

# Evaluation of Capital Utilization Efficiency in Agricultural Listed Firms Based on a Three-Stage Data Envelopment Analysis

**Abstract:** Rural revitalization is closely intertwined with the nation's destiny, and publicly listed companies in the agriculture, forestry, animal husbandry, and fishery sectors play a pivotal role as key drivers of this initiative. In this study, we apply a combined approach utilizing the three-stage Data Envelopment Analysis (DEA) model and the Malmquist Productivity Index (MPI) to assess the capital utilization efficiency of 85 publicly listed companies in China's agricultural, forestry, animal husbandry, and fishery industries over the period from 2018 to 2022. The findings can be summarized as follows: First, an analysis of 85 publicly listed companies in the agriculture, forestry, animal husbandry, and fishery sectors, segmented into four sub-industries, revealed that after controlling for external environmental factors and random disturbances, the comprehensive efficiency of capital utilization in agricultural companies was significantly overestimated in the first stage. After adjustment, the average comprehensive efficiency, technical efficiency, and scale efficiency in the third stage decreased by 29.79%, 3.03%, and 27.37%, respectively. The primary driver of this decline was the substantial reduction in scale efficiency. Second, the overall capital utilization efficiency of China's agricultural trade companies remains relatively low, with scale efficiency being a critical limiting factor. Heavy reliance on government subsidies and an excess of specialized personnel have constrained improvements in capital utilization efficiency within these companies. Third, a dynamic analysis using the DEA-Malmquist model shows that total factor productivity in the agricultural sub-sector is notably low. This is mainly attributed to inefficient capital management and improper scale allocation, both of which hinder performance.

**Keywords:** Agriculture, forestry, animal husbandry, and fishery; Capital utilization efficiency; Rural revitalization; Three-stage DEA-Malmquist index model

## 1. Introduction

Rural revitalization is a key driver in the pursuit of common prosperity and the attainment of the second centenary goal. With the strategic implementation of this initiative and the robust backing of supportive policies, China's agriculture, forestry, animal husbandry, and fishery sectors have experienced significant progress, including a notable increase in the number of listed companies. Despite these advancements, the sectors continue to face challenges such as capital constraints, inefficient capital utilization, and barriers to accessing financing. As a result, enhancing capital utilization efficiency has become a crucial focus for modern enterprises seeking to boost their operational performance.

Data Envelopment Analysis (DEA) has been widely recognized as a powerful method for assessing efficiency across diverse industries. Originally developed by Charnes et al.<sup>[1]</sup>, the

traditional DEA framework was later refined by Fried et al<sup>[2]</sup> through the introduction of the three-stage DEA model, designed to overcome its initial shortcomings. This enhanced approach has since been extensively adopted by researchers globally to evaluate performance across various sectors. For instance, Shyu et al<sup>[3]</sup> employed the three-stage DEA model to examine banking efficiency in Taiwan, Hong Kong, and mainland China, revealing strategies to minimize input waste through optimized resource allocation. Lee<sup>[4]</sup> focused on the efficiency of accounting firm partnerships, underscoring the importance of factors like total practice income and case volume. Liu<sup>[5]</sup> applied this advanced model to analyze the performance of foreign banks in Taiwan, highlighting the accuracy and relevance of efficiency metrics. Zhao et al<sup>[6]</sup> investigated the efficiency of China's provincial power grid enterprises using the three-stage DEA model, identifying the significant influence of external environmental conditions. Finally, Song et al<sup>[7]</sup> utilized this analytical framework to assess the operational efficiency of China's air transport sector, incorporating regional environmental variables and statistical noise to deliver a comprehensive evaluation of regional performance.

In addition to studies focusing on sectors such as education and healthcare resource allocation, performance reforms, and technological innovation<sup>[8-13]</sup>, this paper takes a different approach by treating the listed companies in the agriculture, forestry, animal husbandry, and fishery sectors as open systems. Utilizing the three-stage DEA model combined with the Malmquist index, the study measures the capital utilization efficiency of these companies. By accounting for external environmental factors and random disturbances after the preliminary efficiency values are obtained, this method more accurately reflects the technological and managerial capabilities of these listed companies.

## **2. Research Methodology**

A review of the literature indicates that most researchers leverage Data Envelopment Analysis (DEA) as a foundation, often integrating it with advanced econometric models to examine capital utilization efficiency from multiple perspectives. Recognizing that capital utilization efficiency is susceptible to the effects of environmental regulations and random disturbances, this study utilizes a three-stage DEA model to effectively isolate these external factors and yield a more precise evaluation of efficiency. To address the limitations of DEA in analyzing static efficiency, the Malmquist index model is incorporated to capture dynamic changes. Accordingly, this research classifies 85 listed companies from China's agriculture, forestry, animal husbandry, and fishery sectors into four distinct sub-sectors and employs the DEA-Malmquist index model to comprehensively analyze their capital utilization efficiency within each sub-sector.

### **2.1 Three-Stage DEA**

#### **2.1.1 First Stage**

The traditional DEA model, pioneered by Charnes et al., was initially developed to evaluate the operational efficiency of government departments and to establish benchmarks for service performance. It has since become a widely used tool for assessing the relative efficiency of multiple decision-making units, predicting decision outcomes, and conducting policy evaluations. Over time, its application has expanded into a variety of fields. Recognizing that the traditional DEA model is limited to static efficiency analysis, Fried et al. introduced the three-stage DEA model, which incorporates adjustments for external environmental factors and random

disturbances. DEA methodology includes several variations, most notably the CCR and BCC models, differentiated by their approach to returns to scale. Considering that capital utilization efficiency often demonstrates variable returns to scale, this study employs the BCC model as the most appropriate framework for measuring relative efficiency. Given that output variables are generally uncontrollable while input variables can be regulated, this research utilizes an output-oriented DEA-BCC model to evaluate the capital utilization efficiency of 85 listed companies in China's agriculture, forestry, animal husbandry, and fishery sectors. The corresponding formula is provided as follows:

$$BCC - St. \quad \left\{ \begin{array}{l} \min[\varphi - \varepsilon(\sum_{i=1}^m s_i^- + \sum_{i=1}^n s_i^+)], \\ \sum_{i=1}^n x_i \lambda_i + S^- = \varphi X_0, \\ \sum_{i=1}^n y_i \lambda_i - S^+ = y_0, \\ \lambda_i \geq 0, i = 1, 2, \dots, n, \\ S^+ \geq 0, S^- \geq 0, \end{array} \right. \quad (1)$$

In Equation (1), the input variables are denoted by  $x$ , while the output variables are represented by  $y$ , the weights assigned to these input and output variables are  $u$  and  $v$  respectively. The terms  $s^-$  and  $s^+$  denote the slack variables, and  $\varepsilon$  represents the non-Archimedean infinitesimal. The parameter  $\varphi$  indicates the comprehensive efficiency of the decision-making unit (DMU). A value of  $\varphi=1$  with all slack variables equal to zero signifies that the DMU has achieved optimal input-output efficiency. If  $\varphi=1$  but some slack variables are non-zero, the DMU is considered relatively efficient yet still has room for improvement. Conversely, when  $\varphi < 1$ , it implies that the DMU exhibits a suboptimal input-output efficiency ratio, indicating considerable potential for enhancement.

The Malmquist index serves as a valuable tool for assessing changes in production efficiency across firms or industries over time. Its fundamental principle is to compare production efficiency at two distinct time points, thereby evaluating both technological advancements and shifts in efficiency. Essentially, the Malmquist index quantifies the variation in production efficiency between periods  $t$  and  $t+1$ . The detailed formula for this calculation is as follows:

$$M_0 = M_t = EC * TC = (X_{t+1}, Y_{t+1}, X_t, Y_t) = \left[ \frac{d_0^t(X_{t+1}, Y_{t+1})}{d_0^t(X_t, Y_t)} * \frac{d_0^{t+1}(X_{t+1}, Y_{t+1})}{d_0^{t+1}(X_t, Y_t)} \right]^{\frac{1}{2}} \quad (2)$$

In Equation (2), two fundamental components—technological change (TC) and efficiency change (EC)—play a crucial role in determining the Malmquist Index (MI). This formula essentially evaluates the variations in inputs and outputs between two periods. When  $MI = 1$ , it signifies that capital utilization efficiency has remained stable throughout the specified timeframe, with no notable fluctuations. If  $MI > 1$ , it indicates an enhancement in capital utilization efficiency from one period to the next, highlighting an upward trend. In contrast, a value of  $MI < 1$  suggests a decline in capital utilization efficiency over the observed period.

### 2.1.2 Second Stage

During the second stage, a Stochastic Frontier Analysis (SFA) regression model is developed to analyze the slack variables identified in the first stage. This method incorporates environmental factors and random disturbances to mitigate inefficiencies in input slacks arising from inadequate control. By doing so, it aims to refine the assessment of resource utilization. The associated

formula is as follows:

$$S_{ni} = f(Z_i, \beta^n) + (V_{ni} + U_{ni}) \quad i = 1, 2, \dots, I \quad n = 1, 2, \dots, N \quad (3)$$

In Equation (3), the composite error term, represented by  $V_{ni} + U_{ni}$ , comprises two elements:  $V_{ni}$  which accounts for random noise, and  $U_{ni}$ , which captures managerial inefficiency and follows a truncated normal distribution. To ensure unbiased and precise results, all decision-making units (DMUs) are evaluated under standardized external conditions. The modified equation is as follows:

$$X_{ni}^B = X_{ni} + [\max(f(Z_i; \beta_n)) - f(Z_i; \beta_n) + [\max(V_{ni} - U_{ni})]] \quad (4)$$

The adjustment accounts for external environmental factors, ensuring that all decision-making units (DMUs) are evaluated under uniform external conditions for a more consistent and accurate comparison.

### 2.1.3 Third Stage

Following the adjustment of input slack variables in the second stage, the revised input and output values are integrated into the traditional one-stage DEA model. This integration enables a recalculation of each decision-making unit's (DMU) relative efficiency, offering a more precise evaluation of their actual utilization efficiency.

## 2.2 Selection of Evaluation Indicators and Data Sources

This study establishes a framework for evaluating capital utilization efficiency by selecting highly relevant indicators from the input-output perspective, as well as considering external environmental factors. The goal is to assess technical efficiency, scale efficiency, and overall efficiency. To ensure the scientific rigor and validity of the analysis, this paper draws upon the work of numerous previous scholars. It identifies operating cash flow per share and operating costs as input variables. The output variables, reflecting the company's operational performance, financial health, and cash flow over a given period, include net profit, cash flow from operating activities, and operating cash outflows. In addition, environmental factors, such as government subsidies and the number of technical personnel, are treated as external variables influencing the efficiency outcomes. Given the DEA model requirement that the number of DMUs (Decision-Making Units) must be at least twice the number of input-output indicators, companies with significant data gaps were excluded. Ultimately, the study evaluates the capital utilization efficiency of 85 listed companies in the agriculture, forestry, animal husbandry, and fishery sectors in China.

To eliminate the influence of different units of measurement and ensure the comparability of environmental variables, the data were standardized. All data used in this analysis are reliable and sourced from reputable platforms such as Sina Finance, the Shanghai Stock Exchange, and annual reports of listed companies. Table 1 provides a detailed overview of the selected indicators.

Table 1. Evaluation Index System for Capital Utilization Efficiency of Enterprises

Indicator Type	Indicator Name	Unit
Output Indicators	Net Profit	Ten million CNY
	Cash Inflows from Operating Activities	One hundred million CNY
Input Indicators	Cash Outflows from Operating Activities	Ten million CNY
	Operating Cash Flow per Share	One hundred million CNY
	Operating Costs	One hundred million CNY
Environmental Variables	Government Subsidies	One million CNY
	Number of Technical Professionals	Number of people

A Pearson correlation analysis was conducted to examine the relationship between the capital

input and output variables of the listed companies. The findings revealed that net profit and cash inflows from operating activities exhibited positive correlation coefficients with the output variables, all of which were statistically significant at the 1% level. These results align with the principle of "positive directionality" [20], indicating a consistent association between these financial metrics.

### **3. Empirical Analysis**

#### **3.1 First-Stage DEA Results Analysis**

Based on the core business activities of the listed companies, the 85 publicly traded firms in the agriculture, forestry, animal husbandry, and fishery sectors from 2018 to 2022 were categorized into four sub-industries: agriculture, forestry, animal husbandry, and fishery. To assess their capital input-output efficiency, a two-step approach was adopted. In the first stage, the DEAP2.1 software was employed to calculate the capital utilization efficiency of these 85 companies for the period 2018–2022, using the DEA-BCC model. The efficiency derived from the BCC model satisfies the relationship: overall efficiency = pure technical efficiency \* scale efficiency. Here, overall efficiency refers to the capital utilization efficiency of each DMU. Without accounting for external environmental variables, a longitudinal analysis of the four sub-industries reveals that the mean values of overall efficiency, pure technical efficiency, and scale efficiency in the forestry and fishery sectors have reached the efficiency frontier, indicating a relatively high level of overall efficiency across these two sectors.

Within the agricultural subsector, comprising 37 companies, the average overall technical efficiency is 0.94, with an average pure technical efficiency of 0.99 and a scale efficiency of 0.95. Notably, 10 companies, including RJNS, KNZY, GNGF, BWKJ, and HNXJ, have fully reached the efficiency frontier (1.00). Additionally, 19 companies, such as QLZY, TYGF, YSJT, JJMY, and HZSY, have achieved strong DEA efficiency (above 0.90). Meanwhile, 8 companies, including LSGF, MHGF, and YSGF, exhibit weak DEA efficiency (below 0.90). In the livestock subsector, comprising a total of 37 companies, the average overall technical efficiency stands at 0.91, with an average pure technical efficiency of 0.97 and scale efficiency at 0.94. Among these, 11 companies, including SWGF, BDH, ZLTY, and HLSW, have fully reached the efficiency frontier (1.00). Additionally, 8 companies, such as ZMGF, FCGF, JXNM, and PLK, have achieved strong DEA efficiency (above 0.90). However, 18 companies, including XWF, ANSW, TMKJ, and ZHKJ, demonstrate weak DEA efficiency (below 0.90). In the forestry subsector, all companies have successfully attained the efficiency frontier, while in the fishery subsector, all but KCGJ have reached the DEA efficiency frontier. Consequently, the ranking of capital utilization efficiency is as follows: forestry companies outperform fishery companies, which in turn exceed agricultural companies, with livestock companies trailing behind. Across all four subsectors, a consistent pattern emerges where pure technical efficiency surpasses scale efficiency. This observation indicates that the enhancement of capital utilization efficiency is predominantly driven by improvements in pure technical efficiency, suggesting that the contributions of technical efficiency are more significant than those stemming from scale advancements. Furthermore, the majority of companies exhibit decreasing returns to scale, implying that excessive scale hampers the efficiency of capital utilization among listed companies. To address this issue, it is imperative to optimize the allocation of capital resources, foster appropriately scaled operations, and ultimately enhance the capital utilization efficiency of these companies.

From a horizontal analysis perspective, the average Malmquist index (MI) of 85 listed companies in the agricultural, forestry, animal husbandry, and fishery sectors exhibited minor fluctuations around the value of 1.00 during the period from 2018 to 2022. Specifically, the MI values for agricultural companies were recorded at 0.90, 1.03, 0.97, and 1.00; for animal husbandry companies, the values were 1.01, 1.02, 0.97, and 1.01; for forestry companies, the values stood at 0.92, 1.18, 0.98, and 1.05; while for fishery companies, the values were 0.99, 1.11, 0.92, and 1.07. These findings indicate that the dynamic changes in funding utilization efficiency across the various sub-industries exhibit distinct characteristics, providing valuable insights for further research. Among the agricultural companies, ZLKJ and among the fishery companies, HDJ exhibited similar trends, as both demonstrated the highest fluctuations in their Malmquist index (MI) efficiency values. During the period from 2019 to 2020, ZLKJ recorded a peak MI efficiency value of 2.48, while HDJ reached a maximum of 1.43, positioning both ahead of their respective industry peers. However, in the subsequent period from 2020 to 2021, ZLKJ's MI efficiency value plummeted to its lowest point at 0.45, and HDJ's MI efficiency also declined to 0.72. These dynamics highlight the volatility of funding utilization efficiency within these sectors, emphasizing the need for targeted strategies to enhance stability and performance. Among the agricultural companies, ZLKJ and among the fishery companies, HDJ exhibited similar trends, as both demonstrated the highest fluctuations in their Malmquist index (MI) efficiency values. During the period from 2019 to 2020, ZLKJ recorded a peak MI efficiency value of 2.48, while HDJ reached a maximum of 1.43, positioning both ahead of their respective industry peers. However, in the subsequent period from 2020 to 2021, ZLKJ's MI efficiency value plummeted to its lowest point at 0.45, and HDJ's MI efficiency also declined to 0.72. These dynamics highlight the volatility of funding utilization efficiency within these sectors, emphasizing the need for targeted strategies to enhance stability and performance.

**Table 2. Overall Efficiency Changes of Four Sub-Sectors in the First Stage (2018–2022)**

NO.	Stock code	Sub-sector/DMU	TE1	PTE1	SE1	Returns to scale	EC				TC				MI			
							18-19	19-20	20-21	21-22	18-19	19-20	20-21	21-22	18-19	19-20	20-21	21-22
		Agricultural																
1	bj830964	RNJS	1.00	1.00	1.00	-	0.93	1.07	0.96	0.99	0.95	1.03	1.01	0.99	0.89	1.10	0.97	0.98
2	bj831087	QLZY	0.92	1.00	0.92	drs	1.01	0.99	1.09	0.97	0.98	1.01	1.01	0.97	0.99	1.00	1.10	0.94
3	bj832023	TYGF	0.90	1.00	0.90	drs	1.06	0.93	1.12	0.95	0.97	1.01	1.01	0.99	1.03	0.93	1.13	0.94
4	bj832419	LSGF	0.85	1.00	0.85	drs	1.03	1.01	0.99	1.02	0.96	0.99	1.02	0.99	0.99	1.00	1.01	1.00
5	bj837403	KNZY	1.00	1.00	1.00	-	0.95	1.05	0.97	1.02	0.93	0.97	0.90	0.98	0.89	1.03	0.87	1.00
6	sh600108	YSJT	0.97	0.99	0.99	drs	0.95	1.02	1.00	1.03	1.02	1.00	1.02	0.97	0.97	1.02	1.02	1.00
7	sh600127	JJMY	0.97	0.98	0.99	drs	0.97	1.03	1.00	0.98	1.02	0.99	1.00	1.01	0.98	1.02	0.99	0.99
8	sh600191	HZSY	0.98	0.99	0.99	drs	1.01	1.01	1.00	1.00	0.98	1.05	1.10	0.85	0.99	1.06	1.10	0.85
9	sh600251	GNGF	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	0.98	1.85	0.68	1.05	0.98	1.85	0.68	1.05
10	sh600313	NFZY	0.97	0.98	0.99	drs	0.97	1.03	0.99	1.04	1.03	1.00	1.01	1.02	1.00	1.04	1.00	1.05
11	sh600354	DHZY	0.93	0.98	0.95	drs	1.00	1.00	1.00	1.07	1.00	1.00	1.00	0.97	1.00	1.00	1.01	1.04
12	sh600371	WXDN	0.92	1.00	0.92	drs	1.03	1.04	1.01	1.00	0.97	1.00	1.04	0.95	0.99	1.05	1.06	0.95
13	sh600540	XSGF	0.96	0.99	0.97	drs	0.98	1.07	1.00	0.94	0.98	1.01	1.12	0.81	0.96	1.08	1.12	0.76
14	sh600883	BWKJ	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	1.10	1.09	0.92	1.22	1.10	1.09	0.92	1.22
15	sh600962	GTZL	0.98	0.99	0.98	drs	1.03	1.00	0.87	1.14	1.05	0.99	1.00	0.97	1.08	0.99	0.87	1.10
16	sh601118	HNXJ	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	1.06	1.04	0.98	1.04	1.06	1.04	0.98	1.04
17	sh603336	HHGS	1.00	1.00	1.00	-	0.94	1.01	1.00	1.02	0.98	1.00	1.01	0.98	0.91	1.01	1.01	1.00
18	sz000639	XWSP	1.00	1.00	1.00	-	0.97	1.01	0.96	0.99	1.03	1.01	1.00	1.00	1.00	1.02	0.96	1.00
19	sz000713	FLZY	0.96	0.98	0.98	drs	0.96	0.98	1.00	1.04	1.02	1.02	1.02	0.96	0.98	0.99	1.02	0.99
20	sz000911	GNTY	0.89	0.90	0.99	drs	1.00	1.14	0.91	1.04	1.01	0.93	1.00	0.97	1.01	1.05	0.90	1.01
21	bj830964	ZLKJ	1.00	1.00	1.00	-	0.77	1.30	0.84	1.19	0.85	1.92	0.54	1.07	0.66	2.48	0.45	1.28
22	sz000972	ZJK	0.93	0.97	0.96	drs	1.07	1.00	1.00	1.00	1.08	0.84	0.90	1.04	1.16	0.84	0.89	1.04
23	sz000998	LPGK	0.96	1.00	0.96	drs	0.98	1.06	1.00	1.00	1.02	1.05	0.98	0.93	0.99	1.12	0.98	0.93
24	sz002041	DHZY	0.92	0.98	0.94	drs	1.07	1.02	1.00	1.00	0.98	1.02	0.99	0.97	1.04	1.04	0.99	0.97
25	sz002234	MHGF	0.85	1.00	0.85	drs	1.02	1.08	0.99	1.09	1.12	0.74	1.03	0.96	1.15	0.79	1.01	1.05
26	sz002458	YSGF	0.85	1.00	0.85	drs	1.18	0.94	0.97	1.03	1.16	0.74	1.03	0.96	1.37	0.70	0.99	0.99
27	sz002548	JXN	0.97	0.98	1.00	drs	0.95	1.03	0.97	1.03	1.00	1.01	1.01	0.98	0.95	1.04	0.98	1.01
28	sz002746	XTGF	0.87	1.00	0.87	drs	1.06	1.03	0.97	1.04	1.05	0.91	1.02	0.98	1.11	0.94	0.99	1.02
29	sz002772	ZXJY	0.88	0.99	0.89	drs	1.01	1.03	1.07	0.97	0.96	0.97	1.05	0.89	0.98	1.01	1.12	0.86
30	sz300021	DYJS	1.00	1.00	1.00	-	1.00	0.95	0.98	1.04	0.99	0.99	1.03	0.96	0.99	0.94	1.01	1.00
31	sz300119	RPSW	0.91	0.99	0.91	drs	1.00	1.06	0.95	1.03	0.98	0.95	1.03	0.94	0.98	1.01	0.98	0.97
32	sz300138	CGSW	0.98	0.99	0.99	drs	1.02	0.97	1.00	1.03	1.00	0.99	1.01	0.99	1.02	0.96	1.01	1.02
33	sz300175	LYGF	0.96	1.00	0.96	drs	1.00	1.02	0.99	1.01	0.98	1.01	1.01	1.00	0.98	1.02	1.00	1.00
34	sz300189	SNKJ	1.00	1.00	1.00	-	0.97	1.03	0.98	0.99	0.89	1.01	0.98	1.00	0.87	1.03	0.96	0.99
35	sz300511	XRSW	0.90	0.99	0.91	drs	1.01	0.98	0.99	1.04	1.00	1.01	0.99	0.96	1.00	0.99	0.98	1.00
36	sz300673	PDGF	0.78	1.00	0.78	drs	1.28	0.87	1.09	1.01	0.98	0.97	1.03	0.97	1.25	0.84	1.12	0.98
37	sz300972	WCJT	0.78	1.00	0.78	drs	0.94	1.35	0.89	1.02	0.96	0.73	0.99	0.99	0.90	0.99	0.88	1.01
		Mean	0.94	0.99	0.95		1.00	1.03	0.99	1.02	1.00	1.01	0.98	0.98	0.90	1.03	0.97	1.00
		Animal Husbandry																
38	sh600195	ZMGF	0.91	0.98	0.93	drs	1.11	0.78	1.17	1.10	1.00	1.11	0.88	0.97	1.11	0.86	1.03	1.06
39	sh600201	SWGf	1.00	1.00	1.00	-	0.80	1.23	1.00	0.97	1.05	0.96	0.92	1.00	0.84	1.18	0.91	0.97

40	sh600598	BDH	1.00	1.00	1.00	-	1.00	0.92	1.09	1.00	0.99	1.15	0.90	0.95	0.99	1.06	0.98	0.95
41	sh600737	ZLTY	1.00	1.00	1.00	-	0.98	0.89	1.14	1.00	1.06	1.15	0.89	1.06	1.04	1.03	1.02	1.06
42	sh600965	FCGF	0.92	0.97	0.95	drs	1.09	0.89	1.09	1.02	1.25	0.82	0.94	0.97	1.36	0.73	1.02	0.99
43	sh600975	XWF	0.83	0.97	0.86	drs	1.12	0.88	1.21	0.92	0.91	1.07	0.95	0.95	1.02	0.95	1.16	0.88
44	sh603363	ANSW	0.84	0.86	0.98	drs	0.97	0.96	1.08	1.01	1.03	1.14	0.89	1.00	1.00	1.10	0.95	1.01
45	sh603477	JXNM	0.96	1.00	0.96	drs	0.93	0.94	1.08	0.94	1.02	0.98	0.91	0.99	0.95	0.92	0.99	0.93
46	sh603566	PLK	0.95	1.00	0.95	drs	0.91	0.98	1.04	1.00	1.05	1.00	0.94	1.00	0.95	0.98	0.97	1.00
47	sh603609	HFGF	0.93	0.95	0.98	drs	0.96	0.93	1.13	1.02	1.06	1.12	0.92	1.02	1.02	1.04	1.04	1.04
48	sh603668	TMKJ	0.82	0.97	0.85	drs	0.90	0.98	1.20	1.05	1.14	0.95	0.89	1.00	1.03	0.93	1.07	1.05
49	sh603718	HLSW	1.00	1.00	1.00	-	0.95	1.06	0.96	1.04	1.06	0.97	0.97	1.17	1.00	1.03	0.93	1.21
50	sz000702	ZHKJ	0.87	0.97	0.90	drs	0.97	1.18	1.00	1.00	0.98	1.04	0.98	0.97	0.96	1.23	0.98	0.97
51	sz000735	LNS	0.86	0.98	0.88	drs	1.10	0.98	1.09	0.98	0.91	1.04	0.93	0.84	0.99	1.02	1.01	0.83
52	sz000876	XXW	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	1.07	1.12	1.21	0.82	1.07	1.12	1.21	0.82
53	sz002100	TKSW	1.00	1.00	1.00	-	0.90	1.11	0.87	1.05	0.84	1.09	0.85	1.00	0.76	1.21	0.74	1.05
54	sz002124	TBSP	0.89	0.93	0.96	drs	0.99	1.11	0.85	1.13	1.02	1.11	0.89	1.00	1.01	1.23	0.76	1.13
55	sz002286	BLB	0.84	0.96	0.87	drs	1.03	0.88	1.17	1.09	0.98	1.05	0.91	0.99	1.00	0.92	1.06	1.07
56	sz002299	SNFZ	1.00	1.00	1.00	drs	0.98	0.82	1.12	1.00	1.16	1.08	0.81	0.99	1.14	0.89	0.90	0.99
57	sz002321	HYNY	0.89	0.95	0.93	drs	1.00	1.06	0.86	1.21	1.10	1.11	0.97	0.98	1.10	1.18	0.84	1.18
58	sz002385	BDN	0.93	0.94	0.99	drs	0.97	1.02	1.03	1.00	1.07	1.04	0.94	1.02	1.03	1.06	0.96	1.02
59	sz002481	STSP	0.87	0.97	0.90	drs	1.15	0.89	1.13	0.92	0.97	1.19	0.89	0.94	1.12	1.06	1.00	0.87
60	sz002505	PDNM	0.88	0.90	0.98	drs	0.97	1.01	1.08	1.00	1.03	1.00	0.94	0.99	1.00	1.01	1.02	0.99
61	sz002556	HLGF	0.82	0.92	0.90	drs	0.93	1.05	1.06	1.03	1.13	1.04	0.95	1.00	1.05	1.09	1.00	1.02
62	sz002679	FJJS	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	0.89	0.94	1.05	0.90	0.89	0.94	1.05	0.90
63	sz002688	JHSW	0.87	0.97	0.90	drs	0.99	0.98	1.07	1.01	0.99	1.00	0.94	0.99	0.98	0.99	1.01	1.01
64	sz002696	BYGF	0.88	0.97	0.91	drs	0.88	1.08	1.09	0.95	0.99	1.06	0.94	0.99	0.87	1.14	1.03	0.94
65	sz002714	MYGF	0.94	0.95	0.99	drs	1.06	1.00	1.00	1.00	1.26	1.19	0.77	1.02	1.34	1.19	0.77	1.02
66	sz002852	DDQ	0.85	0.96	0.88	drs	1.18	0.82	1.19	0.91	0.99	1.04	0.90	0.98	1.17	0.86	1.07	0.89
67	sz002868	LKSH	0.90	0.99	0.90	drs	1.09	1.03	0.99	1.01	0.92	1.04	0.97	1.04	1.00	1.07	0.96	1.05
68	sz002891	ZCGF	0.85	0.97	0.88	drs	0.99	1.00	0.98	1.07	0.97	1.10	0.91	1.00	0.96	1.10	0.89	1.07
69	sz300094	GLSC	0.86	0.97	0.89	drs	1.07	0.99	0.99	1.03	1.00	1.03	0.95	1.00	1.07	1.02	0.94	1.03
70	sz300268	*STJW	1.00	1.00	1.00	-	0.74	1.00	1.05	1.08	0.77	1.10	0.87	0.94	0.57	1.10	0.91	1.01
71	sz300313	*STTS	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	0.97	1.10	1.02	1.21	0.97	1.10	1.02	1.21
72	sz300498	WSGF	1.00	1.00	1.00	-	1.00	1.00	0.94	1.07	1.10	0.99	0.97	1.04	1.10	0.99	0.91	1.11
73	sz300761	LHGF	0.87	1.00	0.87	drs	1.04	0.88	1.07	1.03	1.03	1.12	0.82	0.95	1.07	0.98	0.88	0.99
74	sz300967	XMGF	0.81	0.99	0.81	drs	1.18	0.87	1.04	1.07	0.95	0.99	0.95	1.00	1.12	0.87	0.98	1.07
		Mean	0.91	0.97	0.94		0.99	0.97	1.05	1.02	1.02	1.05	0.92	0.99	1.01	1.02	0.97	1.01
		Forestry					18-19	19-20	20-21	21-22	18-19	19-20	20-21	21-22	18-19	19-20	20-21	21-22
75	sh600265	*STJG	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	0.69	1.71	0.74	1.08	0.69	1.71	0.74	1.08
76	sz000592	PTFZ	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	1.09	1.11	0.83	0.93	1.09	1.11	0.83	0.93
77	sz000663	YALY	1.00	1.00	1.00	-	0.91	1.10	1.00	1.00	1.04	0.92	1.16	1.23	0.95	1.01	1.16	1.23
78	sz002567	TRS	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	1.00	1.01	1.31	0.99	1.00	1.01	1.31	0.99
		Mean	1.00	1.00	1.00		0.98	1.02	1.00	1.00	0.94	1.15	0.98	1.05	0.92	1.18	0.98	1.05
		Fishery					18-19	19-20	20-21	21-22	18-19	19-20	20-21	21-22	18-19	19-20	20-21	21-22
79	sh600097	KCGJ	0.99	1.00	0.99	drs	1.01	1.00	0.91	1.04	0.96	1.04	1.05	1.00	0.97	1.04	0.95	1.03
80	sh600257	THGF	1.00	1.00	1.00	-	0.98	1.00	1.02	1.00	0.96	1.07	0.94	1.00	0.94	1.07	0.96	1.00

81	sh600359	XNKF	1.00	1.00	1.00	irs	1.00	1.00	1.00	1.00	1.04	1.16	0.92	1.05	1.04	1.16	0.92	1.05
82	sh600467	HDJ	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	1.05	1.43	0.72	0.96	1.05	1.43	0.72	0.96
83	sz000798	ZSYU	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	1.02	1.04	1.02	1.28	1.02	1.04	1.02	1.28
84	sz002069	ZZD	1.00	1.00	1.00	-	1.00	1.00	1.01	1.00	0.98	1.02	0.98	1.01	0.98	1.01	0.99	1.01
85	sz300087	QYGK	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	0.94	1.09	0.95	1.21	0.94	1.09	0.95	1.21
		Mean	1.00	1.00	1.00		1.00	1.00	0.99	1.01	0.99	1.11	0.93	1.07	0.99	1.11	0.92	1.07

Note:bj refers to the Beijing Stock Exchange, sh refers to the Shanghai Stock Exchange, sz refers to the Shenzhen Stock Exchange. TE1 represents the overall efficiency score in the initial phase. PTE1 denotes the pure technical efficiency in the first stage, while SE1 reflects the scale efficiency at this stage. irs signifies increasing returns to scale, dre denotes decreasing returns to scale, and "-" indicates constant returns to scale.

UNDER PEER REVIEW

### 3.2 Second-Stage SFA Regression Analysis

To ensure accuracy and reliability in the results, slack variables for input factors were calculated by subtracting the original input values from the target input values derived in the first stage. These slack variables were then utilized as dependent variables, while government subsidies and the number of technical professionals were incorporated as independent variables representing external environmental factors. To address dimensional effects, the environmental variables were standardized, and data estimation was performed using Frontier 4.1 software. The regression outcomes are detailed in Table 3. The LR test statistics for all three models were significant at the 1% level, underscoring the necessity of accounting for external environmental influences and random disturbances in this analysis. With the exception of the slack value of operating cash flow per share, the  $\gamma$  values for the other variables were 532.27 and met the 1% significance threshold, indicating that both managerial inefficiency and random noise significantly impact the capital utilization efficiency of listed firms in the agriculture, forestry, animal husbandry, and fishery sectors. A negative regression coefficient reveals that an increase in the environmental variable reduces input redundancy, thereby enhancing capital utilization efficiency. Conversely, a positive regression coefficient implies that the environmental variable hinders progress in capital utilization efficiency.

Government subsidies are found to have a significant positive correlation with the slack values of cash outflows from operating activities and operating costs, yet they exert no meaningful impact on the slack value of operating cash flow per share. Although government subsidies can bolster capital inputs for companies in the agriculture, forestry, animal husbandry, and fishery sectors by leveraging resource allocation mechanisms, they may simultaneously diminish these firms' motivation to enhance capital utilization efficiency, despite providing some relief from financial constraints. Likewise, the number of technical professionals is positively correlated with the slack values of cash outflows and operating costs, without significantly influencing the slack value of operating cash flow per share. While technical professionals undoubtedly add substantial value to companies and drive subsequent rounds of research and development, their contributions can also lead to elevated expectations and an expansion of business operations, resulting in increased capital and labor investments. However, if not managed properly, this unchecked growth may lead to inefficient use of production resources, thereby raising input slack. Moreover, inadequate management practices can further impede the overall efficiency of capital utilization.

**Table 3. Second-Stage SFA Regression Results**

Project	Slack Value of Cash Outflows from Operating Activities		Slack Value of Operating Cash Flow per Share		Slack Value of Operating Costs	
	Result	t-value	Result	t-value	Result	t-value
Constant	-28.36***	-3.292	0.28	36.59	-28.36***	-3.29
Government Subsidies	37.54 ***	9.98	0.02	3.92	37.54***	9.98
Technical Professionals	10.14 ***	3.28	0.01	1.37	10.14 ***	3.28
$\sigma^2$	39051.57***	37767.99	0.01	8.54	39051.57***	37767.99
$\gamma$	0.93***	168.17	0.48	7.66	0.93***	168.17
LR Value	532.27		68.92		532.27	

Note: \*, \*\*, \*\*\* represent significant levels at 10%, 5%, and 1%, respectively.

### 3.3 Third Stage Adjusted DEA Results Analysis

After excluding external environmental factors and random disturbances, the input and output variables of China's agricultural, forestry, animal husbandry, and fishery listed companies over the past five years were readjusted and recalculated using the DEAP 2.1 software. A comparison of

the longitudinal data in Tables 1 and 4 reveals that, after removing the impact of external factors on efficiency, the average comprehensive efficiency of agricultural companies decreased from 0.94 to 0.66, while the average scale efficiency dropped from 0.95 to 0.69. This represents significant declines of 29.79% and 27.37%, respectively. These findings underscore the substantial impact of external variables on the efficiency metrics within the agricultural sector, indicating a pressing need for companies to adapt their operational strategies accordingly.

Following the adjustments, the average comprehensive technical efficiency, technical efficiency, and scale efficiency did not reach the efficiency frontier. Among the four sub-industries, the capital utilization efficiency of agricultural companies was found to be significantly overestimated. During the study period, after adjusting the inputs, 46 agricultural, forestry, animal husbandry, and fishery listed companies experienced a decline in efficiency, with most companies having their capital utilization efficiency overestimated prior to adjustments. Notably, RJNS and HNXJ showed the most significant declines, dropping from an adjusted efficiency of 1.00 to 0.56. In contrast, after adjusting the inputs, 24 companies, including ZMGF and FCGF, demonstrated improved capital utilization efficiency, indicating that external environmental factors negatively affected their capital utilization activities. The most pronounced improvement was observed in XMGF, which increased from an adjusted efficiency of 0.81 to 0.96. After excluding the influence of external factors, only the agricultural sub-industry exhibited significant variability in capital utilization efficiency, with ZLKJ emerging as the sole company in this sector to achieve efficiency frontier status. These results highlight the critical need for accurate assessments of capital efficiency, particularly in the agricultural sector, where external influences can markedly distort efficiency evaluations.

In terms of pure technical efficiency, after adjusting the inputs, four companies in the agricultural, forestry, animal husbandry, and fishery sectors, namely XSGF, LNS, BDN, and MYGF, exhibited improvements in efficiency. However, the majority of companies had their pure technical efficiency overestimated prior to adjustments. Notably, 30 companies, including ZLKJ, SWGF, and HLSW, maintained their status at the efficiency frontier, with no changes in pure technical efficiency before and after the input adjustments. After accounting for external environmental factors, it was found that, except for the agricultural sector, the differences in pure technical efficiency among the remaining three sub-industries were minimal. This suggests that, while some companies have room for improvement, others have effectively optimized their operations to remain at the efficiency frontier. Overall, these findings underline the importance of precise input adjustments to accurately assess and enhance technical efficiency across these sectors.

In terms of scale efficiency, the adjustment of inputs led to a decline in efficiency for 42 companies in the agricultural, forestry, animal husbandry, and fishery sectors, including PDNM, YALY, and ZSYY. This trend suggests that the decrease in capital utilization efficiency is primarily driven by a reduction in scale efficiency. Among these companies, HNXJ exhibited the most pronounced decline in scale efficiency, plummeting from 0.98 before the adjustments to 0.57 afterward. Conversely, 24 companies, including XWF, ANSW, and TMKJ, improved their scale efficiency following the input adjustments. After excluding the influence of external environmental factors, the disparities in scale efficiency among the three sub-sectors, aside from agriculture, were minimal.

From a horizontal analysis perspective, following adjustments during the period from 2018 to

2022, the mean Malmquist Index (MI) for 85 listed companies in the agriculture, forestry, animal husbandry, and fishery sectors stands at 1.00. The average technical progress efficiency is 0.86, while the average scale efficiency is 1.15. The scale efficiency exceeding 1 indicates an improvement, whereas the technical efficiency below 1 signals a regression in the utilization of technology among these companies. Specifically, the MI averages for agricultural companies are recorded at 1.05, 0.96, 1.00, and 0.98; for animal husbandry companies, the figures are 1.02, 1.04, 0.96, and 1.01; for forestry companies, the MI averages are 1.00, 1.02, 1.05, and 1.02; and for fishery companies, they stand at 1.00, 1.05, 0.96, and 1.07. Notably, both agricultural and animal husbandry companies show slight improvements in total factor productivity compared to pre-adjustment figures. In contrast, forestry and fishery companies experience minor declines in their total factor productivity relative to the previous period.

Among the agricultural companies, ZLKJ exhibits significant fluctuations in its Malmquist Index (MI) after adjustments. During the period from 2018 to 2019, its MI increased dramatically from 0.66 to 4.68, while the Technical Change (TC) index rose from 0.85 to 4.68. However, in the subsequent period of 2019 to 2020, the MI plummeted from 2.48 to 0.19, with the TC index also declining from 1.98 to 0.19. Several factors contribute to these fluctuations within the context of the prevailing economic landscape. First, macroeconomic volatility, shifts in industry demand, raw material prices, and imbalances in market supply and demand can directly impact operational costs and revenues, leading to variations in capital utilization efficiency. Second, significant technological advancements or regressions within the company may also cause considerable volatility in the MI. Third, unexpected external factors such as global economic conditions, geopolitical risks, natural disasters, and public health emergencies (such as pandemics) can destabilize company operations, resulting in short-term fluctuations in capital utilization efficiency. These elements collectively influence the efficiency of capital utilization in different years, causing the MI to exhibit substantial variations in certain periods.

Overall, as shown in Table 5, the Malmquist Index (MI) for the 85 agricultural, forestry, animal husbandry, and fishery listed companies exhibited a gradual annual increase from 2018 to 2020. This trend may be attributed to the post-pandemic recovery, during which government support policies enabled these companies to promptly adjust their strategic planning, capital utilization strategies, and management measures in alignment with their current development status.

**Table 4. Overall Efficiency Changes of Four Sub-Sectors in the Third Stage (2018–2022)**

NO.	Stock code	Sub-sector	TE3	PTE3	SE3	Returns to scale	EC				TC				MI			
							18-19	19-20	20-21	21-22	18-19	19-20	20-21	21-22	18-19	19-20	20-21	21-22
		Agricultural																
1	bj830964	RNJS	0.56	0.96	0.58	drs	0.12	8.79	0.80	1.01	7.93	0.11	1.21	0.98	0.98	0.98	0.97	0.99
2	bj831087	QLZY	0.67	0.96	0.70	drs	1.18	1.09	0.75	1.17	0.84	0.91	1.23	0.88	0.99	1.00	0.92	1.02
3	bj832023	TYGF	0.67	0.96	0.70	drs	1.20	1.08	0.86	1.06	0.85	0.91	1.19	0.94	1.01	0.98	1.03	0.99
4	bj832419	LSGF	0.67	0.96	0.69	drs	1.13	1.13	0.83	1.11	0.88	0.89	1.21	0.91	0.99	1.01	1.00	1.00
5	bj837403	KNZY	0.67	0.96	0.70	drs	1.08	1.14	0.83	1.19	0.98	0.84	1.25	0.92	1.06	0.96	1.04	1.09
6	sh600108	YSJT	0.63	0.96	0.66	drs	1.33	1.02	0.87	1.02	0.75	0.98	1.13	0.97	1.01	1.00	0.98	0.99
7	sh600127	JJMY	0.62	0.95	0.65	drs	1.34	1.00	0.95	0.90	0.73	1.04	1.01	1.05	0.97	1.04	0.96	0.95
8	sh600191	HZSY	0.66	0.95	0.69	drs	1.26	1.05	0.87	1.13	0.79	0.95	1.16	0.95	1.00	0.99	1.01	1.08
9	sh600251	GNGF	0.62	0.96	0.64	drs	1.01	1.61	0.76	0.98	0.84	1.21	0.87	0.95	0.85	1.94	0.66	0.92
10	sh600313	NFZY	0.62	0.96	0.65	drs	1.36	0.99	0.92	1.03	0.72	1.00	1.11	1.01	0.98	0.99	1.02	1.03
11	sh600354	DHZY	0.65	0.94	0.69	drs	1.27	1.06	0.84	1.04	0.77	0.94	1.18	0.91	0.98	0.99	1.00	0.95
12	sh600371	WXDN	0.67	0.96	0.70	drs	1.20	1.11	0.81	1.10	0.83	0.94	1.18	0.92	1.00	1.04	0.95	1.01
13	sh600540	XSGF	0.64	0.96	0.67	drs	1.24	1.14	1.12	0.72	0.79	0.98	1.01	0.86	0.98	1.11	1.13	0.62
14	sh600883	BWKJ	0.66	0.96	0.69	drs	1.26	1.06	0.86	1.06	0.79	0.95	1.16	0.95	0.99	1.01	1.00	1.01
15	sh600962	GTZL	0.64	0.96	0.67	drs	1.56	0.88	0.78	1.05	0.71	1.06	1.15	0.90	1.11	0.93	0.89	0.94
16	sh601118	HNXJ	0.56	0.98	0.57	drs	1.71	0.88	1.19	0.74	0.57	1.17	0.84	1.37	0.97	1.03	1.00	1.02
17	sh603336	HHGS	0.65	0.96	0.68	drs	1.25	1.07	0.88	1.04	0.76	0.95	1.15	0.97	0.95	1.01	1.01	1.00
18	sz000639	XWSP	0.59	0.99	0.60	drs	1.26	1.07	1.03	0.89	0.82	0.96	1.06	1.02	1.03	1.03	1.10	0.91
19	sz000713	FLZY	0.65	0.96	0.68	drs	1.20	1.05	0.90	1.00	0.77	0.93	1.16	0.94	0.93	0.98	1.05	0.93
20	sz000911	GNTY	0.65	0.89	0.73	drs	1.19	1.12	0.92	1.03	1.64	0.44	1.20	0.95	1.95	0.49	1.11	0.98
21	bj830964	ZLKJ	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	4.68	0.19	0.66	1.65	4.68	0.19	0.66	1.65
22	sz000972	ZJJK	0.64	0.93	0.68	drs	1.25	1.09	0.91	0.99	0.86	0.93	1.14	0.95	1.08	1.02	1.04	0.94
23	sz000998	LPGK	0.68	1.00	0.68	drs	1.22	1.03	0.76	1.19	0.77	0.90	1.26	0.88	0.94	0.92	0.95	1.04
24	sz002041	DHZY	0.66	0.95	0.70	drs	1.21	1.09	0.83	1.13	0.81	0.90	1.21	0.93	0.98	0.98	1.01	1.05
25	sz002234	MHGF	0.66	0.98	0.67	drs	0.60	2.07	0.91	1.29	1.34	0.65	1.19	0.93	0.80	1.35	1.09	1.20
26	sz002458	YSGF	0.66	0.97	0.68	drs	0.76	1.69	0.86	1.02	1.19	0.76	1.14	0.96	0.91	1.29	0.99	0.98
27	sz002548	JXN	0.60	0.94	0.64	drs	1.26	1.12	0.84	1.06	0.80	0.90	1.15	1.00	1.02	1.01	0.96	1.06
28	sz002746	XTGF	0.65	0.98	0.66	drs	0.93	1.31	0.96	0.93	1.25	0.71	1.16	0.99	1.16	0.93	1.11	0.91
29	sz002772	ZXJY	0.67	0.96	0.69	drs	1.03	1.21	1.15	0.77	0.93	0.84	1.13	0.89	0.96	1.01	1.29	0.69
30	sz300021	DYJS	0.65	0.96	0.68	drs	1.36	1.02	0.80	1.02	0.84	1.01	1.13	0.95	1.14	1.03	0.90	0.97
31	sz300119	RPSW	0.68	0.97	0.70	drs	1.04	1.19	0.82	1.12	0.92	0.85	1.26	0.88	0.95	1.00	1.03	0.99
32	sz300138	CGSW	0.76	0.97	0.79	drs	1.26	1.04	1.00	1.00	0.80	0.86	1.26	0.97	1.01	0.89	1.26	0.97
33	sz300175	LYGF	0.66	0.96	0.69	drs	1.25	1.03	0.87	1.07	0.79	0.95	1.17	0.94	0.99	0.98	1.01	1.00
34	sz300189	SNKJ	0.67	0.96	0.70	drs	1.25	1.05	0.86	1.06	0.83	0.95	1.17	0.95	1.04	0.99	1.01	1.01
35	sz300511	XRSW	0.71	0.97	0.74	drs	0.91	1.25	0.83	1.07	1.01	0.81	1.23	0.91	0.93	1.02	1.02	0.97
36	sz300673	PDGF	0.66	0.96	0.69	drs	1.37	0.90	0.94	0.94	0.84	0.94	1.18	0.93	1.15	0.84	1.12	0.87
37	sz300972	WCJT	0.67	0.96	0.69	drs	0.93	1.29	0.86	1.14	1.01	0.80	1.24	0.89	0.95	1.03	1.06	1.02
		Mean	0.66	0.96	0.69		1.10	1.18	0.89	1.02	0.96	0.81	1.13	0.96	1.05	0.96	1.00	0.98
		AnimalHusban																
38	sh600195	ZMGF	0.95	0.97	0.98	drs	0.99	0.81	1.24	1.05	1.02	1.16	0.83	1.00	1.01	0.94	1.03	1.05
39	sh600201	SWGf	1.00	1.00	1.00	-	0.97	0.81	1.26	1.00	0.99	1.23	0.81	1.02	0.96	1.00	1.02	1.02

40	sh600598	BDH	1.00	1.00	1.00	-	0.98	0.82	1.21	0.98	1.01	1.24	0.79	1.02	0.99	1.01	0.96	1.01
41	sh600737	ZLTY	0.95	0.95	1.00	drs	0.94	0.88	1.28	1.00	1.12	1.14	0.86	1.04	1.06	1.00	1.10	1.04
42	sh600965	FCGF	0.94	0.97	0.98	drs	1.04	0.83	1.21	0.98	1.00	1.15	0.85	1.01	1.03	0.96	1.03	0.99
43	sh600975	XWF	0.96	0.97	0.99	drs	1.01	0.86	1.21	0.95	0.99	1.13	0.89	0.98	1.00	0.96	1.08	0.93
44	sh603363	ANSW	0.85	0.86	0.99	drs	1.09	0.79	1.13	1.02	1.03	1.22	0.82	0.99	1.12	0.97	0.94	1.01
45	sh603477	JXNM	0.97	0.97	0.99	drs	1.00	0.77	1.30	0.93	1.00	1.23	0.82	1.02	1.00	0.94	1.06	0.94
46	sh603566	PLK	1.00	1.00	1.00	irs	1.00	0.77	1.30	0.94	1.01	1.29	0.77	1.02	1.01	1.00	1.00	0.96
47	sh603609	HFGF	0.92	0.94	0.98	drs	0.92	0.87	1.23	1.02	1.10	1.18	0.85	1.03	1.02	1.02	1.04	1.06
48	sh603668	TMKJ	0.94	0.96	0.98	drs	1.01	0.73	1.34	1.02	1.01	1.39	0.79	1.01	1.02	1.01	1.06	1.03
49	sh603718	HLSW	0.98	1.00	0.98	irs	1.00	0.84	1.21	1.01	1.00	1.17	0.85	1.02	0.99	0.98	1.03	1.03
50	sz000702	ZHKJ	0.94	0.97	0.97	drs	1.00	1.00	1.02	1.05	0.99	1.13	0.87	1.01	0.99	1.12	0.88	1.06
51	sz000735	LNS	1.00	1.00	1.00	-	1.00	0.92	1.08	1.00	1.00	1.12	0.79	1.02	1.00	1.03	0.86	1.02
52	sz000876	XXW	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	1.11	1.17	1.12	0.84	1.11	1.17	1.12	0.84
53	sz002100	TKSW	1.00	1.00	1.00	-	0.92	1.08	0.81	1.15	0.91	1.12	0.82	0.99	0.84	1.22	0.66	1.14
54	sz002124	TBSP	0.91	0.92	0.99	drs	1.01	0.69	1.24	1.24	1.03	1.37	0.72	1.00	1.04	0.95	0.89	1.24
55	sz002286	BLB	0.95	0.96	0.99	drs	0.99	0.75	1.35	1.02	1.00	1.26	0.79	1.02	0.99	0.94	1.06	1.04
56	sz002299	SNFZ	1.00	1.00	1.00	-	1.00	0.61	1.51	0.97	1.10	1.56	0.67	1.00	1.10	0.96	1.01	0.97
57	sz002321	HYNY	0.94	0.95	0.99	drs	0.95	1.02	0.93	1.16	1.04	1.19	0.90	0.99	0.99	1.22	0.83	1.15
58	sz002385	BDN	1.00	1.00	1.00	-	0.96	0.96	1.00	1.00	1.09	1.16	0.85	1.03	1.05	1.10	0.84	1.03
59	sz002481	STSP	0.94	0.96	0.97	drs	1.02	0.85	1.22	0.96	1.00	1.17	0.83	1.01	1.02	0.99	1.01	0.97
60	sz002505	PDNM	0.86	0.9	0.96	drs	1.00	0.92	1.19	0.96	1.03	1.09	0.87	0.99	1.04	1.01	1.03	0.96
61	sz002556	HLGF	0.85	0.91	0.93	drs	0.91	0.95	1.18	0.97	1.12	1.19	0.84	1.00	1.02	1.13	1.00	0.97
62	sz002679	FJJS	1.00	1.00	1.00	irs	1.00	0.87	1.16	1.00	1.00	1.15	0.84	1.02	1.00	1.00	0.97	1.02
63	sz002688	JHSW	0.97	0.97	0.99	drs	0.98	0.84	1.22	0.99	1.00	1.19	0.84	1.01	0.98	1.01	1.02	1.00
64	sz002696	BYGF	0.94	0.96	0.97	drs	0.96	0.93	1.18	0.95	1.01	1.20	0.87	1.01	0.97	1.12	1.03	0.96
65	sz002714	MYGF	0.97	0.98	1.00	drs	1.03	1.00	1.00	1.00	1.16	1.97	0.66	1.02	1.19	1.97	0.66	1.02
66	sz002852	DDQ	0.95	0.96	0.98	drs	1.06	0.82	1.19	0.88	1.00	1.09	0.87	0.99	1.06	0.89	1.03	0.88
67	sz002868	LKSH	0.97	0.97	1.00	-	1.03	0.77	1.27	1.02	1.01	1.27	0.83	1.01	1.04	0.98	1.05	1.03
68	sz002891	ZCGF	0.94	0.96	0.97	drs	1.00	0.90	1.09	1.00	0.99	1.17	0.83	1.02	1.00	1.06	0.91	1.02
69	sz300094	GLSC	0.95	0.97	0.98	drs	0.96	0.97	1.08	1.00	1.01	1.09	0.87	1.01	0.98	1.06	0.94	1.01
70	sz300268	*STJW	1.00	1.00	1.00	-	0.87	0.83	1.20	0.93	0.89	1.29	0.77	1.01	0.78	1.07	0.92	0.95
71	sz300313	*STTS	0.88	0.88	1.00	-	1.13	0.86	1.17	0.98	1.00	1.13	0.87	1.01	1.13	0.98	1.02	0.99
72	sz300498	WSGF	1.00	1.00	1.00	-	1.00	1.00	0.83	1.20	1.20	1.09	0.93	1.07	1.20	1.09	0.78	1.28
73	sz300761	LHGF	0.97	1.00	0.97	drs	0.97	0.81	1.13	1.02	1.07	1.36	0.76	1.00	1.04	1.11	0.86	1.02
74	sz300967	XMGF	0.96	0.96	1.00	drs	1.00	0.80	1.25	0.98	1.01	1.33	0.79	1.02	1.01	1.06	0.98	1.00
		Mean	0.96	0.97	0.99		0.99	0.86	1.16	1.01	1.03	1.22	0.83	1.01	1.02	1.04	0.96	1.01
		Forestry					18-19	19-20	20-21	21-22	18-19	19-20	20-21	21-22	18-19	19-20	20-21	21-22
75	sh600265	*STJG	1.00	1.00	1.00	-	1.00	0.96	1.04	1.00	1.01	0.99	1.03	1.00	1.01	0.95	1.07	1.00
76	sz000592	PTFZ	1.00	1.00	1.00	-	1.00	1.00	0.99	1.02	0.98	1.01	0.98	1.01	0.98	1.01	0.97	1.02
77	sz000663	YALY	0.96	1.00	0.96	irs	1.03	1.01	1.00	1.00	0.98	1.03	0.96	1.02	1.01	1.04	0.96	1.02
78	sz002567	TRS	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	1.00	1.07	1.23	1.05	1.00	1.07	1.23	1.05
		Mean	0.99	1.00	0.99		1.01	0.99	1.01	1.00	0.99	1.02	1.04	1.02	1.00	1.02	1.05	1.02
		Fishery					18-19	19-20	20-21	21-22	18-19	19-20	20-21	21-22	18-19	19-20	20-21	21-22
79	sh600097	KCGJ	0.97	1.00	0.97	drs	1.02	0.97	0.98	1.00	1.00	1.04	1.02	0.99	1.01	1.01	1.00	0.99
80	sh600257	THGF	1.00	1.00	1.00	-	0.98	1.00	1.00	0.99	0.98	1.03	0.97	0.99	0.96	1.03	0.98	0.99

81	sh600359	XNKF	0.99	1.00	0.99	irs	1.01	1.00	0.98	0.99	1.01	0.99	1.02	1.01	1.03	0.99	1.00	1.00
82	sh600467	HDJ	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	1.03	1.16	0.84	1.01	1.03	1.16	0.84	1.01
83	sz000798	ZSYY	0.99	1.00	0.99	drs	1.00	0.98	0.97	1.05	1.00	1.04	0.97	1.27	1.00	1.02	0.95	1.34
84	sz002069	ZZD	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00	0.95	1.06	1.02	0.98	0.95	1.06	1.02	0.98
85	sz300087	QYGK	1.00	1.00	1.00	drs	1.00	1.00	1.00	1.00	1.02	1.06	0.95	1.24	1.02	1.06	0.95	1.24
		Mean	0.99	1.00	0.99		1.00	0.99	0.99	1.01	1.00	1.05	0.97	1.06	1.00	1.05	0.96	1.07

Note:TE3 represents the comprehensive efficiency score in the third stage.PTE3 denotes the pure technical efficiency in the third stage, while SE3 represents the scale efficiency at the third stage.

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**Table 5. Malmquist Index of 85 Listed Companies in the Agriculture, Forestry, Animal Husbandry, and Fishery Sectors (2018–2022)**

Year	Comprehensive Efficiency	Technological Progress Efficiency	Pure Technical Efficiency	Scale Efficiency	Malmquist 指数
2018-2019	1.38	0.71	1.01	1.38	0.99
2019-2020	1.15	0.86	1.00	1.15	0.99
2020-2021	0.95	1.07	0.90	1.05	1.01
2021-2022	1.19	0.84	1.13	1.05	1.00
Mean	1.16	0.86	1.01	1.15	1.00

#### 4. Conclusion

This study employs a three-stage Data Envelopment Analysis (DEA) model to assess the capital utilization efficiency of 85 listed companies in China's agricultural, forestry, animal husbandry, and fishery sectors. Additionally, it incorporates the Malmquist Index to evaluate the dynamic changes in capital utilization efficiency after adjustments. The findings offer valuable insights for listed enterprises in these sectors seeking to enhance their capital efficiency and provide guidance for many agricultural, forestry, animal husbandry, and fishery companies aiming for public listing. Overall, between 2018 and 2022, the capital utilization efficiency of 85 listed companies in China's agricultural, forestry, animal husbandry, and fishery sectors was relatively low. This can be attributed not only to intrinsic factors within the companies but also to the impacts of the global pandemic and related policies and regulations. Based on the comprehensiveness and objectivity of this study, the following conclusions can be drawn:

First, the comprehensive efficiency of the 85 listed companies in China's agricultural, forestry, animal husbandry, and fishery sectors was significantly overestimated during the initial phase of analysis. Government support and the limitations of professional technical personnel have constrained improvements in capital utilization efficiency, indicating that external environmental factors exert a considerable influence on the capital utilization efficiency of these companies.

Second, after excluding the disturbances from external environmental factors and random interference, the analysis revealed that the average comprehensive efficiency of agricultural companies in the sub-sector decreased from 0.94 to 0.66, while the average scale efficiency fell from 0.95 to 0.69, representing declines of 29.79% and 27.37%, respectively. This indicates that scale efficiency is a critical factor limiting the enhancement of capital utilization efficiency in agricultural firms. The decreasing returns to scale suggest excessive expansion without achieving optimal scale efficiency. To address this, agricultural companies need to enhance their management capabilities, streamline their organizations, integrate internal resources, accelerate structural adjustments, minimize ineffective inputs, and elevate output levels.

Third, between 2018 and 2022, the DEA-Malmquist dynamic analysis indicated a generally steady increase in the Malmquist index (MI) for the 85 listed companies in the agricultural, forestry, animal husbandry, and fishery sectors. Among the sub-sectors, agricultural companies exhibited relatively low total factor productivity, with ZLKJ showing the most significant fluctuations in its MI index. The primary reasons for this variability may include low efficiency in capital management, improper scale allocation, unexpected external risks, and the influence of related policies and regulations.

Based on the conclusions drawn, the following recommendations are proposed:

First, optimizing capital allocation and management while reducing the scale of government support funding is essential. The primary factor limiting the improvement of capital utilization efficiency in China's agricultural, forestry, animal husbandry, and fishery sectors is low scale efficiency, which is exacerbated by excessive government support funding. Over 90% of these companies are experiencing decreasing returns to scale. Therefore, these firms should rationally increase government support funding in accordance with their operational capabilities to fully leverage scale efficiency. This approach would also help diminish reliance on government funding, ultimately enhancing overall capital utilization efficiency within the agricultural, forestry, animal husbandry, and fishery industries.

Second, establishing a robust talent development and financial management system is crucial. Skilled technical personnel are the most vital resource in the commercialization of company products. Currently, there is an oversupply of personnel due to the expanded investment in research and development by companies. It is imperative to enhance talent management performance to retain the specialized technical personnel necessary for the company while lowering labor costs. Moreover, organizations should create clear training and promotion pathways for their skilled workers. Strengthening financial planning and forecasting will ensure stability in the company's financial health and implementing a reasonable capital utilization plan will further improve capital efficiency.

Third, it is imperative to increase investments in technological innovation and cultivate high-level scientific and technological talent. The adjusted average pure technical efficiency values indicate that many companies have not yet reached the efficiency frontier, highlighting significant room for scientific and technological advancement. Companies should focus on training specialized agricultural scientists to develop practical technologies that drive progress and innovation in agricultural practices.

Fourth, regular assessments of capital utilization efficiency should be conducted. Agricultural, forestry, animal husbandry, and fishery companies must establish a scientific evaluation system to periodically analyze capital utilization efficiency. This will enable them to identify and optimize any issues related to capital use in a timely manner. Additionally, employing methods such as Data Envelopment Analysis (DEA) can facilitate quantitative evaluations of capital efficiency, ensuring continuous improvement.

Fifth, enhancing capital structure management is essential. Companies in the agricultural, forestry, animal husbandry, and fishery sectors should strategically plan their capital structure, maintaining an appropriate debt-to-asset ratio to avoid excessive financial pressure from reliance on external financing. By optimizing financing methods and selecting suitable capital instruments, such as bonds and equity, they can reduce capital costs and improve capital utilization efficiency.

Sixth, the promotion of green finance and sustainable development strategies is crucial. Companies should actively respond to government policies regarding carbon peaking and carbon neutrality. By leveraging green financial tools, they can invest in sustainable development projects, such as renewable energy and environmental protection technologies. This not only enhances capital utilization efficiency but also attracts policy support and social recognition, thereby strengthening their competitive position in the market.

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