Research on the mechanism of the role of national science and technology awards on science and technology innovation: Based on the case of award-winning projects in the power company

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Abstract. The National Science and Technology Award is a recognition of the highest level of science and technology projects in China, which has an extraordinary incentive effect on science and technology innovation. By referring to Michael Porter diamond model, the incentive diamond model of science and technology awards is constructed. It is considered that the incentive effect of science and technology awards on enterprise science and technology innovation is mainly through influencing the foundation and motivation of science and technology innovation, which is thus implemented in four aspects: leading the advancement of technology, promoting economic development, supporting policy implementation, and cultivating research teams. Based on the case of "Qinshan 600 MW Nuclear Power Plant Design and Construction" project in the power industry, the model is confirmed. It is argued that the superiority and inferiority effect brought by national science and technology rewards can help China build a leading science and technology enterprise and build a world science and technology power.

1 Introduction

For a long time, as a major recognition of scientific and technological achievements and their researchers, science and technology awards have been one of the major driving forces of scientific and technological innovation. Among them, the National Science and Technology Award, the highest level of award in the field of science and technology in China, has played a significant role in promoting science and technology innovation in China since its establishment in 2000 by inspiring Chinese researchers, rewarding many high-tech scientific achievements and fostering a good research atmosphere. Therefore, how to further play the role of national science and technology awards to promote China's scientific and technological innovation has become one of the important tasks of the national science and technology awards in the future.

Considering that the electric power industry is a basic industry related to the national economy and people's livelihood, and the scientific and technological development of electric power enterprises has been fruitful in recent years, winning the national science and technology awards many times and going through the process of scientific and technological innovation from following to leading [1]. In addition, the process of research, application, and promotion of scientific and technological achievements, including scientific and technological awards, is closely related to the development needs of enterprises. And there is less literature that explores the relationship between science and technology awards and science and technology innovation from case studies. In addition, further clarification of the role of award-winning projects for science and technology innovation after receiving science and technology awards will help further the expansion of enterprise research results. Therefore, the proposed diamond model of electric power enterprises' incentive for science and technology innovation after receiving national science and technology awards, through case studies, clarifies the incentive role of the power company, which generates and supplies electricity after receiving science and technology awards, and provides certain decision-making references for the future science and technology award system.

2 Literature review

Generally, science and technology rewards can be divided into material rewards represented by bonuses,

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financial support for scientific research and improvement of related welfare benefits, and spiritual rewards including honorary certificates and honorary titles [2]. The current academic community is unanimous in its understanding of the nature of science and technology rewards, i.e., they have the basic roles of competition and motivation. For example, Merton [3] argues that the S&T reward system is a product of the interaction between the normative structure of science and the establishment goals of science and that the S&T reward system provides a set of rules for competition in the scientific community. Gaston [4] argues that the S&T reward system reflects the relationship between how scientists perform in their scientific roles and the corresponding rewards. Ruan et al [5] stated that science and technology rewards should be a recognition and evaluation of scientists' scientific abilities and achievements by society and the scientific community. According to Rao et al [6], science and technology rewards are an intrinsic mechanism of scientific and technological activities, a means for a country or a scientific community to effectively manage scientific and technological research activities and high honor and recognition of scientists' contributions by society. In general, a science and technology reward is a kind of spiritual or material guarantee that acts directly or indirectly on science and technology workers.

Scholars have further studied that the overall performance of science and technology rewards is closely related to their operational mechanisms. For example, scholar Xiong [7] pointed out that science and technology rewards, as an institutionalized incentive, can play its proper role only through the operation. According to Liu [8], the key to whether science and technology rewards can give full play to their function of promoting science and technology development lies in how well they operate. Further, domestic scholars analyze the role path of science and technology rewards from three perspectives, such as individual, enterprise, and role model. In terms of individual perspective, Kong et al [9], based on the empirical analysis of grassroots science and technology workers, obtained that several factors, such as the science and technology rewards received, would have a significant positive impact on the innovation ability of grassroots science and technology workers. In terms of enterprise research, Zhang et al [10] used an empirical test to demonstrate that there is a positive effect of government patent rewards on the performance of SMEs. In terms of the mode of action, Yu et al [11] took national defense science and technology rewards as an example and analyzed that science and technology rewards mainly promote innovation through innovation motivation, team, competition, and fostering innovation subjects. Zheng [12] analyzed that science and technology rewards promote social innovation process and transformation of achievements through the model of "motivation + resources + environment" in the case of Guangdong Province. Xu [13] analyzed the role of science and technology rewards in the independent innovation strategy through four mechanisms: recognition, orientation, incentive, and competition, using the Ho Leung Ho Lee Foundation Award as an example. In summary, there is a rich accumulation of academic research on the role of science and technology awards, but the influence mechanism of science and technology awards received by enterprises on science and technology innovation still deserves further addition.

In this paper, we believe that the influence mechanism should be reflected from two aspects, namely, the foundation of science and technology innovation and the motivation of science and technology innovation. On the one hand, the foundation of enterprise science and technology innovation mainly includes three aspects: technology, talents, and capital. First, technology, as a new tool for innovation, can directly help enterprises create new value [14]. Secondly, scientific and technological talents, as the main body of enterprise scientific and technological innovation activities [15], need to undertake the main tasks of scientific and technological research and reinvention and have a pivotal role in creating value and innovating development models [16]. Thirdly, capital (including government subsidies, technological innovation inputs, etc.) is the main material guarantee for enterprises to carry out production, scientific research, and innovation, which can positively contribute to the growth of enterprises [17] and achieve sustainable development.

On the other hand, regarding the reasons for enterprises' participation in science and technology innovation, since the current academic community [18-19] considers the purpose of enterprises as a multifaceted complex system, there are mainly three hypotheses such as "profit maximization", "customer creation", and "social responsibility". Social responsibility" and other hypotheses. The first one, the "profit maximization" hypothesis, tends to believe that maximizing profits is the most fundamental motivation for firms to carry out autonomous innovation activities. In a highly competitive market, leading companies [20] continuously improve the quality, structure, and function of their products and production efficiency through independent innovation, so that they dominate the market and have a long-lasting competitive advantage and earn high-profit returns. For example, if a grid company has a patent on a particular power generation technology, it can improve the efficiency of power generation or even form a technical barrier that prevents other competitors from catching up, thus giving the company an advantage in the market. In contrast, imitation-following and survival-adaptive enterprises refer respectively to firms that respond to technological innovation by leading firms by means of replication, imitation and piracy, and firms that respond to new situations of technological innovation brought about by leading firms by means of passive adaptation. They tend to adopt technological upgrading to cope with market competition, will be gradually eliminated due to the lack of scientific and technological innovation capabilities and their inability to gain more market share [20]. The second "customer creation" hypothesis argues that companies can increase their market share by creating customers for the purpose of increasing the number of existing customers and their demand. This tends to

suggest that satisfying market demand is the main motivation for continuous innovation. The survey data of Chidong Zhang and Yuan Wang show that 75% of technological innovation is driven by market demand [21], which proves this view. The third "social responsibility" hypothesis suggests that the main driving force for enterprises to participate in science and technology innovation is to create more social value. The above three hypotheses are supported by the results of the survey conducted by the Enterprise Research Institute of the Development Research Center of the State Council on enterprise innovation drivers. According to the survey results [22], 79. 7% of enterprises choose market pressure; 82. 1% choose user demand; and 74. 8% choose to increase their strategic reserves.

3 Influence mechanism

From a psychological point of view, science and technology rewards can be considered as a form of psychological motivation that meets and satisfies scientific workers [23-24]. According to motivation theory, motivation is a "psychological process of continuous motivation" and the higher the level of motivation, the stronger the level of effort and satisfaction in accomplishing goals and the higher the effectiveness of work [25]. Motivation theory argues that since people have multiple needs, if appropriate incentives can be taken to meet their needs and goals, they can transform individuals' needs into work motivation, effectively mobilize work motivation, and improve productivity and productivity [26]. Therefore, tapping the mechanism of the role of science and technology rewards on science and technology innovation can help rationalize the operation mechanism of science and technology rewards and further encourage the work motivation of scientific researchers.

According to Wang Yankun [27], the operation mechanism of science and technology rewards is the most central and complex part of the whole science and technology reward system, and a scientific and reasonable operation mechanism of science and technology rewards is conducive to encouraging the enthusiasm and creativity of scientific research institutions and the general scientific and technological personnel to conduct scientific research, promoting scientific and technological achievements and mature technologies into enterprises and markets, and accelerating market development and product renewal.

Referring to the "diamond model" proposed by Michael Porter, this paper considers that the factors affecting scientific and technological innovation include scientific and technological strength, economic foundation, policy support, and scientific research team. Similarly, there is a mutual influence relationship among these four factors; at the same time, there is also a path of influence beyond these four factors [28]. As proposed by the Cole [29], science and technology reward awards should perform an important motivational function for individual scientists, awarding institutions, and the scientific community as a whole. This paper thus obtains the operational mechanism of science and technology rewards as shown in Fig.1.

This paper argues that national science and technology awards will play a certain incentive role for award-winning enterprises, which is reflected in two aspects: strengthening the foundation of science and technology innovation and stimulating the motivation of science and technology innovation. On the one hand, in terms of innovation foundation, the basic elements of enterprise science and technology innovation include technology, talents, and capital.

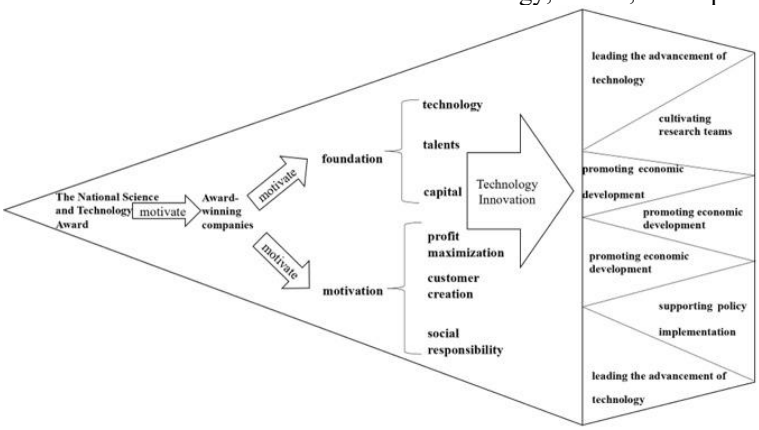

Fig. 1. Incentive Diamond Model for Technology Rewards

First of all, from the technical point of view, scientific awards are the recognition of the priority of scientific discoveries and the results of scientific research labor by society [30], and the national science and technology awards represent the highest level of scientific research achievements in China at present. In the case of electric power enterprises, for example, the technical achievements that have won national science and technology awards will achieve a certain series of technological breakthroughs, usually leading to local upgrades in the field of power generation and consumption, or triggering the overall transformation and development of the electric power industry. It can be said that once a certain core technology identified by the national science and technology awards is achieved, it will have a qualitative impact on an industry or

technology field, changing the original development method, bringing about a non-progressive leap forward in development, and ultimately achieving scientific and technological progress.

Second, from the perspective of talent, scientific awards are a recognition of the scientific research contributions made by existing projects and can further help enterprises cultivate their scientific research teams. After receiving scientific and technological awards, the scientific staff in the enterprise can, on the one hand, improve their self-fulfillment value and gain legitimate wealth [29], so that they can continue to shine in the research field to expand their original scientific influence and obtain more scientific research funds, which can help them to be promoted to the next level and thus obtain more personal academic opportunities; on the other hand, it can improve the scientific staff's visibility and academic authority, so that they can obtain more academic resources and help them to obtain more personal academic opportunities. On the other hand, it can improve the visibility and academic authority of the researchers themselves, thus gaining more academic resources and helping them to incubate more innovative talents [25], thus providing a sufficient reserve army for scientific and technological innovation. For the power industry, on the one hand, there is a before-and-after chain effect of national science and technology awards; after winning the award, the recognition and influence of the project are enhanced, which is conducive to the continuation of other levels of awards; after winning the award, the advantages of innovation resource allocation are revealed, and the award promotes the burst of relevant knowledge achievements and guides the public to pay attention to intellectual property protection and form a fair and orderly market competition; the award-winning project directly enhances the organization's development, continuity, and influence; and indirectly, it has an important role in promoting the extension of relevant disciplines and specialties in universities/research institutes. On the other hand, at the team level, national science and technology awards guide the community to actively build several innovation teams, and cultivate more high-quality technical and skilled personnel, skilled craftsmen, and great craftsmen; more effectively guiding the gathering of global outstanding talents. At the same time, it has a derivative effect on the stability of the project team and the improvement of the team's scientific and technological output level.

Finally, from the financial point of view, science and technology awards bring direct incentive bonuses for enterprises and are likely to bring more project opportunities and cooperation opportunities due to the increased visibility of the project, thus realizing the transformation of results and gaining economic benefits. As far as the electric power industry is concerned, the recognition of national science and technology awards is conducive to the promotion of continuous research and development innovation and promotion and application of the achievements, which has a comprehensive role in promoting the industrial development of the electric power industry, especially with key technologies as a breakthrough to achieve independent design, independent production and batch production, enhance the overall industrial level of the electric power industry, help restructuring and industrial upgrading of the electric power industry and related industries, promote electric power equipment Manufacturing level on the stage, drive the upstream and downstream related industries of the electric power industry synergistic development, inject strong momentum for economic and social development, with strong economic benefits.

On the other hand, from the perspective of innovation motivation, enterprise innovation motivation mainly includes "profit maximization", "customer creation" and "social responsibility" three hypotheses. Firstly, the scientific reward is the certification of the creation of great economic benefits in scientific and technological innovation, the transformation of scientific and technological achievements, and the industrialization of high technology [30]. Under the "profit maximization" hypothesis, there are three main motivations for companies to continuously participate in science and technology innovation. First, to reduce input costs. After winning the award, enterprises can effectively break through the technical barriers, improve the quality of products, improve the structure and function of products, reduce production costs, improve production efficiency, have a long-term competitive advantage, and obtain high-profit returns. The second is to cater to market demand. After winning the award, to further gain more profits, enterprises can rely on the significant progress in the field, further market-oriented, and broaden the visibility of the industry-academia combination, leading the industry to iterate and update the trend, to meet the new market demand. At the same time, enterprises can promote the marketization of scientific and technological achievements through the influence of award-winning projects, promote industrial structure reform, and achieve innovative development of the industrial chain [19]. Thirdly, they can obtain policy subsidies. After winning the award, enterprises can solve their scientific research funding problems to a certain extent, and to a greater extent, they can improve the possibility of obtaining financial subsidies and tax incentives in industrial incentive policies.

Secondly, under the "customer creation" hypothesis, enterprises need to meet the explicit and implicit needs of customers. Under this hypothesis, companies need to find and solve market pain points and difficulties, so that they can use innovative means to engage in new service development activities. Therefore, award-winning companies can better utilize innovative technological tools, use customer feedback, observe customers' usage habits, and based on mastering customers' explicit needs, tap and analyze customers' implicit needs so that customers' potential needs can be satisfied. According to customer needs, we can develop new products and intelligent services, obtain and maintain target customers, expand the company's popularity, and create brand effects, thus achieving economic development.

Third, under the "social value" hypothesis, there are two main motivations for enterprises to continuously participate in science and technology innovation. First,

to gain social status. Since scientific awards are recognized for making particularly significant contributions to social benefits, economic and social development, and national security. After the award, researchers and their units can make society understand the scientific research project and team members through the window of press coverage and publicity, which can add cultural value to the charm of the enterprise, lay a good innovation environment for the enterprise, and even cause a good culture of respecting science in the whole society and continuously guide the social opinion toward positive energy. Secondly, it enriches social relationships. After the award, the enterprise can strengthen contact with the same stakeholder groups, greatly expand the enterprise's social network and enhance the relationship between the viscosity, and social responsibility won by the social image and corporate reputation for the enterprise to accumulate social capital, thus stimulating its social benefit potential.

For the power industry, on the one hand, the award-winning power projects focus on the national strategic needs, focus on the major technical issues related to national security and people's livelihood, and the application of innovative results directly support the implementation of national strategies, and powerfully maintain national security and serve the construction of a better life for the people. On the other hand, the award-winning power projects continue to play a role in the implementation of "One Belt and One Road", maintenance of China's energy security, scientific and technological self-reliance and self-improvement, intelligent manufacturing, sustainable development, western development, rural revitalization and other major developments related to national security and the lifeblood of the national economy by cultivating new industries, opening up the supply chain upstream and downstream, and driving equipment manufacturing to the sea. The national economic lifeline of the major development strategies plays a major role.

4 Case study

4.1 Case Introduction

The "Qinshan 600 MW Nuclear Power Plant Design and Construction" project (hereinafter referred to as "Qinshan Project II"), is the first 300,000 kW pressurized water reactor nuclear power plant designed, built, and operated by China itself. The project is a scientific research project mainly completed by the Second Research and Design Institute of Nuclear Industry (NRI) and others, including Chicco Ye. After a six-year R&D cycle, the Qinshan Project II developed or selected technically superior equipment on the main equipment for the first time under a unified standard specification system, and scientifically and reasonably handled the compatibility of standard specifications and consistency of interfaces, so that the comprehensive technical level of the nuclear power plant reached the international level of similar nuclear power plants, equivalent to the international level in the 1990s. The project won the first prize in the National Science and Technology Progress Award in 2004. By 2022, the Qinshan Project II will have been in safe operation for 20 years. Since the first unit was connected to the grid in 2002, the cumulative power generation has exceeded 304.5 billion kWh.

4.2 Case analysis

4.2.1 Leading the advancement of technology

After the award, the technology of the Qinshan Project II has had a remarkable effect on leading technological progress. On the one hand, it is manifested in the extremely important role played by the R&D team of nuclear power plants with design as the leader in the field of nuclear power in China. After the award, Qinshan Project II, in terms of actual operation, is designed, built, managed, and operated independently by China, and is a large commercial pressurized water reactor nuclear power plant, which is a domestic nuclear power project designed and built independently by China, realizing 30%-49% of the technology output from the main innovation points of the relying project in use. At the same time, the project adopts the world's technically mature, safe, and reliable pressurized water reactor type, taking Daya Bay Nuclear Power as a reference, and realizes the first international direct commercial reactor construction for a new reactor type, which has extraordinary scientific guidance significance.

On the other hand, the technology related to the innovation point of Qinshan Project II has played a crucial role in the development process of nuclear power in China. The concrete verification of the Qinshan Project II has laid the groundwork for the birth of Hualong-1, a third-generation nuclear power technology that China will begin to design independently in 2014 and officially operate in 2022. This is reflected in the fact that the current "Hualong-1" core has been transformed from 157 components to 177 components, precisely through the practice of Qinshan Project II. China's "Hualong No. 1" fully draws on the advanced design concepts of the integration of the three generations of nuclear power technology and China's existing experience in the design, construction, commissioning and operation of pressurized water reactor nuclear power plants, as well as the development of nuclear power since the Qinshan Project II and the results of research, fully absorbing the Fukushima nuclear accident experience feedback, is in China more than 30 years of nuclear power research, design, construction, and operation experience. It is a third-generation advanced pressurized water reactor nuclear power plant with complete independent intellectual property rights, which can resist the impact of large commercial airliners, based on China's 30 years of experience in nuclear power research, design, construction and operation, and adopting the highest international safety standards.

4.2.2 Promoting economic development

After the award, the technology of Qinshan Project II has a remarkable effect on promoting economic development. First, it successfully promotes product localization. The development results of this project lay a solid technical foundation for the independent design, independent construction, equipment manufacturing localization, independent commissioning and operation, and independent management of 600MWe nuclear power units. The technical data, design documents, and drawings, software, manufacturing technologies, construction technologies, and procedures, commissioning technologies and procedures, and quality assurance procedures created by implementing this project can be used for the construction of new 600MWe nuclear power units and can be used for the development of megawatt-class nuclear power units. According to the data of the questionnaire, after the award, the project, to achieve a domestic market share of 11-30%, to achieve a market share of about 25% of all similar localized products, including the results of the project, to obtain the technology and products of the total domestic and international market revenue of about 2 billion yuan per year.

The second is to drive the development of upstream and downstream related enterprises. The design and construction of Qinshan Project II has greatly enhanced the visibility and competitiveness of the participating enterprises in the domestic industry and established the brand of commercial nuclear power plant with independent design, independent construction, independent management, and independent operation in China. According to the survey, compared with the time of the award, the technical achievements of the project have been transformed and applied to at least 2 other industries, including equipment manufacturing and instrumentation industry.

Third, to promote the green development of the local economy, as of April 2019, Qinshan Project II has generated a total of 550 billion kWh of electricity safely, equivalent to the afforestation of about 1.9 million hectares, reducing the consumption of standard coal by about 174 million tons, making positive contributions to improving the power supply structure and promoting the prevention and control of air pollution. It has become a model and a benchmark for the harmonious development of national major projects and local economy and society.

4.2.3 Supporting policy implementation

After the award, Qinshan Project II responds to the national strategy of landing outstanding effects, first, to maintain China's national energy security; second, to implement the "One Belt, One Road" strategy; third, to actively respond to the rural revitalization policy.

First of all, Qinshan Project II is built by the way of "We are the main contractor and Sino-foreign cooperation", which grasps the core technology and has an important strategic value to guarantee the energy security of China. The core was reduced from 157 components to 121 components, and the three-loop circuit was changed to a two-loop circuit. Hundreds of design and analysis software were introduced, and a whole set of drawing materials and standard specifications of the reference power plant were collected; at the same time, a core hydraulic and flow test rig, a flow vibration test rig, a control rod drive mechanism and drive line test rig, a seismic test rig, etc. were also established, and a large number of related scientific research tests were carried out, and a lot of research and test verification work was carried out so that the effective digestion of this unit technology was finally realized The project is of great significance to the maintenance of national energy security in China, and the basic mastery of core technology.

Second, based on the Qinshan Project II, China's independent intellectual property rights of the third-generation nuclear power technology "Hualong One" to achieve overseas landing construction, to promote the development of China's "One Belt, One Road" strategy. 2015 "Hualong No. 1" exported to Karachi, Pakistan, is the second foreign aid nuclear power project after Chashma nuclear power project and is also the largest nuclear power project in Pakistan, the construction of this project is of great significance to the international influence of China's nuclear power technology and the accelerated development of nuclear power industry. On March 18, 2021, Unit 2 in Karachi, Pakistan, was successfully connected to the grid for the first time, which is expected to generate nearly 10 billion kilowatts of electricity per year and meet the annual production and living needs of 1 million people in the region, greatly promoting China's "One Belt, One Road" national strategy. This will greatly promote China's "One Belt, One Road" national strategy.

Finally, Qinshan Project II is actively integrated into local economic and social development, accelerating local infrastructure construction and greatly promoting national rural revitalization. Qinshan Project II has joined hands with the government of Haiyan, Zhejiang Province to build a special town. Based on the per capita consumption expenditure of urban residents of 34,430,000 yuan/year in 2017, it is conservatively estimated that the nuclear power population contributes at least 1.6 billion yuan per year to Haiyan's local area. In addition, Qinshan Nuclear Power Science and Technology Museum, as the largest science and technology museum in China with the richest public experience and strongest public applicability, has received 120,000 public visits and more than 5,000 foreign guests from more than 40 countries and regions.

4.2.4 Cultivating research teams

After the award, the Qinshan 600MW nuclear power plant project technology has had a remarkable effect on the cultivation of the research team.As shown in Table.1, on the one hand, the scientific and technological achievements after the award are fruitful. The number of industry-level standards formulated or revised after the award increased from 2 before the award to more than 30, the number of software copyrights obtained increased significantly from 5 to 12, and the number

of published monographs increased explosively from 1 to more than 10. On the other hand, the performance of the post-award science and technology innovation team is bright. After the award, the project team has undertaken more than 20 national projects and more than 100 provincial and ministerial projects in this field; 2 of the project completers have obtained the title of provincial and ministerial talents; the project team has received 8 national awards and more than 50 provincial and ministerial awards. At the same time, after the award, the project team is all in research and continues to engage in research in this industry, and has trained about 10 postgraduates in this technical field, helping to build the national research team. It is worth recognizing that since winning the National Science and Technology Award in 2004, the Qinshan 600MW nuclear power plant project has achieved explosive scientific research results and attracted and cultivated an excellent scientific and technological innovation team. The award has a large driving force and explosive effect. Therefore, horizontally, for enterprises, the National Science and Technology Award also has a certain screening function, and there may be a fierce process of elimination of winners and losers, so that the award and resources are tilted to the strongest, making the "strongest stronger" and creating leading enterprises.

Table 1. Statistics of achievements before and after the award.

Number of industry-level standards (developed or revised)		**Number of software copyrights obtained**	
Before winning the award	After winning the award	Before winning the award	After winning the award
2 items	30 items	5 items	12 items
Number of published monographs		**Project team undertakes scientific research (after winning the award)**	
Before winning the award	After winning the award	National level	Provincial and ministerial level
1 items	10 items	20 items	100 items

5 Conclusion

The National Science and Technology Award has four positive effects on science and technology innovation by influencing the scientific and technological innovation base and scientific and technological creativity of enterprises, thus motivating researchers and their units. These positive effects are reflected in the promotion of project sustainability by influencing four aspects: scientific and technological progress, economic development, strategic landing, and scientific research team. This helps China to further build a number of leading science and technology enterprises, to play the main role of enterprises in the socialist market economy, to fully implement the innovation-driven development strategy, and to build a world science and technology power.

Funding

This thesis was funded by project (1400-202157233A-0-0-00).

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