	0.009
Observation	435.000	435.000	435.000

Note: *** and ** represent significance at 1% and 5%, respectively.

The study also reveals that AEs located near the port experience a greater change in MTFP compared to those situated elsewhere. This finding suggests that the AEs near the port, often characterized by high dynamism, large scale, and broad markets, might experience more significant enhancements in MTFP relative to smaller-scale AEs. Additionally, the findings from Table 9 indicate that enterprises involved in export activities demonstrate higher TEC than those not engaged in exports. This could be attributed to the fact that exporting AEs generate greater value-added or profits, potentially leading to enhanced technical efficiency compared to enterprises focusing solely on the domestic market. Regarding the gender of AE owners, the results suggest that male owners experience less change in MTFP compared to their female counterparts. This difference may stem from varying management styles, access to resources, or gender-specific factors influencing decision-making processes within agricultural enterprises. Finally, investments in R&D exhibit a significant positive relationship at the 1% significance level with the MTFP of AEs.

5. Conclusions

This study provides important insights into the performance of the studied enterprises from the period 2016–2021. The findings demonstrate a modest increase in average technical efficiency of 6.5% over the period, indicating some improvement in the utilization of resources. The average technological change shows a concerning downward trend, declining at a rate of 12.7% per year. This decline highlights potential challenges related to technological innovation and the overall state of the agricultural sector. The mean MTFP change also exhibits a downward trajectory, declining by 7.1% annually. This decline in MTFP reinforces the notion that the AEs are facing significant challenges in achieving overall productivity growth. It is likely that the decrease in technological change contributes to this decline, as technological advancements play a crucial role in driving MTFP improvements.

The random effect regression analysis shows that the variable "COOP" demonstrates a negative relationship with technological change, indicating that agricultural cooperatives, often constrained by limited scale and capital, face challenges in investing in scientific and technological activities. Additionally, the study highlights that larger-scale AEs and those located near the port experience better changes in MTFP compared to their smaller-scale counterparts.

The findings underscore the importance of providing support to agricultural cooperatives, encouraging investments in R&D, and promoting innovation across the agricultural sector. Addressing these issues can help improve the efficiency and competitiveness of AEs, ultimately contributing to the sustainable development of the agricultural sector.

Acknowledgments

This research is funded by the Department of Science and Technology, Hau Giang province (34/HĐ-KHCN). The authors express their gratitude to the anonymous reviewers and editors for their valuable feedback, which significantly contributed to enhancing the quality of this paper.

Declaration of Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Asiedu, M., Effah, N. A. A., & Arthur, B. (2023). Innovation and firm productivity in Central America. *Journal of the Knowledge Economy*, *15*(1), 1-34.

Bao, Q., Xu, H., & Lai, M. (2003). How does export trade promote economic growth. An empirical study based on total factor productivity. *Shanghai J. Econ, 3*, 3-10.

Baráth, L., Fertő, I., & Bojnec, Š. (2020). The effect of investment, LFA and agri-environmental subsidies on the components of total factor productivity: The case of Slovenian farms. *Journal of Agricultural Economics, 71*(3), 853-876.

Breustedt, G., Latacz-Lohmann, U., & Tiedemann, T. (2011). Organic or conventional? Optimal dairy farming technology under the EU milk quota system and organic subsidies. *Food Policy, 36*(2), 223-229.

Che, T. N., Kompas, T., & Vousden, N. (2006). Market reform, incentives and economic development in Vietnamese rice production. *Comparative Economic Studies, 48*(2), 277-301.

Cheung, C., & Chow, S. (2006). An investigation of the success factors of young Chinese entrepreneurs in Hong Kong. *International Journal of Entrepreneurship, 10*, 43.

Christoplos, I., Sen, L. T. H., & Ngoan, L. D. (2014). Changing approaches to food security in Viet Nam. In I. Christoplos & A. Pain (Eds.) *New Challenges to Food Security* (pp. 255-271). Routledge.

Coelli, T. (1996). A guide to DEAP version 2.1: A data envelopment analysis (computer program) (Working paper 96/08). *Centre for Efficiency and Productivity Analysis,* University of New England, Australia.

Coelli, T. J., & Rao, D. P. (2005). Total factor productivity growth in agriculture: A Malmquist index analysis of 93 countries, 1980–2000. *Agricultural Economics, 32*(s1), 115-134.

Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005). *An introduction to efficiency and productivity analysis*. Springer.

Cohen, B. (2006). Urbanization in developing countries: Current trends, future projections, and key challenges for sustainability. *Technology in Society, 28*(1-2), 63-80.

Coomes, O. T., Barham, B. L., MacDonald, G. K., Ramankutty, N., & Chavas, J.-P. (2019). Leveraging total factor productivity growth for sustainable and resilient farming. *Nature Sustainability, 2*(1), 22-28.

Cox, A., & Le, V. (2017). Governmental influences on the evolution of agricultural cooperatives in Vietnam: An institutional perspective with case studies. In C. Rowley & J. Michie (Eds.) *Mutual, Cooperative and Employee-Owned Businesses in the Asia Pacific* (pp. 93-110). Routledge.

Cuong, T. T., Sang, L., & Anh, N. (2007). Vietnam's small-and medium-sized enterprises development: Characteristics, constraints and policy recommendations. In *SME in Asia and Globalization, ERIA Research Project Report, 5*, 323-364.

Duong, H. N., Lai, H. H., Nguyen, H. H. N., Le, G. T. H., & Hua, Y. H. (2013). Factors affecting TFP productivity: A survey in six industries in Ho Chi

Minh city. *VNUHCM Journal of Science and Technology Development 16*(2), 16-24.

Färe, R., Grosskopf, S., Norris, M., & Zhang, Z. (1994). Productivity growth, technical progress, and efficiency change in industrialized countries. *The American Economic Review*, *8*(1), 66-83.

Felipe, J. (1999). Total factor productivity growth in East Asia: A critical survey. *The Journal of Development Studies, 35*(4), 1-41.

Gallardo, R. K., & Sauer, J. (2018). Adoption of labor-saving technologies in agriculture. *Annual Review of Resource Economics, 10*, 185-206.

Ge, Y., & Chen, Y. (2008). Foreign ownership and productivity of joint ventures. *Economic Development and Cultural Change, 56*(4), 895-920.

Giang, M. H., Xuan, T. D., Trung, B. H., & Que, M. T. (2019). Total factor productivity of agricultural firms in Vietnam and its relevant determinants. *Economies, 7*(1), 4.

GSO. (2023). *Statistical yearbook of Vietnam 2022*. Statistical Publishing House.

Han, J.-S., & Lee, J.-W. (2020). Demographic change, human capital, and economic growth in Korea. *Japan and the World Economy, 53*, 100984.

Harniati, H., & Anwarudin, O. (2018). The interest and action of young agricultural entrepreneur on agribusiness in Cianjur Regency, West Java. *Jurnal Penyuluhan, 14*(2).

HGSO. (2022). Statistical yearbook of Hau Giang in 2021. *Statistical Publishing House*.

Hien, H. T. (2021). Impact of export behavior on total factor productivity: Evidence from Vietnamese firms. *Journal of Economics and Development, 289*(7/2021), 74-82.

Kompas, T. (2004). *Market reform, productivity and efficiency in Vietnamese rice production* (Working paper idec04-4). International and Development Economics Program. Australian National University.

Krishnasamy, G., & Ahmed, E. M. (2009). Productivity growth analysis in OECD countries: Application of metafrontier functions. *The Journal of the Korean Economy, 10*(2), 225-244.

Li, C. (2010). Whether there is a "productivity paradox" in Chinese export companies: A test based on the data of Chinese manufacturing companies. *World Economics, 33*, 64-81.

Liu, D., Zhu, X., & Wang, Y. (2021). China's agricultural green total factor productivity based on carbon emission: An analysis of evolution trend and influencing factors. *Journal of Cleaner Production, 278*, 123692.

Liu, Q., Lu, R., & Yang, C. (2020). International joint ventures and technology diffusion: Evidence from China. *The World Economy, 43*(1), 146-169.

Luong, N. T., & Danh, V. T. (2020). An analysis of total factor productivity growth in agriculture of the Mekong Delta during the 1990–2005 period. *Can Tho University Journal of Science, 56*(3D), 213-222.

Nghiem, H. S., & Coelli, T. (2002). The effect of incentive reforms upon productivity: Evidence from the Vietnamese rice industry. *Journal of Development Studies, 39*(1), 74-93.

Nhut, Q. M. (2018). An affect of applying advance of science and technology on business activity result of the enterprises specializing in agriculture in

Ben Tre province. *Can Tho University Journal of Science, 54*(1), 187-192. https://doi.org/10.22144/ctu.jvn.2018.022

Parry, M. A., & Hawkesford, M. J. (2010). Food security: Increasing yield and improving resource use efficiency. *Proceedings of the Nutrition Society, 69*(4), 592-600.

Pham, T. T. T. (2015). Does exporting spur firm productivity? Evidence from Vietnam. *Journal of Southeast Asian Economies*, 84-105.

Song, M., Peng, L., Shang, Y., & Zhao, X. (2022). Green technology progress and total factor productivity of resource-based enterprises: A perspective of technical compensation of environmental regulation. *Technological Forecasting and Social Change, 174*, 121276.

Thanh, V., Cuong, T. T., Dung, B., & Chieu, T. (2011). Small and medium enterprises access to finance in Vietnam. In *Jakarta: Economic Research Institute for ASEAN and East Asia (ERIA).*

Tran, N. L. D., Rañola Jr, R. F., Ole Sander, B., Reiner, W., Nguyen, D. T., & Nong, N. K. N. (2020). Determinants of adoption of climate-smart agriculture technologies in rice production in Vietnam. *International Journal of Climate Change Strategies and Management, 12*(2), 238-256.

Trinh, N. T., & Lee, S. (2023). The role of nonagricultural income in poverty alleviation in rural Vietnam. *Southeast Asian Journal of Economics, 11*(3), 167-208.

Tu, V. H. (2017). Resource use efficiency and economic losses: Implications for sustainable rice production in Vietnam. *Environment, Development and Sustainability, 19*, 285-300.

Tu, V. H., Can, N. D., Takahashi, Y., Kopp, S. W., & Yabe, M. (2018). Modelling the factors affecting the adoption of eco-friendly rice production in the Vietnamese Mekong Delta. *Cogent Food & Agriculture, 4*(1), 1432538.

Umetsu, C., Lekprichakul, T., & Chakravorty, U. (2003). Efficiency and technical change in the Philippine rice sector: A Malmquist total factor productivity analysis. *American Journal of Agricultural Economics, 85*(4), 943-963.

World Bank. (2016). *Transforming Vietnamese agriculture: Gaining more for less*. World Bank.