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Original Article

Questionnaire survey and DEMATEL method approach for analysis the influent factors of chinese scientific Principal Investigators

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Abstract: Objective: The objective of this study was to use DEMATEL method to analyze main influent factors of Chinese scientific Principal Investigators (PI). Methods: Questionnaire survey method, Expert consultation method, DEMATEL method. Results: We found there were 24 factors influence function of PI scientific research management mode. Through questionnaire survey at first, it came out the top five affecting factors-PI autonomy, stable funding for research, academic environment, PI group culture and improvement of auxiliary center. However, through DEMATEL method to analyze 24 factors, we could find the extent ion of affecting determinants, including the strongest and weakest affecting function. Determinants of PI autonomy, stable funding for research, management mechanism of review, personnel incentives and the management mechanism of experimental platform were certainly affecting determinants on the system, which were placed in the cause group and ranked as the first to fifth priorities, respectively. While academic environment, laboratory personnel quality, PI group culture, cultivation mechanism, working enthusiasm were partially affected, which were placed in the effect group and ranked priorities. The results suggested that PI autonomy and working enthusiasm were identified as the most affecting and affected determinants on the coordinates and diagram, respectively. Conclusions: Giving the PI autonomy, increasing the funding for research, keeping the good atmosphere of the scientific research institutions and excellent scientific research teams have positive effects on Chinese scientific Principal Investigators (PI).

Keywords: Principal investigators (PI), DEMATEL method, questionnaire survey

Introduction

Principal Investigators (PI), which first appeared on the applications of research in Europe and U.S.A, that is defined by The National Science Foundation (NSF) as "the individual, who is responsible for the direction of the project of science and technology", meanwhile, it also points out that the term is generally used in the field [1, 2]. The National Institutes of Health (NIH) defined PI as the individual with certain powers and responsibilities of guiding fund project or plan, and the powers and responsibilities are determined by the application organization [1, 3, 4]. PI system is a scientific research management mechanism of material resources allocation to share scientific research resources, which takes PI as the core of human resource allocation, project funding cost accounting, the allocation of financial resources, and also sharing of scientific research resources. PI plays an important role in different disciplines, including the development and implementation of a strategy to maximize enrollment, optimize data quality, and ensure patient retention [3, 5].

PI system is relatively mature in foreign countries [2, 3, 6, 7]. Generally, a PI is in charge of a laboratory in the United States [6, 8]. Although there is no specific requirement for the applicants with titles and qualifications, PI is responsible for the scientific research projects, especially engaged in basic research. It means that PI must possess the ability of organization and academic. A large amount of scientific research

Table 1. The demographic variables of 24 experts

Demographic variables	Number (N = 24)	Percentage
Gender		
Male	16	66.67%
Female	8	33.33%
Age		
Below 30 years old	1	4.12%
31~40	7	29.17%
41~50	12	50.00%
51 years old and above	4	16.67%
Educational		
Bachelor	3	12.50%
Master	5	20.83%
Doctoral	16	66.67%
The length field		
>20	14	58.33%
>5 and <20	10	41.67%
>3 and <5	0	0

institutions, get down to implement PI system of scientific research management mode in China [2, 5]. In 1999, the Chinese academy of social sciences began to try out the PI system. The success has been fully proved that the mechanism is more effective in encouraging competition, mobilizing the enthusiasm of researchers, and promoting scientific and technological innovation [3, 9]. Since 2003, in order to return to scientific research itself, National Institute of Building Science (NIBS) has taken PI system as a reference to enroll international well-known scientists to construct scientific steering committee. It advocated that there is absolute autonomy for the scientific research personnel to do research, and for the lab directors to decide each laboratory's project without any interference from superintendent and administrative staff [2, 9, 10]. Under the PI system of scientific research management mode, NIBS published many high level articles in famous journals worldwide, which occupied an important seat in the field of domestic scientific research in a short time. Due to its unique high efficiency, PI system reduced the number of intermediate links and unnecessary losses to expertise scientific research. Meanwhile, the effective and rational uses of funds took up an undeniable role in the laboratory project well-going. However, most of research institutions also encountered many problems in the implementation of the PI system in China. With the increase of investment to scientific research and the expansion of scientific research teams, the shortcomings of the PI system restrict the development of scientific research more and more. It means that the mechanism of scientific research institutions in China weakened the autonomy of PI system. As a result, mediocre greatly reduce the efficiency of the PI system, but the gifted scientist is hard to display his ability. The PI assessment mechanisms of some teams are not sufficient, leading to laboratory staff inactive, team management confusion and so on [2, 11, 12]. Therefore, the purpose of this study is to use DEMATEL method to summarize the key factors which influence the scientific management mode of PI system. It can help us use the PI system better, and improve the effective performance of the scientific research institutions, especially those in the field of basic research of life science in China [9, 13].

DEMATEL method is a development of expert meeting prediction method, which is a process that researchers carefully organize [13-16]. In this process, the researchers used a series of questionnaire, and requested for experts' advice by implementing several rounds on some certain topic [11]. Until the panel members tend to agree. With its practical benefits, the DEMATEL method has been widely applied in various fields, including education [14], investment [17], supply chain management [15] and influential factors [13, 17]. The DEMATEL method is better than the questionnaire method to help researchers understand the nature of problem further.

The purpose of this study is to use DEMATEL method and Questionnaire survey to analyze the main influential factors of Chinese scientific Principal Investigators (PI) [18, 19], and compare with relevant influential factors that have positive effects on Chinese scientific Principal Investigators (PI).

Materials and methods

Questionnaires

Consultant for evaluating the condition of the results has an important role, who will directly affect the scientific nature and rationality of index system. In order to receive more compre-

Table 2. PI system of scientific research management

Category	Elements
The essence of people (9)	Management mechanism of review
	Personnel incentives
	Leadership
	PI autonomy
	Laboratory personnel quality
	PI group culture
	Knowledge reserve
	Working enthusiasm
	Cultivation mechanism
The aspects of content (3)	Improvement of auxiliary Center
	Management mechanism of research platform
	Improvement of the database
The elements of fortune (7)	Stable research source of funding
	Source of funding
	Avoid unnecessary waste
	Service efficiency of funds
	Regulation and transparency
	Safeguard mechanism (Housing, transportation, health care)
	Team members' income
Other elements (5)	Safeguard mechanism (spouse employment)
	Decision-making democracy and fairness
	Scientific research achievements transformation support
	Academic environment
	Cooperation platform of academic exchanges

hensively collected expert advice and to improve the credibility of research conclusion, the experts were selected in the concrete implementation, such as age, geography, research direction. Therefore, 24 experts come from the four famous research institutes in China, including the Beijing institute of life sciences, Chinese academy of sciences, Shanghai institute of neuroscience and life sciences of Xiamen university. The experts' details are described as **Table 1**.

In order to take a good data questionnaires system, there is need to develop a policy with clear guidelines to implement easily. The formation of the questionnaire as follows:

(1) Advisory letter. Brief introduction of the research and evaluation methods, to focus on the research purpose and content. First, to prepare papers including related literature material, the development and original of PI system, and its running situation domestic and overseas. Secondly, to send paper to the six famous experts from four different institutions. To combine experts' feedback and their experience, then to confirm the factors that would affect the PI system of scientific research management mode. (2) Collect and organize all six experts' second opinions, pick up the second factor libraries, and divide it into three aspects: the factors would all agree, the factors some should be deleted, and the factors some should be joined. Then send this factor library to the experts and ask them to review it. (3) Collect and organize all six experts' third opinions, that they almost get agreement to total four categories of 24 factors such as **Table 2**; all 24 factors directly or indirectly affect the expression of the PI system of scientific research management mode. (4) Two kinds of questionnaires including Likert level measurement and scoring method. The pair-wise comparison designated by four levels: 0, 1, 2, and 3 to represent "No influence", "Low influence", "High influence", and "Very high influence", and Likert level measurement was issued to 16 experts. Grading method of the questionnaire issued to other 8 experts, 24 factors according to important degree assignment, finally, the value of one thousand points. (5) In our study, questionnaires were issued to the experts through e-mail, and require the experts reply in prescribed time limit (two weeks).

The author visited each expert in person, explained the content of the questionnaire, and requested each expert to complete the questionnaire. Overall, 24 questionnaires were distributed and returned. The valid return rate was 100%.

DEMATEL method

Expert Profiles: The target population consisted of 16 experts. We conducted a questionnaire to

Table 3. The scores of the experts' view on 24 elements according to the important degree of evaluation index

Components	Experts' Responses					
	Completely agreed	Agreed	No Comment	Disagreed	Completely Disagreed	Median
Management mechanism of review	13	5	0	0	0	45
Personnel incentives	13	5	0	0	0	45
Leadership	11	7	0	0	0	40
PI autonomy	16	2	0	0	0	61.67
Laboratory personnel quality	13	5	0	0	0	45
PI group culture	14	4	0	0	0	51.67
Knowledge reserve	11	7	0	0	0	41.67
Working enthusiasm	9	9	0	0	0	33.33
Cultivation mechanism	11	7	0	0	0	41.67
Management mechanism of research platform	13	5	0	0	0	45
Improvement of auxiliary Center	14	4	0	0	0	51.67
Improvement of the database	5	11	2	0	0	28.33
Stable research source of funding	15	3	0	0	0	60
Source of funding	5	12	1	0	0	28.33
Avoid unnecessary waste	4	13	2	0	0	26.67
Service efficiency of funds	12	6	0	0	0	43.33
Regulation and transparency	8	10	0	0	0	36.67
Safeguard mechanism (Housing, transportation, health care)	8	10	0	0	0	36.67
Team members' income	10	4	2	0	0	38.33
Safeguard mechanism (spouse employment)	10	5	1	0	0	38.33
Decision-making democracy and fairness	9	8	1	0	0	30
Scientific research achievements transformation support	7	10	1	0	0	35
Academic environment	14	4	0	0	0	53.33
Cooperation platform of academic exchanges	12	6	0	0	0	43.33

gather the opinions of experts. A total of 16 eco-travel experts participated in our questionnaire using the Delphi method.

Obtain average matrix from experts: Based on the relationship among elements, a scale of influence degree was developed for pair-wise comparisons. Specifically, each interviewee's cognition of each aspect's influence degree was assessed through the pair-wise comparison of aspects (elements). In the assessment scale, 0, 1, 2, and 3 denoted no influence, low influence, moderate influence, and high influence, among the aspects (elements), respectively.

Normalize the average matrix to get initial direct-relation matrix: The count of elements was denoted as n. Expert opinions were collected by conducting a questionnaire survey. Elements were compared in pairs based on their relationship and degree of influence. Therefore, an n×n direct-relation matrix (denoted as M) was obtained [11], in which M_{ij} indicated the influence degree of element i on element j, and the diagonal elements M_{ii} were set as 0.

Compute the total relation matrix: Normalize the initial direct-relation matrix. The normalized direct-relation matrix X = B×k can be obtained from (1) and (2)

$$k = \frac{1}{\max\limits_{1 \le i \le n} \sum\limits_{j=1}^{n} M_{ij}} (i, j = 1, 2, \ldots, n) \quad (1)$$

$$X = B \times k \quad (2)$$

The total relation matrix T is obtained by using the following numerical calculation: the total-relation matrix (T) total relation matrix is calculated with basis on matrix M and the identity matrix I.

$$T = M(I-M)^{-1} \quad (3)$$

Step calculates the sum of rows and columns of total relation matrix: Calculate the sum of

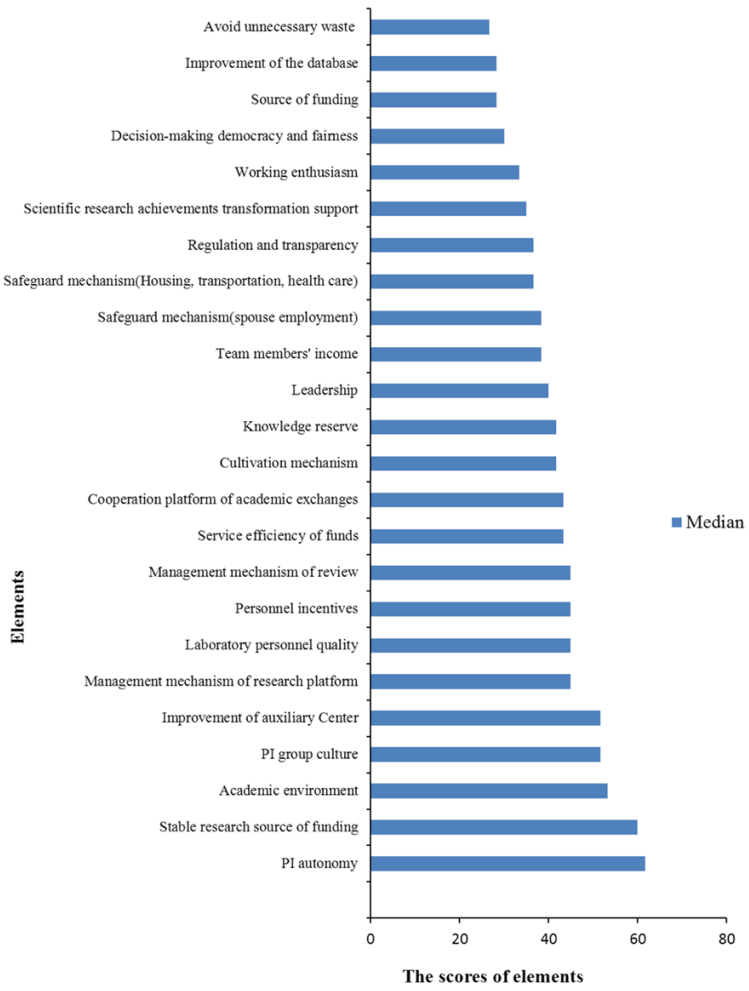

Figure 1. The elements of sorting by scores with median value of expert evaluation through questionnaire survey.

rows and columns of matrix T. The sum of rows and the sum of columns are separately denoted as vector D and vector R as follows.

$$T = [M_{ji}]_{n\times n},\ i, j = \{1, 2, ..., n\} \quad (4)$$

$$D = \left[\sum_{i=1}^{n} M_{ij}\right]_{n\times 1} = [M_{ij}]_{n\times 1} \quad (5)$$

$$R = \left[\sum_{j=1}^{n} M_{ij}\right]_{n\times 1} = [M_{ij}]_{1\times n} \quad (6)$$

Explain the causal diagram: The values of (D+R) on the horizontal axis were defined as prominence, indicated the total degree to which an element exerted influence on and was influenced by other elements. Therefore, (D+R) showed the degree to which element k was at the core of all problems. In addition, the values of (D-R) on the vertical axis were defined as relation, representing difference in the degree to which an element affect and was affected by other elements. Thus, (D-R) showed the causal degree of element k in all problems [16, 20, 21].

Statistical analysis

The final scores were analyzed using MATLAB 7.9.0 and Spss 19.0.

Result

According to factor assignment and total 1000 calculated points, questionnaire scale shows there are 24 factors that influence the function of PI scientific research management mode. And the present study findings showed that PI autonomy, Stable research source of funding, Academic environment, PI group culture and Improvement of auxiliary center affecting determinants on the system, were placed in the cause group and ranked as the first to fifth priorities (**Table 3** and **Figure 1**).

In the causal diagram, dividing into four quadrants (**Figure 2**), (D+R, D-R) represented the horizontal and vertical axes. The mean value and 0.0 were used as the dividing points on the horizontal axis (D+R) and vertical axis (D-R), respectively [13, 21].

According to the positive value of SC (D-R), DEMATEL analyses showed that PI autonomy (S12), stable funding for research (20), management mechanism of review (S18), personnel incentives (S22) and the management mechanism of experimental platform (S24) certainly affected determinants on the system, which were placed in the cause group and ranked as the first to fifth priorities. While academic environment (S5), laboratory personnel quality (S8), PI group culture (S6), cultivation mechanism (S9), working enthusiasm (S23) were partially affected, which were placed in

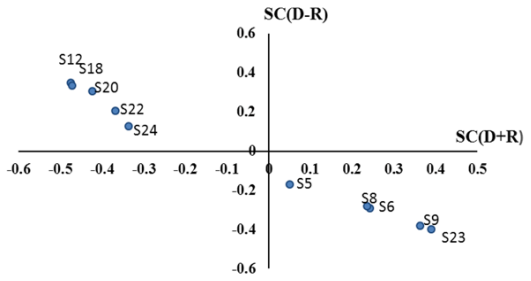

Figure 2. DEMATEL models distribution diagram for the extent ion of affecting determinants.

the effect group and ranked priority (**Table 4**; **Figure 2**).

The values of SC (D+R) were defined as prominence, indicated the total the degree to which an element affect and was affected by other elements. So, PI autonomy (S12) and academic environment (S5) were identified as the most affecting and affected determinants on the coordinates and diagram, respectively (**Table 4**; **Figure 2**).

Discussion

The role of PI and the qualification is usually well described in the requests for proposals by four famous Chinese institutes. And experts of the PI are defined as "At least 5 years working background on the position of the management, or even more than 20 years".

This paper presented a new study comparing two different methods, which influenced the function of scientific research management mode of PI system. We could find that PI autonomy and Stable research source of funding were two main affecting factors. Secondly, research atmosphere of scientific research institutions and research teams also played an important role in effecting the function. Management mechanism of review, Personnel incentives, Management mechanism of research platform and laboratory personnel quality were four main factors, which played the same role in the scientific research management mode function of PI system. The results, the present situation and preliminary analysis of data were similar to the western developed countries [6, 8, 22].

In our study, PI autonomy should be placed in the first place of all the factors that influence the function of PI system, whether we constructed experts to consult the 24 factors or used the DEMATEL method to analyze. Life science research team was composed of scientific research staffs, serving for a common scientific research objectives. The researchers in the team had good self-management ability and were willing to take responsibilities of the common goal. And the autonomy extent of the PI determined the height and width of the team's resources. Especially in the field of basic scientific research, original innovation depended on enough autonomy. Basic research of life science research projects often needed large precision instrument and a large amount of funds. Stable research source of funding would make researchers put much time and energy in doing research work, rather than in getting the project and evaluating the fund.

Scientific research is a team work, and cooperative research atmosphere can promote the communication and cooperation between and inside the research teams. The evaluation of Management mechanism included the appraisal period, the appraisal standard, the expert composition as well as the result processing, such as promotion and elimination system. For PI system, the choices of lab and lab members were vital. It means that a strong scientific research team guarantees the scientific results. After determining the development direction of laboratory team and research, process and result assessment could keep laboratory studies in the right way. The rationality, comprehensiveness and fairness of the evaluation were the core contents of the management mechanism. And an evaluation criterion often acted as the leading role of policy. In order to ensure that the researchers can concentrate on academic and make some achievements, as incentive theory says, PI should pay attention to talent incentive system, including the material incentive and spiritual incentive, and reflect the contribution, particularly senior talent and the crowd of high cultural quality. So researchers could find their sense of accomplishment and achieve their value in the process. Platform support was the foundation of the scientific research work. Due to the lack of sharing of large scientific research platform, some experimental facilities, instruments and equipment were distributed in different scientific research institutions. The research groups were even

Table 4. The experts' view on 24 elements according to the total-relation matrix

Order	Elements	D	R	SC (D+R)	SC (D-R)
S1	Cooperation platform of academic exchanges	-0.03583	0.01503	-0.0208	-0.05087
S2	Regulation and transparency	-0.03480	-0.04029	-0.07508	0.00549
S3	Leadership	-0.03615	0.08849	0.05234	-0.12464
S4	Improvement of the database	-0.04899	-0.15583	-0.20481	0.10684
S5	Academic environment	-0.00361	0.39444	0.39083	-0.39806
S6	PI group culture	-0.02440	0.26843	0.24403	-0.29283
S7	Knowledge reserve	-0.03600	-0.10675	-0.14275	0.07075
S8	Laboratory personnel quality	-0.00887	0.37289	0.36402	-0.38175
S9	Cultivation mechanism	-0.02333	0.25975	0.23642	-0.28308
S10	Improvement of auxiliary Center	-0.05344	-0.08764	-0.14107	0.03420
S11	Safeguard mechanism (Housing, transportation, health care)	-0.07304	-0.14439	-0.21743	0.07135
S12	PI autonomy	-0.06294	-0.41095	-0.47389	0.34802
S13	Scientific research achievements transformation support	-0.06510	-0.09108	-0.15618	0.02598
S14	Source of funding	-0.04811	0.07413	0.02602	-0.12224
S15	Avoid unnecessary waste	-0.05917	-0.00438	-0.06355	-0.05479
S16	Service efficiency of funds	-0.06662	-0.10807	-0.17469	0.04144
S17	Safeguard mechanism (spouse employment)	-0.06449	-0.15691	-0.22140	0.09242
S18	Management mechanism of review	-0.05943	-0.36276	-0.42219	0.30332
S19	Team members' income	-0.05676	-0.08429	-0.14105	0.02752
S20	Stable research source of funding	-0.06762	-0.40272	-0.47035	0.33510
S21	Decision-making democracy and fairness	-0.01100	-0.09576	-0.10676	0.08475
S22	Personnel incentives	-0.08143	-0.28563	-0.36706	0.20420
S23	Working enthusiasm	-0.05899	0.11077	0.05178	-0.16976
S24	Management mechanism of experimental platform	-0.10400	-0.23066	-0.33466	0.12666

hard to take and complete major innovative research projects that affect the sustainable development of the PI system. Therefore, in order to implement the PI system successfully, it was necessary to establish a comprehensive laboratory platform to achieve resource and platform sharing. The quality of the experimental personnel was related to the successful development, the experimental work directly, and results of the study further. As auxiliary personnel of scientific research team, experimental personnel should take part in training to improve their level of experimental skills and equipment operations. The cultivation of talent quality could not be separated from the establishment of evaluation and incentive system. We should combine the characteristic, positioning of experiment personnel and the assessment in a targeted manner, including business skills, service attitude, work enthusiasm and learning ability. The assessment method not only applied to own department inside, but also could invite the staff of the cooperative laboratory to join in. The application of the assessment results could stimulate personnel for work enthusiastically, promote the quality of talent, and improve the overall quality of the experimental personnel as the goal.

Conclusions

In summary, our study suggests that PI autonomy and stable research source of funding are the most important factors to restrict the function of scientific research management mode of PI in China. Research atmosphere of scientific research institutions and research teams also plays an important role in effecting the function. Management mechanism of review. Giving the PI autonomy, increasing the funding for research, keeping the good atmosphere of the scientific research institutions and excellent scientific research teams have positive effects on Chinese scientific Principal Investigators (PI).

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Disclosure of conflict of interest

None.

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