文章编号 1674-2915(2011)04-0340-15

Evaluation of independent innovation capability of institutes based on hawk-dove quantum games

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Abstract: Innovation capability is the major driving force for the technology and economic development of a country. Establishment of a scientific evaluation method for innovation capability can be helpful to enhance such a capability for those institutes in a country and can provide references for government to make policies in science and technology development. In this paper, a new evaluation method is created based on the hawk-dove game theory. Corresponding to basic factors of quantum game theory, the physical meanings in an innovation system are introduced and a evaluation model of technology innovation capability is established based on the hawk-dove game theory. Then, the relation between entanglement and benefits matrix is analyzed and a method is established in which the entanglement from various participants in hawk-dove quantum game theory is used to indicate innovation capability. Furthermore, the capacity of independent innovation of research institutes is explained with hawk-dove quantum game theory, an index system for independent innovation capability is constructed and a combinational calculation method, namely, the calculation of quantum entanglement, is also set up. Finally, institutes of Chinese Academy of Sciences are chosen as the evaluation examples and evaluation data from this method and the simple statistical method of China Academy of Engineering Physics are compared. The result shows that this new method is rational and operable.

Key words: quantum game; independent innovation capacity; entanglement

基于鹰鸽量子博弈理论评价科研院所的科技自主创新能力

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摘要: 科研院所的科技自主创新能力是推动国家科技进步和经济发展, 应对国际经济危机的主要动力, 创建科学、完善的科技创新能力评价方法有助于提升科研院所科技创新能力, 并为国家制定科技创新决策提供参考依据。本文基于鹰鸽

收稿日期: 2011-03-12; **修订日期**: 2011-07-15

基金项目: Supported by Key Program for International S&T Cooperation Projects of China (2011DFA50590)

量子博弈理论,提出了一种评价科研院所自主创新能力的方法。介绍了量子博弈论的各基本要素在科技自主创新体系中所对应的物理内涵,根据鹰鸽量子博弈理论建立了科技自主创新能力评价模型,分析了纠缠度与收益矩阵之间的关系,确立了依靠各参与者在鹰鸽量子博弈中的纠缠度来表征科技自主创新能力的方法。给出了科研院所科技自主创新能力的量子博弈论解释,构建了科技自主创新能力评价指标体系,并确定了评价的合成计算方法,即量子纠缠度的计算方法。最后,以中科院部分研究所为实例进行了科技自主创新能力的评价,并利用主成份分析法和中物院的简单统计方法对得到的数据进行了对比分析,结果证明了提出的方法合理且有可操作性。

关　键　词:量子博弈;自主创新能力;纠缠度

中图分类号:F224.32; O431.2　　**文献标识码**:A

1　Introduction

The global financial crisis was triggered by U. S. subprime mortgage crisis since 2008. World's economic development has suffered great turmoil. A new model of economic development is in urgent need to overcome the crisis. This new model of economic growth must be based on technology development and by means of innovation productivity. In another word, technology innovation will be the strategic choice to conquer the economic crisis. Technology innovations from institutes have always been in a dominant position in the development of this country. There are many research institutes, and their researches focus on variety of fields and categories. They are the major entities of technology innovation[1-7]. Therefore, it is very important to establish a scientific analysis method and survey system to evaluate the innovation capability of those institutes. Correctly analysis and evaluation of the innovation capability of institutes not only enhance those capabilities and raise the innovation level, but also provide the strategic references for the government in decisions of research emphasis, funding distribution and policy making in a certain period of time. It will enhance the macro-control and the guidance of the technology development of the country. However, technological innovation capability is a complicate and systematic economic activity. Correspondingly, the analysis and evaluation of such a system must be a multi-task, combinatory and complicated system. So far, the evaluation system in this country is still in the development stage. Specially during the innovation of those institutes, the differences in the understanding of those basic concepts, in the interpretation of information, have limited the exploration of new innovation and restricted the dynamic development of evaluation mechanisms. The quantum game theory studies entanglement of relevant factors, strategic optimization with new perspectives, new ideas and new features from the results. With the concept of the uncertainty analysis and the concept of quantum entanglement, the application of quantum game theory has obtained more accurate, comprehensive results and have provides a broad space for the technology innovative development.

In this paper, by applying the hawk-dove quantum theory, we have established an evaluation method for the innovation capability of institutes. The basic theory of the method, concepts of the factors, construction of the model and evaluation indices are described. The evaluation of the innovation capability of institutes of the Chinese Academy of Sciences is investigated by using this method and the obtained results are discussed.

2　Quantum game theory explanation of independent innovation capability

The essence of scientific and technological innovation is technology innovation based on knowledge innovation. Scientific and technological independent innovation has common characteristics of cooperation and competition, and also has features of non-physical outputs, huge risk, and many unknown factors.

Quantum game theory, as a theory widely used in economics, politics and military decision-making, computer science, has opened up new horizons for the study of social science phenomena, based on great advantages in individual competition capturing and collaboration pattern of behavior[9-13]. Through analyzing of coin model, prisoner's dilemma and the hawk-dove game model[14-16], it could be made sure that it is reasonable to use quantum game theory and method to study and assess scientific and technological independent innovation. And any cooperation and mutual competition can be considered as a quantum game process. Meanwhile, quantum analysis could be done. Therefore, a proper quantum game model should be established to relate itself and practical scientific and technological independent innovation.

2.1 Quantum game basic factor and actual direction of scientific and technological independent innovation

Quantum game analysis of scientific and technological independent innovation is the same as others, for they all consist of six basic elements of participants, strategy space, payment functions, information structure, income matrix, and entanglement, as shown in Fig. 1.

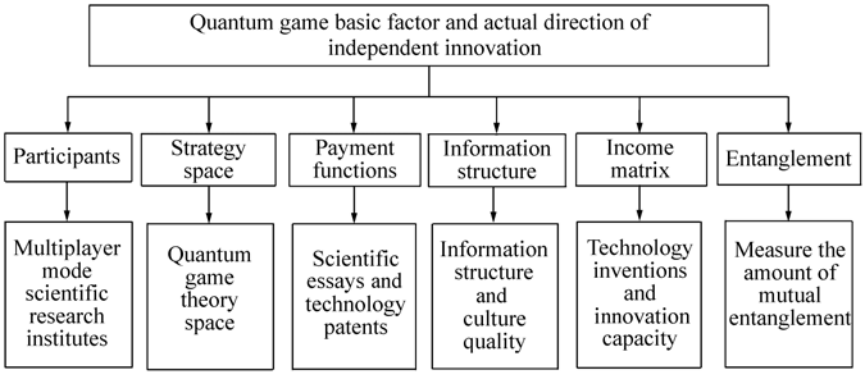

Fig. 1 Basic element contents and actual points of quantum game for independent innovation capacity

The basic element of any game is its participants, who are the independent rational decision makers, where participants in quantum game are related scientific research institutes. In order to achieve independent innovation ability in scientific research institutes of different disciplines, different levels and different areas, the multiplayer mode has been chosen. The independent innovation ability assessment system focuses on influence among scientific research institutes, relationship of cooperation and competition in decision-making process of income matrix.

Participant's strategy is a plan of action throughout the game. It provides participants in advance reasonable responses for each possible way. However, strategy cannot be selected at random in technological innovation of scientific research institutes. It is always running in a specific stage or environment that its operating strategy must be constrained by its environment. Therefore there is a need to measure the strategy well or not through specific conditions. Quantum game theory has made great contribution to classical game theory, which is attributed to the ability of expanding the strategy space in classical game theory, providing more strategy choices for participants, and making choices not entirely two possibilities of Yes/No. That greatly enriches the connotation of game theory and further closes to the actual evaluation of scientific and technological innovation in scientific research institutes, and enhances the coaching skills.

In the game theory, the payment function is

level of effectiveness obtained from game by participants. It is a strategy or action function of participants, which is the something each participant really cares about. For the research institutes, the benefits of science and technology can not be limited to income ratio of material wealth. Science area has features of scientific, innovative and theory which are different from other areas. Academic and technology patents are scientific records of academic subjects in experimental, theoretical or predictive research and results of a new or innovative scientific ideas and knowledge.

Information structure is also very important in science and technology innovation. It not only selects independent innovation of information technology terms in research institutes, but also considers the information schedule established in the long process of information implement and communicate as well as culture quality and experience accumulated by scientific researchers for a long time.

Income matrix consists of each strategy and corresponding natural state. It is the ability of new scientific discoveries, new theories, new methods and technology inventions obtained by scientific research institutes. It also includes the ability of integrated innovation and the introduction of advanced technology to further develop, explore and reveal the unknown law.

From the point of quantum theory, quantum entanglement always emphasizes entanglement among quantum states of different particles. Meanwhile the performance of quantum entanglement is the link among quantum states. In quantum entanglement, entanglement is the amount of entanglement of the study state where it is to measure the amount of mutual entanglement between scientific and technological innovation.

2.2 Hawk-dove quantum game model for independent innovation capability

Hawk-dove game is not only the game between the two animals of hawk and dove, but also the strategy and balance problems of the same species, internal competition and conflict. Hawk and dove refer to attack and peaceful type. In the classic hawk-dove game, the nash equilibrium is (hawks, doves) and (hawks, doves). From the perspective of maximizing benefit, there can be only one optimal result rather than win-win result. And when the two sides take quantum entanglement strategy beyond the classical strategy, the miracle occurs. The introduction of quantum entanglement makes their game the original selfish character act into cooperation, and thus gains more benefits, and the nash equilibrium becomes win-win (dove, hawk) strategy[17-20].

Quantum entanglement is not discussed in various link states of self-strategies in the independent innovation capability. It is not a choice association dove strategies or hawk strategies, but it is association among each strategy of participants choose. In the two participants systems, the relationship between strategies which one party choose hawk strategy and the other choice dove strategy.

Quantum entanglement which is a special separable judge is introduced in the hawk-dove quantum game theory, because it is not only able to distinguish whether is the entangled quantum state, but also can quantitatively describe entangled quantum states. Entanglement describes the amount of entangled quantum states. It is essentially indicated that different quantum entanglement establish quantitative comparatively relationship for the description of entanglement. When the quantum entanglement $\gamma = 0$ and the high-risk set in game, income of the quantum dove strategy space is zero, as shown in Fig. 2. When the quantum entanglement is maximum value $\gamma = \pi/2$, a new state appears in the quantum dove strategy space, as shown in Fig. 3, appearing a "win-win" situation.

Based on analysis of quantum entanglement, if the target entanglement exceeds a certain degree of the entanglement threshold in quantum hawk-dove game, participants will reasonably pay attention to

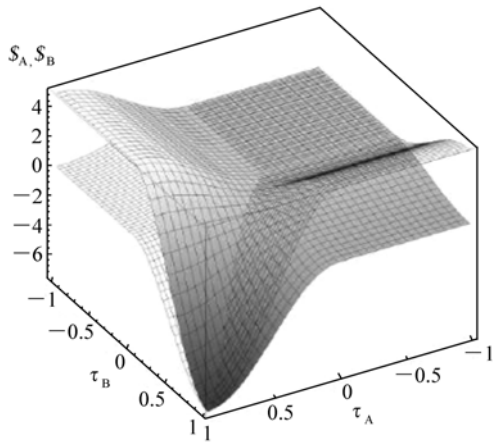

Fig. 2 Payoff surface of player A (solid) and player B (wired) as a function within a non-entangled quantum game (γ) using quantum dove strategy subset and the high risk parameter setting.

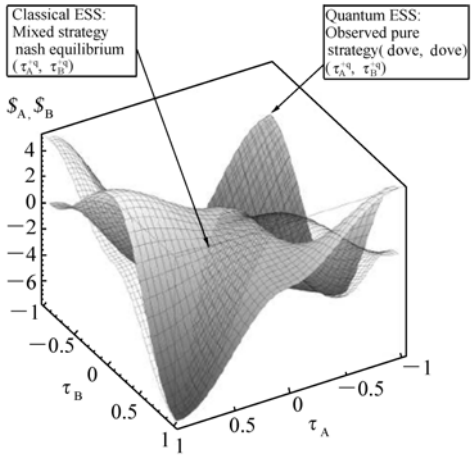

Fig. 3 Payoff surface of player A (solid) and player B (wired) as a function within a maximally entangled quantum game ($\gamma = \pi/2$) using quantum dove strategy subset and the high risk parameter setting

the various factors of independent innovation and take non-aggressive strategies after the analysis of the situation. In contrast, if the entanglement is lower than this threshold, the participants will ignore these factors and take the classic game.

In addition, The amount of entanglement shows boundaries of local spatial and it demonstrates that the real world has the operational process of local, and space is limited, and praxis is an objective existence which is independent of man's awareness and exist in different space. It makes existence intertwine to show for the local behavior through operating some existence. The greater entanglement have local more sparse, the more fuzzy of the boundary, the more complex in expression. Conversely, the smaller of the entanglement have the more compact in local boundary, the nature of existence and course of action is also relatively simple. Therefore, measuring the size of entanglement mainly use the strategy which various elements of the capabilities adopted, entangled relationships among the various strategies in science and technology innovation. It measures the size of capacity through calculating entanglement of the various elements strategy. You can calculate and evaluate the comprehensive system of independent innovation and understand ability of the technological innovation of scientific research institutes by selecting of dove strategy and the calculation of quantum entanglement.

2.3 Evaluation index system for independent innovation capability of research institutes

According to hawk-dove quantum game theory, we can get:

(1) Associated of which collaboration and innovation between the research institutes can be quantitatively described by entanglement.

(2) Because of the presence of association, the hawk-dove quantum game theory is a new high-value area appearing in the pigeon space compared with an unrelated game situation (corresponding to the situation in the classical game), this point also in line with the reality of the real world .

(3) Hawk-dove game is the most basic simple model of which individual enterprise and competition each other, and it is also sufficient to characterize the basic principles and basic conclusions.

Therefore, a set of strict description language of hawk-dove quantum theory meet the need of describing the ability of science and technology independ-

ent innovation. Quantum game skills (science and technology innovation capacity) have a relation with the space structure of quantum strategies of participants and the choice capacity of quantum strategy. The strength of strategy selection capability process that participants can choose the size of the space, room for maneuver amount, the size of the right to speak in the whole game. Therefore, it is the size of game ability of participants. In addition, the quantum strategy structure and quantum strategy selection of participants depend on the conditions of its information. Meanwhile, the ability of quantum game (independent innovation capacity) are bound with the quantum payoff function of participants. As a participant, winning the maximize pay ability of balance interests is the basic pursuit.

From the above findings, we can naturally get expression of quantum game of independent innovation capability:

$$SA = SS \otimes SI \otimes SP. \quad (1)$$

Among them, SA is the independent innovation ability; SS is information of the independent innovation ability; SI is independent innovation strategy ability; SP is independent innovation payoff.

We can see the independent innovation explained by hawk-dove quantum game which includes a quantum payoff function, strategy and providing information from the above capacity. The three interaction factors form an integrated capability. They are not the relationship of adding, but getting to entangle each other. For this reason, there is a zero among of three, and the total capacity of entanglement will drop in quantum game even if the other two re-strong.

If the capacity of independent innovation makes up of the strategy of capacity, information capacity and payment functions by the way of direct product, then the ability of independent innovation index should also be slightly composed by the ability of independent innovation index, the ability of information index and payment functions index. The new "information-strategy-payment" of the three elements will aim at the previous evaluation system to re-integrate.

Index selection method used: (1) base on the internal logic relations between independent innovation ability evaluation of index system; (2) using the previous related evaluation system of indicators and methods as a reference. Select a total of 12 specific evaluation indicators form the three categories.

Making the weight of all the indicators correspond to the table and combining these different indicators into a single comprehensive evaluation index of independent innovation ability, we get a complete evaluation system of independent innovation ability, as seen in Tab. 1.

Tab. 1　Evaluation index system based on quantum game for technology independent innovation capability

Basic elements of innovation capability	Sub-elements	Evaluation indicator	Weight
Information capacity of independent innovation	Culture diathesis of technology workers	Numbers of professional and technical personnel	1
	Information conditions of technology innovation	Collection books	0.5
	Information system arrange	Domestic information system associate with international information	0.5
Strategy capacity of independent innovation	Cultivate capacity of technology staff	Number of graduate students	0.5
		All personnel engaged in scientific and technological work	1
	Investment capacity of independent Innovation	Per capita R&D expenditure	1

Table continued

Basic elements of innovation capability	Sub-elements	Evaluation indicator	Weight
Payment fuction of independent Innovation	Arrange capacity of technology independent innovation	Scientific equipment original condition	0.5
		Sum of technology collection	1
		Institute and local government collaborate	0.5
	Technology paper	Per capita technology composing	0.6
		Quality factor of technology composing	1
	Technology patents	Per capita registered of software and patents	1
	science and technology income ratio	Unit of funding output for innovation	0.6

3 Synthesis method of independent innovation capability of research institutes

Based on the hawk-dove quantum game theory, calculation for weight of quantum entanglement is the decision indicator which measures the ability of independent innovation index. Quantum entanglement is the amount of entanglement which the entanglement of the research carried. Description of the entanglement is essentially establishing quantitative and comparable relationship which aims to different entanglements. Here is the description of the calculation of entanglement in the processing of the actual problem.

3.1 Index data processing

First, the target system of the quantum pure states which the object being evaluated is established. This process determines the quantitative data of each index. Index system used $\omega(\omega_1, \omega_2, \omega_3, \cdots, \omega_n)$ described by the established. Among them, making the qualitative evaluation of peer experts and relevant departments transformed into quantitative data, and ultimately the performance evaluation of the evaluation of the object are given, as shown in Tab. 1, the weight data(or quantitative data).

Second, idealized samples are structured. This process makes all evaluation index non-dimensional in order to facilitate the synthesis and comparison of indicators. The expression which a physical quantity expressed by some basic quantities power multiply or divide is said dimension.

After the units selected, the basic physical quantities unit can express either physical quantity. And all physical quantities which have dimension can be dimensionless, and the dimensionless expression can be simplified after treatment. They used to compare the relationship among various physical quantities which have no relation to each other. The usual dimensionless handled have normalized the ratio of ranking methods.

Here, the process of dimensionless indicators is calculating the standard value of each index, making the best value of each evaluation object as the idealized symbol of the sample:

the standard value of indicators = the actual value of indicators/the best sample value of indicators (2).

Best value can select from evaluated objects which participate in evaluation, and it can also use artificial setting by experience. Some indicators use the maximum as well, some indicators use the minimum as well and some indicators use the average as well in terms of different factors. Based on the best value, idealized sample of index value can be struc-

tured. The maximum value of index looks as the symbol of ideal sample.

There are m evaluation of objects, and each object has n index evaluation. The evaluation sample is:

$$X_i(k) = (X_1(1), X_i(2), X_i(3), \cdots, X_i(n), \quad i \in (1,m),\ k \in (1,n), \tag{3}$$

where m represents the Institute, n represents indicators factors of each institute.

In order to make sample accurately reflecting the overall environment, it need to have clear provisions for the overall environment; general observation of all units must be homogeneous; we must abide by the principle of randomization in the process of sampling; sample observation unit should also have sufficient quantity. Therefore, the ideal sample selection should fully reflect the maximize of all factors and comprehensiveness of the various factors. The maximum of indicators factors can better reflect the two aspects, so selecting the maximum value of each factor as ideal sample.

Idealized sample is:

$$X_0(k) = (X_0(1), X_0(2), X_0(3), \cdots, X_0(n) \quad i \in (1,m),\ k \in (1,n). \tag{4}$$

3.2 Calculation of quantum entanglement

First, calculating the least value, calculating the ratio relationship between the evaluated samples and the idealized samples, and calculating the maximum and minimum values

$$\Delta ik = |[X_i(k)/X_0(k) - 1|;$$
$$\Delta_{\max} = \max(\max(\Delta_{ik}));$$
$$\Delta_{\min} = \min(\min(\Delta_{ik}));$$

Second, the entanglement coefficient of the index is calculated: $c_{ik} n_{ik}/\sqrt{M_k}$, of which:

$$n_{ik} = ([\Delta_{\min} + \zeta(\Delta_{\max})]/[\Delta_{ik} + \zeta(\Delta_{\min})])$$

ζ is the resolution ratio, general chosen 0.5.

$$M_k = \sum_i n_{ik}^2 = \sum_i ([\Delta_{\min} + \zeta(\Delta_{\max})]/[\Delta_{ik} + \zeta(\Delta_{\max})])^2 \tag{5}$$

Finally, quantum entanglement is calculated. In general, arbitrary quantum state ψ can be expanded as $|\psi> = c_1|x_1> + c_2|x_2> + \cdots, c_k$ is the complex and meet the normalization condition $|c_1|^2 + |c_2|^2 + \cdots = 1$, $|c_k|^2$, is the probability of the system in the state of x_i. So entanglement of quantum pure states can be written as:

$$E(\psi) = -\sum |c_i|^2 \lg |c_i|^2. \tag{6}$$

Quantum game expression is got from index of independent innovation capability which makes up of all indicators. That indicators are from information elements of the independent innovation, strategy elements of independent innovation capacity and the payment function of independent innovation[21]:

$$NC = E(\psi). \tag{7}$$

At this point, the reasons why capability of technology independent innovation of research institutes selects the quantum game theory as the method of evaluation are given. The hawk-dove game is used to model description of the ability of independent innovation. The monotonic relationship between entanglement and the payoff matrix[14] is used to establish corresponding relationship which entanglement together with capacity of independent innovation of research institutes in theory. From that, we can get relationship of which ability of independent innovation of each research institutes through calculating entanglement of each research institutes strong or feebleness.

The relationship of theory and function is given by the method that makes discrete index to entanglement. The entanglement can be studied by these discrete index in order to achieve the purposes which evaluate independent innovation ability of research institutes.

4 Evaluation and analysis of independent innovation capability of institutes in Chinese Academy of Sciences based on quantum game theory

The purpose of this paper is using the hawk-dove

quantum game theory to establish a evaluation system of technology independent innovation ability of scientific research institutes. Based on above evaluation system, the level of independent innovation which makes the Chinese Academy of Sciences institute as the object is analyzed.

4.1 Evaluation of independent innovation capacity of institutes in Chinese Academy of Sciences based on quantum game theory

The research institutes of Chinese Academy of Sciences are the most representative scientific research institutes. The institutes cover the broad field, including many disciplines, scattering geographical distribution, and have large numbers and excellent results. Especially in recent years, the research institutes of Chinese Academy of Sciences carried out the knowledge innovation project having made such great progress in the scientific research system, research direction and research production. So parts of institutes of Chinese Academy of Sciences are selected as an example for the capacity evaluation of scientific and technological independent innovation. All data from Yearbook 2005 of the Chinese Academy of Sciences Institute.

The first step investigates to take the basic data for evaluation based on the indicators in Tab. 1 through the process of quantitative indicators of data, and then using formula (3) – (7) to calculate entanglement and entanglement coefficient (see Tab. 2(1 – 14) in specific data tables), finally getting evaluation results of research institutions technological independent innovation, seen in below table.

Tab. 2 Ranking of independent innovation capability for institutes

Sort	Institute	Entanglement
1	China Science & Technology University	1.095 1
2	Institute of Physics	1.039 1
3	Shanghai Institute of Life Science	0.885 5
4	Dalian Institute of Chemical Physics	0.701 4
5	Shanghai Institute of Optics & Fine Mechanics	0.690 0
6	Shanghai Institute of Organic Chemistry	0.683 1
7	Institute of Theoretical Physics	0.678 7
8	Institute of Electronics	0.677 8
9	Changchun Institute of Optics, Fine Mechanics and Physics	0.675 8
10	Center for Space Science and Applied Research	0.633 7
11	Hefei Institute of Physical Sciences	0.628 8
12	Changchun Institute of Applied Chemistry	0.618 8
13	Institute of Computing Technology	0.614 8
14	Institute of High Energy Physics	0.606 8
15	Xi′an Institute of Optics and Precision Mechanics	0.597 8
16	Institute of Geographic Sciences and Natural Resources Research	0.592 6
17	National Observatory	0.591 4
18	Institute of Theoretical Physics	0.591 2
13	Academy of Opto-Electronics	0.614 8
19	Institute of Theoretical Physics	0.587 9
20	Shanghai Institute of Applied Physics	0.581 2
21	Lanzhou Institute of Chemical Physics	0.567 2
22	Shenyang Institute of Computing Technology	0.565 8
23	Guangzhou Institute of Energy	0.550 3
24	Institute of Microelectronics	0.548 9
25	Institute of Psychology	0.546 1
26	Qinghai Institute of Salt Lakes	0.493 2

4.2 Relevant methods of evaluation

To verify the proposed method which bases on hawk-dove quantum game accuracy, advanced and practical, principal component analysis and simple statistical methods of Chinese Academy of Engineering Physics are used to evaluate and analysis of basic data of 26 scientific research institutes under the Chinese Academy of Sciences. It acts as comparative analysis to the evaluation method based on quantum game theory.

4.2.1 *Evaluation of principal component analysis*

The basic principle of principal component analysis is to find the common factors which independent and adequately reflect the raw data from a large number of relevant statistical data. It can use principal components that are less than the dimension of the original variable and unrelated replace the original variable. Its weight is calculated by the variance contribution. Principal component analysis can not only reflect the amount of information of the original target, but also solve the problem of overlapping information between indicators and weights selected, so as to achieve reducing dimension and the computational cost. Its objectivity is better. Its calculation process is divided into: (1) Centers standardization of raw data; (2) Calculate the correlation coefficient matrix $R_{p\times p}$ of $[Z_{ij}]_{n\times p}$; (3) Determine the number of principal components and calculate the principal components; (4) Calculate the evaluation value of the principal component (the correlation matrix, eigenvector, value and the contribution rate, five principal components loading data, see Tab. 2(15 – 20). The final total score and ranking are shown in Tab. 3.

Tab. 3　Ranking of independent innovation capability of institutes and their total scores by principle component analysis

Sort	Institute	F_1	F_2	F_3	F_4	F_5	F_6	Score
1	China Science & Technology University	−1.354 3	−0.405 1	−0.443 8	0.009 9	0.032 2	−2.161 2	26
2	Institute of Physics	0.116 5	−0.651 9	−0.055 5	−0.089 6	−0.006 1	−0.686 5	25
3	Shanghai Life Science	−0.256 2	−0.371 4	0.098 6	−0.003 9	−0.009 8	−0.542 8	24
4	Hefei Institutes of Physical Science	−0.249	−0.204 6	0.015 7	−0.011 5	−0.000 7	−0.45	23
5	Changchun Institute of Optics, Fine Mechanics and Physics	−0.291 3	−0.162 2	0.021 6	0.002 4	0.038 2	−0.391 2	22
6	Shanghai Institute of Organic Chemistry	−0.021 4	−0.336 7	−0.031 7	−0.018 5	0.023 3	−0.385	21
7	Dalian Institute of Chemical Physics	−0.110 7	−0.289 1	0.038 3	−0.057 8	0.041 2	−0.378 1	20
8	Institute of High Energy Physics	−0.177 8	−0.181 4	0.023 1	0.015	−0.007 9	−0.329	19
9	Shanghai Institute of Optics and Fine Mechanics	−0.079 8	−0.221 9	0.001 5	−0.093 2	0.077 7	−0.315 6	18
10	Institute of Theoretical Physics	0.131 1	−0.353 8	−0.080 9	0.002 3	−0.009 5	−0.310 8	17
11	Changchun Institute of Applied Chemistry	−0.068 8	−0.226 3	0.010 6	−0.035 3	0.028 3	−0.291 6	16
12	Lanzhou Institute of Chemical Physics	−0.037	−0.185 5	−0.036 4	−0.051 9	0.026 5	−0.284 2	15

Table continued

Sort	Institute	F_1	F_2	F_3	F_4	F_5	F_6	Score
13	Institute of Computing Technology	−0.126 2	−0.179	−0.033 2	0.011 4	0.053 1	−0.273 9	14
14	Institute of Geographic Sciences and Natural Resources	−0.101	−0.177 2	−0.008 7	0.017 4	0.026 2	−0.243 3	13
15	National Observatory	−0.097 5	−0.184 8	−0.004 9	0.027 8	0.016 9	−0.242 5	12
16	Theory Research Institute	−0.001 1	−0.214 9	−0.007 6	−0.076	0.075 6	−0.223 9	11
17	Optoelectronic Technology Institute	−0.183 4	−0.113 3	0.024 5	0.018 5	0.031 1	−0.222 7	10
18	Shanghai Institute of Applied Physics	−0.126 3	−0.117 4	0.017 9	0.025 3	0.033 8	−0.166 7	9
19	Xi′an Institute of Optics and Precision Mechanics	−0.135 4	−0.114 2	0.032 6	0.012 5	0.043 7	−0.160 8	8
20	Guangzhou Institute of Energy	−0.011 4	−0.123	−0.017 9	−0.030 1	0.048 7	−0.133 6	7
21	Shenyang Institute of Automation	−0.069 6	−0.103 9	0.006 2	0.001	0.050 4	−0.115 7	6
22	Institute of Psychology	−0.041 6	−0.095 2	−0.024 8	0.005 5	0.041 8	−0.114 3	5
23	Space Science and Applied Research	−0.044 9	−0.168 1	0.017 6	0.04	0.043 1	−0.112 2	4
24	Institute of Microelectronics	−0.044 3	−0.114 3	0.009 8	0.013 7	0.023 2	−0.111 9	3
25	Institute of Electronics	−0.062 5	−0.178 1	0.021 1	0.053 1	0.055 8	−0.110 5	2
26	Qinghai Institute of Salt Lakes	−0.044 9	−0.055 1	−0.017 7	0.006 1	0.013 8	−0.097 8	1

4.2.2 *Assessment method from China Academy of Engineering Physics*

Chinese Academy of Engineering Physics has established and perfected the scientific standardized evaluation system of research institutes, and it has evaluated from different types of activities, major research projects, scientific research projects and innovation at all levels pre-scientific organizations and individual values orientation. The specific weight of evaluation index system and evaluation method are from experience. The list of evaluation scores of independent innovation capability calculated is shown as in Tab. 4.

Tab. 4 Ranking of independent innovation capability of institutes and their total scores by weight evaluation method from China Academy of Engineering Physics

Sort	Institute	Entanglement
1	Institute of Physics	6.272 7
2	China Science & Technology University	6.103 2
3	Shanghai Institute of Life Science	5.561 3
4	Dalian Institute of Chemical Physics	4.566 7
5	Shanghai Institute of Organic Chemistry	4.205 1
6	Changchun Institute of Optics, Fine Mechanics and Physics	4.075 9
7	Shanghai Institute of Optics & Fine Mechanics	3.814 8
8	Institute of Electronics	3.768 4
9	Hefei Institute of Physical Sciences	3.451 8

Table continued

Sort	Institute	Entanglement
10	Theory Research Institute - - - - -	3.323 9
11	Changchun Institute of Applied Chemistry	3.269 7
12	Institute of Computing Technology	3.197
13	Xi'an Institute of Optics and Precision Mechanics	3.180 5
14	National Observatory	2.965 6
15	Space Science and Applied Research	2.959 3
16	Institute of High Energy Physics	2.904 9
17	Institute of Theoretical Physics	2.904 8
18	Optoelectronic Technology Institute	2.881 8
19	Institute of Geographic Sciences and Natural Resources	2.795 2
20	Shanghai Institute of Applied Physics	2.594 2
21	Lanzhou Institute of Chemical Physics	2.214 9
22	Shenyang Institute of Computing Technology	2.195 2
23	Institute of Microelectronics	1.919 1
24	Institute of Psychology	1.523 5
25	Guangzhou Institute of Energy	1.922 5
26	Qinghai Institute of Salt Lakes	0.814 7

5　Discussion

In order to facilitate evaluate the results of the table, the institutes which are analyzed by the quantum game order in linear order. While the institutes which used the other two methods obtained are listed in the Fig. 4 corresponding first order value of the institute. Quantum game analysis use '·', principal

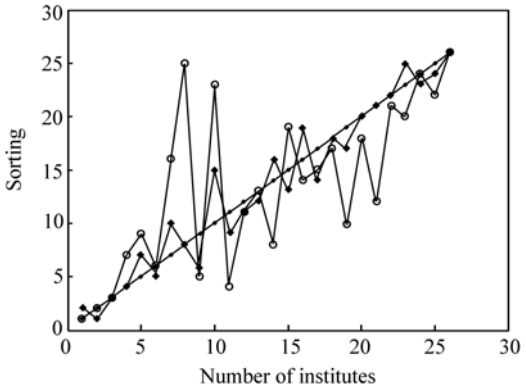

Fig. 4　Comparison of independent innovation capability evaluated by three methods

component analysis use '○', weight evaluation of China Academy of Engineering Physics use '*' to indicate.

By analyzing the above tables and the evaluation results on the map, you can see that the rank order is basically the same or change in a small area in addition to relatively large changes in individual studies although using three different methods. There are large changes in the scope including Institute of Theoretical Physics, Institute of Electronics, Space Science and Applied Research, Institute of High Energy Physics, Institute of Theoretical Physics and Lanzhou Institute of Chemical Physics. Among them, six research institutes have small difference in the quantum game evaluation methods and Chinese Academy of Engineering Physics the law of the weight, because both methods are more comprehensively and completely analysis and evaluate the institute from the basis of factors. Principal component analysis has a different results than the other methods in these six research. It is actually a dimension reduction method, which is usually chosen less than the original number of variables, it can explain variation of several new variables in most of the data, called principal components. It explains comprehensive index of the information. It is the pursuit of the main ingredi-

ents for this reason, and there is missing information in certain aspects or evaluation process of research institute.

Using weight evaluation of Chinese Academy of Engineering Physics and quantum game analysis, the six institutes' order have not large difference, but still have small fluctuations. Chinese Academy of Engineering Physics has established perfect scientific research and evaluation system through classifying and evaluating the different nature of the research, production activities, major research projects, research projects, innovation at all levels of organizations and various personal technology values and so on. Evaluation has comprehensive factors but also contains redundant components, classification of factor category but not outstand importance. At the same time, it contains human factors in the evaluation. Evaluation methods of quantum game systematically analysis the relationship and influence from entanglement among the various elements.

Above evaluation results show that:

(1) First is University of Science and Technology which is the largest scale and has the most people in Chinese Academy of Sciences with the strongest independent innovation ability(ability of independent innovation quantum game). It not only ranks top of "various research technology innovation", but also makes the other institutes far behind. Independent innovation's capacity index of University of Science and Technology is 1.095 1, while the second is Institute of Physics, and it's capacity of independent innovation are the 1.0391. The difference is up to 0.054. The result obtained by exponential function, so it a great difference.

(2) Ranked from 3 to 10 research institutes followed by Shanghai Life Science, Shanghai Institute of Optics and Fine Mechanics, Shanghai Institute of Organic Chemistry, Theory Institute of Technology, Dalian Institute of Chemical Physics, Changchun Institute of Applied Chemistry, Hefei Institutes of Physical Science, Institute of Theoretical Physics, Changchun Institute of Optics and Precision Instruments, National Astronomical Observatory, Institute of High Energy Physics, Space Science and Applied Research Centre, Institute of Psychology and so on. Other institutes are ranked out of the top 10, mainly because overall strength is weak. They may have a single discipline, specializing in subject, or strong in project and weak in theory, or the direction of research is cold, or research units too small and funding and staff are relatively small. Thus they are less capable in independent innovation of science and technology.

(3) Analyzing and comparing from the method of principal component analysis and weights evaluation of Chinese Academy of Engineering Physics, quantum game systematically analysis the relationship and influence from entanglement among the various elements. Principal component analysis starts from the perspective of principal components; grasps the principal contradiction; reveals the characteristics of the sample data itself; obtains independent principal components by linear, and determines the main components effective dimension and weight by ensuring the premise of the original data reliability, finally evaluates influence of principal components to the results. Weight evaluation system of Chinese Academy of Engineering Physics uses multiple indicators to evaluate multiple institutes, and assigned the weights to indicators of evaluation index system, at last, tests and evaluates the weights. At the results of evaluation, although using different methods, the order of rank is basically the same in addition to small changes in ranking. Compared with methods, evaluation method of independent innovation ability of technology research institutes based on quantum game, not only meet the principal component analysis, but also more comprehensively and completely evaluate the scientific research institutes.

(4) It accumulates rich experience in the assessment and evaluation of Chinese Academy of Engineering Physics. Compared to it, All 13 basic indi-

cators of evaluation include scientific and operational combined, representativeness and comparability combined; it also has a qualitative and quantitative combined; realistic and operational combined in the quantum game evaluation system of independent innovation ability. It should be said that the evaluation index system are more scientific, systematic and comprehensive.

(5) Overall, the evaluation results obtained based on the quantum game evaluation system of independent innovation capacity of research institutes are closer to our common sense and objective conditions. They are more credibility. The results show that the evaluation method of science and technology independent innovation ability which based on the hawk-dove quantum game is correct in theory; the tools of quantum game theory is used advanced; the conclusion is reliable; data analysis is persuasive.

6 Conclusions

In this paper, we have created a method to evaluate the innovation capability by using hawk-dove quantum theory. By application of the theory to the innovation capability evaluation, a hawk-dove quantum model was established for the evaluation system, and an index system is constructed. Innovation capabilities of institutes are investigated by using this method. Result shows that the method is theoretically correct; the constructed model is rational; analysis of data is operable and objective and the obtained results are reliable and convincing. The theory and the method are not only applicable to the evaluation of the innovation capability, but also are valuable references to the establishment and optimization of other evaluation.

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