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Influences of Technical Innovation Mode on Innovation Strategy of Energy Enterprises

Abstract Technical innovation is the core for enterprise competence and sustaining. Technical innovation strategy is the policy which the enterprise carries out for technology innovation in a long term. The paper took the practice of the technology innovation strategy in PetroChina Changqing Oilfield Company as a case study, and illustrated the significance, function and features of the self-developed technology innovation, cooperation development technology innovation and introduction-innovation based on the strategy structure of the energy enterprises. The suggestions for technology innovation strategy structure for large energy enterprise were proposed in the paper.

Keywords: energy enterprise, technical innovation, innovation strategy

1 Introduction

After implementing the policy of reform and opening up, China has been developing rapidly and moves into a stage of transforming and upgrading, but existing development model has encountered a series of bottlenecks, such as resources, environment, and marketing, especially the outstanding conflict of supply and demand of recourses. China has changed from resource exporter to resource importer. China imports various commodities, including oil, coal, iron ore and manufactures, influenced greatly by the fluctuate prices of international commodities. At the meantime, large national resource enterprises are improving their capacity to filter the influence on Chinese economy, making it inescapable responsibility and duty to ensure the smooth and healthy development of economy. Currently, China is advancing the development of innovation-based enterprises to increase the enterprises' abilities to innovate and to increase international competitiveness, which is beneficial for transforming economic growth mode. Technical innovation is the key to build innovation-based enterprises, the most direct reflection of competitiveness and the foundation for resource-based sustainable enterprises.

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2 Literature review

2.1 Technology innovation strategy

Since Schumpeter came up with the notion of "innovation" the first time in 1912, many related theories about technical innovation have been developed. According to Schumpeter and his latest research results, people view his "innovation" theory as "technical innovation", which is called natural technology innovation and traditional technology innovation as well, and is equal to the system technology innovation. In the following 30 years, economists would focus their attention on balanced long-term stable state. Not until the mid-1950s did many scholars begin to emphasize the problems of Technical Innovation. Solow (1957) proposed the famous Solow Growth Model. In this model, economic growth gained from labor and capital is basically stable in the long term, and only the technology improvement is the key source to achieve economic growth. Schmookler (1966), the first one to use patent statistical analysis to test technology improvement, thinks technology invention is pulled by needs, not by technology research and development (R&D), to expand the range of both theory and practice. Romer (1990) built the famous Romer Endogenous Growth Model, in which knowledge and technology are the production inputs, to increase marginal benefit. Professors from Tsinghua University,

including Li (1994), state their theory in the book *The economics of technological innovation*, that entrepreneur should capture market potential profitable opportunities, and recombine production conditions, elements and organizations, so as to build a production operation process with stronger efficacy, higher efficiency and lower expenses. This theory is called Narrow Technical Innovation Theory, and "R&D-narrow technical innovation-whole process of innovation diffusion" is called Generalized Technical Innovation Theory. They thought cumulative effects of the Generalized Theory were macro-progressive technical levels and effective growth in national economy.

Strategy is a plan or a policy with significant, overall decisions of global problems. Zhang (2005) thought corporate strategy involved the formulation and implementation of the major goals and initiatives taken by a company's top management on behalf of owners, based on the consideration of resources and the assessment of the internal and external environment in which the organization competes. Technical innovation is not only limited in the R&D department, but in every link involved in production operations, and every department should take the different responsibilities and work in the process of technical innovation. Therefore, technical innovation strategy means global deployment and arrangements in economic technical and innovation activities.

2.2 Technical innovation strategy in energy enterprises

2.2.1 Independent research and development

The core technique in independent technical innovation is internal technological breakthroughs. Depending on the strength of enterprises, they obtain technology by independent R&D. Enterprises can be provided with unique knowledge and abilities, which lead to a series of technical innovations, form innovation clusters, so as to promote the development of enterprises.

Under the current external environment, enterprises choose strategies such as setting technical innovation targets, choosing technical innovation directions and rationally allocating internal resources. Under the premise to ensure normal business operations, enterprises choose strategies to guarantee labors, funds and supplies in the technical innovation and develop in the correct direction, in order to maximize the investment return.

Technical innovation in resource-based enterprises need to integrate various internal resources, key technology, and supporting R&D technology, launch field tests, and advance the development of enterprises effectively. Independent R&D requires large numbers of labors, funds and supply inputs, and also requires enterprises to create a favorable environment for scientific research. However, technology innovation investment needs large funds, long R&D period and low effectiveness. In order to ensure advantages in technology, enterprises need ongoing R&D activities, and put the innovation throughout the entire production and business activities. This requires enterprises to put more investment in human resource and capital. Meanwhile, due to the complexity and uncertainty in technology exploration, the funds may have strong spillover effect and hysteresis. Therefore, to make technical innovation, the enterprises must take huge risks.

Technical personal resource is the key to improve the technical innovation of enterprises. Independent R&D is beneficial to train a group of outstanding technical personnel. In scientific and technological research, leaders in the technical department play important roles, and young technology personnel are trained continuously.

2.2.2 Technological innovation strategy developed in cooperation

The first thing to propose is to optimize the allocation of resources needed. In market-oriented economy, enterprises face the challenges such as the dedication and coagulation of assets, inertia of organizations, and finiteness of enterprise resource and infiniteness of social resources. As a result, enterprises have to cooperate with other enterprises, organizations and agencies, to introduce a variety of resources and capacity needs for the development of the enterprises, to improve competitiveness, and to make profits. Zhou and Xiao (2012) thought technological innovation developed in cooperation was the need for enterprises to improve the core competitiveness. In the economic globalization background, traditional independent innovation method has no longer caught up with the pace of technology improvement, and it has to depend on cooperative development of innovative models, so as to promote the upgrading technical abilities.

Cooperation between resource-based enterprises usually involves two aspects. one is interest factors enterprise resource development, and the other is the strength of their own technical innovation capability. When enterprises possess both rich resource reserves and strong technical innovation capabilities, its expectation of benefits or technology innovation is higher. Meanwhile, it can offer more available resources. Therefore, it emphasizes on cooperating with major multinational corporations based on strategy, and the cooperation will involve a series of elements such as government policies, public relations coordination and capital market. These elements and enterprises strategy will influence the formulation and implementation of cooperation technical innovation strategy.

With the continuous development of China's international economic, enterprise innovation activities have taken place in more complicated environment. Technology clustering has become stronger. Therefore, patterns of technological innovation strategy developed in cooperation,

by internalizing external technical resources and achieving resource sharing, become the inevitable trend of enterprise technology innovation under the new situation.

Developing technical innovation in cooperation is relevant to amortizing innovative costs, innovative risks and scale of cooperative projects. Generally speaking, the bigger the project is, the more complicated of contents, the higher costs and the bigger risks are. In addition, the role of risk diversification is more significantly. It is also possible that communication between the cooperation parties, such as exchanging technical experience, can reduce time and resource waste during the process.

2.2.3 Introduce technical innovation strategy

Introducing technical innovation strategy has to follow "take the initiative, combine horizontally" concept. Firstly, by communication and cooperation at home and abroad, enterprises have to learn relevant information about new technology. Secondly, by multiple communication and cooperation with foreign-related enterprises, research institutes and universities or launch joint researches on scientific projects, enterprises have to grasp the key knowledge of relevant technology. Thirdly, by imitating innovative ideas and key innovative techniques of advanced enterprises, enterprises have to learn from both success and failure, to buy the core technology or decipher technology secrets, so as to combine with their own resources and then innovate.

3 Energy enterprises technical innovation strategy influential elements analysis

Based on the Resource Dependence Theory, great differences of resources lie between enterprises. Many resources cannot be traded in markets through pricing. Also, enterprises do not have all the necessary resources. There always exist some strategic gaps between the target and resource. Therefore, to obtain these resources, enterprises will interact with other business entities to control the environment in which these resources are organized. Because of the environment, the organization will try to dominate and plan their responses to infrequent events, avoiding reliance on markets. In recent years, the rapid development of information technology makes the competitive environment more complex. The enterprises have to look to the interior from the external market environment, focusing on its unique resources and knowledge accumulation, which other companies cannot get or copy. To form a unique core competitiveness of enterprises, they make great efforts to obtain resources and build the fundamental competitive advantages.

On the project of Energy Enterprise Technology Innovation Strategy Design, Xu and Chen (2005) thought enterprises should follow the frameworks of different levels like strategic objective level of innovation, strategic objective level of technological innovation and innovation strategic level of technology, to design enterprise innovation strategies. When the energy research enterprise technology innovation strategy and building issues are considered, according to the characteristics of resource-based enterprises, combined with practical technology innovation strategy of Changqing Oilfield Co., the internal and external factors are proposed (*Figure 1*). They are simultaneously considered from technical management levels and from technological innovation levels. Several factors lay the groundwork for enterprise technological innovation, including the tissue culture technology innovation and management, scientific research organizations and management, technical personnel training and technology management process of construction enterprises. Based on these factors, analysis can be conducted to determine the business objectives of technological innovation, positioning, patterns and configuration of resources according to enterprise resource properties. Thus, to form resource-based enterprise technology innovation strategy, the technical innovation mode is used to decide the most significant content of technology innovation strategy and is discussed and analyzed in this part.

It can be clearly seen that the technical innovation of enterprises is influenced by many factors from both internal and external environment. The interdependent and restricting relationship among different research institutes, technical staff and staff in other departments has a restricting effect on the choosing technical innovation strategies for energy enterprises.

In the external environment, the factors, including the government policies, intellectual property system, marketed services, marketing structure, capitalized market, labor market, the collaboration of external environment, difficulty of technical innovation and rate of technology diffusing, have a series of interactions on information, knowledge and service with internal environment, influencing the technical innovation strategy in energy enterprises. The external factors influencing technical innovation strategy of energy enterprises are as follows (see Table 1).

4 Case study in choosing technical innovation strategy for energy enterprises

Making technical innovation strategy is supposed to firstly put forward innovation issues that are arisen in the process of developing, processing and competing. These issues, including resource development technology and technical innovation technology, need to be solved from the technical point of view. Based on extensively solicit opinions and scientific proof, it is important to study kinds of factors to make the final technical innovation strategy for the enterprise.

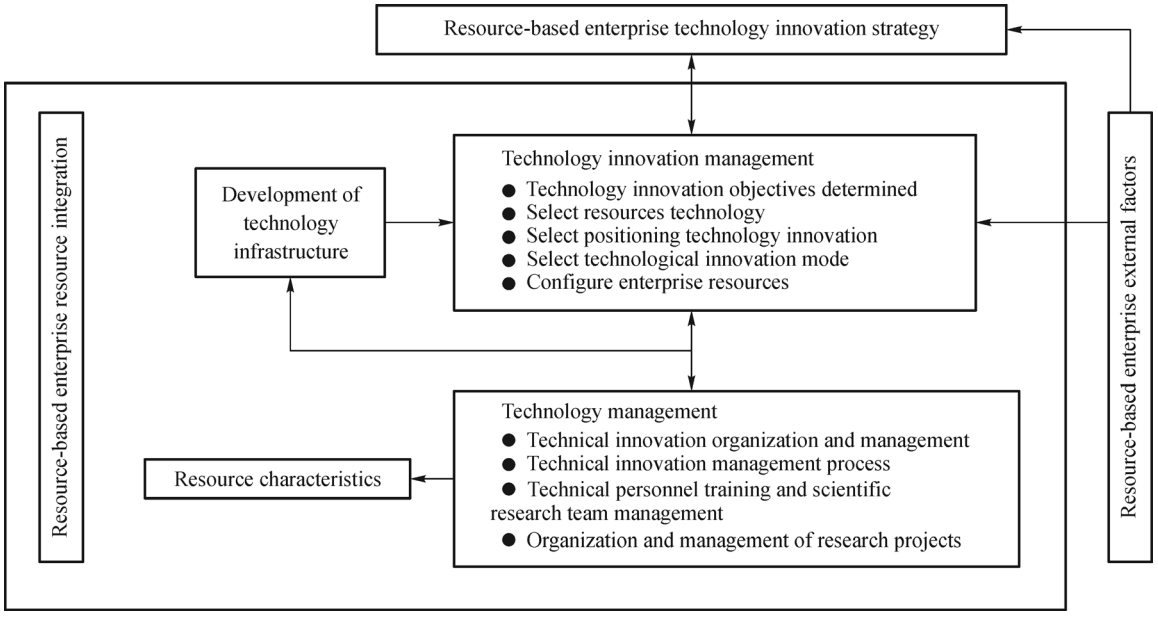

Figure 1. Schematic diagram of energy technology innovation strategy of enterprise architecture.

Table 1

Resource Type Enterprise External Factors

Factors	Model	Independent innovation	Cooperative innovation	Introduction to re-innovation
Government policy	Supply-based	Favorable	General	General
	Demand-based	General	General	Favorable
	Environment-based	General	Favorable	General
Intellectual property system	Perfect	Favorable	General	Unfavorable
	Imperfect	General	General	Favorable
Collaboration of external environment	High	Favorable	Favorable	General
	Low	Unfavorable	Favorable	Favorable
Marketed service	Good	Favorable	Favorable	Favorable
	Poor	Unfavorable		Unfavorable
Market structure	Oligopoly	Favorable	Favorable	Unfavorable
	Monopolistic competition	General	General	Favorable
Capitalized market	Good	Favorable	Favorable	General
	Poor	General	General	Unfavorable
Labor market	Good	Favorable	Favorable	General
	Poor	Unfavorable	General	General
Difficulty of technical innovation	Difficult	Unfavorable	General	Favorable
	Easy	Favorable	General	Unfavorable
Rate of technology diffusing	Fast	Unfavorable	General	Favorable
	Slow	Favorable	General	Unfavorable

As the main part of Chinese technical innovation for resources development, energy enterprises make and implement technical innovation strategy, which hold significant influences on the ability to develop technical innovation and resources in Chinese resource-based enterprises. This research will take Changqing Oilfield, the current biggest oil and gas production company in China, as a case study.

4.1 Overview of Changqing Oilfield

PetroChina Changqing Oilfield Company (abbreviated to Changqing Oilfield) was set up in 1970, with its headquarter settled in Xi'an, Shaanxi province. Its primary operations are exploration, development, production, storage, transportation and sale of oil and gas in Ordos Basin, which located its oil and gas field in five provinces including Shaanxi, Gansu, Ningxia, Inner Mongolia and Shanxi. After long-term exploration, Changqing Oilfield has increased reserve and production during the recent 10 years in China, with an annual production capacity of 55 million tons of oil equivalent, becoming Chinese new-born energy base and making contractions to ensure Chinese energy security. During the practice, the low permeability, low pressure and low abundance reservoir development technology has reached the world's leading level.

4.2 Internal factors of technical innovation strategy in Changqing Oilfield

The most oil fields in Ordos Basin are typically "three-low" reservoirs, with the features of "low permeability, low pressure and low abundance". Its average effective permeability rate is only 0.49 mD, compared with the international definition of Lean Reservoir as 0.1–50 mD. The factors that influence lean reservoir are mainly penetration level, natural energy strength and reservoir depth. The main resource in Changqing Oilfield is lean resource, with low formation pressure, single well and no natural reserve, which is needed to restructure the reservoir and use stimulation pumping exploitation. After mining, formation energy declined quickly, leading to the rapid diminishing of single well production. It is rare in the world because of its great difficulty of development, large cost, low recovery and poor revenue, and is a typical marginally-revenue oilfield.

4.3 External factors of technical innovation strategy in Changqing Oilfield

To solve the technical bottlenecks in oilfield development, Changqing Oilfield takes long-term explorations and practices, forming a technical innovation strategy combined with the features of resources. Changqing Oilfield is significant national strategic oil field and received a huge amount of labor and resources for development from PetroChina. Meanwhile, it is located in the natural gas pipeline network hub, including the first and second line of the West-East Gas Transmitting Project, Shanjing first and second Lines, Jingxi Line, Changning Line, Changhu Line, Seninglan extended Line and extended line from Sichuan to Xi'an, and Chinese major onshore gas pipeline network, which all indicated its strategic status in Chinese oil and gas enterprises. To exert this effect and develop the existing resource, Changqing Oilfield makes use of the features of "three-low" gas and oil reserves, improve the technical ability of independent innovation, cooperative development and introduction of re-innovation, by various methods such as enhancing the management of research proposals, strengthening the management of technical personnel training, optimizing technical management process. In conclusion, the aims are that through the efforts and struggles of a period, the technological innovation is significantly enhanced, and professional and technical levels are significantly increased. In addition, the technological innovation system is further improved, and so is the tight gas exploration and development technology.

4.4 Choice of technical innovation strategy in Changqing Oilfield

Proposition 1: Energy enterprises should choose independent innovation strategy.

Recently, unconventional oil and gas resources, represented by tight gas and tight oil, are important in China. Its proportion will continue to increase in Chinese oil and gas future production and national energy strategy will rely more on unconventional oil and gas resources. Promoting technological innovation needs to clarify the direction of technical innovation firstly. Considering the features of tight oil and gas reservoirs in Ordos basin, where there is a large storage of tight oil and gas, the enterprise is supposed to set up and promote "1,277" technological innovation engineering, including 12 key technologies and 7 equipment, concentrates the superior technology and carry out joint research in various disciplines at all levels to solve the key technological issues that are restricting the development of oilfield and promote upgrading technology for the exploration and development of low permeable oil and gas field.

Actively promoting the use of mature technologies, absorbing and utilizing practical technology and developing specialized technology will help to form fast drilling technology, technology of hydraulic jet fracturing and domination fracture, leading oilfield water injection and gas down hole choke. Such a large number of independent intellectual property rights of low permeability oil and gas field development core technologies come from a series of complementary technologies.

Facing international tight oil and gas field, technical workers in Changqing are always insisting to be guided by technology and exploring actively in development approaches that make oil and gas field sigh-revenue. They are constantly challenging the limits of recovery to expand development, which will allow them to form a series of complementary technologies of "three-low", which has its own competitive advantages. The development in low permeable and extreme low permeable economy has been achieved. Maling, Ansai, Xifeng and Huaqing oilfield lodes have been created, and Qingbian, Yulin, Sulige gas field mode and a series of suitable

comprehensive solutions have been completed. The specialized Changqing technology has been made. Based on the analysis above, the following suggestions are proposed.

Proposition 2: Setting the independent innovation strategy as the leading premise, energy enterprises are supposed to select cooperative technical innovation strategy.

In 2002, many large-scale multinational companies, such as France's Total Oil Company, South Korea's Samsung, British National Oil Company and American Philips Oil Company, bought Changqing Oilfield. Changqing Oilfield consists of two kinds of resources, two kinds of funds and two kinds of management. It gains complementary advantages and achievement win-win by composing the operational platform with foreign large-scale oil companies.

Finally, the Ordos Changbei Oilfield as an operation project was analyzed. The project team strengthened and accelerated learning for advanced technology partners, by promoting the use of domestic and foreign world-class professional contractors, of a large number of world-leading technologies and equipment, and of its own advanced and practical technology. As a result, it achieved "foreign binding" and "integrated innovation" and increased gas reservoir drilling rate and reservoir recovery rate. The dual-lateral horizontal well drilling technology has produced the single horizontal well length of 2,251 m in Chinese onshore oil and gas fields, and the total length of a single well horizontal section of 4,969 m, the longest single-well drill horizontal section footage of more than 500 m, creating more than 10 new history records, forming a well structure optimization technology, coiled tubing drilling technology and large reach well trajectory control technology, which formed the five characteristics of technology that has reached the international advanced level (Tang, Hui, & Yang, 2009). Through cooperating with international oil companies, introducing its advanced management experience, developing technology and innovating development and management of low-grade oil and gas resources, the project team improves the development level of oil and gas reservoirs in the Ordos Basin and in other oil and gas fields.

Proposition 3: Under the independent innovation strategy as the leading premise, taking cooperative technical innovation strategy into consideration, energy enterprises ought to introduce to re-innovation strategy.

Dozens of large technological communications have been organized with American Halliburton, BJ and Core Lab, Norway national oil enterprise and domestic oil and gas enterprises that supports the learning among institutes and managements. The professional personnel that have taken part in national cooperation projects in technology and management are up to 300. Projects about introducing technology cooperation and related researches have been taken with domestic universities and institutes. Through multi-level and multi-form introduction of foreign oil and gas field development technology, ideas and management experience, combined with the thoughts of technical personnel in Changqing Oilfield, according to the Ordos Basin geological conditions, re-innovation has been used to make positive influence on Sulige oil and gas field, 0.3 mD low-permeable development technology and site management in oil and gas field.

5 Conclusions

In the times of knowledge economy, innovation can increase the competitiveness of enterprises. However, technological innovation activities involve huge risks, and choosing technology innovation strategy is therefore very crucial. Technical innovation has huge influence on effectiveness of enterprise technology innovation (Liao, 2009). In the case study of Changqing Oilfield, choosing the technology innovation strategy for this enterprise, we have found the history of this company is essentially a history of technology innovation. It solves world-class technical problems like low permeability, super low permeability oil field development. Since last century, Changqing Oilfield has put in a lot of manpower and material resources every year, and has carried out extensive cooperation in innovative technologies and technical introduction. Every major technology breakthrough of Changqing Oilfield has contributed to productivity leap and has improved production technology.

5.1 Building a sound technology development and management system

Resource-based enterprises, whose development strategies are expanding their enterprises and improving resource development. Those strategies are based on enhancing the technical capacity, which needs clear technical organization system, technical staff team, technical management system and scientific management process. Changqing Oilfield has built their professional R&D teams that cover all areas of expertise. It employs 3,096 people for professional technical research, Changqing Oilfield has developed a series of standards, norms and institutions on development technology of low permeability oilfield, and has built R&D system in the main body of "1 center, 2 institutes, 3 schools". Based on the "One entirety, two level" technical innovation system of building requirements and "Unify technology plans, projects, thesis proposal, inspection and acceptance. Put in hierarchically and manage hierarchically." Changqing Oilfield has built a technology running mode of "Unify platform, manage classification, revolve targets and integrate innovation".

5.2 Play the leading role in technical innovation strategy

Resource developing capability is the foundation for continued operation and development of energy enterprises. This capability depends on the level of technology. Changqing Oilfield kept annual output for 1.3 million tons for over 10 years since 1970s. The fundamental reason is a lack of resource development capacity. To solve this problem, starting from the technical innovation, Changqing Oilfield makes a technical innovation for different reservoir properties and oil field development goals. After ten years of efforts, Changqing Oilfield has been a front-runner in the low-grade oil and gas development field and has received a number of national and provincial scientific and technological progress awards. Its technologies, including forming a dense low-permeability oil and gas field reservoir wells optimization technology, a stable technical countermeasure, a low-yielding wells inefficient management method, the on-site technical support research results, were brought to the international oil meeting and drew widespread attentions. Changqing Oilfield led the construction of low permeability oil and gas field exploration and the development of the National Engineering Laboratory. Also, it has developed a pilot test base, has enhanced the core technology research and test, has worked on 26 major research projects and has received a total of 1.84 billion JPY investment in science and technology. It has received provincial achievement awards 50 and patents 90. The low permeability, super low permeability of the world's top oil and gas development technology has helped the company to build the country's largest oil and gas fields successfully.

5.3 Integrating technical innovation models effectively

When establishing its technical innovation strategy, energy enterprises are always combing internal and external environmental features and its resources to carry out independent innovation vigorously. But in the current information-driven era, there are more cooperation in multi-fields, more cross-disciplinary knowledge, and higher degree of research specialization. It is difficult and uneconomical for individual technologies to support enterprises to develop an industrial system, while it is effective for multi-disciplinary and multi-skilled professional integration to solve technical innovation problems in enterprises. Therefore, large resource-based should have independent technical innovation strategy, and also should consider cooperative technical innovation strategy, so as to introduce re-innovation strategy. By emphasizing technical innovation, energy enterprises can advance technology effectively, improve resource development and competitiveness, and realize sustainable development.

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