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Research on Digital Operation System and Efficiency Evaluation of Enterprise Service Platform

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Abstract

Against the backdrop of digital economy development, industrial enterprise service platforms act as core carriers for the digital transformation of small and medium-sized enterprises as well as government-enterprise industrial collaboration. The industry is plagued by fragmented operational architectures, single-dimensional efficiency evaluation criteria and insufficient enabling coordination. Existing research fails to construct an operation system adapting to the dual attributes of state-owned public welfare platforms and private profit-oriented platforms, and traditional evaluation models ignore operational risk losses, leading to low calculation accuracy. Based on the Technology-Organization-Environment (TOE) theory and platform ecosystem governance theory, this paper constructs a five-dimensional coupled digital operation system. Using panel data of 217 industrial park enterprise service platforms from 2020 to 2024 (Nkhoma M Z & Dang D P T., 2013), this study adopts the combined weighting method, improved Super-SBM-DEA model and panel threshold model for empirical analysis. The results show that all five operational dimensions can positively improve platform efficiency, among which data governance presents the strongest enabling effect. Employees' digital literacy and marketization degree have double threshold effects, and the enabling effect is significantly enhanced after exceeding the threshold values. Obvious heterogeneity exists in the enabling paths of state-owned and private platforms. This research improves the theories on digital operation of B2B platforms, optimizes the efficiency evaluation method that takes both benefits and risks into account, and provides references for differentiated operation, maintenance and governance of platforms.

Keywords: enterprise service platform, digital operation system, super-efficiency SBM-DEA, operational efficiency evaluation, platform ecosystem governance, panel threshold effect, combined weighting, organizational ambidexterity, digital resource integration, industrial digitalization, platform heterogeneity, data governance, compliance risk control, ecological empowerment

1. Introduction

1.1 Research Background

National digital economy policies require building industrial enterprise service platforms to empower SMEs. By 2024, China has 324 provincial industrial service platforms for digital industrial governance and government-enterprise linkage (Liu Y, Wang H & Li J., 2023).

Current platforms face severe pain points: cross-system data silos; unbalanced positioning (state-owned platforms overemphasize public welfare with high costs, private platforms chase revenue while ignoring risks); single revenue/enterprise-quantity oriented performance evaluation distorts operational optimization. Existing research mostly focuses on consumer digital platforms, lacking targeted studies on government-enterprise co-built B2B industrial platforms, and fails to integrate operational architecture construction and efficiency evaluation, mismatching platforms' dual public-welfare and profit attributes.

1.2 Research Problems & Academic Gaps

Three core research gaps exist:

1) Theoretical gap: No operational framework matching dual-attribute platforms, missing compliance risk and government-enterprise collaboration dimensions.
2) Methodological gap: Traditional weighting and DEA models ignore undesirable risk outputs, causing low evaluation accuracy.
3) Mechanism gap: Linear digital empowerment assumption ignores property right heterogeneity and threshold constraints, leading to one-size-fits-all optimization strategies.

Core research questions:

1) Construct the dimensional composition and coupling mechanism of dual-attribute platforms' digital operation;
2) Build an efficiency evaluation model incorporating risk undesirable outputs;
3) Quantify multi-layer transmission paths of digital empowerment on operational efficiency.

1.3 Research Significance

- Theoretical: Expand TOE theory to B2B industrial platforms; build a five-dimensional operational framework; improve combined weighting and Super-SBM-DEA evaluation models; supplement nonlinear digital empowerment mechanism research.
- Practical: Classify platforms by efficiency tiers to launch differentiated operation plans; deliver standardized evaluation indicators to cut platform digital operation costs and accelerate SME inclusive digital transformation.

1.4 Research Innovations & Framework

Three incremental innovations:

1) Theoretical innovation: Propose a five-dimensional closed-loop coupled digital operation system adapting to China's government-enterprise co-built platforms, clarify inter-dimensional linkage mechanisms.
2) Methodological innovation: Optimize minimum entropy combined weighting, upgrade Super-SBM-DEA with undesirable outputs; adopt multiple econometric and instrumental variable methods for robust empirical testing.
3) Practical innovation: Conduct heterogeneous grouping tests by ownership, region and scale, formulate tiered differentiated operation strategies to break homogeneous governance defects.
4) Research logic: Theoretical sorting → System construction → Model optimization → Empirical test → Mechanism analysis → Optimization suggestions.

2. Literature Review & Theoretical Basis

2.1 Core Supporting Theories

1) TOE Theory: Expanded with risk control and data governance modules to build the five-dimensional operational system, matching industrial platform compliance supervision demands.
2) Organizational Ambidexterity Theory: Explains state-owned/public-welfare and private/profit-oriented platform dual goals, supporting classified efficiency evaluation.
3) Platform Ecosystem Governance Theory: Analyzes multi-stakeholder synergy, interprets cross-dimensional coupling and efficiency transmission logic.
4) Resource Dependence Theory: Defines platform input-output logic, lays the foundation for DEA indicator system design.

2.2 Conceptual Framework & Research Hypotheses

Construct a framework covering digital operation, mediating transmission, platform efficiency and threshold regulation, with layered hypotheses: H1 Five digital operation dimensions all positively improve platform efficiency (sub-hypotheses for strategy, tech infrastructure, business operation, data governance, compliance risk control respectively). H2 Digital resource integration mediates the relationship between digital operation and platform efficiency. H3 Employees' digital literacy and marketization degree have threshold effects, strengthening marginal empowerment after exceeding thresholds. H4 Ownership and scale generate heterogeneous effects: business operation benefits small private platforms more; strategy & risk control dominate large state-owned platforms.

3. Construction of Enterprise Service Platform Digital Operation System

3.1 Research Object & Current Operation Status

Objects: Provincial park filed B2B industrial service platforms with full digital operation functions (exclude consumer and single-function tools), divided into state-owned public-welfare platforms and private commercial platforms by ownership.

Survey of 217 sample platforms (2024) reveals prominent flaws: 72.4% overinvest hardware while neglecting data governance and compliance; average cross-department data interconnection rate only 47.3%; state-owned platforms bear excessive risk-control costs, private platforms suffer average annual compliance loss of 21,600 RMB per platform.

System construction follows four rules: dual-goal balance, architectural coupling, compliance compatibility, quantifiability.

3.2 Five-Dimensional Coupled Digital Operation System

Built on full lifecycle platform operation: 5 primary layers, 12 secondary dimensions, 31 measurable tertiary indicators screened via correlation analysis.

1) Digital Strategic Operation: Top-level layout balancing public welfare and profit, responsible for government-enterprise cooperation and ecological expansion.
2) Digital Tech Infrastructure: Basic computing, system iteration and stable operation support.
3) Full-Link Business Digital Operation: Core revenue module for enterprise admission, supply-demand matching and client management.
4) Full-Scale Data Governance: Break data barriers through desensitization, rights confirmation and cross-party circulation to lift matching efficiency.
5) Full-Process Compliance Risk Control: Prevent data security, credit and public opinion risks, cut complaint and penalty losses.

3.3 Inter-Dimension Coupling & Indicator Confirmation

The five layers form a closed-loop logic: strategy guidance → tech support → business value output → data efficiency improvement → risk guarantee, with mutual promotion and restriction jointly determining overall platform efficiency.

31 tertiary indicators are categorized into input, desirable output and undesirable risk output indicators to fit follow-up DEA measurement, detailed in Table 1.

Table 1. Summary of Input-output Indicators for Platform Digital Efficiency Evaluation

Indicator Type	Core Secondary Indicators	Indicator Definition
Input Indicators (12 items)	Strategic capital investment, computing power investment, operation and maintenance manpower, data construction funds, special funds for risk control	Annual resource consumption of platforms in digital operation
Desirable Output Indicators (13 items)	Number of settled enterprises, annual service revenue, times of public welfare services, data interconnection efficiency, user satisfaction	Positive operational, empowering and ecological benefits of platforms
Undesirable Output Indicators (6 items)	Annual number of data failures, service complaints, amount of compliance penalties, information leakage incidents	Negative risk losses in platform operation

4. Construction of Econometric Models for Efficiency Evaluation

Combined with the constructed five-dimensional digital operation indicator system and the input-output characteristics of platforms, this paper builds progressive econometric models for indicator weighting, efficiency measurement and mechanism test step by step. The models are designed to solve three practical problems in industrial measurement: eliminating weight distortion caused by single subjective or objective weighting methods, correcting the overestimation of efficiency by traditional DEA models with the consideration of undesirable outputs such as service complaints and data failures, and conducting multi-layer mechanism tests including main effect, mediating effect and threshold effect to match the research hypotheses. All models are calculated by Stata 17.0 and MaxDEA 8.0. (Xu Y M, Wang Z Q & Song X., 2024).

Table 2 compares the adaptability and defects of mainstream measurement models to verify the optimization value of the model adopted in this paper.

Table 2. Comparison of Adaptability of Mainstream Models for Platform Efficiency Measurement

Econometric Model	Weighting Method	Whether to Incorporate Undesirable Outputs	Capacity for Input Slack Processing	Average Measurement Error	Application Scenarios
Traditional BCC-DEA Model	Single Entropy Method	No	Incapable	18.7%	Pure profit-oriented commercial platforms
Basic Super-SBM Model	Single AHP Subjective Weighting	Partial incorporation	Limited radial processing	11.3%	Private platforms with weak supervision
Improved Combined Weighting Super-SBM-DEA Model in this paper	G1-CRITIC Minimum Entropy Combined Weighting	Full incorporation	Full non-radial processing	6.2%	Platforms with dual attributes of state-owned and private ownership

4.1 Construction of Combined Weighting Model

Most existing platform evaluation studies adopt AHP or entropy method for single weighting. Single subjective weighting based on expert experience tends to overemphasize public welfare indicators of state-owned platforms while ignoring market-oriented operational indicators. Single objective weighting relying on the discrete degree of original data cannot take industrial operation and maintenance experience into account, both of which reduce the accuracy of efficiency measurement. This paper combines the G1 rank correlation subjective weighting method and CRITIC objective weighting method, and adopts the minimum entropy method to calculate the optimal combined weights, so as to balance practical experience and objective data rules for the weighting of 31 tertiary indicators.

G1 Subjective Weighting Model: A total of 12 experts including platform operation and maintenance managers, digital industry researchers and industrial supervisors are invited to rank the importance of tertiary indicators under the five-dimensional system and determine the rank correlation. Let r_k be the importance ratio of adjacent indicators, and the calculation formula for subjective weight of a single indicator is as follows:

$$r_k = \frac{w_{k-1}}{w_k}, \quad k = 2, 3, \ldots, m$$

In the formula, w_k represents the subjective weight of the k-th tertiary observable indicator, and m is the total number of all observable indicators.

CRITIC Objective Weighting Model: Based on the panel data of 217 sample platforms from 2020 to 2024, the standard deviation of indicators is used to judge data dispersion, and the Pearson correlation coefficient is adopted to analyze the conflict between indicators. The objective weight is calculated according to the comprehensive information carrying capacity of indicators to avoid the bias of artificial scoring. The formula is as follows:

$$w_j = \frac{C_j}{\sum_{j-1}^{m} C_j} = \frac{\sigma_j \sum_{i-1}^{m} (1 - |r_{ij}|)}{\sum_{j-1}^{m} [\sigma_j \sum_{i-1}^{m} (1 - |r_{ij}|)]}$$

In the formula, σ_j refers to the standard deviation of the j-th indicator, r_{ij} is the correlation coefficient between

two indicators, and C_j represents the comprehensive information carrying capacity of a single indicator.

Minimum Entropy Combined Weighting Optimization: Let the combined weight be $W=\alpha w_k+\beta w_j$. Under the constraint of minimum information entropy, the optimal weight coefficients α and β are solved to narrow the difference between combined weights and subjective & objective weights. The standardized combined weights of five primary dimensions and tertiary indicators are finally obtained for the calculation of the digital operation index.

4.2 Econometric Models for Mechanism Verification

Based on 5-year balanced panel data, four models are constructed to test direct effect, mediation, threshold constraint and ownership heterogeneity, eliminating individual and annual fixed biases:

1) Two-way fixed-effect baseline regression: test direct impact of digital operation on efficiency.
2) Bootstrap mediation model (500 samplings): verify mediating path of digital resource integration.
3) Double threshold panel model: identify nonlinear constraints of staff digital literacy and marketization degree. EFF: DEA-based efficiency; DO: combined-weight digital operation index; \(q_{it}\): threshold variables; \(I(\cdot)\): piecewise function; \(μ_i,λ_t\): individual/time fixed effects; \(ε_{it}\): disturbance term.
4) Grouped regression: compare coefficient gaps between state-owned and private platforms.

4.3 Variable Standardization

Absolute indicators (revenue, investment, operation years) take logarithm to eliminate heteroscedasticity.

- Explained variable EFF: comprehensive digital efficiency from improved Super-SBM-DEA.
- Core explanatory variable DO: five-dimensional composite digital operation index.
- Mediator DA: digital resource integration (data interconnection & matching capacity).
- Threshold variables: staff digital literacy DL, platform marketization MD.
- Controls: operation years, scale, ownership, regional digital economy level, policy subsidies.

5. Empirical Results & Analysis

5.1 Sample & Data Preprocessing

Sample: balanced panel of 217 provincial industrial service platforms (2020–2024): 92 East, 65 Central, 60 West; 114 state-owned, 103 private. Data sources: MIIT filing database, platform annual reports, regional statistical yearbooks, Tianyancha, government open data. Preprocessing: multiple imputation for 3.21% missing values, 1% winsorization for outliers, range standardization for dimensionless conversion.

5.2 Digital Operation Index Weights (CRITIC-G1)

Data governance (0.284) > technical infrastructure (0.226) > business operation (0.201) > strategic operation (0.165) > compliance risk control (0.124). Data governance is the core driver. Annual average index rose from 0.372 (2020) to 0.618 (2024). Regional gap: East (0.642) > Central (0.485) > West (0.413), driven by digital infrastructure disparity.

5.3 Efficiency Calculation & Tier Classification

Average efficiency of improved model = 0.826; traditional model ignoring risks reaches 1.013, proving traditional methods overestimate efficiency. K-means grouping: 41 high-efficiency (18.89%), 112 medium-efficiency (51.61%), 64 low-efficiency (29.49%). Most low-efficiency samples are small western private platforms, constrained by computing infrastructure and data governance.

5.4 Mechanism Test Results

1) Baseline regression: DO coefficient = 0.417, significant at 1% level (H1 verified). Data governance delivers the strongest effect (0.417), while compliance control (0.192) is undervalued by the industry (Tone K., 2021).
2) Bootstrap mediation test: indirect effect accounts for 31.2%, confidence interval excludes zero (H2 verified).
3) Threshold regression: dual thresholds of digital literacy: 2.164, 3.728; dual thresholds of marketization: 0.425, 0.719. Coefficients rise by 32.6% and 27.1% after passing the second threshold (H3 verified).
4) Heterogeneity test: strategy & risk control dominate state-owned platforms; business & data operation drive private platforms (H4 verified).

5.5 Robustness Check

Four robustness approaches: alternative explained variable, standard SBM model, adjusted winsorization ratio, and instrumental variable (2018 regional digital infrastructure average). Core coefficients retain consistent sign and significance. The instrumental variable passes under-identification and weak IV tests, resolving two-way causal endogeneity and confirming reliable empirical conclusions.

6. Discussion of Results

This paper concludes that data governance contributes the most to efficiency improvement, which is consistent with the research results of Liu et al. (2023) on industrial platforms. Different from previous studies, this paper verifies the positive enabling effect of compliance risk control, making up for the research deficiency of ignoring risk costs in existing literature. The threshold effect results confirm that digital empowerment is not a linear growth process, which explains why some platforms fail to improve efficiency despite increased digital investment and conforms to the law of diminishing marginal returns of resources.

Restricted by local supervision, investment in compliance risk control and government-enterprise strategy of state-owned platforms can obtain policy subsidies and business access qualifications, thus empowering long-term platform development. Private platforms have higher market flexibility and do not need redundant risk control investment. They can rapidly improve operational efficiency by focusing on business matching and data monetization. The operational priorities of the two types of platforms are inherently different, so homogeneous operation schemes have poor adaptability.

Compared with DEA models based on single weighting, the combined weighting model with undesirable outputs adopted in this paper reduces the measurement error from 18.7% to 6.2%, which greatly improves the quantitative accuracy. The model can be applied to the regular evaluation of industrial platforms and meet the practical needs of industrial supervision.

7. Management Implications for Digital Operation Optimization of Platforms

7.1 Tiered Optimization Path for Overall Platform Operation

According to the efficiency tiers divided by K-means clustering and the resource endowments and core deficiencies of each tier, hierarchical digital operation improvement schemes are formulated to avoid homogeneous resource investment.

Low-efficiency private platforms in western China are weak in computing power infrastructure and data governance. They should first increase investment in computing power infrastructure and data operation and maintenance, break internal business data silos, and reduce undesirable outputs such as data failures and service complaints to make up for basic digital deficiencies and improve efficiency. Medium-efficiency platforms, which account for more than half of the total samples, need to balance resource allocation among the five operational dimensions, abandon the extensive operation mode of emphasizing business revenue while neglecting risk control, and build a joint operation and maintenance mechanism integrating data governance and compliance verification to balance input and output and steadily move towards the high-efficiency tier.

High-efficiency platforms have sound digital infrastructure and do not need to increase investment in hardware. They can build an intelligent autonomous operation and maintenance system based on existing digital architectures, cooperate with industrial platforms in other regions to build cross-regional service ecosystems, and amplify the long-term enabling value relying on ecological operation.

7.2 Differentiated Operation Strategies Based on Property Rights

There are essential differences in value orientation and enabling logic between state-owned and private platforms, so differentiated operation and management are required. State-owned public welfare platforms take the inclusive empowerment of regional small and medium-sized enterprises as the core goal and are subject to strong local supervision. They need to establish a full-process regular compliance risk control system, reduce the weight of market-oriented revenue assessment, connect with government service ports to realize government-enterprise data interconnection, balance social public welfare value and operation and maintenance costs, and avoid resource waste caused by redundant risk control.

Private commercial platforms have high market autonomy and weak supervision constraints. They can streamline redundant risk control processes to save operation and maintenance costs, focus on two core businesses including enterprise supply-demand matching and data asset monetization, organize regular digital skill training for employees, iterate service categories according to market-oriented pricing mechanisms, and maximize operational efficiency.

7.3 Long-term Governance Countermeasures for the Industry

Top-level mechanisms should be improved from the perspective of industrial supervision and platform governance to optimize the overall digital operation ecosystem. Industrial competent departments shall formulate unified

operation and maintenance evaluation standards for industrial park enterprise service platforms based on the input-output indicator system of this paper, and build a comprehensive evaluation system covering economic benefits, public welfare value and risk losses, replacing the traditional evaluation mode relying merely on revenue and settlement volume.

Platforms need to optimize internal organizational structures and set up independent departments for data operation and compliance risk control to realize professional division of labor in digital operation and maintenance. Industrial associations should build communication and empowerment mechanisms among platforms to make up for the deficiencies of small and medium-sized platforms in digital operation, improve industrial digital operation and maintenance standards, and promote the standardized and long-term development of domestic industrial platforms.

8. Conclusions, Research Limitations and Prospects

8.1 Main Research Conclusions

Theoretically, combined with the dual attributes of public welfare empowerment and market-oriented profitability of enterprise service platforms, this paper constructs a five-dimensional closed-loop digital operation system and clarifies the coupling and enabling mechanism of all dimensions. It expands the application boundary of TOE theory and platform ecosystem governance theory, and makes up for the theoretical deficiencies in the research on digital operation of B2B industrial service platforms.

Methodologically, this paper optimizes the Super-SBM-DEA model based on G1-CRITIC combined weighting and fully incorporates undesirable output indicators, which significantly reduces the efficiency measurement error and forms a compound efficiency evaluation paradigm adapting to dual-attribute platforms.

Empirically, verified by the panel data of 217 platforms from 2020 to 2024, digital operation can significantly improve platform efficiency (Wang L & Zhang S., 2022), and data governance has the highest contribution to efficiency improvement. Digital resource integration plays a mediating role in the transmission process. Employees' digital literacy and marketization degree have double threshold effects. Significant property right heterogeneity exists in the enabling paths of state-owned and private platforms, so differentiated operation and governance are more conducive to the long-term development of platforms.

8.2 Research Limitations

This research has certain limitations. The samples only include domestic provincial local enterprise service platforms, and cross-border platforms are not included for international comparative analysis, so the research conclusions have limited cross-border adaptability. This study focuses on the internal steady-state operational factors of platforms and does not incorporate exogenous sudden shocks such as new digital supervision regulations and industrial public opinions, so it cannot describe the dynamic fluctuation characteristics of efficiency. In addition, static panel models are adopted for annual empirical analysis, and time-series algorithms are not introduced to study high-frequency dynamic operational rules, resulting in insufficient timeliness of the models.

8.3 Future Research Prospects

Based on the existing deficiencies, future research can expand samples to cross-border platforms and conduct comparative research on the operation mechanisms of Chinese and foreign platforms. Policy shock variables can be introduced to build dynamic efficiency models and analyze the evolution rules of platform efficiency under external supervision shocks. ESG green operation indicators can be integrated to iterate the existing operation and evaluation system in line with the development trend of industrial green digitalization. LSTM deep learning algorithms can be adopted to build dynamic efficiency early warning models, so as to enhance the practical guiding value of research results for real-time operation and maintenance of platforms.

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