

A DEA-MALMQUIST ANALYSIS OF MILITARY-CIVILIAN COLLABORATIVE INNOVATION EFFICIENCY

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Abstract: Taking listed companies involved in civil-military integration (CMI) in Sichuan Province as the research sample, this paper constructs a multi-dimensional evaluation system comprising resource input, technological output, economic output, and strategic output. Notably, government subsidies are incorporated as an output indicator measuring the "strategic value" of enterprises. On this basis, the DEA-BCC model and Malmquist index model are employed to conduct static measurement and dynamic evolution analysis of the collaborative innovation efficiency of these enterprises from 2022 to 2024. The study finds that: the low scale efficiency of innovation in Sichuan's CMI enterprises is the main factor restricting the improvement of overall effectiveness, and there is significant efficiency differentiation within the industry, Total Factor Productivity (TFP) shows a slight overall upward trend but fluctuates significantly due to the external environment, presenting a non-equilibrium characteristic of being significantly driven by technological progress while lagging in management efficiency catch-up. The conclusions of this paper provide a reference for optimizing the allocation of regional civil-military integration resources.

Keywords: Civil-military integration; Collaborative innovation; DEA-Malmquist model; Strategic value

1 INTRODUCTION

Under the macro trend of increasingly fierce global technological competition and deepening game between major powers, coordinating development and security has risen to the core essence of national strategy. The report of the 20th National Congress of the Communist Party of China explicitly proposed to "consolidate and improve the integrated national strategic system and capabilities." This important assertion marks that China's civil-military integration development has moved beyond the stage of simple industrial combination and embarked on a new journey of deep integration across all factors, multiple fields, and high efficiency.

As a strategic rear area of the country and an important region for the national defense science and technology industry, Sichuan Province has become a comprehensive innovation and reform pilot zone and a national civil-military integration innovation demonstration zone, shouldering extremely special and major historical missions and practical responsibilities. In recent years, it has built a national defense science and technology industrial system characterized by distinct features such as nuclear energy, aerospace, and electronic information. However, limited by institutional barriers, private enterprises find it difficult to integrate into the military industrial resource system, and cannot effectively integrate their own advantageous resources with military industrial resources. This leads to problems such as low conversion rates of scientific research results and weak industrial chain synergy effects, which seriously restrict the improvement and breakthrough of regional innovation capabilities. How to scientifically evaluate the resource allocation efficiency of civil-military sci-tech collaborative innovation? How to identify key obstacles restricting collaborative innovation? These are urgent practical needs for guiding local governments to optimize policy supply and promote high-quality industrial development.

This study takes 14 listed companies participating in civil-military sci-tech collaborative innovation in Sichuan from 2022 to 2024 as the research objects. Using DEA and Malmquist index analysis methods, empirical research is carried out on the static efficiency and dynamic evolution of civil-military sci-tech collaborative innovation. It analyzes the key factors affecting the efficiency of civil-military sci-tech collaborative innovation and evaluates the efficiency of collaborative innovation, providing a policy basis for improving the development of civil-military collaborative innovation in Sichuan.

2 LITERATURE REVIEW

A review of existing literature reveals that research on civil-military science and technology collaborative innovation primarily addresses two areas. The first involves collaborative mechanisms. Li X L et al. explored the technological innovation ecosystem of civil-military integration (CMI) enterprises, emphasizing how interactions among enterprises, universities, and research institutions enhance innovation performance[1]. Lai Y et al. focused on information platform construction within the CMI ecosystem, arguing that such platforms effectively integrate resources and enhance collaborative efficiency[2]. The second area focuses on efficiency evaluation. Sun Z B and Li N et al. empirically analyzed the impact of fiscal and tax policies using the DEA-Tobit model, finding that moderate fiscal support significantly promotes innovation output[3]. Chen X et al. evaluated regional CMI innovation efficiency using a

stochastic frontier panel data model, identifying the institutional environment and market openness as major influencing factors[4]. Sun Z B further constructed a multi-dimensional evaluation method based on innovation environment, resource input, innovation mechanism, and output capability[5].

However, when constructing indicator systems, previous efficiency evaluation studies often follow traditional paradigms, overlooking the specific institutional context of CMI enterprises. This is particularly evident in the cognitive bias regarding the definition of "government subsidies." Traditional views typically treat government subsidies as financial instruments to correct market failures, focusing on their direct supplementary effect on R&D investment. However, Tang Q Q pointed out that government subsidies are not merely tools for regulating the market economy but also serve significant policy-based screening purposes[6]. Based on signaling theory, government subsidies possess a distinct "certification effect." Kleer R demonstrated that government R&D subsidies act as a "quality signal" rather than just financial support, implying that the recipient enterprise has passed strict qualification reviews and technical screening[7]. Feldman M P et al. further noted that obtaining government funding creates a "halo effect," conveying positive signals of high growth potential and strategic consistency to the market[8]. In the Chinese context, Guo Y similarly confirmed that government innovation subsidies signal technological advantages to external investors[9].

In summary, while existing research on collaborative mechanisms and innovation evaluation has laid a solid foundation for understanding CMI operations, several aspects remain to be improved. First, existing literature mostly treats government subsidies as exogenous environmental variables or pure financial inputs, focusing on their unidirectional incentive effect on innovation performance. It ignores that in the CMI context, obtaining subsidies signifies passing strict qualification reviews and strategic screening, thus possessing significant "signaling" functions and "strategic certification" attributes. Second, existing evaluation systems largely focus on explicit market performance such as patent counts or financial returns. They rarely include strategic value reflecting national will in output considerations, making it difficult to fully capture the dual identity of CMI enterprises as both "market economic entities" and "national defense construction carriers." Accordingly, this paper expands upon existing research by innovatively treating government subsidies as an output indicator measuring corporate "Strategic Value." By incorporating this into the DEA-Malmquist model, we aim to evaluate collaborative innovation efficiency more objectively and comprehensively.

3 RESEARCH METHODOLOGY

We use Data Envelopment Analysis (DEA) to evaluate the relative efficiency of complex Decision Making Units (DMUs) with multiple inputs and multiple outputs. The research objects of this paper are civil-military sci-tech collaborative innovation enterprises. Such enterprises are often affected by the dual influence of policies, markets, and technological cycles, making it difficult to operate under a completely ideal state of constant returns to scale. Moreover, input factors (such as R&D funds and personnel) have stronger controllability compared to output factors. Therefore, this paper selects the Input-oriented BCC model for static efficiency measurement. This model can further decompose Technical Efficiency (TE) into Pure Technical Efficiency (PTE) and Scale Efficiency (SE), thereby more accurately identifying the root causes of inefficiency.

Assuming there are n decision-making units (DMUs), each with p inputs and q outputs. Let x_{ij} be the i -th input of the j -th DMU, and y_{rj} be the r -th output of the j -th DMU. The planning form of the input-oriented BCC model is as follows:

$$\min \left[\theta - \left(\sum_{i=1}^p s_i^- + \sum_{r=1}^q s_r^+ \right) \right] \quad (1)$$

$$\sum_{j=1}^n \lambda_j x_{ij} + s_i^- = \theta x_{i0}, \quad i=1, 2, \dots, p \quad (2)$$

$$\sum_{j=1}^n \lambda_j y_{rj} - s_r^+ = y_{r0}, \quad r=1, 2, \dots, q \quad (3)$$

$$\sum_{j=1}^n \lambda_j = 1 \quad (4)$$

$$\lambda_j \geq 0, s_i^- \geq 0, s_r^+ \geq 0 \quad (5)$$

Where θ represents the comprehensive technical efficiency value of the decision-making unit ($0 < \theta \leq 1$). If $\theta=1$ and slack variables $s_i^-=0, s_r^+=0$, the DMU is DEA strongly effective; if $\theta < 1$, it indicates non-DEA effective. λ_j is the weighting coefficient; s_i^- and s_r^+ are the slack variables for input and output, respectively. Based on this model, Technical Efficiency (TE) can be decomposed into the product of Pure Technical Efficiency (PTE) and Scale Efficiency (SE), i.e.:

$$TE = PTE \times SE \quad (6)$$

To reveal the dynamic change trend and driving factors of innovation efficiency of civil-military integration enterprises in Sichuan Province, this paper further introduces the Malmquist Total Factor Productivity Index. The Malmquist index uses the distance function to quantitatively measure the productivity change of the decision-making unit from period t to period $t+1$. The output-based Malmquist index can be defined as:

$$M(x_{t+1}, y_{t+1}, x_t, y_t) = \left[\frac{D^t(x_{t+1}, y_{t+1})}{D^t(x_t, y_t)} \times \frac{D^{t+1}(x_{t+1}, y_{t+1})}{D^{t+1}(x_t, y_t)} \right]^{\frac{1}{2}} \quad (7)$$

Where $D^t(x_t, y_t)$ and $D^{t+1}(x_{t+1}, y_{t+1})$ represent the distance functions of period t and period $t+1$ respectively. This index can be further decomposed into Technical Efficiency Change (TEFCH) and Technological Progress Change (TECHCH):

$$TFPCH = TEFCH \times TECHCH \quad (8)$$

4 RESEARCH DESIGN

4.1 Sample Selection

Based on the "Measures for the Recognition of Civil-Military Integration Enterprises (Units) in Sichuan Province" (2018), this paper selects 14 listed civil-military integration companies in Sichuan Province covering key fields such as aerospace, advanced equipment manufacturing, digital economy, electronic information, and advanced materials as research objects. The period from 2022 to 2024 is set as the research period for collaborative innovation efficiency. ST stocks, *ST stocks, and enterprises with significant data deficiencies were excluded. Using the DEA method to evaluate collaborative innovation efficiency requires the number of Decision Making Units (DMUs) to be greater than 2 times the sum of input and output numbers. The number of civil-military integration listed companies selected in this paper is greater than 2 times the sum of input and output items, satisfying the rule of thumb for DEA usage. Relevant data mainly comes from CNINFO, the China National Intellectual Property Administration (CNIPA), and corporate annual reports. The overview of the sample companies is shown in Table 1.

Table 1 Decision-making Unit Information

Enterprise	Stock Code	Type	Scope of Business
Jiuyuan Yin Hai	002777	Military-to-Civilian	Information system integration, classified system construction
Wisesoft	002253	Civilian-to-Military	Air traffic control, radar control
Sichuan Changhong	002268	Military-to-Civilian	Nitrocellulose products
Dongfang Electric	600875	Civilian-to-Military	Hydroelectric power equipment, steam turbine generators
AECC Aero Science	600391	Military-to-Civilian	Engine systems
Chengfei Integration	002190	Military-to-Civilian	Lithium batteries
Yahua Group	002497	Civilian-to-Military	Industrial explosives, civilian blasting equipment
Tianqi Lithium	002466	Civilian-to-Military	Industrial lithium carbonate
Guibao Tech	300019	Civilian-to-Military	Silicone sealants
North Chemical	000710	Military-to-Civilian	Organic silicone room temperature rubber, silane coupling agents
Haite High-Tech	002023	Civilian-to-Military	Aviation power systems, aircraft maintenance
Sichuan Jiuzhou	300101	Civilian-to-Military	Radar, communications, electronics
Xuguang Electronics	600353	Civilian-to-Military	Metal-ceramic electric vacuum devices
Leejun Industrial	002651	Civilian-to-Military	Roller presses

4.2 Indicator Construction

Civil-military sci-tech collaborative innovation enterprises are characterized by fast development, high technological content, and the unification of economic and social values. A review of relevant literature reveals that when measuring innovation efficiency, most studies select two main categories of indicators: innovation input and innovation output. Some studies also consider factors such as information sufficiency and financial institution support [10,11]. This paper primarily measures the collaborative innovation efficiency values of the 14 sample enterprises from 2022 to 2024 from the aspects of innovation input and innovation output. The indicator selection is shown in Table 2.

4.2.1 Input indicators

In terms of input, drawing on the research of Wang Dandan and Xu Xin [12,13], three indicators are selected: R&D expenditure input, Number of R&D personnel, and Total assets, to measure the scale and intensity of resource input of enterprises in the process of civil-military sci-tech collaborative innovation. R&D expenditure directly reflects the financial support intensity for technological innovation activities; the number of R&D personnel reflects the core intellectual resource reserve for participating in collaborative innovation, and its scale and structure directly affect the execution efficiency and quality of results of innovation activities; total assets portray the enterprise's economic strength and resource allocation ability from an overall level, providing necessary material guarantees and risk buffering space for collaborative innovation.

4.2.2 Output indicators

In terms of output, this paper constructs a multi-dimensional evaluation system containing technological innovation output, economic benefit output, and strategic value output. First, referring to the practices of Sun Zhenqing and Guo Shufen [14,15], the Number of new invention patents and Operating income are selected as measurement indicators for

technological and economic outputs, respectively. The number of new invention patents intuitively reflects the original output scale of the enterprise's technological innovation activities; considering that CMI enterprises generally possess high-tech characteristics, operating income can effectively measure the market recognition and commercial realization capability of their technological achievements. Second, addressing the limitation that traditional research often treats government subsidies as exogenous environmental input variables, this paper combines the special institutional logic in the context of civil-military integration and takes Government subsidies recorded in current profit and loss as a Strategic Value Output Indicator. According to An J, government subsidies have a significant positive impact on corporate green innovation and the realization of social responsibility[16]. In the field of CMI, government subsidies often have a strong "screening mechanism" and usually only flow to advantageous enterprises that meet national strategic needs, break through key core technologies, or undertake major national defense tasks. Whether for continuous subsidies or to maintain a good political image, enterprises have strong motivations to strive for more external resources by improving comprehensive performance or actively engaging in production activities that conform to national strategic orientation. Therefore, this paper believes that government subsidies are essentially a "institutional certification" by the state of the enterprise's strategic value. Including it in the output system can effectively quantify the enterprise's response degree and contribution to national security strategy and policy orientation, thereby making up for the defect of "valuing market over strategy" in traditional evaluation systems.

Table 2 Civil-Military Sci-Tech Collaborative Innovation Efficiency Evaluation Indicator System

Category	Indicator	Indicator Meaning and Explanation
Input	R&D Expenditure Input I ₁	Direct expenses invested in carrying out technological R&D activities, reflecting the intensity of innovation capital input.
	Number of R&D Personnel I ₂	Total number of employees specifically engaged in R&D work, reflecting the level of enterprise innovation talent.
	Total Assets I ₃	The sum of all economic resources owned or controlled, reflecting the enterprise's comprehensive resource input capability.
Output	Number of New Invention Patents O ₁	Total number of invention patent applications submitted to CNIPA, measuring the output level of technological innovation results.
	Operating Income O ₂	Total income generated by the enterprise through core businesses, measuring market competitiveness and economies of scale.
	Government Subsidies O ₃	Financial fund subsidies received during the research period and directly recorded in the current income statement, reflecting the intensity of contribution to national defense strategy and policy support.

By constructing the DEA-Malmquist model evaluation system containing the above 6 indicators, it is possible to systematically analyze the full-chain efficiency characteristics of "Resource Input - Process Transformation-Value Creation" in the process of civil-military sci-tech collaborative innovation.

5 EMPIRICAL ANALYSIS

5.1 Descriptive Analysis of Input and Output

Taking 2022 as the base period (setting the value to 1), standardization processing was performed on relevant data to plot the trend of changes in input and output of civil-military sci-tech collaborative innovation in Sichuan from 2022 to 2024 (Figures 1 and 2 omitted, description follows).

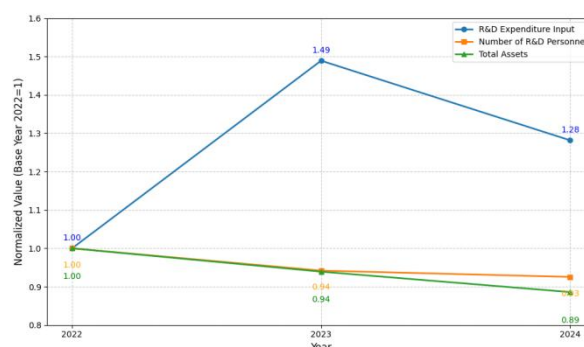


Figure 1 2022-2024 Trends in Sci-Tech Collaborative Innovation Inputs

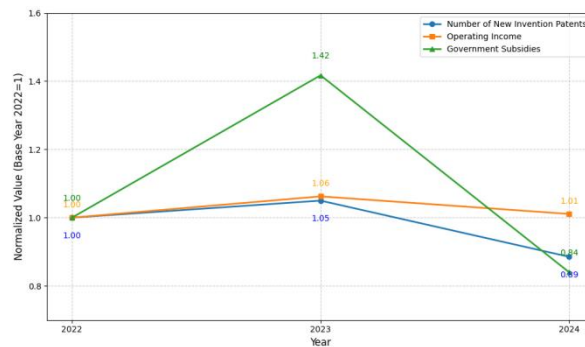


Figure 2 2022-2024 Trends in Sci-Tech Collaborative Innovation Output

From the trend analysis, the inputs and outputs of civil-military sci-tech collaborative innovation in Sichuan have shown fluctuations over the past three years. Looking at the input, R&D expenditure investment showed a dramatic increase in 2023. However, the number of R&D personnel and total assets did not expand with the increase in funds but instead showed a continuous slow downward trend. This phenomenon of "increasing money while decreasing people" indicates that the growth of investment during this period was mainly reflected in the increase of capital flow, which may be used more for equipment procurement, outsourcing services, or coping with rising costs, rather than effectively transforming into substantive accumulation of internal talent teams and asset scale, revealing the insufficiency of the enterprise's endogenous growth momentum.

Looking at the output, the trend of government subsidies is highly synchronized with R&D expenditure investment, peaking in 2023 and then falling in 2024. This situation indicates that the increase in R&D investment in 2023 may have been driven by government subsidies rather than spontaneous investment by enterprises based on market profits. More critically, the high amount of capital investment failed to translate into corresponding technological achievements; the number of new invention patents only rose slightly in 2023 and then declined in 2024. Main business income remained relatively stable but lacked explosive power, presenting an overall passive characteristic of fluctuating with policy changes.

5.2 DEA Model Static Analysis

This paper uses DEA 2.1 software to measure collaborative innovation efficiency. The overall results and specific results of the static evaluation of sci-tech collaborative innovation in 2024 for the selected 14 private high-tech enterprises participating in national defense industry construction are shown in Table 3 and Table 4.

Table 3 Overall Innovation Situation of Listed CMI Enterprises in Sichuan (2024)

Efficiency status	pure technical efficiency	scale merit (SE)	technical efficiency (TE)
Effective Quantity	10 (71%)	7 (50%)	7
Non-effective Quantity	4 (29%)	7 (50%)	7
Average Value	0.927	0.916	0.847

Table 4 Efficiency Measurement of Sichuan CMI Innovation Enterprises (2024)

Enterprise Code	Technical Efficiency (TE)	Pure Technical Efficiency (PTE)	Scale Efficiency (SE)	Effectiveness	Returns to Scale
Jiuyuan	1	1	1	DEA Strongly Effective	Constant
Yinhai	1	1	1	DEA Strongly Effective	Constant
Wisesoft	1	1	1	DEA Strongly Effective	Constant
Sichuan Changhong	1	1	1	DEA Strongly Effective	Constant
Dongfang Electric	0.672	1	0.672	Non-DEA Effective	Decreasing
AECC Aero Science	0.646	0.679	0.952	Non-DEA Effective	Increasing
Chengfei Integration	0.559	0.617	0.905	Non-DEA Effective	Increasing
Yahua Group	1	1	1	DEA Strongly Effective	Constant
Tianqi Lithium	1	1	1	DEA Strongly Effective	Constant
Guibao Tech	1	1	1	DEA Strongly Effective	Constant

Enterprise Code	Technical Efficiency (TE)	Pure Technical Efficiency (PTE)	Scale Efficiency (SE)	Effectiveness	Returns to Scale
North Chemical	0.825	0.993	0.831	Non-DEA Effective	Decreasing
Haite High-Tech	1	1	1	DEA Strongly Effective	Constant
Sichuan Jiuzhou	0.731	1	0.731	Non-DEA Effective	Decreasing
Xuguang Electronics	0.68	0.691	0.985	Non-DEA Effective	Increasing
Leejun Industrial	0.75	1	0.75	Non-DEA Effective	Increasing

Technical Efficiency (TE), as the core output indicator of the DEA model, reflects the ability of a decision-making unit to maximize output under given input constraints. Based on the empirical measurement of 14 CMI listed companies in Sichuan Province in 2024, the average technical efficiency of the sample enterprises reached 0.8471, indicating that there is 15.29% room for efficiency improvement in the industry as a whole. Further analysis reveals significant efficiency differentiation: DEA strongly effective enterprises and ineffective enterprises each account for 50% (7 companies each). This structural contradiction reveals a possible "innovation polarization" phenomenon in Sichuan's civil-military collaborative innovation field.

Pure Technical Efficiency (PTE) focuses on measuring the management level, technology conversion capability, and internal process efficiency of the DMU after eliminating the interference of scale factors. The results show that the PTE mean of the sample enterprises in 2024 reached 0.927, which is in a relatively high range. Among them, 10 enterprises were PTE effective (71.4%). Comparing TE and PTE, the main contradiction restricting efficiency is likely not universal management technology shortcomings, but rather improper scale allocation. Specifically, 71.4% of enterprises achieved optimal management technology under the given scale, but only 50% achieved comprehensive efficiency effectiveness.

Scale Efficiency (SE) measures whether the decision-making unit is operating at the "optimal production scale." The mean SE of the sample enterprises in 2024 was 0.916. Comparing the data, the pure technical efficiency mean is lower than the scale efficiency mean; however, the number of scale-ineffective enterprises (7) is far greater than that of pure technical ineffective enterprises (4). This verifies the deduction that improper scale allocation is the primary reason for the low innovation efficiency of sample enterprises.

In summary, the innovation efficiency of the 14 CMI listed companies in Sichuan in 2024 presents three core characteristics:

1. Moderate efficiency, huge potential: The overall technical benefit mean is passable, but there is still huge potential for improvement (15.3%) by optimizing resource allocation.
2. Polarization with prominent benchmarks: The industry presents a clear "7 strong, 7 weak" differentiation pattern.
3. Scale constraints, followed by management: The root cause of efficiency loss mainly comes from diseconomies of scale, followed by low pure technical and management efficiency.

5.3 Malmquist Index Dynamic Analysis

Since the DEA model is limited to static analysis, to make the results more scientific, this paper constructs the Malmquist Total Factor Productivity Index (TFPCH) based on panel data to explore the dynamic evolution trend and real drivers from 2022 to 2024. The results are shown in Table 5 and Table 6.

Table 5 Overall Malmquist Index of Sichuan CMI Innovation Listed Companies (2022-2024)

Time	Effch	Techch	Pech	Sech	Tfpch
2022-2023	1.189	0.38	1.121	1.061	0.451
2023-2024	0.665	2.41	0.875	0.76	1.602
2022-2024	0.927	1.395	0.998	0.9105	1.0265

Table 6 Malmquist Index Decomposition by Company (2022-2024)

Enterprise Code	Effch	Techch	Pech	Sech	Tfpch
Jiuyuan Yinhai	0.839	1.361	1	0.839	1.142
Wisesoft	1.181	0.913	1.382	0.855	1.078
Sichuan Changhong	0.725	0.887	0.846	0.857	0.643
Dongfang Electric	0.419	0.979	0.514	0.816	0.411
AECC Aero Science	1	0.8	1	1	0.8
Chengfei Integration	0.952	0.408	1	0.952	0.389

Enterprise Code	Effch	Techch	Pech	Sech	Tfpch
Yahua Group	0.648	0.97	0.802	0.809	0.629
Tianqi Lithium	0.621	1.163	0.728	0.853	0.722
Guibao Tech	0.931	0.639	0.931	1	0.595
North Chemical	0.647	0.758	0.815	0.793	0.49
Haite High-Tech	1.651	1.764	1.388	1.19	2.913
Sichuan Jiuzhou	1.702	1.124	1.931	0.881	1.912
Xuguang Electronics	1.357	1.721	1.23	1.104	2.336
Leejun Industrial	0.729	0.816	1	0.729	0.595
Jiuyuan Yin Hai	0.957	1.022	1.041	0.906	1.047

From an overall perspective, the Total Factor Productivity (TFP) of civil-military sci-tech collaborative innovation in Sichuan presents a slight overall increase but with severe fluctuations. The TFPCH mean for 2022-2024 is 1.0265, indicating an average annual growth of about 2.65%. However, this growth is not stable. In 2022-2023, TFP plummeted to a low of 0.451 due to a sharp decline in the Technological Progress Index (TECHCH = 0.38), indicating a huge impact from the contraction of the external technological environment or policy support. In 2023-2024, thanks to the explosive expansion of the technological frontier (TECHCH jumped to 2.41), TFP rebounded strongly to 1.602. This extreme volatility reveals that the current innovation system has not yet formed a stable endogenous growth mechanism. Notably, in 2023-2024, while the technological frontier expanded, the Technical Efficiency Change Index (EFFCH) dropped to 0.665, indicating that management capacity lagged behind the rapid rise in technical thresholds.

From an individual perspective, differentiation among enterprises is extremely significant. Leading enterprises like Haite High-Tech (TFPCH=2.913), Xuguang Electronics (2.336), and Sichuan Jiuzhou (1.702) achieved multiplied innovation efficiency through technological progress and efficiency improvement. However, companies like Chengfei Integration (0.389) and Dongfang Electric (0.411) are in a deep adjustment period. The decomposition of means shows that the sample enterprises' PECH mean is 1.041 (management is generally effective), while the SECH mean is only 0.906, becoming the main shortcoming dragging down overall performance.

6 CONCLUSION AND POLICY SUGGESTIONS

In this paper, we use the DEA-BCC model and Malmquist index model to empirically evaluate the collaborative innovation efficiency of 14 sample enterprises in Sichuan Province from 2022 to 2024. This paper provides several observations.

Observation 1. Low scale efficiency is the "short board" restricting the overall effectiveness of the industry. Empirical results show high Pure Technical Efficiency (PTE mean 0.927) but relatively low Scale Efficiency (SE mean 0.916). The main contradiction lies in the mismatch between resource input scale and output structure.

Observation 2. Sichuan's CMI innovation presents a non-equilibrium growth characteristic of "Driven by technological progress, but lagging in management catch-up." TFPCH > 1 indicates slight growth. Technological progress (TECHCH) is the sole core engine, while Technical Efficiency Change (EFFCH < 1) implies that most enterprises fail to keep up with the moving speed of the technological frontier ("Tech advances, Management retreats").

Observation 3. The industry presents a distinct "Dual Structure." There is a significant gap between the "7 strong" leading enterprises (like Haite High-Tech) and the "7 weak" enterprises in transition. The advantages of leading enterprises have not effectively spilled over to the entire industrial chain.

Based on the above conclusions, the following suggestions are proposed to further enhance the efficiency of military-civilian collaborative innovation in Sichuan Province:

Suggestions 1. Implement a differentiated "Scale Adaptation" strategy. For enterprises with decreasing returns to scale (mostly traditional heavy-asset types), guide them to control blind asset expansion and improve scale efficiency by divesting inefficient assets. For enterprises with increasing returns to scale (mostly emerging technology types), increase factor support (special funds, financing) to help them expand capacity.

Suggestions 2. Strengthen management empowerment and technology absorption to repair the "Catch-up Effect." Enterprises should shift focus from pure technology introduction to the innovation of internal management mechanisms, establishing agile management systems matching the speed of technological iteration. The government can build generic technology service platforms to reduce trial-and-error costs for SMEs.

Suggestions 3. Leverage the demonstration effect of "Chain Masters" to alleviate the "Dual Differentiation." Encourage leading "Chain Master" enterprises with leading TFP to lead the formation of innovation consortiums. Through technology standard sharing and management model output, drive downstream enterprises to improve management levels and repair the industry's overall "catch-up effect."

COMPETING INTERESTS

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