

R&D Internationalization and the Reformation of Chinese S&T System

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ABSTRACT: In the 1990s, Chinese R&D internationalization has grown rapidly. International R&D brings new challenges facing Chinese traditional S&T system, having a far-reaching impact on the reformation of Chinese S&T system. In this paper, the state of art and its future trends of 28 leading Chinese firm for its international R&D activities are illustrated. A case about Huawei, with its active international R&D feature, is also brought forward. Then a 3-stage model is conducted for the evolution of R&D internationalization in China. Based on above analysis, this paper summarizes the challenges to the traditional S&T system in China. The author claims, in the future, R&D internationalization should be considered as an important factor in the reformation of Chinese S&T system. Some policy suggestions are brought forward in this paper.

KEY WORDS: R&D internationalization; China; S&T system

1 Introduction

In order to make use of worldwide scientific and technological resources, adapt differences of worldwide market, multinational corporations (MNCs) in developed countries changes their traditional approach of centralizing innovation activities, and decentralizes R&D activities in global scale increasingly. In the mid-1980s, Dutch and Swiss companies had more R&D units outside than inside (Pearce and Singh, 1991). Between 1987 and 1995, foreign R&D expenditure by US-affiliated companies abroad had more than tripled (Niosi and Godin, 1999). Nowadays, R&D internationalization has been an effective method for MNCs to maintain their competitive status and improve their technological capabilities.

There is much literature about internationalization of R&D. From the past study of R&D internationalization (e.g. Pearce, 1989, 1992, 1999; Håkanson and Nobel, 1993; Casson and Singh, 1993; Kuemmerle, 1997, 1998, 1999a, 1999b; Zander, 1997, 1998, 1999; Cantwell and Janne, 1999a; Dunning and Wymbs, 1999; Breschi, et.al.1998; Cantwell and Piscitello, 1999,2000) , it is found that the tasks of oversea R&D subsidiaries vary. The early researches find that the first phenomenon is to establish oversea R&D units to transform technology created by parent companies in home country (Mansfield, 1979; Ronstadt, 1977,1984). When differences of market conditions emerged, MNCs establishes oversea R&D units to adapt to local market conditions and consuming preferences of consumers (Pearce and Papanastassiou, 1999; Niosi and Godin, 1999; Dalton and Serapio, 1999; etc). Pearce (1992) insisted on the significance of locally relevant innovation: support for local manufacturing

was found to be the major activity of expatriate R&D establishments. Additionally, with the development of internationalization of R&D, MNCs take internationalization of R&D not only as the way to improve their competitiveness based on local market conditions, but also establish technology centers based on local technology and resource advantages to improve technological capabilities, and take them as complementary source of special technology (Zander, 1997; Breschi, 1998; Cantwell and Piscitello, 1999).

Zedtwitz and Gassmann (1999) proposed that R&D internationalization were evolved along research dimension or development dimension, which former was driven by technology and later was driven by market.

Patel and Vega (1999) summarized three kinds of incentive to international technology innovation: 1) improving products, process and materials for foreign market(s), providing technical assistance for manufacturing department abroad; 2) tracking and monitoring dynamic development of foreign technology; 3) To innovate core products and key technologies outside home country.

Gerybadze and Reger (1999) developed a framework to serve as a basic for analyzing four different patterns of internationalization of R&D too. There is some slightly difference conclusion since difference nation enterprises and difference focus were stressed.

For many decades, countries have differed in the scale of their international R&D (Cantwell, 1995). Håkanson (1992) found that the heavy and early involvement of Swedish MNCs in foreign R&D was pulled by demand factors, such as market

potential and market adaptation, more than supply-related factors. However, Japanese R&D internationalization is very different from the Swedish. Sakakibara 和 Westney (1992) summarized five stages of Japanese R&D abroad: technology scanning units, technology-transfer units, technical cooperation units, local product-development units and basic research units.

Whatever the evolutionary path of R&D internationalization, the fact remains that the arguments about national S&T policy-making has been in existence for some years. Some researchers argue that under the circumstances of business and technologies being increasingly transnational, national policies are definitely failed (Ostry and Nelson, 1995). Within the European Union, in ever more fields policies are coordinated internationally, including S&T policies.

S&T policies, as well as innovation policies are difficult to define (Jacobs, 1998), especially when national S&T system is faced with R&D internationalization. Ergas (1986) mentioned the shift from mission-oriented to diffusion-oriented policies. And slowly, there has been a growing insight, to some extent translated into policies, into the importance of more integrated and diffusion-oriented policies (Boekholt, 1994). Of course, mission-oriented policies still have their role. However, in respect of the stimulation from S&T policies to the performance of R&D internationalization, the picture is less clear. For example, the S&T policies which mean to stimulate high-tech may lead overinvestment in the same industry. Brahm (1996) gave some examples of this. Therefore, how to reform the S&T system to facilitate and manage R&D internationalization effectively, is heating up in recent years.

Some authors contend that R&D activities has been centralized in the triangular area—Europe, America, and Eastern Asia-Pacific region (Ohmae, 1995; Freeman and Soete, 1997). China is right in this area, which creates a very suitable environment for R&D internationalization.

China is in the course of transformation from the planned economic system to market economic system. Enterprises are becoming main bodies of innovation. With the Chinese entry into WTO, the domestic and international markets are getting more and more integration. How to meet the requirements of international competition by effective technological innovation, is a very urgent challenge facing Chinese enterprises. Large Chinese firms have tried to enhance their technical capabilities by internationalized R&D activities. However, Because of the limited capabilities and the situation of the country, Chinese enterprises haven't begun to expand R&D abroad until 1990s.

For Chinese firms, there are 4 reasons for the R&D Internationalization:

- With Chinese entry WTO, the knowledge needed by Chinese enterprise becomes more and more globalized, and everlasting open-door policies create the prerequisites for the free flow of knowledge.
- The concept of Made-in-China via advanced manufacturing base (AMB) has been accepted by Chinese firms, which promotes the technology connections between Chinese companies and international MNCs.
- Transition from acquisition & development (A&D) to R&D based growth make enterprises more technology-intensified, which need to absorb advanced

technological knowledge abroad to enhance the corporate technological capabilities.

- Becoming MNC is the way which many Chinese enterprises want to take, and MNC will expand technological activities to other countries inevitably for a lot kinds of reasons.

In accordance with the characteristics of Chinese R&D, it is very urgent for the government to reform the S&T policies system to provide appropriate environments for Chinese R&D internationalization and support corporate strategies of international R&D, leveraging the corporate technological capabilities, the whole S&T level and international competences of China.

2 The practices of Chinese R&D internationalization

Questionnaire survey is used in our research. In the early 2002, we choose 279 large and medium size companies as our research samples. 230 companies are from IT industry, automobile industry, mechanical industry, home appliances industry and pharmacy industry. And 49 companies are from other industries. We sent our questionnaires to all these 279 sample companies. Until the early 2003, we received 67 letters in reply, but only 28 companies answer our questionnaires completely. This response is not active, and we may explain it in two reasons. First, the degree of Chinese international R&D is so low that many firms haven't expanded their technological activities abroad yet. Thus, they can't answer most questions listed in our questionnaires. Secondly, because of the intensive competition in certain Chinese

industries, a part of enterprises are not willing to answer all the questions on the consideration of secrecy.

There are many factors influencing international technological activities (Fig.1). The data in our study show that two key factors are taken into account when Chinese firms are expanding their R&D abroad: responding to competition and implementing corporate strategy, and expanding and exploring the technical potential. Additional, recruiting highly skilled personnel and absorbing new knowledge, and monitoring competitors and the international trends of technology are also the important drivers of Chinese R&D internationalization. For example, a Chinese famous company—Haier company pushes six “Internationalizations” which include the globalized design and globalized R&D.

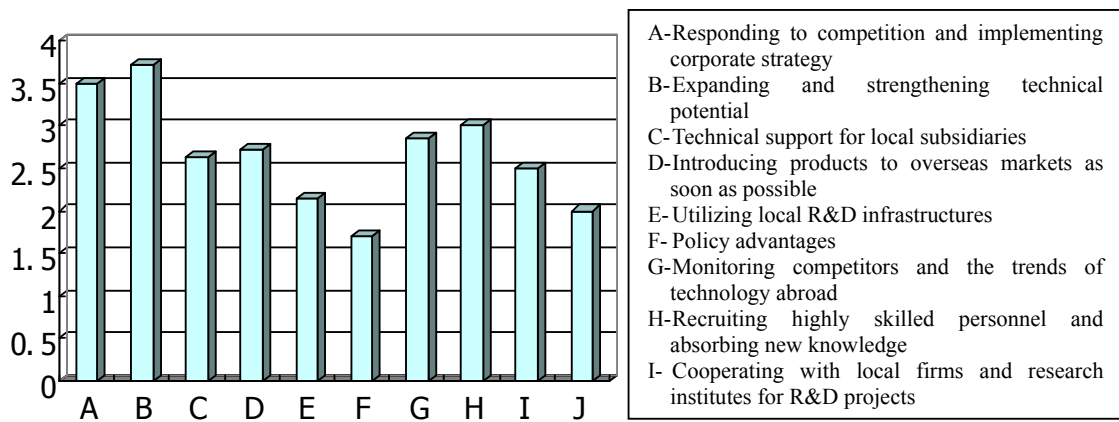


Fig 1 The strategic factors of Chinese R&D internationalization

However, the factor of international markets mentioned by many scientists seems not be attached much importance by Chinese enterprises. This can be explained by the low degree of Chinese R&D internationalization, too. In most Chinese enterprises’ opinion, it is enough to own domestic markets at present time, even expanding technological capabilities and absorbing knowledge internationally are aim at

short-term commercial products development for domestic markets, lacking the long-term strategic consideration for overseas markets. So their international R&D activities tend to be driven by non-market factors. One thing should be noted is that the factors of policies and geographical convenience are considered as the least important.

R&D internationalization is a very recent phenomenon for Chinese enterprises. Most firms included in our empirical study established their R&D units abroad between 1995 and 1999, and 30% expanded to other countries after 2000.

When the investigated enterprises were asked to report their most recent annual R&D budget of overseas R&D subsidiaries, 33% reported annual expenditure of less than RMB 5 million, and no one reported annual expenditure of more than RMB 100 million. 44% enterprise reported annual expenditure was between RMB 5 million and RMB 20 million, and 22% reported annual expenditure was between RMB 20 million and RMB 50 million. When surveyed enterprises were asked to report their annual R&D budget in next 5 years, almost all enterprises stress that the budget of overseas R&D subsidiaries will be increased. It is estimated that annual R&D budget of 66% of enterprises will exceed RMB 20 million in 2005 (Fig 2).

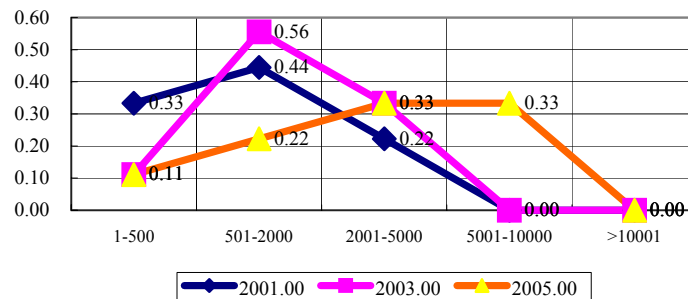


Fig 2 Oversea R&D investment by Chinese leading firms

Furthermore, we find that 40% of total R&D subsidiaries are located in US, 13.3% are located in Europe, 7% are in Japan, 13% are in east Asia and 27% are located in other areas (Fig 3). By the trends, US will be the dominant partners for R&D Internationalization of Chinese Firms.

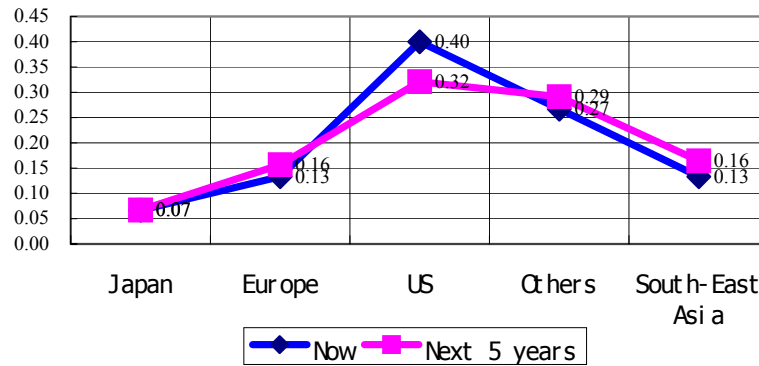


Fig 3 Geographic Distribution of R&D Center abroad

By our research, five types of international R&D are identified:

- A- Basic research (long term);
- B- Pre-commercially applied research based on basic research, aimed at creating potentially commercial application (middle term);
- C- Commercially applied product development for particular market(s) (short term);
- D- Improving product development (short term);
- E- Process improvement responding to markets (short term).

The investigation shows that type C and D are the most common type of overseas R&D subsidiaries, and type E is the second choice of Chinese enterprises, while basic research is attracted little attention. It is a rational forecast that the international R&D of Chinese enterprises will be increasingly expanding in next 5 years and product

development, applied research, and basic research will be attracted more attention. But short term R&D, type C and D will be taken first place, and basic research will be the last choice yet. (Fig 4)

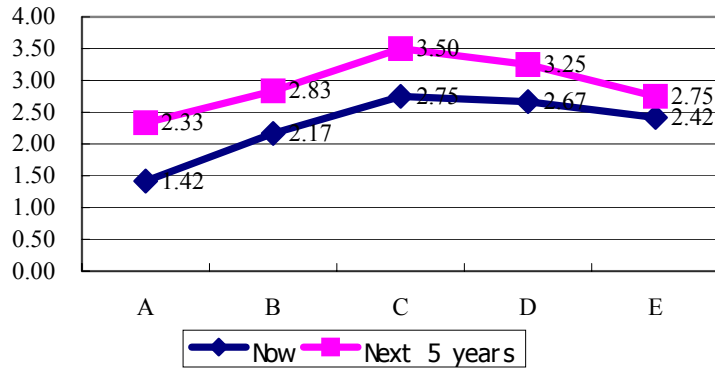


Fig 4 The types of R&D Internationalization by Chinese leading firms

3 A case of Chinese R&D Internationalization: Huawei Technologies Ltd.

3.1 Introduction of Huawei

Established in 1988, Huawei Technologies Ltd. (we will call it Huawei for convenience) is a private high-tech enterprise fully owned by its employees. Huawei specializes in R&D, production and marketing of communications equipment, providing customized network solutions for telecom carriers in fixed, mobile and data communications networks. Besides the headquarter, Huawei has established 6 R&D units in other Chinese cities including Beijing, Shanghai, Hefei, Hangzhou, Xi-an and Nanning, as well as 33 domestic offices and more than 40 overseas offices. Its products are sold in more than 40 countries, such as Germany, Russia, Spain, Brazil, Thailand, Singapore and Egypt, etc.

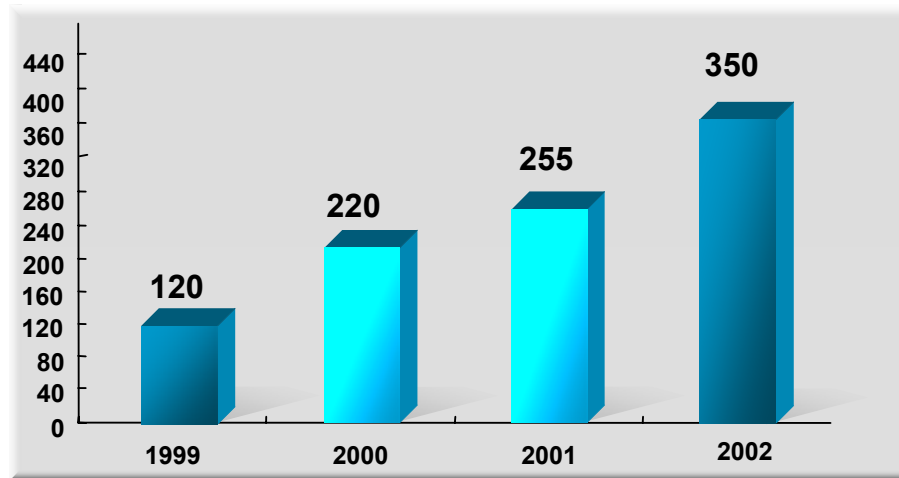


Fig 5 The growth of total sales of Huawei (hundred million RMB Yuan)

Huawei has developed series of products such as switch, access network, transmission media, wireless network, intelligent network, supporting network, ATM, access server, router, LAN Switch and multimedia product etc. And in another side, the sales of Huawei increase rapidly (Fig 6). At present, five R&D units have been established in USA, Sweden, India and Russia etc. More than 10% of sales of Huawei are invested in R&D every year, and in 2002, R&D expenditure are more than 3 billions RMB. Now, number of employees of Huawei are 20 thousands, and about 46.5% of the staff is R&D researcher.

Huawei pays much attention to integrated research of technologies and operational mode, and has become a formal Sector Member of ITU-T (International Telecommunications Union). Huawei Indian Research Institute is the first R&D institution owned by Chinese enterprise to acquire CMM (Computerized Modular Monitoring) four – star international certificate. Huawei TELLIN intellectual net won the first prize of the national scientific and technological progress.

3.2 Huawei's Global R&D system

Though technical development and cooperation become more and more international, Huawei is just a follower with lots of disadvantages compared with those leading communication equipment manufacturers such as Siemens. As a consequence, the international R&D system of Huawei has its own unique characteristics.

3.2.1 Strategy for R&D Internationalization

Contrast to MNEs, The goal of Huawei's internationalization strategy of R& D is to drive internationalization of manufacturing and marketing of the whole enterprise by internationalizing R&D activities. In the ideas of Huawei, because the company is a new entrant of communication equipment manufacturing, the internationalization strategy of R&D should start from the beginning and drive the development of total business of company with fast development of technological capabilities by means of learning valuable experiences from famous MNEs.

In the course of internationalization of R&D, Huawei had a definite strategy which aim at adopting the updated research results of communication equipment manufacturing broadly, learning from successful enterprises and establishing a core technology system based on R&D independently and collaboration with other organizations openly. By means of internationalization of R&D, Huawei wants to achieve three specific goals (Fig 6).

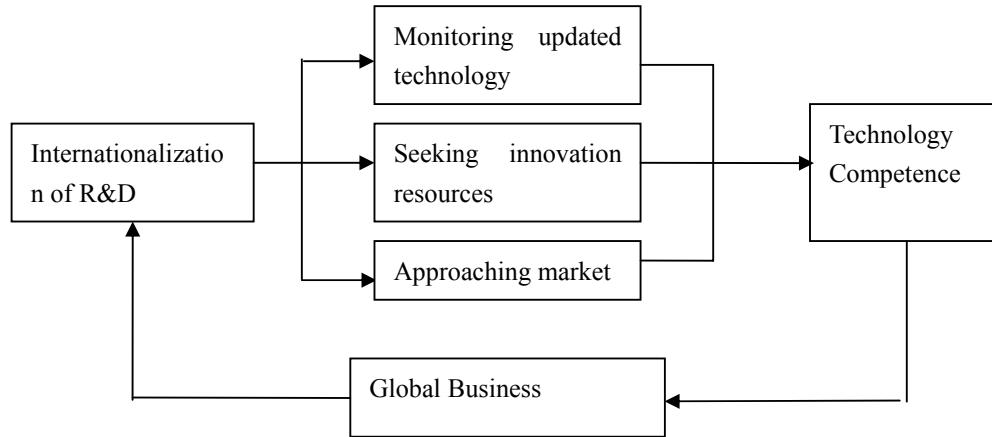


Fig 6 the strategy of internationalization of R&D of Huawei

According to Fig 6, the strategic goals of Huawei's international R&D activities can be listed as below:

- To establish technology information monitoring units, monitor updated technology from host countries and competitors, and adopt local technological innovation spillover as supplements of special technology.
- To approach knowledge excellence centers of the world, utilize R&D human resources and R&D environments, cut down R&D cost, and improve technological innovation efficiency.
- To respond to the differentiated demands of customers and local manufacturing, conditions in different countries, and realize localization of technology to support local manufacturing subsidiaries effectively.

3.2.2 The development of overseas R&D activities

To achieve the established strategic objective of internationalization of R&D, Huawei defines the three-stage developing strategy.

At the first stage, Huawei set up technological alliances with famous foreign

companies to improve its R&D ability by learning in the course of cooperating with them. Huawei has set up many R&D laboratories respectively with the first-class companies such as TI, Motorola, IBM, Intel, Lucent, ALTERA, SUN in order to establish long-term, friendly, open and double-win relationship with them, and then realize its internationalization of technology research and cooperation by cooperating with them in technology and market widely. For example, Huawei sets up digit signal disposal laboratory with TI (Texas Instruments) and makes common efforts in developing DSP products. Huawei-Lucent joined laboratory will devote to the research in microelectronics and optics.

At the second stage, in order to trace the new development of communication technology in the world and approach the technological excellence centers of the world, Huawei start to establish R&D units abroad. Its main business focuses on domestic market, in the context of which Huawei must compete with domestic enterprises and subsidiaries of MNCs in China.

The distribution of technological tracing R&D activities associates positively with the total distribution of global technological innovation activities, and basic research R&D activities need to work together with local universities and institutes abroad, so its very important for R&D activities of the type of basic research to approach the excellence centers (Cantwell and Hadson, 1991, Håkanson, 1992 and Pearce and Singh, 1991). The objective of establishing R&D units abroad is to make it convenient for the company to trace the new development of communication technology in the world and approach the technological excellence centers of the

world so as to adopt foreign R&D spillovers.

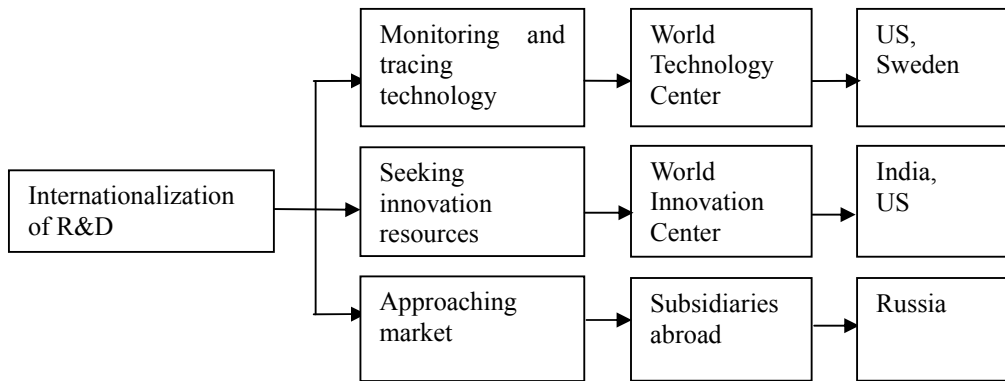


Fig 7 The location of R&D units of Huawei

Huawei chooses rationally the location of its R&D Units abroad (Fig 7). America is the modern science and technology center of the world, and Silicon Valley is the famous high-tech base of the world. So, America is the first objective for Huawei to choose locations to establish R&D Units abroad. Huawei has established its American (Silicon Valley) subsidiaries and Dallas R&D unit, which aim at tracing the development of research of optic products and other communication products. Sweden is the research center of GSM and WCDMA in Europe, so Huawei establishes R&D unit in Sweden to follow the developing trends of GSM, WCDMA in Europe, and to do research on mobile communication technology. As to the type of resource-seeking R&D activities, the location selection of R&D units abroad was decided by the supply of technological persons with ability and the conditions of technical facility in host country. At the present time, CMM (Capability Maturity Model For Software) is the most popular and practical criterion of software production process in the world and is an authentication criterion of the maturation of software enterprise. India has the best CMM environment of the world. Therefore,

Huawei establishes an R&D unit in Bangalore, “the Silicon Valley” in India in June 1999.

At the third stage, with constant improvement of technology and gradual extension of domestic market, Huawei starts to focus on international market. International business has become the main objective in Huawei business strategy. Furthermore, with the advancement of internationalization of market, Huawei finds that even within communication equipment industry, which is characterized by high standardization, the differences of market conditions and customer demands are very significant in different areas. In order to expend overseas market effectively, Huawei starts to establish overseas R&D units aiming at specific overseas market. It is very important to adapt to conditions of specific market and approach current manufacturing subsidiaries and consumers for manufacture supporting or market driven R&D activities that aim mainly at adjusting and improving technologies transferred from parent company (Kumar, 2001). Hence, it is an obviously successful case that Huawei establishes an R&D unit in Russia, aiming at leading Russian communication market and localization of technologies.

Currently, the internationalization of R&D of Huawei is developing to a diversification and globalization stage. Global R&D network of Huawei consists of technology alliances, overseas R&D units and domestic R&D organizations in different regions. With this R&D network, Huawei realizes integrated model of technological innovation. In this integrated R&D network (Fig 8), decision-making is centralized as well as decentralized. Resources are decentralized in light of strategic

objective of firms and the importance of R&D subsidiaries in total R&D system. All R&D units depend on each other and specialize in integrative R&D projects. At the same time, resources, personnel and information flow between R&D units freely.

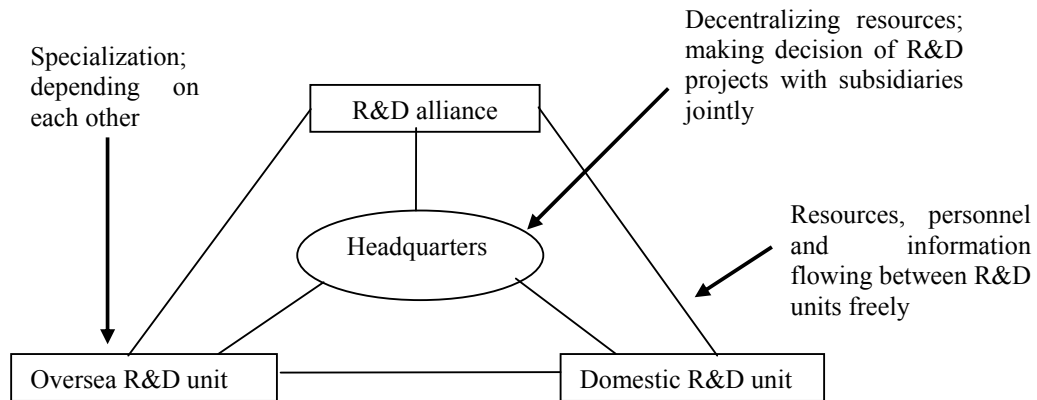


Fig 8 Integrated R&D network of Huawei

CDMA is a successful case of practice of integrated model of technological innovation of Huawei. Russian and Sweden R&D units are responsible for the research on technology of radio frequency, while Indian and American R&D units focus on the research of software. In China, R&D units put emphasis on different area in CDMA too, and cooperate with lots of universities such as Tsinghua University, etc. Based on dividing the work of the R&D of CDMA, all R&D units realize information sharing and cooperating in total integrating of the technology of CDMA. On October 12, 2001, Huawei launched product of CDMA 1 X, which meant that communication equipment manufacturing of China in CDMA has kept up with the worldwide leading technology.

4 A Three-stage Pattern of Chinese R&D Internationalization

Huawei is just a typical case of Chinese R&D internationalization. According to the Huawei case and the information provided by the other firms investigated, we consider a three-stage pattern of Chinese R&D internationalization: start-up stage, developing stage, and mature stage.

4.1 Start-up stage

Our survey shows that 60% of the existing overseas R&D units owned by Chinese firms were established during 1995~1999, and few companies establish overseas R&D units independently. Furthermore, R&D capabilities of these overseas R&D units are weak, and the input of personnel and finance of the existing overseas R&D units are little.

In this stage, the strategic motivations are technology learning by R&D project cooperated with MNCs, obtaining overflow of R&D production by approaching overseas R&D environments, and recruiting excellent overseas R&D researchers. By international technology cooperation and the establishment of technological monitoring R&D organization, Chinese companies can understand the trends of technology development in time and learn the advanced technology from developed countries (Fig 9). Hence, these overseas R&D units are usually established in technology excellence centers.

The organizational structure of international R&D system in this stage is centralized hub form. Subsidiaries of R&D are in charge of R&D information searching and the development of minitype projects. Headquarters made decisions for establishing overseas R&D objective, laying out overseas R&D projects and

recruiting overseas R&D researchers as well. Subsidiaries of R&D, which were dictated by R&D center in headquarters, contact little with each other. Overseas R&D information transfer from branches to headquarter, while the information about decision-making transfer from headquarters to branches. For these firms, it is not important to implement successful R&D overseas, but to utilize the foreign existing technological results or innovative ideas from overseas markets. This centralized hub form guarantees the rapid development of new products or processes. But the headquarter may misunderstand the information about supplies and demands in overseas markets, so the centralized R&D may not always meet the markets. Moreover, the overseas R&D units lack opportunities to learn in host countries because of limited resources and the role of technology scanner. Most strategic assets are centralized in headquarters. Headquarters mainly invest R&D resources in overseas R&D units. Employees coming from parent company and overseas Chinese consist of the personnel of overseas R&D units. Most capital inputs are also mainly invested by parent company (Fig 10).

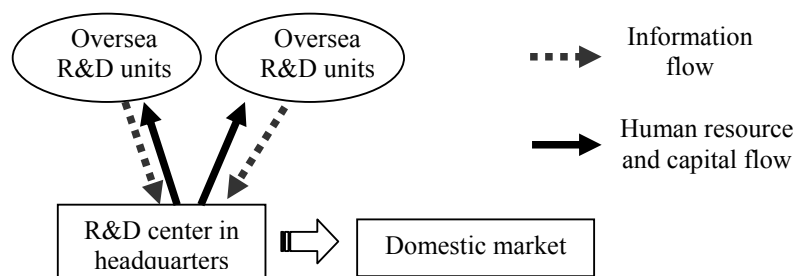


Fig 10 The resource flow in start-up stage of internationalization of R&D

4.2 Development stage

With the development of R&D internationalization, Chinese companies can

accumulate strategic assets and capabilities and expand their overseas markets as well. The type of market supporting overseas R&D activities that aim at adjusting and improving technologies transferred from parent company in home country will become flourished with the globalization of business. At the same time, various overseas R&D activities such as technology scanning, technology learning, etc. will also become more and more popular. The improvement of technological capabilities and the development of overseas markets of Chinese firms will push their R&D internationalization into a higher level.

At the aspect of strategy, Chinese companies will establish more and more overseas R&D units by direct investment and acquisition. The combination of indigenous innovation and overseas innovation will be the further strategic approach for Chinese companies to develop their overseas markets. The emphasis of strategy is to approach the advanced innovation environment in the world, make use of the overflow of technological innovation, absorb leading S&T in order to improve potential technology capability of company and take R&D activities according to local market conditions in order to support to overseas manufacture and marketing.

On the other side, in next a few years, parallel star form will be the primary organizational structure for Chinese international R&D. The responsibilities of the overseas R&D units are not only to track the trend of technology, but also to transfer the technologies aboard or to develop the products based on the overseas market conditions. The status of overseas R&D branches is improved, although it still depends much on the resource and instruction of the headquarters. On the condition

that the attention is paid increasingly on the horizontal communication in the multinational innovation project, centralized hub organization will absolutely lead to the low efficiency of scattered globe action and rare face-to-face communication among the branches. Therefore, it is necessary to build a parallel structure, setting up a committee that cooperates with the hierarchical structure, to direct the international R&D. The parallel committee not only is in charge of the planning the innovation strategies, but also serves as a platform for information intercommunion. The committee is composed of the managers from the overseas subsidiaries, R&D units and the domestic R&D center. Thus, the formal and informal channels of communication co-exist, which enriches the opportunity of communication among the units. In this structure, resources are obviously decentralized. Oversea R&D units have different amounts of resources according to their importance in total R&D strategy. More and more employees are recruited from host country. Parent company, oversea subsidiaries, venture capital and all kinds of nonprofit organizations may be main bodies of investment. At the same time, information flows between R&D units gradually (Fig 11).

4.3 Maturity stage

Because of the increase of geographically dispersed R&D units and the complexity of organizational structure, efficient technological innovation to integrate functions of geographically dispersed R&D units, and strengthen communication and coordination between each R&D units become the focus.

In this stage, international markets have equal importance to domestic markets

for Chinese firms, and the corporate R&D activities will be aimed at global markets directly. The companies will make use of global innovation resources to increase their potential technology capacities, and expand their shares in global market by reciprocity of the globalization of technological innovation and market expansion. To gain worldwide competitive advantages, a company will decentralize its resources. Thus, global-linked R&D network is shaped gradually (Fig 12).

Each R&D unit has special task according to different strategic status in company, which makes more self-determination and specialization of every R&D unit. In the whole R&D system, all R&D units depend on each other. The former function of central R&D will disappear, and the complex processes of coordination and cooperation are determined by domestic R&D units and expatriate R&D branches together. However, The overhead expenses are far more than that of the former two organizational forms. As for resources deploying, resources will no more centralized in the headquarters. Resources are allocated to each R&D units according to their importance in the R&D network. Oversea R&D units can obtain resources from various channels. Employee recruitment realizes globalization. Information is fully shared among R&D units.

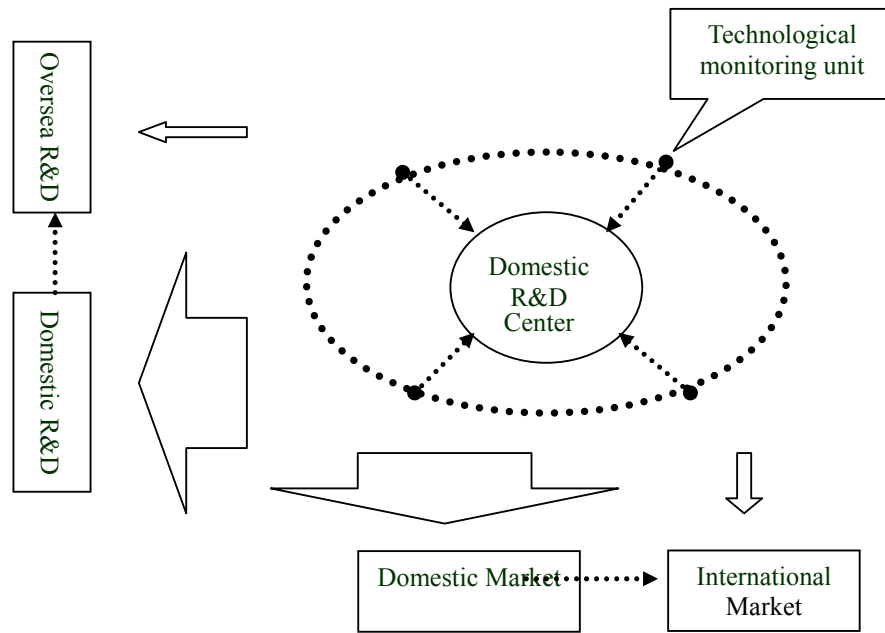


Fig 9 the strategy of start-up stage of Chinese R&D internationalization

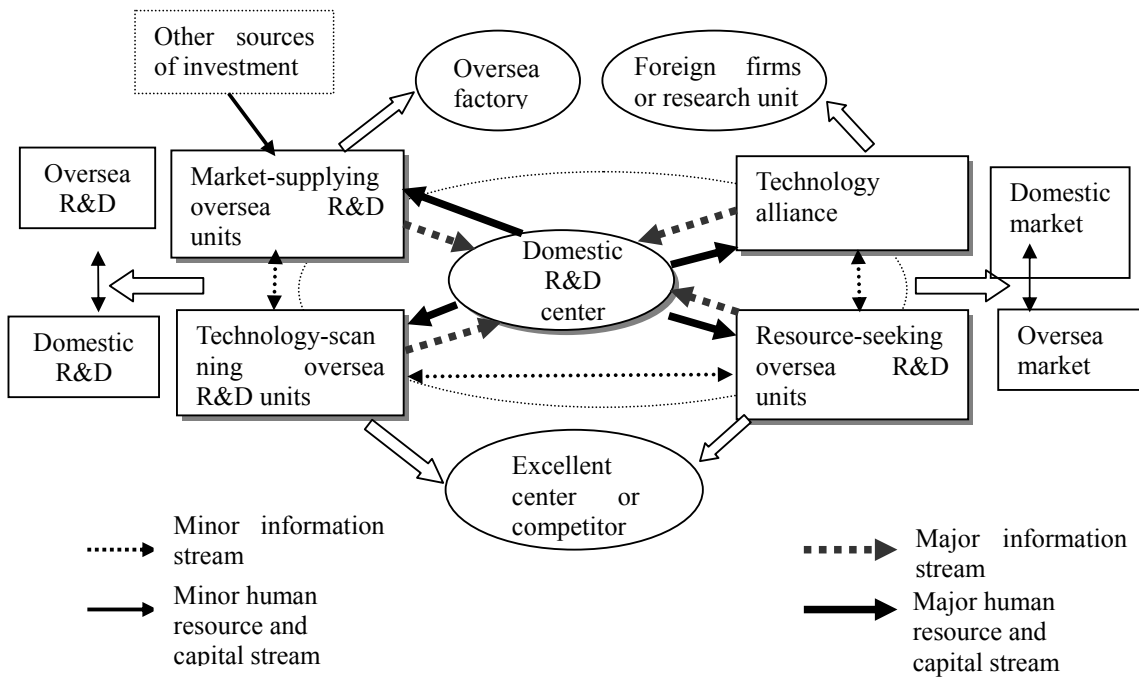


Fig11 The development stage of Chinese R&D internationalization

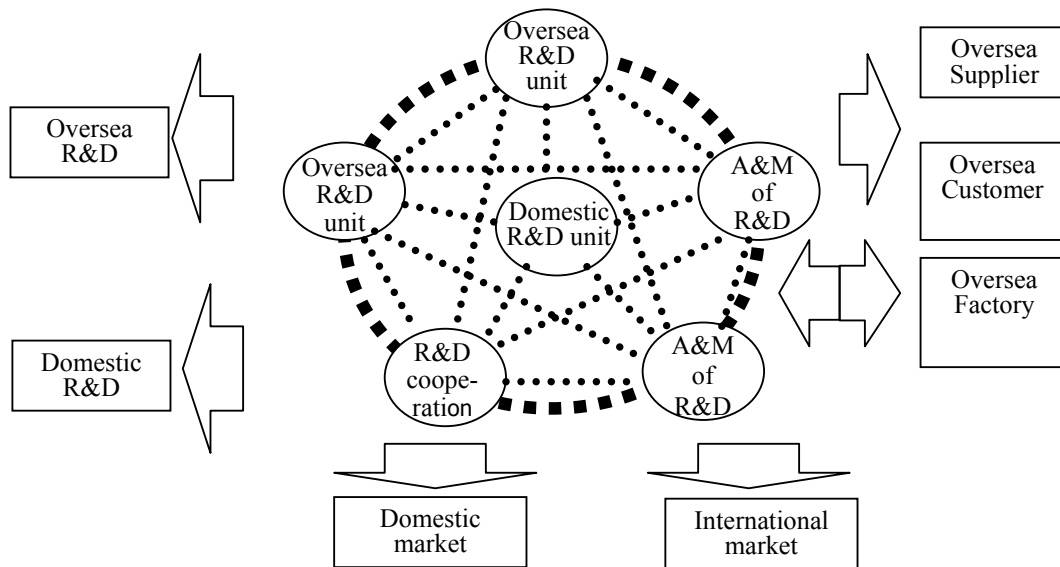


Fig 12 The maturity stage of Chinese R&D internationalization

To sum up, the evolution of Chinese R&D internationalization can be showed in

Table 1:

Table 1 The evolutionary mode of Chinese R&D internationalization

		Start-up stage	Developing stage	Mature stage
Strategy	Motivation	Understanding the trends of technological development, absorbing international advanced technologies and scientific knowledge, and enhancing corporate technological capabilities.	Approaching advantaged S&T environments, absorbing international advanced technologies and scientific knowledge, and expanding corporate technological capabilities. Supporting local manufacturing according to international markets.	Utilizing innovation resources and S&T environments worldwide, accessing major markets. R&D and market expansion promote reciprocally.
	Location	Influenced mainly by S&T system and R&D resources of host countries. Normally in world technology excellences.	Influenced by S&T system R&D resources of host countries, and market factors become important variables for reference.	According to S&T system R&D resources, and market factors of host countries, make reasonable allocation of R&D forces.
	Path	Centralizing R&D mainly in China, and establishing technology-monitoring units to seek international cooperation.	Centralizing R&D mainly in China, and taking some resource-seeking, market-supporting and technology-acquiring R&D activities abroad.	No R&D headquarters. R&D activities are allocate worldwide according to corporate strategic emphasis and regional advantages of host countries.

Organization	Organizational form	Centralized hub form.	Parallel star form.	Global-linked R&D network.
	R&D avidities involving expatriate units	Idea generation	Limited product development	Comprehensive R&D
	Power of decision-making	Absolute centralization	Centralization with involvement of subsidiaries	Decentralization
	Knowledge creation and diffusion	Headquarters develop and own relevant knowledge	Headquarters develop it and transfer it to overseas laboratories	Knowledge are developed and shared globally
Resource collocation	Information	Simple and one-way	Complex and double way	Complex and double way
	Human resource	Mainly sent by headquarters	Local recruitment and flow across R&D units	Worldwide recruitment and frequent flow across R&D units
	Funds	From parent company	Diversified input	Diversified input

5 The challenges and opportunities brought by international R&D facing Chinese S&T system

For a long time Chinese S&T policies have been inclined to attract R&D investment from developed countries in order to improve technological capabilities fleetly and catch international technological trends. However, the concerns about expanding Chinese R&D activities abroad are little. In general, there are some characteristics of Chinese S&T policies in the field of external technological cooperation:

- Encouraging foreign companies to make R&D investment in China;
- Benefiting from foreign R&D investment as much as possible;
- Expanding technological activities to other countries is not supported.

The global economies become more and more integrated. It is the certain trend of national innovation systems that enhancing the connection of domestic and global technological innovation systems, and getting more benefit from global innovation systems than depending only on domestic innovations. Many countries begin to

realize this issue. Apparently, concurrent Chinese S&T system can't meet the requirements of this kind of innovation. R&D internationalization brings some new challenges and opportunities to Chinese S&T system.

Chinese S&T system puts much emphasis on attracting foreign R&D investments by MNCs. On the other hand, the attention paid to expatriate R&D units established by Chinese firms is very little. The logic of this kind of policies is looking at and learning from others, without giving away one's own knowledge. Different authors argue that this kind of policies is increasingly illusory (Ostry and Nelson, 1995; Krugman, 1996). To build a more effective connection between Chinese NIS (National Innovation System) and GIS (Global Innovation System), the balance of indigenous R&D and global R&D must be achieved.

Under the traditional system, the decision making of Chinese S&T policies seldom consults social institutions widely. Nowadays, with the development of market economy, science researches and technology developments become distributed in public departments, private departments, governmental units, universities and enterprises. Faced with the new issues such R&D internationalization, Chinese S&T system should think about how to mine the increasing experiences of companies, universities and research units, in order to adjust R&D policies to the global economy system that changes continually.

With the rapid development of S&T cooperation with other countries and R&D internationalization, China realizes the importance and imminency of protecting intellectual properties in accordance with international standards (including Chinese

own intellectual properties). At present, the legislation of intellectual properties in China still needs more improvement. Furthermore, the corporate and public's consciousness of protection needs to be strengthened so that the law can work more efficiently.

In China, there is a great demand for acquiring advanced technologies from other countries by joint venture or technology import. These strategies of technology acquirement may meet the corporate advantages in some areas (although not all areas), but depart from the national R&D objectives. R&D internationalization makes this problem more complex. Acquiring advanced technologies depends not only on investments from other countries or technology import, but also on setting up oversea R&D units to learn technologies directly, which will be more and more prevalent. Thereby, the policy system coordinating technology imports and R&D internationalization will be needed to balance the advantage of technology transfer between domestic and international R&D.

In the meantime, some preferential areas should be identified by Chinese S&T system so that corporate international R&D resources will not be wasted on some projects, which cannot facilitate the improvement of Chinese S&T capabilities even they are executed successfully. The new S&T system requires new modes for the cooperation of the government and enterprises in order to make the short-term demands and long-term visions of enterprises accord with the objectives of decision-makers and R&D teams, and to make the development of Chinese S&T in the right direction.

From the results of our investigation, we can find that 53.9% of the companies think the cost as the most important factor to restrain R&D internationalization. Actually, the cost of setting up R&D units abroad is much higher than expanding in China. Meanwhile, most Chinese firms invest less in R&D relative to foreign MNCs. On the other hand, the investments in S&T activities by government are focused on basic research projects, not the commercially applied development which is attached much importance by companies. So the development of corporate R&D internationalization can't count on direct financial support from the government. The problem of cost restricts many Chinese enterprises to implement the strategies of international R&D.

As for Chinese S&T system, we can't ignore the impact of *institutional revolution*. Institutional revolution not only made China trail industrialized countries in technology capability, but also had a severe influence on Chinese S&T education. At present, most backbone workers of Chinese S&T system are over the age of 40. The education and training they received at that time was also influenced badly. On the other hand, R&D internationalization set much higher requirements for S&T workers, including knowledge, experience, and language. Hence until today Chinese S&T system is still short of international talents, which is realized by both enterprises and public departments.

The modern information technology is a powerful driver of R&D internationalization, such as video conferencing system and telnet access system, which set high requirements for R&D infrastructures. Nevertheless, the level of

Chinese S&T infrastructure is low in general, and inter-personal relationship is attached much importance in Chinese culture. Therefore, though Internet has become widespread in China, the comprehensive application of information technology in Chinese S&T system will lie on the progress of S&T infrastructures and the vicissitude of social culture.

At last, quite a lot of Chinese S&T policies are not explicit in diction. In other words, they are unclear. For an instance, “anchor one end securely, let the other roam free”. This kind of phrases can express the complex connotation with few words, allowing people to explain the thoughts of decision-makers who encourage entrepreneurship and innovation from different point of views, which once accelerated the development of Chinese S&T. However, in order to integrate Chinese S&T system into the global innovation systems farther, the expression of policies about international R&D should be more precise, using the S&T policies of developed countries for reference.

6 Implication and Suggestion for the reformation of Chinese R&D system

In order to make our suggestions more clear, we should understand the roles of S&T system in the field of innovation policy firstly. Based on the conceptual framework developed by Jacobs (1998), we identified four roles of Chinese S&T system. (1) Resource: providing the infrastructure—the material and the knowledge infrastructures necessary to make the S&T system work. (2) Organizing: constituting necessary processes to achieve certain concrete policy objectives in the field of

innovation. (3) Operational mode: implementing some governmental behaviors and achieving objectives through different kinds of incentives to market mechanisms. (4) Framework: providing a framework to enhance the understanding of the knowledge-based economy (appropriate statistics, indicators that help to map progresses in the field of innovation, technology foresight and social learning) and setting the future vision of the country.

Therefore, according to the four roles mentioned above, Chinese S&T system ought to have six functions to facilitate corporate international R&D (Table 2).

Table 2 Functions of Chinese S&T system

Function as a central government	Establishing policies and assigning resources at national level
	Constituting regulative policies
Function as an executor	Funding innovative activities at executive level
	Taking some detailed activities relevant to international R&D
	Developing global human resources and reinforcing competences
	Providing infrastructures

However, the policy system and management system such as specific information consulting service aimed at corporate R&D internationalization in Chinese S&T system haven't been constituted for the moment. Thereby we suggest that the government should take some activities to help Chinese S&T system to implement those four roles and six functions, promoting international R&D. These activities include not only direct leadership and R&D subsidies, but also indirect policy supports such as tax policies, creating policy environments propitious to enterprises.

- A framework to promote innovation should be constituted, in which

industries are considered as main bodies, and the connection among enterprises, universities and social research institutions should be enhanced.

- The principles and methods to support R&D internationalization ought to be defined in the establishment of policies and statutes about R&D internationalization.

- The governmental macro management system should be framed, and the government and enterprises should be differentiated clearly.

- Except supports by financial policies, the venture capital mechanism about R&D internationalization should also be set up under the circumstances of WTO agreements. With the introduction of venture capitals, companies can get enough funds in capital markets. The problem of insufficient investment in R&D internationalization can be solved effectively.

- Providing more subsidies to help firms to purchase patents and other soft technologies, supporting international R&D activities such as imitation; increasing the protection of patent rights, leading global R&D activities to independent innovation.

Furthermore, Chinese S&T system should provide more public services to support domestic companies:

- Providing more information services, including international technologies and markets information. Because most Chinese enterprises have centralized their production and business in China, neglecting the markets, environments, cultures and policies of other countries. So the services of information consultation will

promote R&D internationalization greatly.

- Educating and training qualified people for corporate R&D internationalization. Human resource is the key to successful technology innovation. Experienced R&D managers can bridge the culture differences, and communicate with different people flexibly. But at the present time, the lack of international talents exists in most Chinese firms. On the other hand, the costs of recruiting overseas managers can't be afforded by many Chinese enterprises. If Chinese S&T system can help companies to train international managers, R&D internationalization will develop more quickly. For example, the government can encourage more S&T workers to study in industrialized countries, helping train experienced international R&D managers.

- Making use of WTO agreements, helping companies to obtain more policy advantages of host countries, and creating good external environments for corporate R&D activities in host countries. For an instance, signing a bilateral agreement with a host country to protect corporate investments.

7 Conclusion

We take the Foreign R&D as the parts of National Innovation System (NIS), but the increase domestic R&D via NIS as well as GIS (Global Innovation System) is also important. Traditionally Chinese International S&T concerned more about Research Institute and University, then we should balancing the R&D internationalization of research institute, university (more on research issue) and firm side (more on

development issue).

Chinese S&T system is still short of international talents, then Chinese government attracting oversea Chinese continuously and try to formulate the Silicon valley-Hsinchu-Shanghai triangle flow, but we should have a long-term motivation of domestic R&D staff, but the continuous training for the international management, there should be some better communication between MOST, CAS and MOE.

The modern Information and Communication Technologies (ICT) are powerful drivers of R&D internationalization. Now, geographical distance can be “shorten” by modern information technologies, and dispersed R&D can be integrated by the technological platform with high-efficiency. However, the capacity of information technology will be limited because of social structure (De Mayer, 1991), especially in the multi-culture environments. Therefore, Chinese S&T system should consider both Hard Side (Infrastructure, IT, Information Supply) and Soft Side (Relentless communication about internationalization among entrepreneurs, researchers, venture capitalists and governmental officers) to promote the development of Chinese R&D internationalization.

Chinese firms start international R&D very recently, which is an effective way to leverage technological level and corporate competences. R&D internationalization is getting more and more attention because of its rapid development. Nevertheless, Chinese traditional S&T system doesn't respond to this new phenomenon positively, which is adverse to the further development of international R&D by Chinese enterprises. Hence R&D internationalization should be taken into account in the

reform of Chinese S&T system, and relevant policy system and management system should be established.

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