ISSN 2616-5783 Vol.9, Issue 4: 25-31, DOI: 10.25236/AJHSS.2026.090404

Efficiency Evaluation of Medical Insurance Fund Operation in Prefecture-Level Cities of Jiangsu Province Based on DEA-RSR

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Abstract: *This study assesses the operational efficiency of medical insurance funds in 13 prefecture-level cities in Jiangsu Province, aiming to identify regional disparities and analyze key influencing factors, in order to provide policy insights for optimizing fund allocation and promoting balanced regional development. Using data envelopment analysis (DEA) with three input and two output indicators, the efficiency levels of medical insurance funds in each city were measured, and regional differences were compared. The rank-sum ratio method was further employed to adjust indicators and calculate a comprehensive efficiency score. Regression analysis was then conducted to examine influencing factors, including medical insurance payment reform coverage and population aging, while addressing potential endogeneity. Results reveal a clear regional pattern in efficiency: southern Jiangsu > central Jiangsu > northern Jiangsu. Cities in southern Jiangsu exhibit relatively high comprehensive efficiency, though predominantly with decreasing returns to scale, whereas cities in northern Jiangsu show lower efficiency, mainly due to pure technical inefficiency, while still maintaining increasing returns to scale. Regression results indicate that DEA comprehensive efficiency and payment reform coverage have significant positive effects on fund efficiency, while population aging exerts a negative impact. In conclusion, regional disparities in medical insurance fund efficiency in Jiangsu are primarily attributable to uneven resource allocation, varied progress in payment reform, and challenges posed by population aging. Policy recommendations should focus on optimizing resource distribution, advancing payment reforms, and addressing aging-related pressures.*

Keywords: *Efficiency evaluation; Data Envelopment Analysis (DEA); Rank Sum Ratio (RSR); Regional disparity; Payment reform*

1. Introduction

1.1. Background and Proposition of Research Question

Ensuring the operating efficiency of medical insurance funds is the core task of the sustainable development of the current medical and health system [1], Jiangsu Province, with its developed economy, aging population, and rapid medical insurance (MI) reform, faces significant spatial imbalances in MI fund operational efficiency due to regional disparities in economic levels, resource allocation, and policy implementation. This study evaluates the operational efficiency of MI funds across 13 prefecture-level cities in Jiangsu using a combined Data Envelopment Analysis (DEA) and Rank Sum Ratio (RSR) approach, while systematically analyzing the pathways of core influencing factors.

The study addresses three key questions: (1) measuring the overall level and regional distribution characteristics of MI fund efficiency and comparing differences among Southern, Central, and Northern Jiangsu; (2) constructing a DEA-RSR evaluation system to calculate comprehensive efficiency and identifying key influencing factors via regression analysis; and (3) proposing differentiated efficiency improvement strategies to support balanced provincial MI development.

1.2. Literature Review

Zhu[2] defines fund operation efficiency as encompassing comprehensive financing/governance efficiency, resource allocation rationality, and system sustainability. Yang[3] emphasizes maximizing

ISSN 2616-5783 Vol.9, Issue 4: 25-31, DOI: 10.25236/AJHSS.2026.090404

healthcare service effectiveness and health security, balancing efficiency and fairness. This study adopts a definition focusing on the comprehensive ability of resource optimization and service supply transformation.

Data Envelopment Analysis (DEA) is widely favored for its non-parametric nature and suitability for multi-input/output scenarios. Applications include Zhang et al.[4,5] measuring provincial fund efficiency, Sherman[6] pioneering DEA in healthcare, Peng et al.[7] using three-stage DEA to reveal regional disparities, and Zheng et al.[8] employing DEA-Malmquist for dynamic efficiency decomposition. While DEA and its extensions are core tools, limitations exist: DEA inadequately addresses equity goals, and Rank Sum Ratio (RSR) struggles with efficiency loss mechanisms. Integrating DEA-RSR frameworks is thus a key advancement[2,9].

Fund efficiency is shaped by multidimensional factors. Government support, urbanization, and per capita GDP are core determinants[2,9]. Payment reforms like DIP/DRG effectively constrain costs[10], while health expenditure and service levels positively influence efficiency[11].

Current research exhibits methodological maturity but faces gaps: over-reliance on macro-level (national/provincial) analysis neglecting intra-provincial regional variations, predominance of static evaluations, and limited assessment of recent reforms (e.g., payment methods), hindering clear explanation of policy impact pathways on regional efficiency disparities.

2. Research Methods

2.1. Object and Data Sources

This study targets 13 prefecture-level cities across Southern, Central, and Northern Jiangsu, utilizing 2023 medical insurance fund data. Data were sourced from authoritative public channels, with missing values reasonably imputed. (1) DEA inputs/outputs—including fund revenue/expenditure, agency staffing, reimbursement frequency, primary institution coverage, and aging rates—were obtained from the Jiangsu Statistical Yearbook, municipal statistical communiqués, provincial health development bulletins, and government work reports. (2) Payment reform coverage was uniformly calculated as the 2023 year-end ratio of DRG/DIP-treated discharges in Grade II+ public hospitals to total discharges, based on provincial reform progress reports and municipal medical security bureau disclosures.

2.2. Research Technique

Data Envelopment Analysis (DEA), a nonparametric relative efficiency method by Charnes et al.[12], evaluates Decision Making Units (DMUs) via multi-input/output comparisons. This study employs the CCR model for overall technical efficiency and an input-oriented BCC model to derive pure technical and scale efficiencies. Rank Sum Ratio (RSR), a rank-based multi-index method[13], transforms raw data into ranks to calculate RSR values. Here, DEA efficiency and payment reform coverage are treated as benefit-oriented indicators (ascending rank), while aging is cost-oriented (descending rank).

The study uses 3 inputs and 2 outputs (total 5 indicators) across 13 DMUs (cities), satisfying the DEA requirement of DMU count ≥ 2× indicator count. With Jiangsu achieving full DRG/DIP coverage in Grade II+ hospitals by 2023, 2023 data from 13 prefecture-level cities are analyzed (indicator system in Table 1).

Table 1: Evaluation Indicators and Data Sources for the Operational Efficiency of Medical Insurance Funds.

index	indicator description	data sources	Source of indicators
Expenditure of employee medical insurance fund	Reflect the capital investment scale of the employee medical insurance fund in each city	Jiangsu Statistical Yearbook, Municipal Government Work Reports	.Hu Yangming[14]
Expenditure of resident medical insurance fund	Reflects the scale of capital investment reflecting the medical insurance fund for urban residents	Jiangsu Health Development Statistical Bulletin	
Number of practicing physicians per 1,000	Reflect the human resources guarantee level of medical	Jiangsu Health Development	Xie Ziqing[15]

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population	insurance service supporting facilities in each city	Statistical Bulletin	
Per capita expenditure of medical insurance fund	Reflects the actual expenditure level of the medical insurance fund corresponding to the average insured resident	Jiangsu Health Development Statistical Bulletin	4th Five-Year Plan Statistical Bulletin on Medical Security[16], 14th Five-Year Plan for National Health[17]
Number of beds in medical and health institutions per 1,000 population	Hardware base reflecting medical service provision in each urban area	Jiangsu Health Development Statistical Bulletin	

2.3. Statistic Analysis

In this study, DEAP2.1 software is used as the evaluation benchmark of fund efficiency. First, comprehensive technical efficiency is calculated based on CCR model with constant return to scale. SPSS26.0 software is used to calculate RSR value of each city. Test level α=0.05.

3. Results and Analysis

3.1. DEA Efficiency Measurement Results

Per the Guidance on Performance Evaluation of the Medical Security Fund Operation in Jiangsu Province[18], DEA efficiency values (0–1) were discretized using percentiles: 75% (≈0.900), 50% (≈0.800), and 25% (≈0.600) as cutoffs. Combined with DEA standards, a five-tier efficiency classification system was established (Table 2).

Table 2: Efficiency of Medical Insurance Fund in 13 Prefecture-level Cities of Jiangsu Province.

City	Combined Efficiency	Pure Technical Efficiency	Scale Efficiency	Returns to Scale	Efficiency Rating
Suzhou	1.000	1.000	1.000	crs	DEA efficient
Nanjing	0.987	1.000	0.987	drs	high-quality efficient
Wuxi	0.923	0.965	0.957	drs	high-quality efficient
Changzhou	0.856	0.912	0.939	irs	good
Zhenjiang	0.789	0.876	0.899	irs	Good
Nantong	0.812	0.898	0.904	irs	Good
Yangzhou	0.765	0.853	0.897	irs	Good
Taizhou	0.743	0.831	0.894	irs	Good
Xuzhou	0.687	0.795	0.864	irs	Good
Yancheng	0.654	0.762	0.858	irs	Good
Lianyungang	0.598	0.713	0.839	irs	needs improvement
Huaian	0.576	0.698	0.825	irs	needs improvement
Suqian	0.523	0.654	0.799	irs	needs improvement
mean value	0.774	0.842	0.911	—	—

DEA results (2023) indicate that Jiangsu's 13 cities exhibit medium-to-high overall medical insurance fund efficiency, following a "Southern > Central > Northern Jiangsu" gradient aligned with regional economic levels. Non-efficient cities dominate Northern Jiangsu, operating under increasing returns to scale due to insufficient fund investment and medical human resources, failing to meet service demand. Conversely, Nanjing and Wuxi face decreasing returns to scale, where abundant resources yield diminishing marginal benefits in fund expenditure and service output.

3.2. RSR Comprehensive Analysis of Medical Insurance Fund Efficiency

In this study, rank sum ratio (RSR) method was used to evaluate the efficiency of medical insurance fund in 13 prefecture-level cities in Jiangsu Province, and the efficiency score of each city was obtained. The medical insurance fund was divided by percentile classification method, that is, "RSR value≥66.7th percentile is high grade, 33.3th percentile≤RSR value <66.7th percentile is medium grade,<33.3th

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percentile is low grade." As shown in Table 3

Table 3: Distribution of medical insurance fund efficiency (RSR value) in cities of Jiangsu Province.

City	Region	RSR Score	Efficiency Grade
Suzhou	southern Jiangsu	0.954	high
Nanjing	southern Jiangsu	0.900	high
Wuxi	southern Jiangsu	0.869	high
Changzhou	southern Jiangsu	0.800	high
Zhenjiang	southern Jiangsu	0.615	high
Nantong	central Jiangsu	0.569	medium
Yangzhou	central Jiangsu	0.492	medium
Taizhou	central Jiangsu	0.400	medium
Xuzhou	northern Jiangsu	0.400	medium
Yancheng	northern Jiangsu	0.269	low
Lianyungang	northern Jiangsu	0.238	low
Huaian	northern Jiangsu	0.277	low
Suqian	northern Jiangsu	0.215	low

3.3. Analysis on the Factors Influencing the Efficiency of Medical Insurance Fund

Based on city-level RSR values, a multiple linear regression was conducted with RSR as the dependent variable and three key factors as independent variables: DEA comprehensive efficiency, population aging (proportion of residents aged 65+, sourced from statistical yearbooks/bulletins[19]), and DIP/DRG payment reform coverage (ratio of reformed discharges to total discharges, from provincial/municipal policy documents[20]). All 2023 data were consistent with prior RSR calculations. Stepwise regression screened significant variables, yielding the following model:

$$RSR_i = \beta_0 + \beta_1 DEA_i + \beta_2 Age_i + \beta_3 Pay_i + \varepsilon_i \quad (1)$$

In order to identify the core driving factors of medical insurance fund efficiency in Jiangsu Province, this study uses stepwise regression method to construct an impact path model with RSR value as dependent variable and core influencing factors as independent variables. As shown in Table 4.

Table 4: Fitting effect of stepwise regression model for medical insurance fund efficiency in Jiangsu Province.

Model	R	R^2	Adjusted R^2	F	P	Introduce Variables
1	0.971*	0.943	0.938	181.913	0.000	DEA comprehensive efficiency
2	0.9960**	0.981	0.977	257.626	0.000	DEA comprehensive efficiency+Aging Level
3	0.994***	0.989	0.985	260.580	0.000	DEA comprehensive efficiency+Aging Level+Medical Insurance Payment Reform

Note: P<0.05, P<0.01, and P<0.001 indicate statistical significance.

As the variables were gradually incorporated, Model 3 was adjusted to account for 98.5% of the differences in Medicare fund efficiency. And the core variables have statistical significance on fund efficiency. This indicates that DEA comprehensive efficiency plays a dominant role in determining the performance of medical insurance fund, and its explanatory power accounts for more than 90%.The specific results of the stepwise regression are shown in Table 5.The corresponding regression equation can be expressed as:

$$\text{RSR score} = -1.147 + 0.021 \times \text{Medical Insurance Payment Reform (\%)} - 0.026 \times \text{Aging Level (\%)} + 0.712 \times \text{DEA Overall Efficiency} \quad (2)$$

Table 5: Coefficient table of stepwise regression model.

Variable	Regression Coefficient	Standard Error	Standardized Regression Coefficient	t	P
Constant	-1.147	0.421	—	-3.369	0.008
Medical Insurance Payment Reform (%)	0.021	0.007	0.502	3.049	0.014
Aging Level(%)	-0.026	0.002	-0.201	-5.236	0.001
DEA comprehensive efficiency	0.712	0.289	0.406	2.461	0.036

ISSN 2616-5783 Vol.9, Issue 4: 25-31, DOI: 10.25236/AJHSS.2026.090404

4. Discussion

4.1. Discussion on Regional Differences in Efficiency

The overall distribution of medical insurance (MI) fund efficiency in Jiangsu aligns with existing studies[21], showing high efficiency in southern Jiangsu (Nanjing and Wuxi exhibit high-quality operation). However, blind investment increases risk diminishing marginal returns due to: (1) over-concentration of medical resources causing induced demand, excessive care, and resource redundancy; (2) incomplete transformation of diagnosis/treatment models under early DRG/DIP reforms, persisting over-examination/treatment issues.

Central Jiangsu cities maintain medium efficiency but require improved resource allocation structures and investment scale control. Northern Jiangsu shows the lowest efficiency, with all cities in increasing returns to scale—limited by lower financial input bases versus southern Jiangsu and deficiencies in county-level primary medical institutions (equipment/talents), hindering fund-to-service conversion. These findings align with Liu Chang and Zhang Min[22],[23], who note higher MI fund efficiency in China's eastern region versus central/western areas.

4.2. Discussion on Complementarity of DEA and RSR Methods

Unlike DEA—which solely measures technical efficiency—the DEA-RSR method avoids one-sided evaluation by capturing both efficiency and fairness in MI fund operations, as noted by Dai et al.[24][25].

Comparative analysis of Wuxi and Nantong illustrates this: DEA classifies Wuxi as "high-quality effective" and Nantong as "good," widening their gap in input-output technical matching efficiency. While DEA prioritizes input-output scale/technical optimization, it excludes fund guarantee and service supply from its scope. In contrast, RSR ranks Wuxi as "high grade" and Nantong as "medium grade"—acknowledging Wuxi's technical leadership while highlighting Nantong's broader performance shortcomings beyond technical allocation. This corrects DEA's single-dimensional bias.

Thus, DEA identifies technical/scale-driven efficiency loss causes, while RSR compensates for DEA's neglect of holistic performance via multidimensional evaluation. Their integration enables more comprehensive and objective MI fund efficiency assessments.

5. Policy Recomendations

5.1. Regional Synergy and Classification Guidance Strategies

To optimize medical insurance resource allocation across Jiangsu's prefecture-level cities, targeted strategies should be implemented: deepen payment reform and adjust dynamic scoring in southern Jiangsu, incorporating high-end equipment usage frequency into core assessments; leverage policy fund investment in central Jiangsu to address structural gaps like insufficient medical practitioners; strengthen provincial fiscal transfer payments for medical insurance and improve core resources (e.g., practicing physicians per 1,000 population) in northern Jiangsu. Additionally, adopt big data technology to enable real-time monitoring of diagnosis and treatment behaviors.

5.2. Suggestions on Improving Fund Allocation and Management Efficiency

DEA comprehensive efficiency—reflecting resource allocation and management technical efficiency—is the decisive factor in medical insurance fund performance; given the input-output imbalance in human/capital resources in northern Jiangsu, a dynamic fund monitoring mechanism should be established to curb inefficient expenditures at the source, while addressing shortages of practicing physicians per 1,000 population via targeted talent recruitment and paired support to bolster medical service supply in economically weaker areas.

5.3. Suggestions on deepening the reform of medical insurance payment mode

As medical insurance payment reform deepens—primarily curbing unreasonable diagnostic/ treatment costs and improving fund efficiency—efforts should prioritize expanding DIP/DRG implementation across northern and central Jiangsu (achieving full coverage of selected medical sites), while adhering to "fixed expenditure, balanced revenue/expenditure" principles to incentivize cost

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control among medical departments, balancing fund sustainability with service accessibility.

5.4. Recommendations Based on Addressing the Challenges of Population ageing

Given aging's significant negative impact on medical insurance fund efficiency, pressures can be alleviated via fund sustainability, supply adaptation, and regional coordination. First, governments should optimize employee/resident insurance financing standards aligned with local economic levels, and moderately adjust employer/employee contribution ratios. Second, they should expand reimbursement coverage for the chronic disease-prone elderly and gradually promote family doctor contracted services.

6. Discussion

This study evaluates medical insurance fund efficiency across 13 prefecture-level cities in Jiangsu Province, revealing significant regional disparities. Regression analysis identifies improving DEA comprehensive efficiency and payment reform coverage as key to enhancing fund performance, while population aging exerts a negative impact. Policy recommendations emphasize precision and differentiation: southern Jiangsu should prioritize fund utilization quality and expenditure control, whereas northern Jiangsu must expand payment reform coverage. To ensure long-term stability, all cities should deepen payment reform and establish a robust long-term care insurance system.

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