

Evaluation of Resource Allocation Efficiency in Innovation and Entrepreneurship Education at Undergraduate Institutions in Jiangsu Province

Fei Shi¹, Fei Xia^{2,*}, Yan Gong¹, Quan Li¹, Huimin Zhang³, Yifei Cheng¹

¹*School of Civil Engineering and Architecture, Suqian University, Suqian, Jiangsu, China*

²*School of Innovation and Entrepreneurship, Suqian University, Suqian, Jiangsu, China*

³*School of Biological and Materials Engineering, Suqian University, Suqian, Jiangsu, China*

**Corresponding Author*

Abstract: Improving the efficiency with which universities allocate resources to innovation and entrepreneurship education is central to converting expanded investment into educational outcomes. Drawing on an input-output framework, this study develops an evaluation system and examines 31 undergraduate institutions in Jiangsu Province. An input-oriented BCC model and a super-efficiency BCC model measure static efficiency in 2025, while the Malmquist index tracks productivity change between 2024 and 2025. The geometric mean of the 2025 super-efficiency scores is 1.174; 28 institutions are on or above the efficiency frontier, yet 64.5% operate under decreasing returns to scale, indicating a mismatch between resource input and output growth. Differences within institutional categories are more pronounced than differences between categories, and static efficiency does not form a stable north-central-south gradient. Total factor productivity increases by 4.1%, driven mainly by improved management and resource utilisation. Growth is faster in Southern Jiangsu, moderate in Central Jiangsu, and nearly flat in Northern Jiangsu. The findings support five policy directions: scale adjustment, resource coordination, pedagogical innovation, differentiated strategies, and dynamic feedback.

Keywords: Undergraduate Institutions; Innovation and Entrepreneurship Education; Resource Allocation Efficiency; Policy Implications; Jiangsu Province

1. Introduction

In the late twentieth century, UNESCO introduced and systematically elaborated the concept of entrepreneurship education and

subsequently identified the development of entrepreneurial awareness and capacity as an important mission of higher education. After 2002, innovation and entrepreneurship education in China progressed from pilot initiatives to more systematic and standardised research and practice [1]. The 2015 guidance on reforming innovation and entrepreneurship education in higher education, together with the establishment of the China Innovation and Entrepreneurship Education Alliance, accelerated this development [2]. Undergraduate institutions have since increased investment in specialised funding, practical training, incubator space, and competitions such as the China International College Students Innovation Competition and the Challenge Cup. As these activities expand, a central policy question is whether universities allocate and use these resources efficiently enough to support educational development and reform.

Hanushek provided an early systematic discussion of educational production and school efficiency [3]. Charnes, Cooper, and Rhodes subsequently developed the constant-returns-to-scale data envelopment analysis model, later termed the CCR model [4], while Banker, Charnes, and Cooper introduced the variable-returns-to-scale BCC model [5]. Both approaches have been widely used to assess resource allocation in higher education. Because conventional DEA assigns a score of 1 to all efficient decision-making units, it cannot distinguish among multiple frontier units. Andersen and Petersen therefore proposed the super-efficiency model for ranking efficient units [6]. Parteka and Wolszczak-Derlacz later used a DEA-Malmquist framework to measure changes in total factor productivity over time [7].

Research on the efficiency of higher education in China began in the 1980s. Lin examined the

economic efficiency of educational processes and the optimisation of investment structures [8]. Subsequent studies used DEA to measure the relative efficiency of higher education resource allocation across regions, provinces, and municipalities [9-11]. As the method developed, Chinese scholars combined DEA with other econometric tools. Guan applied a super-efficiency DEA model to higher education resource allocation [12]; Li et al. used a DEA-Tobit model to assess the efficiency and determinants of innovation and entrepreneurship education in universities [13]; and Jiang et al. combined DEA with the Malmquist index to examine static efficiency and intertemporal changes across 30 provincial-level regions [14]. More recent work has employed the Malmquist index [15], Tobit models [16], and network DEA [17], producing increasingly detailed and diverse assessments. International studies have generally focused on overall institutional performance and research productivity, whereas Chinese research has moved from macro-level educational economic efficiency to micro-level university resource allocation [18]. It has also expanded from efficiency measurement to the analysis of determinants, temporal change, and spatial variation.

Despite this progress, few studies quantify the efficiency of innovation and entrepreneurship education in undergraduate institutions through a detailed input-output framework, and province-wide evidence from Jiangsu remains limited. Systematic comparisons across institutional types and subprovincial regions are especially scarce. Undergraduate institutions account for 48% of Jiangsu Province's higher education institutions and constitute a major platform for innovation and entrepreneurship education. Continued expansion of this field will require further investment, but additional resources will improve outcomes only if universities organise and use them effectively.

This study therefore develops an input-output indicator system and uses panel data for 2024-2025 to assess 31 undergraduate institutions in Jiangsu Province. The input-oriented BCC and super-efficiency BCC models identify relative

efficiency and rank frontier institutions in 2025, while the Malmquist index measures changes in total factor productivity from 2024 to 2025. The analysis then compares institutions by type and by location in Southern, Central, and Northern Jiangsu. The study contributes province-wide institution-level evidence, combines static and dynamic measures, and tests whether variation between regions and institutional categories exceeds variation within them. The findings are intended to support a shift from incremental investment towards more precise and differentiated resource allocation.

2. Study Area Data and Methods

2.1 Study Area

Jiangsu Province is located in the central section of China's eastern seaboard and covers approximately 107,200 km². At the end of 2025, the province had 85.18 million permanent residents, an urbanisation rate of 76.2%, and a gross domestic product of CNY 14.23515 trillion. As of March 2026, Jiangsu had 175 regular higher education institutions, including independent colleges, of which 84 were undergraduate institutions. Their spatial distribution is uneven: Southern Jiangsu contains the largest number, Central Jiangsu an intermediate number, and Northern Jiangsu the fewest. The province nevertheless has a large and diverse undergraduate higher education system.

2.2 Sample Selection

Institutions were selected according to four criteria: undergraduate status, availability of innovation and entrepreneurship education data, diversity of institutional type, and regional representativeness. The final sample contains 31 institutions. By institutional type, the sample includes 6 Double First-Class universities, 6 institutions selected for Jiangsu's First-Class Application-Oriented Undergraduate Development Programme, and 19 other undergraduate institutions. By ownership, 24 are public and 7 are private. By region, 20 are in Southern Jiangsu, 6 in Central Jiangsu, and 5 in Northern Jiangsu (Table 1).

Table 1. Sample Institutions

Institution	Institution type	Ownership	Region	Institution	Institution type	Ownership	Region
University 1	Other undergraduate	Public	Southern Jiangsu	University 17	Other undergraduate	Private	Central Jiangsu
University 2	First-Class Applied	Public	Northern Jiangsu	University 18	Other undergraduate	Private	Southern Jiangsu

University 3	Other undergraduate	Private	Southern Jiangsu	University 19	Double First-Class	Public	Southern Jiangsu
University 4	First-Class Applied	Public	Northern Jiangsu	University 20	Other undergraduate	Public	Southern Jiangsu
University 5	Other undergraduate	Public	Southern Jiangsu	University 21	Other undergraduate	Private	Southern Jiangsu
University 6	First-Class Applied	Public	Southern Jiangsu	University 22	Other undergraduate	Public	Southern Jiangsu
University 7	Other undergraduate	Public	Southern Jiangsu	University 23	First-Class Applied	Public	Southern Jiangsu
University 8	First-Class Applied	Public	Southern Jiangsu	University 24	Other undergraduate	Public	Northern Jiangsu
University 9	Other undergraduate	Public	Southern Jiangsu	University 25	Other undergraduate	Public	Central Jiangsu
University 10	Double First-Class	Public	Southern Jiangsu	University 26	Other undergraduate	Private	Southern Jiangsu
University 11	Double First-Class	Public	Southern Jiangsu	University 27	Other undergraduate	Public	Southern Jiangsu
University 12	Double First-Class	Public	Southern Jiangsu	University 28	Other undergraduate	Public	Northern Jiangsu
University 13	Double First-Class	Public	Southern Jiangsu	University 29	First-Class Applied	Public	Northern Jiangsu
University 14	Double First-Class	Public	Southern Jiangsu	University 30	Other undergraduate	Public	Central Jiangsu
University 15	Other undergraduate	Public	Central Jiangsu	University 31	Other undergraduate	Private	Central Jiangsu
University 16	Other undergraduate	Private	Central Jiangsu				

2.3 Indicator System

Leontief established input-output analysis as a means of expressing quantitative relationships among sectors through inputs, outputs, and technical coefficients [19]. In educational economics, the education production function extends this logic by linking school resources and teaching staff to educational outcomes [3]. Following the principles of scientific validity, representativeness, and data availability, this study constructs an indicator system for the allocation efficiency of innovation and entrepreneurship education in Jiangsu's undergraduate institutions. The input dimension contains three categories—human, physical, and financial resources—and six indicators. The output dimension contains three categories—talent development, research, and social service—and seven indicators (Table 2).

Table 2. Indicator System for Resource Allocation Efficiency in Innovation and Entrepreneurship Education

Dimension	Category	Indicator	Unit
Input	Human resources	Full- and part-time teachers	persons
Input	Human resources	Administrative staff	persons
Input	Human	External instructors	persons

	resources		
Input	Physical resources	Total value of instruments and equipment	CNY 10,000
Input	Physical resources	Area of practice bases	m ²
Input	Financial resources	Earmarked funding	CNY 10,000
Output	Talent development	Student participants	participant-times
Output	Talent development	Start-ups established	firms
Output	Talent development	Disciplinary competition awards	awards/projects
Output	Research	Papers and books	papers/books
Output	Research	Patents and software copyrights	items
Output	Research	Undergraduate innovation and entrepreneurship projects	awards/projects
Output	Social service	Value of commercialised scientific and technological outputs	CNY 10,000

2.4 Efficiency Models

The analytical framework combines an input-oriented BCC and super-efficiency BCC assessment of static performance with a Malmquist assessment of dynamic change. It measures the relative efficiency and frontier ranking of the 31 institutions in 2025 and the change in total factor productivity between 2024 and 2025.

2.4.1 Input oriented BCC and super-efficiency

BCC models

Suppose that n universities constitute the decision-making units (DMUs), each with m input indicators and s output indicators. Let x_j and y_j denote the input and output vectors of DMU j . For the university under evaluation, DMU0, the input-oriented BCC envelopment model is expressed as follows:

$$\begin{aligned} & \min_{\theta} \theta_0^{VRS} \\ \text{s. t. } & \sum_{j=1}^n \lambda_j x_{ij} \leq \theta_0^{VRS} x_{i0}, i=1,2,\dots,m \\ & \sum_{j=1}^n \lambda_j y_{rj} \geq y_{r0}, r=1,2,\dots,s \\ & \sum_{j=1}^n \lambda_j = 1, \lambda_j \geq 0, j=1,2,\dots,n \end{aligned} \quad (1)$$

In these expressions, θ_0 is the radial efficiency score of the BCC model, λ_j is the weight assigned to a reference unit, and $\sum \lambda_j = 1$ imposes variable returns to scale. In the conventional BCC model, $\theta_0 = 1$ indicates that the DMU lies on the efficient frontier under variable returns to scale, whereas $\theta_0 < 1$ indicates that inputs can be reduced proportionally while maintaining the observed output. Returns to scale are classified as increasing (irs), decreasing (drs), or constant (crs) according to the VRS solution and the relevant scale constraints.

Conventional DEA assigns a value of 1 to all efficient units and therefore cannot rank institutions on the frontier. Following Andersen and Petersen, the super-efficiency BCC model excludes DMU0 from the reference set and uses the remaining DMUs to construct a new VRS frontier:

$$\begin{aligned} & \min_{\theta} \theta_0^{SE-BCC} \\ \text{s. t. } & \sum_{j=1, j \neq 0}^n \lambda_j x_{ij} \leq \theta_0^{SE-BCC} x_{i0}, i=1,2,\dots,m \\ & \sum_{j=1, j \neq 0}^n \lambda_j y_{rj} \geq y_{r0}, r=1,2,\dots,s \\ & \sum_{j=1, j \neq 0}^n \lambda_j = 1, \lambda_j \geq 0 \end{aligned} \quad (2)$$

A super-efficiency BCC score may exceed 1; a larger value indicates a stronger relative position compared with the other frontier units. A score below 1 indicates that the institution has not reached the BCC efficiency frontier. The super-efficiency score is used only to rank frontier units. It does not imply “absolute efficiency above 100%” and should not be conflated with change indices such as PECH in the Malmquist framework.

2.4.2 Malmquist index

Static DEA locates a DMU relative to the

contemporaneous production frontier but does not identify intertemporal productivity change or its sources. The Malmquist index compares productivity across adjacent periods using distance functions [20]. Let the input-output vectors in periods t and $t+1$ be (x_t, y_t) and (x_{t+1}, y_{t+1}) , respectively. The Malmquist total factor productivity index is then expressed as follows:

$$M_0^{t,t+1} = \left[\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \times \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^t, y^t)} \right]^{\frac{1}{2}} \quad (3)$$

A Malmquist index greater than 1 indicates higher total factor productivity, a value below 1 indicates a decline, and a value equal to 1 indicates no material change. Following the decomposition proposed by Färe et al., total factor productivity change (TFPCH) is decomposed into technical efficiency change (EFFCH) and technological change (TECHCH). EFFCH can be further decomposed into pure technical efficiency change (PECH) and scale efficiency change (SECH):

$$TFPCH = EFFCH \times TECHCH \quad (4)$$

$$EFFCH = PECH \times SECH \quad (5)$$

EFFCH captures the “catch-up effect,” or whether an institution moves towards or away from the existing best-practice frontier. TECHCH captures movement of the frontier itself. PECH represents changes in organisational, managerial, and operating efficiency at a given scale, while SECH reflects changes in scale configuration. For each component, a value above 1 indicates improvement and a value below 1 indicates deterioration. Because the dataset contains only 2024 and 2025, the Malmquist results represent change over one interval rather than a long-term trend.

2.5 Data Sources and Processing

Data were compiled from undergraduate teaching quality reports, graduate employment quality reports, annual reports on innovation and entrepreneurship education, and statistical information published on the official websites of the sampled institutions for 2024 and 2025. Geometric means are used for comparisons by institutional type and region to reduce the influence of extreme super-efficiency scores and to remain consistent with the multiplicative structure of the Malmquist index.

3. Results

3.1 Static Super-Efficiency BCC Results

3.1.1 Overall distribution

The geometric mean of the 2025 super-efficiency BCC scores is 1.174. Twenty-eight institutions, or 90.3% of the sample, score at least 1, while only three fall below the frontier (Table 3). University 14 records the highest score at 2.750. Universities 17, 20, and 29 follow with scores of 1.746, 1.651, and 1.534, respectively. Universities 12, 24, and 25 score 0.804, 0.996, and 0.989 and therefore do not reach the BCC efficient frontier. Most institutions are thus close to or on the relative frontier, although performance varies substantially among frontier units.

The returns-to-scale classification identifies 20 institutions with decreasing returns to scale (64.5%), 9 with increasing returns (29.0%), and 2 with constant returns. The high share of institutions with decreasing returns suggests that additional staff, facilities, equipment, and earmarked funding do not necessarily yield proportional output growth. For these institutions, the priority should shift from expansion to scale adjustment and integration of existing resources.

3.1.2 Differences by institutional type

As Table 4 shows, the geometric mean super-efficiency score of the First-Class Applied universities is 1.200, slightly above the values for Double First-Class universities (1.179) and other undergraduate institutions (1.165). All First-Class Applied universities are frontier units, indicating relatively stable matching between inputs and outputs. Scores among Double First-Class universities range from 0.804 to 2.750 and are considerably more dispersed. University 14 leads the entire sample, whereas University 12 remains

below the frontier. Resource endowment and institutional status therefore do not automatically translate into equivalent allocation efficiency. Other undergraduate institutions are similarly heterogeneous: Universities 17 and 20 rank near the top, while Universities 24 and 25 score below 1. Differences between category means are smaller than differences among institutions within the same category. Evaluation should consequently focus on the alignment between resource organisation and institutional mission rather than on institutional labels alone.

3.1.3 Regional differences

Static super-efficiency scores do not follow a stable “Southern Jiangsu–Central Jiangsu–Northern Jiangsu” gradient. Central Jiangsu records the highest geometric mean (1.234), followed by Northern Jiangsu (1.161) and Southern Jiangsu (1.160), but the Central Jiangsu result is influenced by high-scoring cases such as Universities 15 and 17. The share of frontier units presents a different ordering: 95.0% in Southern Jiangsu, 83.3% in Central Jiangsu, and 80.0% in Northern Jiangsu (Table 4). The inconsistent rankings show that regional means can conceal substantial institutional heterogeneity. Southern Jiangsu includes both the highest-scoring institution, University 14, and the low-scoring University 12. Northern Jiangsu also contains frontier institutions such as University 29 and institutions that remain below the frontier. Static efficiency is therefore differentiated mainly within regions rather than along a stable regional hierarchy.

Table 3. Super Efficiency BCC Scores and Returns to Scale in 2025

Institution	Institution type	Super-efficiency BCC score	Returns to scale
University 1	Other undergraduate	1.186	irs
University 2	First-Class Applied	1.013	irs
University 3	Other undergraduate	1.178	drs
University 4	First-Class Applied	1.362	drs
University 5	Other undergraduate	1.008	drs
University 6	First-Class Applied	1.091	drs
University 7	Other undergraduate	1.297	drs
University 8	First-Class Applied	1.104	drs
University 9	Other undergraduate	1.122	drs
University 10	Double First-Class	1.014	drs
University 11	Double First-Class	1.157	drs
University 12	Double First-Class	0.804	irs
University 13	Double First-Class	1.036	drs
University 14	Double First-Class	2.750	drs
University 15	Other undergraduate	1.379	drs
University 16	Other undergraduate	1.175	drs
University 17	Other undergraduate	1.746	drs
University 18	Other undergraduate	1.045	irs

University 19	Double First-Class	1.000	—
University 20	Other undergraduate	1.651	drs
University 21	Other undergraduate	1.016	irs
University 22	Other undergraduate	1.181	drs
University 23	First-Class Applied	1.172	drs
University 24	Other undergraduate	0.996	irs
University 25	Other undergraduate	0.989	irs
University 26	Other undergraduate	1.201	drs
University 27	Other undergraduate	1.009	drs
University 28	Other undergraduate	1.000	—
University 29	First-Class Applied	1.534	irs
University 30	Other undergraduate	1.200	drs
University 31	Other undergraduate	1.051	irs

Note: The super-efficiency BCC score is used primarily to rank frontier units. drs, irs, and crs denote decreasing, increasing, and constant returns to scale, respectively.

Table 4. Group Characteristics of Super-Efficiency BCC Scores in 2025

Group	N	Geometric mean score	Frontier units	Frontier share	Minimum	Maximum
Full sample	31	1.174	28	90.3%	0.804	2.750
Double First-Class universities	6	1.179	5	83.3%	0.804	2.750
First-Class Applied universities	6	1.200	6	100.0%	1.013	1.534
Other undergraduate institutions	19	1.165	17	89.5%	0.989	1.746
Southern Jiangsu	20	1.160	19	95.0%	0.804	2.750
Central Jiangsu	6	1.234	5	83.3%	0.989	1.746
Northern Jiangsu	5	1.161	4	80.0%	0.996	1.534

Note: Group means are geometric means. A frontier unit has a super-efficiency BCC score of at least 1.

3.2 Malmquist Results

3.2.1 Overall change

The geometric mean of the Malmquist total factor productivity change index (TFPCH) for 2024-2025 is 1.041, indicating an overall productivity increase of approximately 4.1% (Table 5). EFFCH is 1.042 and TECHCH is 0.999. The further decomposition yields a PECH value of 1.070 and a SECH value of 0.974. Productivity growth during the period was therefore driven mainly by catch-up towards the best-practice frontier, particularly improved pure technical efficiency. The production frontier itself changed little, and declining scale efficiency partly offset the overall improvement.

At the institutional level, TFPCH exceeds 1 for 20 universities, equals 1 for 2, and is below 1 for 9. Growth was therefore not universal. Universities 14, 15, and 29 record TFPCH values of 1.731, 1.273, and 1.423, respectively. By contrast, Universities 4, 6, 17, and 24 record values of 0.781, 0.873, 0.852, and 0.881. Resource allocation in innovation and entrepreneurship education thus exhibits overall improvement alongside marked institutional divergence.

3.2.2 Differences by institutional type

Dynamic performance differs across institutional types. The geometric mean TFPCH of Double First-Class universities is 1.121, above the values

for other undergraduate institutions (1.023) and First-Class Applied universities (1.018) (Table 6). For Double First-Class universities, TECHCH is 1.072, indicating a comparatively clear outward movement of the production frontier. Their SECH, however, is only 0.826, showing that scale efficiency declined substantially. Resource advantages and expansion have therefore not been converted fully into efficiency advantages. The sharp increase at University 14 and decline at University 12 also confirm strong heterogeneity within the Double First-Class group.

First-Class Applied universities record EFFCH, TECHCH, and TFPCH values of 1.011, 1.008, and 1.018, respectively, indicating gradual and relatively stable improvement. University 29 performs particularly well, whereas Universities 4 and 6 decline. Other undergraduate institutions record a TFPCH of 1.023 but a TECHCH of 0.974, suggesting that their productivity improvement depends mainly on internal catch-up while their estimated production frontier contracts slightly.

3.2.3 Regional differences

Southern Jiangsu has the highest regional TFPCH geometric mean at 1.059, followed by Central Jiangsu at 1.018 and Northern Jiangsu at 0.998. Fourteen institutions in Southern Jiangsu, four in Central Jiangsu, and two in Northern Jiangsu record TFPCH values above 1. TECHCH reaches

1.010 in Southern Jiangsu, suggesting that efficiency improvement is supported by a modest outward shift of the production frontier. In Central Jiangsu, EFFCH is 1.032 and TECHCH is 0.986, so growth is driven mainly by internal efficiency gains. Northern Jiangsu remains close to 1 overall, but its TECHCH and PECH values of 0.972 and 0.987 indicate constraints on both frontier movement and pure technical efficiency. A SECH of 1.039 partly offsets these weaknesses. The regional divide is therefore expressed more clearly in institutions' capacity for sustained

improvement than in their static efficiency at one point in time. Southern Jiangsu's industrial base, innovation platforms, and university-industry networks may provide stronger conditions for universities to update educational organisation and resource provision. Some institutions in Central and Northern Jiangsu are already close to the static frontier, but their productivity may stagnate or decline without continuing pedagogical innovation, platform renewal, and mechanisms for translating results into educational and social value.

Table 5. Malmquist Indices and Decomposition for 2024-2025

Institution	EFFCH	TECHCH	PECH	SECH	TFPCH
University 1	0.953	1.079	1.006	0.947	1.028
University 2	0.996	1.013	0.995	1.001	1.010
University 3	1.075	1.018	1.071	1.003	1.094
University 4	0.780	1.002	0.695	1.122	0.781
University 5	0.974	1.012	0.975	0.999	0.986
University 6	0.970	0.900	0.980	0.990	0.873
University 7	1.062	1.002	0.957	1.109	1.065
University 8	1.011	1.047	1.179	0.857	1.058
University 9	0.868	1.233	1.194	0.727	1.070
University 10	1.149	0.912	0.922	1.246	1.048
University 11	0.906	1.232	3.266	0.277	1.116
University 12	0.898	1.038	0.928	0.967	0.932
University 13	0.994	1.056	0.999	0.995	1.050
University 14	1.405	1.232	1.468	0.957	1.731
University 15	1.034	1.231	1.217	0.849	1.273
University 16	0.955	1.059	0.958	0.997	1.012
University 17	1.050	0.812	1.178	0.891	0.852
University 18	1.019	1.019	0.973	1.047	1.038
University 19	1.000	1.0020	1.000	1.000	1.000
University 20	1.022	1.084	1.032	0.990	1.107
University 21	0.986	0.984	0.994	0.993	0.971
University 22	2.227	0.447	1.011	2.202	0.996
University 23	1.023	1.052	1.054	0.971	1.076
University 24	1.071	0.822	0.982	1.090	0.881
University 25	1.055	0.870	0.993	1.063	0.918
University 26	1.024	1.065	1.015	1.009	1.090
University 27	0.914	1.133	0.933	0.980	1.035
University 28	1.000	1.000	1.000	1.000	1.000
University 29	1.367	1.041	1.382	0.990	1.423
University 30	1.033	1.007	1.063	0.972	1.041
University 31	1.070	0.989	1.036	1.033	1.059
Geometric mean	1.042	0.999	1.070	0.974	1.041

Note: EFFCH = technical efficiency change; TECHCH = technological change; PECH = pure technical efficiency change; SECH = scale efficiency change; TFPCH = total factor productivity change. Values above 1 indicate improvement, and values below 1 indicate decline.

Table 6. Geometric Means of Malmquist Components by Institutional Type and Region

Group	N	EFFCH	TECHCH	PECH	SECH	TFPCH	TFPCH > 1
Full sample	31	1.042	0.999	1.070	0.974	1.041	20
Double First-Class universities	6	1.045	1.072	1.265	0.826	1.121	4
First-Class Applied universities	6	1.011	1.008	1.026	0.985	1.018	4
Other undergraduate institutions	19	1.050	0.974	1.028	1.022	1.023	12
Southern Jiangsu	20	1.048	1.010	1.091	0.961	1.059	14

Central Jiangsu	6	1.032	0.986	1.070	0.964	1.018	4
Northern Jiangsu	5	1.026	0.972	0.987	1.039	0.998	2

Note: All group indices are geometric means, preserving the multiplicative decomposition of the Malmquist index.

4. Policy Implications

4.1 Shift from Expansion to Structural Optimisation

The super-efficiency BCC results indicate a high overall level of resource allocation efficiency, but the large share of institutions with decreasing returns to scale shows that resource growth is not always matched by output growth. Institutions with decreasing returns should prioritise the integration and use of existing resources, reduce repeated construction and continued investment in underused platforms, share laboratories across schools, consolidate innovation and entrepreneurship bases, and improve project-level allocation. Institutions with increasing returns should target the bottlenecks that constrain output, particularly teaching staff, practice platforms, and industry partnerships. Institutions with constant returns should maintain a dynamic balance between inputs and outputs and avoid inefficient expansion. Resource investment should become efficiency-oriented and better aligned with educational outputs.

4.2 Strengthen Internal Governance and Resource Conversion

The Malmquist decomposition shows that productivity growth between 2024 and 2025 came mainly from technical efficiency rather than technological change. Improvement therefore depends less on the quantity of resources than on how universities organise and operate them. Institutions should coordinate innovation and entrepreneurship resources across administrative and academic units, reduce information barriers and duplication, and establish whole-process project management that links investment, implementation, output generation, and outcome conversion. Platforms and projects with sustained investment but limited output should be reconfigured or consolidated. Programmes with stable outputs and transfer value should be expanded through internal sharing and regional collaboration. Stronger organisational coordination can release the potential of existing resources and improve allocation efficiency.

4.3 Improve the Quality of Resource Provision

through Pedagogical Innovation

The TECHCH value of 0.999 indicates little outward movement of the production frontier. Future gains cannot rely solely on managerial improvement; they also require innovation in pedagogy and resource provision. Universities should integrate innovation and entrepreneurship education more closely with disciplinary education, industry demand, and research practice by introducing authentic business problems, research commercialisation projects, and community challenges into courses and practical training. Digital platforms, virtual simulation laboratories, and shared online courses should be evaluated by utilisation, student participation, and outcome conversion rather than by construction alone. Coordination among industry mentors, technical service platforms, intellectual property service organisations, and incubators can create a continuous support pathway from coursework and innovation training to competitions and venture incubation.

4.4 Apply Differentiated Strategies across Institutional Types and Regions

The results demonstrate substantial heterogeneity by institutional type and region. Double First-Class universities should improve the conversion of research resources, disciplinary platforms, and scientific outputs into opportunities for student innovation and entrepreneurship. First-Class Applied universities should deepen university-industry integration through enterprise projects, practice bases, and industry colleges. Other undergraduate institutions should prioritise coherent foundation courses, stable teaching teams, and shared practice platforms, while adapting organisational practices from high-efficiency peers. Allocation should not be determined mechanically by regional economic development. Cross-institutional course sharing, faculty exchange, joint competitions, and co-developed technical service platforms can channel high-quality resources towards Central and Northern Jiangsu and raise regional efficiency as a whole.

4.5 Establish a Dynamic Evaluation and Feedback Mechanism

The static and dynamic results show that some

institutions are currently on the efficiency frontier but have limited productivity growth, whereas others have moderate current efficiency but improve rapidly. Universities and education authorities should therefore establish a longitudinal evaluation mechanism based on annual input-output data. BCC efficiency, super-efficiency rankings, Malmquist change, and returns to scale should be considered jointly. For institutions with declining efficiency, diagnosis should distinguish among redundant inputs, insufficient outputs, scale mismatch, and weak organisational performance. Evaluation results can then inform budgets, platform development, project management, and performance assessment through a cycle of evaluation, diagnosis, adjustment, and re-evaluation. Efficiency should not be reduced to the pursuit of a higher input-output ratio; it must also be judged against institutional missions, educational quality, and student development.

5. Conclusions and Limitations

This study develops an input-output indicator system and combines input-oriented BCC, super-efficiency BCC, and Malmquist models to assess the static and dynamic efficiency of innovation and entrepreneurship education resource allocation in 31 undergraduate institutions in Jiangsu Province. Three principal findings emerge. First, overall static efficiency is high, but scale mismatch remains prominent. The geometric mean super-efficiency score in 2025 is 1.174, and 28 institutions reach or exceed the relative frontier, yet 64.5% exhibit decreasing returns to scale. Neither institutional type nor location produces a simple efficiency hierarchy; differences within categories and regions are more pronounced than differences between them. Second, total factor productivity increases by 4.1% between 2024 and 2025, but the main source of growth is internal efficiency improvement. EFFCH is 1.042 and PECH is 1.070, compared with TECHCH of 0.999 and SECH of 0.974. Management improvement, resource organisation, and adjustment of input-output relationships therefore contribute more to short-term growth than frontier innovation or scale expansion. Third, dynamic change varies substantially across institutional types and regions. Double First-Class universities record the largest TFPCH increase at 1.121 but also a marked decline in scale efficiency. First-Class Applied universities improve steadily, while

other undergraduate institutions depend more heavily on internal catch-up. Regionally, TFPCH is 1.059 in Southern Jiangsu, 1.018 in Central Jiangsu, and 0.998 in Northern Jiangsu. These differences concern the capacity for continued improvement and resource optimisation more than economic development alone.

The findings support a transition from incremental investment towards structural optimisation, internal coordination, pedagogical innovation, differentiated governance, and dynamic feedback. Several limitations qualify the interpretation. The 31-DMU sample is small relative to the six inputs and seven outputs, which limits the discriminatory power of DEA and may contribute to the high share of frontier units. The anonymised institution codes also restrict external verification unless the final dataset or institutional list is disclosed. Finally, the two-year window captures a single period of change rather than a persistent trend. Future research should enlarge the sample, extend the observation period, test indicator sensitivity and bootstrap robustness, examine causal mechanisms, and compare Jiangsu with other regions.

Acknowledgments

This paper is supported by the Key Project of the Jiangsu Education Science 14th Five-Year Plan (B/2023/01/128); the Key Project of the Higher Education Scientific Research Planning Programme of the China Association of Higher Education (25NL0204); the Special Project on High-Quality Public Course Teaching Reform in Jiangsu Higher Education Institutions (2025GZJX109); and the Suqian University Innovation and Entrepreneurship Education Research Project (2025cxcy14).

References

- [1] Wang, Z. R. The evolution and development trends of entrepreneurship education in China. *Journal of East China Normal University (Educational Sciences)*, 2016, 34(2), 30-38.
- [2] Hu, L. F., Ren, X. X. Evolution and development of research themes in innovation and entrepreneurship education: A bibliometric analysis of CSSCI journal literature from 1999 to 2025. *Journal of Henan University (Social Science)*, 2025, 65(4), 108-114+155-156.
- [3] Hanushek, E. A. The economics of schooling: Production and efficiency in

- public schools. *Journal of Economic Literature*, 1986, 24(3), 1141-1177.
- [4] Charnes, A., Cooper, W. W., Rhodes, E. Measuring the efficiency of decision making units. *European Journal of Operational Research*, 1978, 2(6), 429-444.
- [5] Banker, R. D., Charnes, A., Cooper, W. W. Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management Science*, 1984, 30(9), 1078-1092.
- [6] Andersen, P., Petersen, N. C. A procedure for ranking efficient units in data envelopment analysis. *Management Science*, 1993, 39(10), 1261-1264.
- [7] Parteka, A., Wolszczak-Derlacz, J. Dynamics of productivity in higher education: Cross-European evidence based on bootstrapped Malmquist indices. *Journal of Productivity Analysis*, 2013, 40(1), 67-82.
- [8] Lin, Z. Y. A preliminary study of the economic efficiency of higher education. *Journal of Anhui Normal University (Philosophy and Social Sciences)*, 1983, (4), 30-35.
- [9] Chen, T., Bai, J. Y. Evaluation of the relative effectiveness of higher education inputs and outputs in Western China. *Journal of Northwest A&F University (Social Science Edition)*, 2003, (2), 102-105.
- [10] Liu, R. Z., Ma, Y. H. The status and trends of industry-education integration in professional postgraduate education: An empirical analysis based on the DEA-Malmquist index. *China Education of Light Industry*, 2024, 27(6), 32-40.
- [11] Zhang, H. Q. Efficiency and determinants of human capital investment in higher education in western ethnic regions: Evidence from a DEA-Malmquist-Tobit model. *Higher Education of Sciences*, 2025, (2), 62-73.
- [12] Guan, Y. G. Analysis of resource allocation efficiency in higher education based on a super-efficiency DEA model. *Heilongjiang Researches on Higher Education*, 2019, 37(2), 84-88.
- [13] Li, A. L., Deng, X. B., Hu, Y. M. Efficiency of innovation and entrepreneurship education in undergraduate institutions in Central and Western China: Evidence from 15 universities in Hunan Province. *Journal of Hunan Agricultural University (Social Sciences)*, 2018, 19(3), 98-102.
- [14] Jiang, Y. C., Liu, S. Y., Hong, Y. G. Regional disparities in higher education resource allocation efficiency from the perspective of industrial labour productivity growth. *Research in Educational Development*, 2020, 40(11), 76-84.
- [15] Song, X. D. Evaluation of resource allocation efficiency in university innovation and entrepreneurship education: Evidence from Jiangxi Province. *Journal of Hubei Adult Education Institute*, 2022, 28(6), 10-15, 31.
- [16] You, L., Kong, Q. P. Evaluation and determinants of higher education resource allocation efficiency under the Double First-Class initiative: A super-efficiency DEA-Malmquist and Tobit analysis. *Education & Economy*, 2021, 37(6), 30-37.
- [17] Xu, L. L. Evaluation of resource allocation efficiency in university scientific and technological innovation using relational network DEA. *Shanxi Science and Technology*, 2019, 34(1), 25-28.
- [18] Xia, F., Shi, F., Gao, Y. Evaluation of resource allocation efficiency in innovation and entrepreneurship education at the school level: A case study of University S. *Journal of Heilongjiang Vocational Institute of Ecological Engineering*, 2026, 39(1), 89-94.
- [19] Leontief, W. W. Quantitative input and output relations in the economic systems of the United States. *The Review of Economics and Statistics*, 1936, 18(3), 105-125.
- [20] Wang, S. T., Liang, H., Zhao, Z. Q. Efficiency of knowledge production in philosophy and social sciences at universities and disciplinary differences: Evidence from a DEA-Malmquist index model. *Hubei Social Sciences*, 2026, (2), 99-110.