Quantitative Assessment of Characteristic Features of Strategic Scientists: An Exploratory and Empirical Study (Postprint)

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Abstract

Cultivating and fostering more strategic scientists represents a crucial proposition for achieving high-level scientific and technological self-reliance and independence in our country. To respond to the central government's requirements and support the "selection, cultivation, retention, and utilization" of strategic scientists, this article comprehensively employs multiple research methods from competency models, constructs a quantitative analysis indicator system for the typical characteristics of strategic scientists based on typical cases of 155 benchmark figures both domestically and internationally, and conducts empirical analysis on the indicator system by selecting 720 leading talents from 297 national key laboratories as representatives of the strategic scientist reserve force. The study reveals that, compared with benchmark figures, representatives of our country's strategic scientist reserve force exhibit significant gaps in strategic vision and practical capabilities, weak corporate strategic scientist capacity, and mismatches between disciplinary distribution and our country's developmental strategic needs, and accordingly proposes relevant countermeasures and suggestions.

Full Text

Preamble

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Abstract

Cultivating more strategic scientists is an important proposition for achieving high-level self-reliance in science and technology in China. In response to the central government's requirements and to support the "selection, cultivation, retention, and utilization" of strategic scientists, this study comprehensively adopts multiple research methods from competency models. Based on 155 typical cases of benchmark figures at home and abroad, we construct a quantitative analysis indicator system for the typical characteristics of strategic scientists. We then select 720 leading talents from 297 State Key Laboratories as representatives of the strategic scientist reserve force to conduct empirical analysis of the indicator system. The study reveals that compared with benchmark figures, China's strategic scientist reserve force exhibits significant gaps in strategic vision and practical capability, a weak contingent of enterprise strategic scientists, and a mismatch between disciplinary distribution and China's strategic development needs. Based on these findings, we propose relevant countermeasures and suggestions.

Keywords: strategic scientist, quantitative indicator system, reserve force, validation analysis research
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1. Introduction

In September 2021, President Xi Jinping proposed the important proposition of "vigorously cultivating and employing strategic scientists" at the Central Talent Work Conference, providing clear direction for how to identify strategic scientists. Various local governments, universities, and enterprises have responded actively. According to statistics from publicly available documents, 22 provinces (autonomous regions and municipalities), 11 prefecture-level governments, 31 "Double First-Class" universities, and 10 central enterprises have issued talent development policies, documents, or guidelines that include strategic scientists. However, analysis of these documents reveals a common problem: unclear positioning of strategic scientists and inconsistent understanding of their characteristics. The identification criteria mainly focus on two categories—prestigious titles and industry recognition—making it difficult to effectively guide the "selection, cultivation, retention, and utilization" of strategic scientists.

To address this gap, this paper attempts to construct a competency model and quantitative indicator system for the typical characteristics of strategic scientists. We aim to provide practical references for the cultivation and employment of strategic scientists by systematizing, standardizing, and normalizing their competency and qualification framework. This study combines quantitative methods with qualitative approaches such as case analysis and expert consultation to propose measurable standards and a complete analytical and validation process.

2. Research Design

Competency refers to the underlying, deep-level personal characteristics that distinguish outstanding performers from average performers in a given position. To identify the traits that differentiate strategic scientists from ordinary scientists and strategic S&T talent, this study comprehensively employs competency modeling methods including the deductive method, grounded theory, internal and external benchmarking, the analytic hierarchy process (AHP), and expert consultation. We summarize the typical characteristics of strategic scientists, construct the indicator system, select indicators and set weights, and validate and refine the system. This enables quantitative and empirical analysis of strategic scientist competencies, achieving "evidence-based selection, goal-oriented cultivation, and directed action."

2.1 Competency Model Indicator System Design

2.1.1 Research Subjects **(1) Domestic Strategic Scientist Benchmark Group Selection.** The scope of this study includes renowned Chinese strategic scientists such as Qian Xuesen, Zhu Guangya, Li Siguang, and Wang Daheng, as well as recipients of the "Republic Medal," "Two Bombs, One Satellite" Meritorious Medal, "July 1 Medal," "People's Scientist" award, National Highest Science and Technology Award, and National Science and Technology Progress Award. Considering their distribution across eras, disciplines, and industries, we selected 71 benchmark figures for case analysis. The birth years of this domestic benchmark group range from 1889 to 1970, representing scientists who matured during multiple important development periods in China. Their professional fields cover essentially all areas of natural science and engineering technology.

(2) Foreign Strategic Scientist Benchmark Group Selection. From the perspectives of authority, representativeness, international vision, and strategic significance, we selected scientist groups from the United States and the United

Kingdom—two traditional scientific and technological powers—who have played leading and key advisory roles in national S&T decision-making. Specifically, we analyzed members of the U.S. President's Council of Advisors on Science and Technology from the past three sessions (71 individuals) and successive UK Government Chief Scientific Advisers (13 individuals). These scientists are top scientists selected by their governments, with broad influence and authority in their respective fields and worldwide reputation. Their work involves national strategic S&T policy formulation and implementation, helping us better understand the role and value of Anglo-American strategic scientists in national S&T strategy development.

2.1.2 Model and Indicator System Construction To ensure that the quantitative analysis results of the indicator system can comprehensively, objectively, and accurately characterize the typical features of strategic scientists and meet selection needs, the model and indicator system design follows three principles: integration of strategic needs and policy guidance, balance of reliability and validity, and combination of qualitative and quantitative methods. Based on these principles, we divided the construction of the strategic scientist competency model into three stages: "preset criteria," "model construction," and "model refinement" [Figure 1: see original paper].

(1) Preset Criteria. This stage employs the deductive method, starting from the missions, visions, talent strategies, and talent environments that the state entrusts to strategic scientists, as well as the standards proposed by the Talent Work Bureau of the Organization Department that strategic scientists should "highlight political quality, practical standards, strategic vision, and industry recognition." Combined with literature research and expert opinions, we clarified the basic criteria for the competencies and qualities that strategic scientists should possess, including political quality, scientific literacy, strategic vision, and practical capability.

(2) Model Construction and Refinement. Feature Induction and Preliminary Model Construction. [Figure 2: see original paper] illustrates the process and method for preliminarily constructing the strategic scientist competency model and indicator system using typical cases as internal benchmarks and grounded theory. By extracting and analyzing behavioral and outcome elements, motivations, personal views, and evaluations from others in 142 documents, we identified content units characterizing strategic scientists and conducted three-level coding to abstract labels, concepts, and categories of typical characteristics from the bottom up. This formed the preliminary competency model with its criteria layers, sub-criteria, and measurement indicators, which were then matched with preset criteria to complete selection and consolidation. shows the coding method and examples for strategic scientist material analysis.

Model Refinement Based on External Benchmarking. We selected 84 foreign strategic scientist benchmark figures (U.S. President's Science and Technology Advisors and UK Chief Scientists) to analyze their unique competency characteristics and supplement the constructed competency model and indicator system according to China's actual conditions and deficiencies, making it more forward-looking and complementary. Through case and resume analysis, we found significant differences in institutional types. Domestic benchmark figures mostly came from the scientific community, while a high proportion of foreign benchmark figures came from the enterprise sector. For example, official documents for UK Government Chief Scientific Advisers and U.S. President's Council of Advisors on Science and Technology list engineers alongside scientists as candidates, with over one-third of foreign benchmark figures coming from enterprises.

(3) Indicator System and Weight Setting and Refinement. Using AHP and Delphi Method in Two Rounds. We used AHP with an expert team of 20 members (consulting experts, research team members, and staff) to conduct pairwise comparisons of indicator importance through questionnaires, using YAANP software to determine and set weights for all model indicators. The Delphi method was then applied, inviting five experts (S&T strategy and talent management experts, strategic scientist research experts, top scientists, and think tank leaders) to provide suggestions on indicator selection, supplementation, and improvement. After two rounds of iteration, the final indicator system and weights were obtained . **Expert Consultation for Indicator Setting.** We conducted expert consultations on indicator selection, importance, and ranking to refine the model.

2.2.1 Quantitative Scoring and Classification of Domestic Benchmark Figures

The 71 domestic benchmark figures selected for this study represent China's recognized strategic scientist group. Using this group's data for regression validation effectively verifies the indicator system design. Based on collected materials and resume data of the 71 benchmark figures, we analyzed their total conformity and criteria layer conformity (definitions and methods are in the Appendix). Measured across four dimensions—political quality, practical capability, strategic vision, and scientific literacy—the 71 domestic benchmark figures demonstrated high overall standards, with mean and median total conformity exceeding 80% [Figure 3: see original paper] and . Political quality and practical capability were particularly prominent, fully reflecting the political attribute that strategic scientists must "have the nation's best interests at heart" and the practical standard that they should "emerge from the main battlefield of S&T innovation and grow from the main force of S&T innovation." These results indicate that the refined indicator system has scientific validity and rationality.

Analyzing the 71 domestic benchmark figures using scientific literacy and strategic vision as baselines (due to space limitations, only these two criteria are discussed), we calculated each scientist's deviation from the median conformity to analyze their relative position to the overall average on these criteria. This method identified three types: outstanding, scientifically literate, and strategically visionary. **Outstanding Type:** These scientists scored above the group average on both strategic vision and scientific literacy, with strategic vision higher than scientific literacy, making their special attributes as strategic scientists particularly prominent. Identified figures include Li Siguang and Bei Shizhang (12 total). **Scientifically Literate Type:** These scientists showed higher conformity in scientific literacy than strategic vision, with strategic vision at or below the median. Identified figures include Zhu Kezhen and Hou Xianglin (26 total). **Strategically Visionary Type:** These scientists showed higher conformity in strategic vision than scientific literacy, with scientific literacy at or below the median. Identified figures include Qian Weichang and Cheng Kaijia (33 total). Classification methods are detailed in the Appendix.

2.3.2 Indicator System Reliability and Validity Analysis

(1) Reliability Analysis. Using test-retest reliability, two groups (2-4 people each) applied the indicator system to measure and calculate the 71 domestic benchmark figures twice based on research data. The Spearman correlation coefficients from IBM SPSS Statistics (v26) analysis were all greater than 0.700, indicating good data reliability.

(2) Validity Analysis. Using the 71 domestic benchmark figures' indicator values as samples, we conducted KMO tests on the 15 third-level indicators. The sample KMO value was 0.505. According to Kaiser's common KMO measurement standards, this indicates that the 15 indicators in this study are not very suitable for factor analysis, suggesting that the indicator structure has good structural validity with appropriate discrimination and coverage.

3. Empirical Research

The 14th Five-Year Plan for National Economic and Social Development of the People's Republic of China and the Long-Range Objectives Through the Year 2035 explicitly propose to "reorganize State Key Laboratories to form a rationally structured and efficiently operating laboratory system." As non-legal-person innovation units affiliated with universities, research institutions, and enterprises, State Key Laboratories are an important extension of national strategic S&T forces. Consciously discovering and cultivating more high-level interdisciplinary talents with strategic scientist potential from these laboratories is significant for forming China's strategic scientist talent pipeline. This section selects 720 leading talents (directors and academic committee chairs, including former ones) from 297 State Key Laboratories rated as "excellent" or "good" by the Ministry of Science and Technology as research subjects. We apply the indicator system to score and calculate their conformity to strategic scientist typical characteristics, identify high-conformity individuals, and classify them according to the strategic scientist classification method to validate the scientific rationality and operability of our indicator system and classification method, providing references for strategic scientist identification and reserve force cultivation.

Among the 720 leading talents from 297 laboratories, there are 364 academicians of the Chinese Academy of Sciences and Chinese Academy of Engineering (50.6%), 84 academician candidates (11.7%), and 272 other leading talents (including professors, research fellows, senior engineers, and other academy members, 37.8%). Of these 720 talents, 274 (38.1%) serve as academic committee chairs (including former and honorary chairs) and 446 (61.9%) as laboratory directors (including former ones). Their institutional types and professional field distributions are shown in .

3.1 Validation of Competency Conformity of Reserve Forces

We calculated the strategic scientist typical characteristic conformity for the three categories of leading talents (academicians, academician candidates, and others), selecting the top 50 highest-scoring individuals from each group (hereinafter "Top50") as validation analysis objects. We analyzed the characteristics of these three Top50 groups in terms of conformity and classification results, as well as differences between benchmark figures and the three groups. Overall, the Top50 group of academicians showed the highest total conformity to benchmark figures (mean difference: -17%, compared to -48% and -40% for the other two groups), identifying six strategic scientists who also appear among the 71 benchmark figures, including Shi Changxu, Zheng Zhemin, and Qian Qihu. Comparing criteria layers, the three Top50 groups were relatively close to benchmark figures in political quality and scientific literacy, while gaps were significantly manifested in strategic vision and practical capability. This indicates that while State Key Laboratories, as important components of national strategic S&T forces, are important sources for discovering strategic scientists, especially the academician group representing top scientists, there are deficiencies in cultivating strategic vision and practical capability among S&T talents.

3.1.1 Academician Group The Top50 group of academicians had mean and median total conformity of 64% and 62% respectively , closest to benchmark figures, with minimum values 3% higher than benchmark figures. Analyzing by criteria layer [Figure 4: see original paper], Top50 academicians showed high political quality and scientific literacy, basically equivalent to benchmark figures, but had certain gaps in practical capability and strategic vision (mean differences both -30%). Some individuals showed relatively high conformity in strategic vision.

3.1.2 Academician Candidate Group The Top50 group of academician candidates had the largest gap from benchmark figures among the three groups (mean: -48%, median: -49%). By criteria layer, this group showed varying gaps from benchmark figures, most notably in strategic vision (mean difference: -74%), showing a skewed distribution with a few high scorers but generally low performance [Figure 5: see original paper] and .

3.1.3 Other Groups The Top50 group of other categories had mean and median total conformity of 41% and 40% respectively, with relatively balanced overall distribution but still substantial gaps from benchmark figures (-40% and -41%). By criteria layer [Figure 6: see original paper] and , this group had relatively smaller gaps in political quality (mean difference: -28%), with over 50% reaching benchmark average levels (median difference: 0). However, gaps in strategic vision and practical capability were large (median differences: -73% and -70%).

3.2 Classification Results of Typical Characteristics of Three Top50 Groups

This section classifies the three Top50 groups from the strategic scientist reserve force using the classification method (see Appendix). Results show that the classification of the academician group is relatively close to benchmark figures —. The outstanding type was found only among benchmark figures and the academician group, with Shi Changxu and Zheng Zhemin appearing in both. The other two groups identified types with prominent strategic vision or scientific literacy. Unlike benchmark figures and the academician group, where the strategically visionary type proportion was higher than the scientifically literate type (+10% to +33%), the latter two groups showed the opposite pattern (+4% for scientifically literate type). These results confirm the Organization Department's definition that "strategic scientists are the 'key minority' in national strategic S&T forces" and validate our conclusion from case analysis that strategic scientists are "strategists among scientists."

3.2.1 Institution Distribution The current institutions of the three Top50 groups from State Key Laboratories are concentrated, mainly in universities and research institutes (total: 86.7%), distributed across 101 institutions. Compared with the overall distribution of 720 leading talents, the proportion from enterprises decreased significantly (-6.0%), while universities and defense systems increased. Among the top 10 institutions by number of people, only the Shanghai Institute of Life Sciences, Chinese Academy of Sciences (4 people) is a research institute; the other nine are universities —. Enterprises, as important entities for applied basic research and major 依托 units of State Key Laboratories (accounting for 26.8% of the 297 laboratories), have a low representation in Top50 groups except for the academician candidate group (14.0% from enterprises).

3.2.2 Age Distribution The overall age distribution of the three Top50 groups concentrates in the 51-60 age group (41.3%) and 61-70 age group (36.7%) [Figure 7: see original paper]. However, age composition varies significantly among groups. The academician group has the most people in the 61-70 age group (40.0% of its own group) and far more people aged 81-100 than the other groups. The academician candidate Top50 group concentrates in the 51-60 age group (44.0%) and 61-70 age group (40.0%). The other group's Top50 concentrates in the 51-60 age group (60.0%), showing a younger overall age structure.

3.2.5 Disciplinary Distribution The three Top50 groups' research fields are mainly distributed in information technology, automation, electronics, life sciences, machinery and transportation, and other disciplines, with high representativeness in strategic emerging industries such as new-generation information technology, biotechnology, new energy, new materials, and high-end equipment, basically aligning with China's 14th Five-Year Plan key area layout . For example, information technology, automation, and electronics rank first (15%), which are core to the new-generation information technology industry and crucial for digital economy development; life sciences rank second (15%), closely related to biotechnology and helpful for accelerating biopharmaceuticals, breeding, materials, and energy industries. However, there are still deficiencies in certain key areas and regions. For instance, despite having many strategic scientists in biotechnology, more are needed with interdisciplinary understanding and innovation capability to promote integration between biotechnology and information technology. Additionally, basic sciences have low overall representation, such as mathematics and physics (5%) and chemistry (6%), mainly distributed in universities and research institutes.

4. Conclusions and Recommendations

4.1 Conclusions

This study aims to construct a quantitative analysis indicator system for the typical characteristics of strategic scientists and conduct empirical analysis using leading talents from State Key Laboratories to explore the cultivation and utilization of strategic scientists in China. Results show that the constructed indicator system has scientific validity, rationality, and operability for identifying and classifying strategic scientists, confirming that strategic scientists are an outstanding minority among scientists with distinguishing attributes in political quality, practical capability, and strategic vision. Empirical analysis also reveals that State Key Laboratories are important cultivation bases and selection sources for strategic scientists, but compared with benchmark figures, there are significant gaps in strategic vision and practical capability, and certain issues remain in personnel structure and research directions that require optimization and adjustment.

Specifically: (1) Enterprises have potential in cultivating strategically visionary reserve forces, but current strategic scientist strength is weak. Compared with research institutes, the number of Top50 individuals from enterprises is significantly lower, far below the proportion of foreign benchmark figures from enterprises, indicating that enterprise strategic scientist forces need strengthening. (2) The age distribution of Top50 reserve forces is concentrated and skews older, but outstanding young talents are emerging. This reveals both the career transition from early-stage pioneering research to later-stage leadership and advisory roles, and that the academician group as an important selection source shows a longer lifecycle of strategic scientist characteristics. (3) The disciplinary distribution of Top50 reserve forces has some mismatch with China's development strategic needs, requiring optimization. This includes insufficient distribution in certain key areas and regions, low representation of basic sciences, and concentration in universities and research institutes.

4.2 Countermeasures and Recommendations

(1) Flexibly introduce and strengthen enterprise strategic scientist forces. In addition to providing favorable policy support and funding for enterprise self-cultivation, we should fully leverage the advantages of universities and research institutes in cultivating and gathering strategic scientists to play their leading role in enterprise S&T innovation. For example, regularly organize forward-looking S&T activities with government, enterprise representatives, and renowned scientists to provide planning directions for national S&T layout; lead the establishment of effective joint S&T 攻关 teams between government, enterprises, and research institutions to tackle key "bottleneck" technologies.

(2) Optimize and coordinate strategic scientist structure and resource allocation according to national strategic needs and competency standards. Prioritize disciplines for introduction and cultivation toward "bottleneck" areas, major S&T frontiers, and advanced fields. Encourage scientists to cooperate with enterprises, organizing teams to conduct collaborative research toward national major needs and industrial development trends. This can exercise organizational leadership in large-team operations while familiarizing scientists with market resource allocation mechanisms and industrial development patterns, strengthening holistic vision. Based on typical characteristic classifications and national/local development needs, introduce different types of strategic scientists and rationally allocate their usage directions to maximize their roles and avoid unreasonable resource allocation.

Due to time and resource constraints, this study has limitations. The research subjects are limited to leading talents from State Key Laboratories as reserve force representatives, not covering all types of strategic scientists. The data used are from public sources and may not be comprehensive, potentially affecting objectivity and accuracy. Future research can expand subjects and data collection methods to provide more comprehensive and in-depth theoretical support for cultivating and utilizing strategic scientists in China.

Appendix: Quantitative Scoring of Indicator System and Classification of Typical Groups

1. Total Conformity

Conformity in this paper refers to the degree of fit calculated by applying the indicator system and weights to target subjects (such as benchmark figures), quantitatively reflecting how well individuals fit the typical characteristics of strategic scientists. The total conformity of strategic scientist typical characteristics is the sum of each of the 15 measurement indicators' values (1 or 0 indicating whether the indicator is met) multiplied by their weights across four criteria.

Let a represent the value of indicator n, b represent the weight of indicator n, and T represent the total conformity of target subject i. The calculation is:

$$T_i = \sum_{n=1}^{15} a_n \times b_n$$

2. Criteria Layer Conformity

Criteria layer conformity represents the degree to which target subjects fit strategic scientist typical characteristics on each criterion (e.g., political quality conformity). Its original value is calculated as the sum of conformity values (0 or 1) of measurement indicators under each criterion multiplied by their weights. To facilitate horizontal comparison between criteria and eliminate interference from weight differences, we linearly normalized the original values, expressing criteria layer conformity as a percentage representing the target subject's position relative to all subjects.

Let NL represent criteria layer conformity and RNL represent its original value. The calculation is:

$$NL_i = \frac{RNL_i - \min(RNL)}{\max(RNL) - \min(RNL)} \times 100\%$$

3. Typical Characteristics Classification

To explore features and strengths of target populations from quantitative scoring results and support stratified classification of strategic scientists, we use median conformity to represent the intermediate level of subjects on a criterion (using median rather than mean due to potential outliers and skewed distributions). We use deviation from median conformity to indicate relative position to the overall average, identifying benchmark figures with common characteristics, such as groups outstanding in both scientific literacy and strategic vision, or types with prominent practical capability but below-average scientific literacy.

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Note: Figure translations are in progress. See original paper for figures.