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The Study on Efficiency Evaluation of Agriculture Enterprise Using DEA-BC2 Model

Taking 88 Poverty-Stricken Counties in Sichuan China as an Example

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ABSTRACT

This article assesses the operational efficiency of agricultural enterprises focused on planting and breeding in 88 poverty-stricken counties within Sichuan Province. The evaluation is conducted through the utilization of the DEA-BC2 model. The aim is to validate the extent to which agricultural enterprises have contributed to the industrial development of impoverished households in recent years. Furthermore, the study intends to offer insights for selecting appropriate agricultural enterprise models in economically disadvantaged regions.

Keywords: Agricultural enterprises, operational efficiency, DEA models

1. Types of agricultural enterprises in China

The spectrum of agricultural enterprises in China encompasses several distinct categories, prominently including family farms, professional cooperatives, and leading companies.

1.1 Family farm

Family farms represent a pivotal facet of agricultural enterprise, marked by their engagement in large-scale, intensive, and commercial agricultural production and management. These farms center their operations around family members as the primary labor force, with agricultural income constituting the principal source of household earnings. The role of family farms in propelling agricultural economic advancement, expediting the trajectory of agricultural commercialization, and mitigating the urban-rural wealth divide is noteworthy. By optimizing returns within the framework of surmounting the economic limitations associated with small-scale peasant economies, family farms pivot the protective function of agriculture towards a profit-oriented stance. From an economic standpoint, the salient features of family farms encompass decision-making autonomy, specialized project execution, expanded production scale, adaptable management strategies, labor efficiency, and judicious resource allocation. As these attributes harmonize, family farms are poised to emerge as

novel catalysts for driving rural economic expansion.

1.2 Rural Professional Cooperatives

Rural professional cooperatives epitomize organizations that foster mutual assistance among their members by providing technological insights, informational resources, and services pertaining to agricultural production and management, all within the framework of rural household contract operations. These cooperatives position farmers as primary economic agents. While the ownership structure adheres to the modality of household contract operations, the integration of labor and capital engenders an innovative ownership framework. In terms of income distribution, the emphasis shifts from profit-centric goals to the equitable redistribution of profits among members, engendering a fresh paradigm of income apportionment. On the management front, rural professional cooperatives adhere to principles such as voluntary membership, the freedom to disengage from the cooperative, and democratic processes like election and decision-making. This management model constitutes a distinct framework.

Professional cooperatives encompass two principal variants: traditional cooperatives, characterized by a more relaxed structure, and joint-stock cooperatives, which foster clearer relationships between debt, rights, and interests, thereby facilitating collaborative risk and benefit sharing.

1.3 Leading companies

Leading companies denote government-certified enterprises that focus on the processing or distribution of agricultural products. These enterprises forge connections with farmers through diverse interest-based linkages, motivating farmers to enter the market fray. This synergy ensures the harmonious integration of production, processing, and sales, all calibrated to meet stipulated standards of scale and management. Leading companies exhibit three predominant characteristics:

- A robust scale, underscored by profitability, scale-driven efficiencies, and substantial production and processing capacities.
- A potent driving force that propels interactions and transformations within the agricultural ecosystem.

• Products that exude competitiveness, aligned with national industrial policies, or bolstered through governmental support.

Owing to their robust demonstration, guiding influence, and radiative impetus, leading companies have progressively garnered enhanced attention within the contours of agricultural industry evolution.

2. Empirical research

2.l Quantitative measurement of production efficiency

Production efficiency was systematically quantified across a cohort of 42,116 agricultural enterprises situated within 88 poverty-stricken counties. These enterprises collectively serve as focal points for evaluation.

Table 1 Operational Overview of Agricultural Enterprises in 88 Poverty-Stricken Counties, Sichuan Province, China (2024)

sort	Type	Subtotal (pcs)	Plant (pcs)	Breed (pcs)	Average output value (Ten thousand yuan RMB)	Average employment (pcs)	Sowing area (mu)	Fattened stock (pcs)	note
1	Family farm	16287	9972	6315	191200	87	319	4987	
2	Farmer cooperatives	24791	13635	11156	461700	146	463	14568	
3	Leading companies	1038	602	436	1172900	585	1577	176349	

Data source: Sichuan agriculture Statistical Yearbook 2024

2.1.1 Calculation method

(1) Quantitative measurement of output capacity

$R_{ij} = W_{ij} / X_{ij}$

In the formula, R represents the output rate of new agricultural management entities J in Region I. W represents the average sown area (number of slaughters). X represents the average output value. The higher the R, the higher the output capacity.

(2) Labor productivity

$K_{ij} = X_{ij} / S_{ij}$

In the formula, K represents the labor productivity of new agricultural management entities J in Region I. X represents the average output value and S represents the number of employees.

The higher the K, the higher the labor productivity.

2.1.2 Calculation results

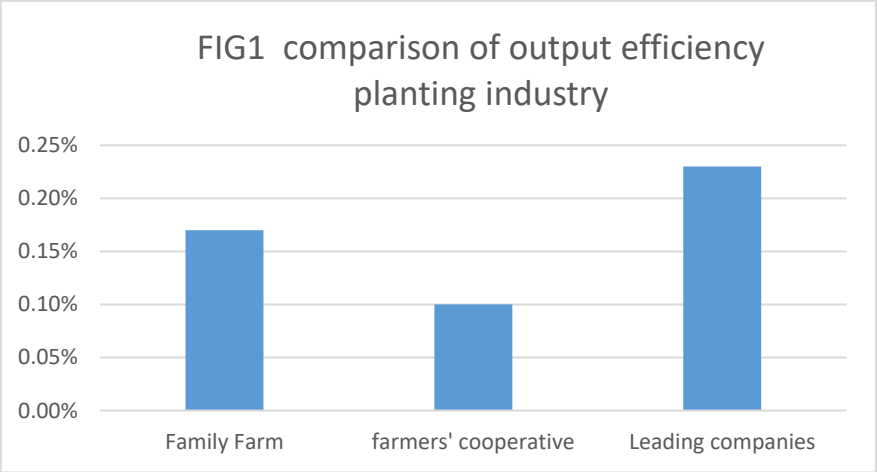
A comparison of the output rate and labor efficiency of family farms, farmer cooperatives and leading companies (see Table 2 for details) reveals that:

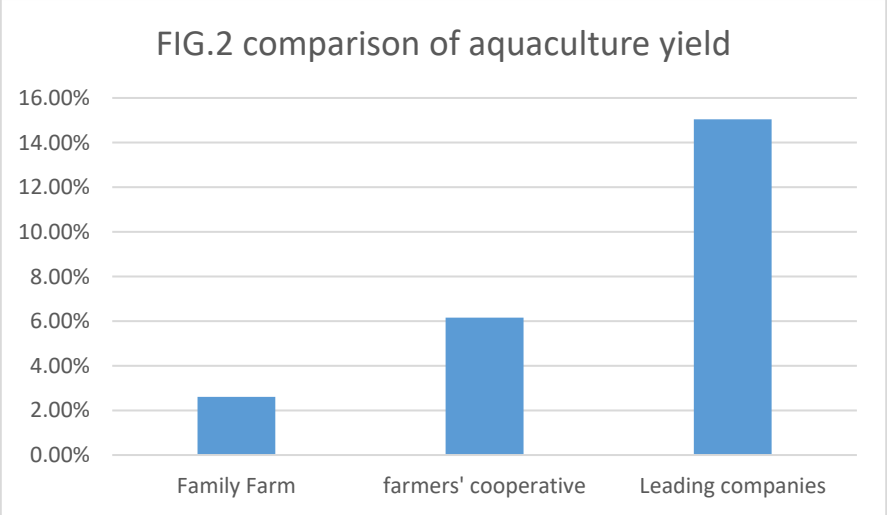
(i) In terms of planting industry, the output rate of leading companies is the highest, followed by family farms, and farmer cooperatives. (See Figure 1 for details)
(ii) In terms of animal husbandry, the output rate of leading companies is among the highest, followed by farmer cooperatives, and family farms. (See Figure 2 for details)
(iii) In terms of labor productivity, the output rate of leading companies is among the highest, followed by family farms and farmer cooperatives. (See Figure 3 for details)

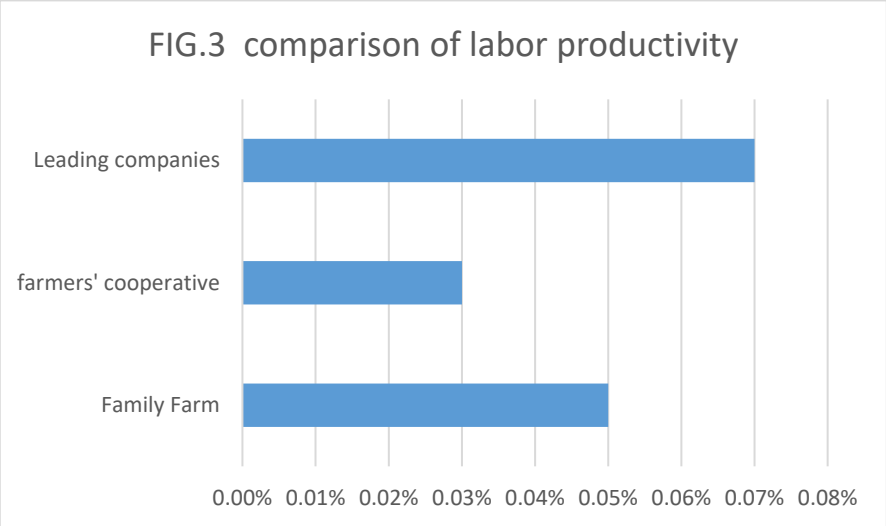
Table 2 Production efficiency of agricultural enterprises in 88 poverty-stricken counties of Sichuan Province, China in 2024

sort	Type	Plant yield rate	Breed output rate	Labor productivity	note
1	Family Farm	0.17%	2.61%	0.05%	
2	farmers' cooperative	0.10%	6.16%	0.03%	
3	Leading companies	0.23%	15.04%	0.07%	

Data source: Sichuan agriculture Statistical Yearbook 2024







2.2 Comparison of production and operation efficiency of new business entities

2.2.l Comparison methods

Considering increasing returns to scale(IRTS)and decreasing returns to scale(DRTS), DEA-BC² model is adopted to evaluate the production and operation efficiency of agricultural enterprise in 88 poverty-stricken counties, and deduce pure technical efficiency (PTE) and scale efficiency (SE), that is, overall efficiency (TE) = pure technical efficiency (PTE) × scale efficiency (SE).

Hypothesis: $X_j=(X_{1j},X_{2j},\ldots X_{mj})^T, j=1,2,3\ldots,n; y_j=(y_{1j},y_{2j}\ldots,y_{mj})^T\ j=1,2,\ldots,n;$

$$\left(D_{BC}^{\ 2}\right)=\begin{cases}\min\theta=V_D\\ s.t.\sum_{j=_1}^{m}x_jy_j+s^-=\theta x_{j_0}\\ \sum_{j=_1}^{m}y_jy_j-s^+=y_{j_0}\\ \sum_{j=_1}^{m}y_j=1\\ s^-\geq 0,s^+=\geq 0,y_j\geq 0,j=1,2,\ldots,n\end{cases}$$

If any optimal solution $y^o,s^{-o},s^{+o},\theta^o$ of linear programming problem D_{BC^2} has $\theta^o=1$, then DMU j_o is weakly DEA efficient. If $\theta^o=1$ and $s^{-o},s^{+o}=0.$ then DMU j_o is DAE efficient.

When introducing non Archimedes infinitesimal ε After that, we can obtain:

$$(\overline{D}\varepsilon)\begin{cases}\min\theta - \varepsilon\left(\hat{e}^T S^- + e^T s^+\right)\\ s.t.\sum_{j=1}^{m} x_j y_j + s^- = \theta x_{j_0}\\ \sum_{j=1}^{m} y_j y_j - s^+ = y_{j0}\\ \sum_{j=1}^{m} y_j = 1\\ s^- \geq 0, s^+ \geq 0,\ j = 1,2\ldots,n\end{cases}$$

Among them: $\hat{e}^T = (1,1,...,1) \in E^m, e^T = (1,1,...,1) \in E^m$ .Hypothesis ε is a non archimedes infinitesimal, and the optimal solution of the union is $y^o, s^{-o}, s^{+o}, \theta^o$.then there are: if $\theta^o=1$, then the decision unit j_o is weak DAE effective. $\theta^o=1$ and $S^{-o}=0, S^{+o}=0$, then the decision unit j_o is DEA effective.

The evaluation process is underpinned by distinct input variables, tailored to different dimensions of analysis, while the output variables remain consistent across the evaluation frameworks.

Evaluation Based on Total Output Value:

The input variables within this assessment stem from the evaluation of total output value. These encompass labor, sown area, and total expenditure. The output variable, in this context, remains the total output value.

Evaluation Based on Output Value per Unit Area:

In the framework considering output value per unit area, the input variables shift to average labor per unit area (mu) and average expenditure per unit area (mu). The output variable corresponds to the land output rate.

Evaluation Based on Unit Labor:

Within the purview of unit labor evaluation, the input variables retain the average labor per unit area (mu) and average expenditure per unit area (mu). The output variable, however, pertains to labor productivity.

Each evaluation approach encapsulates a distinct facet of agricultural enterprise efficiency, fostering a comprehensive understanding of the operational dynamics across varying dimensions.

2.2.2 Conclusion

This study highlights discernible variations in the production efficiency among various new business entities, with a prevailing trend indicating higher production efficiency within leading companies. In impoverished regions, family farms exhibit relatively elevated comprehensive efficiency, attributable to the robust development of the planting industry. Conversely, farmer cooperatives emerge as more efficient within the breeding industry. Specific findings are as follows:

Planting Industry: The comprehensive efficiency within the planting industry is notably higher for leading companies, while farmer cooperatives lag behind. The disparities in technical efficiency stand out as the principal driver for the overall efficiency gap, as detailed in Table 3.

Breeding Industry: Within the breeding sector, leading companies again showcase superior comprehensive efficiency, while family farms manifest comparatively lower efficiency levels. Although leading companies hold an advantage in technical efficiency over farmer cooperatives, their overall efficiency advantage is less pronounced due to the recent impact of environmental protection policies on scale efficiency. Refer to Table 4 for a comprehensive breakdown.

In summation, this analysis underscores the intricate landscape of production efficiency across different enterprise types. While leading companies tend to excel overall, the nuanced dynamics in specific industries and external factors, such as environmental policies, substantiate the need for a multi-dimensional evaluation approach. The insights gleaned from this study contribute to a more informed decision-making process for selecting and promoting agricultural enterprise models in impoverished areas.

Table 3 Comparison of production efficiency values of planting industry

Categories	Overall efficiency	Technical efficiency	Soale efficiency	Scale efficieney Increases counting	Scale efficieney Constant counts	Scale efficieney Constant down	note
Family Farm	0.44	0.58	0.76	3	2	6	
farmers' cooperative	0.41	0.54	0.76	9	1	12	
Leading companies	0.58	0.71	0.81	2	2	2	

Data source: Sichuan agriculture Statistical Yearbook 2024

Table 4 Comparison of production efficiency values in the breeding industry

Categories	Overall efficiency	Technical aiency	Soale efficiency	Scale efficiency Inoreases counting	Soale efficiencyconstant counts	Soale efficienay counts down	note
Family Farm	0.52	0.55	0.86	0	0	8	
farmers'	0.79	0.71	0.90	5	0	12	

cooperative						
Leading companies	0.81	0.91	0.89	2	3	7

Data source: Sichuan agriculture Statistical Yearbook 2024

3. Existing problems

3.l Overall Development Lag:

The developmental disparities are evident across distinct regions, as exemplified by the progress of farmer cooperatives in Deyang City (a developed area), Guangyuan City (a poor area), and Liangshan City (a deeply impoverished area). As of the close of 2024, the number of cooperatives in these cities stood at 3308, 3859, and 6667, with corresponding member counts of 71, 45, and 24. These cooperatives collectively sold agricultural products amounting to 930,000 yuan, 457,700 yuan, and 132,700 yuan, respectively. In contrast, Ganzi City has cultivated 2,865 farmer cooperatives housing 58,300 members, including 56,700 farmer members, translating to a mere 20 members per cooperative. Notably, only 676 farmer cooperatives uniformly vend over 80% of agricultural products, with each cooperative generating sales of 67,300 yuan. This figure constitutes a substantial 78.62% of the average operational income across the cooperatives.

The observed disparities underscore the need for targeted interventions to bridge the development gap among different regions and foster equitable progress in the realm of farmer cooperatives.

Table 5 Comparison table of operation quality of cooperatives in 2024

Regions	Number of oooperatives (PCS)	The community drivesthe number of farmers (Households)	Total value ofagricultural products sold （Ten thousand yuan RMB）	note
Deyang City	3308	71	93	Non-poor areas
Guangyuan city	3859	45	45.77	Poor area
Liangshan city	6667	24	13.27	Partial Deep Poverty
Ganzhi city	2865	20	6.73	Deep poverty across the board

Data source: Sichuan agriculture Statistical Yearbook 2024

3.2 There are flaws in leading farmers to become rich:

The advancement of agricultural enterprises in impoverished areas is hampered by limited organizational scale and inadequate socialized services. There remains a substantial gap between impoverished and non-impoverished regions concerning member engagement, industry development, and the alignment of production and sales. This deficiency impedes the immediate potential for these enterprises to take on a leadership role.

3.3 Nonstandard Operation:

Using cooperatives as a lens, it's apparent that cooperatives in impoverished regions are often characterized by loose structures. Some even lack proper management organizations or authentic membership. Transparency in operations is lacking, and internal oversight mechanisms are inadequate. Persistent issues in business management, financial accounting, and capital oversight persist. Instances arise wherein cooperatives pursue individual gains under the guise of collective efforts. Financial investments intended for infrastructure, seeds, labor, and project subsidies occasionally divert to cooperatives and enterprises, instead of being distributed to members and the impoverished.

4. Countermeasures and Suggestions:

4.1 Deepening Rural Reform:

It is advisable to undertake the separation of collective land ownership, rural household contracting rights, and land management rights. By delving into the reform of rural land systems, agricultural operational mechanisms, and the collective property rights system, conditions can be established to effectively augment the property-based income of impoverished households. Measures like revitalizing dormant assets, converting collective assets into equities, and transforming land into shares can be employed to bolster such efforts.

4.2 Development and Expansion of Agricultural Enterprises:

Enhancing the agricultural investment climate is recommended, along with incentivizing entities and individuals to lead and establish novel agricultural management entities. Concurrently, supporting the growth of socialized service organizations is essential. Furthermore, advocating for standardized farmers' cooperative organizations and demonstrating the construction of such cooperatives can have a positive impact. Fostering provincial-level exemplar cooperatives and family farms, expediting the agricultural professional manager system, and heightening cooperative management proficiency and competitiveness should be priorities.

4.3 Development of Appropriate-Scale Operations:

Guided by principles of legality, voluntariness, and compensation, the market's resource allocation influence should be harnessed. Diversified large-scale operations, like land transformation and service-oriented initiatives, can be nurtured through measures such as management rights circulation, cooperative shareholding, substitutional cultivation and planting, and land trusteeship. Encouraging

agricultural enterprises to establish multi-level interest connections with impoverished households can facilitate a more equitable distribution of industrial developmental dividends.

The recommended measures and suggestions collectively foster a comprehensive strategy to address the identified problems and pave the way for enhanced efficiency and growth in the agricultural enterprise sector within impoverished areas.

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