National innovation system and university spin-offs

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1. Introduction

1.1 From Linear Model to System Model

The road to innovation was once a moot point. The different explanations would lead to the different organization structure, strategy, and operation process. The linear model of innovation is a flow of "basic research → applied research → development → manufacture → sale" (Kline & Rosenberg, 1985; Miyata,2002). The logic of it is just like a baton that is to be passed from one to the next in a relay race (Myers & Rosenbloom, 1996). During this relay race, technology is no more than a baton (Myers & Rosenbloom,1996), and the reactive relations among the stages are ignored. The typical organizations based on this logic process of innovation, are central research institutes mainly in giant corporations in America from the end of 19th century (Houshell, 1996). It is hard to deny that central research institutes made a huge contribution to innovation. However, it is also a fact that many potential research results and inventions could hardly raise direct economic effect.

Then another luminous model—the "chain-linked model" was suggested by Kline and Rosenberg in 1986. Kline and Rosenberg argued that linear model badly misspecified the nature and direction of causal factors at work, mainly in two viewpoints—one is that there is only a single central path, and the other is that science plays the central initiating role. Instead, they proposed the process of innovation as series of changes with lots of uncertainties in a complete system, controlled by both of the market and technology forces. Based upon them, their chain-linked model emphasizes that (1) there are iterated feedbacks and links among every stage of design, testing, production, marketing and service; and (2) instead of science, it is the market need that pushes innovation; (3) the process of innovation is a learning process. However, beyond Kline and Rosenberg's indications, when innovation is an open process in a specific environment, learning is not only inside an organization, but exceeding its definite boundary—how to learn, how to accumulate and how to foster competive-

ness are challenges.

Due to high cost, great difficulty, inefficiency of the total process held in a firm, the speed requested by global market competition and so on, central research institutes are downsizing[1] (Mowery & Teece, 1996, pp.111-129; Sakakibara, 2005, pp.62-65). Restructuring of central research institutes makes the outsourcing of R&D and cooperative alliance essential strategies and improved the cooperation among government, industry and universities. The restructuring resources in a social system free the innovation chance in a much wider range. The free mobility of technology and knowledge, human capital once restocked in giant corporations, and the outsourcing business chances, demand for strategy alliance are the fertile ground for development for new start ups.

1.2 The Dilemma of Innovator

"New markets do not emerge in their (leading firms) full scale or with clearly identifiable needs but start out as messy, uncertain and risky places with small size and dubious growth prospects (Tidd, Bessant, Pavitt, 2005, p31)." There is a dilemma that the existing corporations are no more than the leaders of incremental innovation, but losers in radical innovation. Particularly in the fields of computing information and communication technology, robots, new materials, biotechnology and so on, it is the start-ups that play a more active role.

The contribution of the research on automobile industry by Abernathy (1978), is the basic construction of innovation theory. (1) Innovation is described into two patterns —the process (incremental) innovation emphasizing the maximizing of product performance, and the production (radical) innovation driving for cost reduction; (2) In the production process in an industry, there are a fluid stage, a transitional stage and a specific stage. This theory predicts that productive units at different stages of development will respond to differing stimuli and undertake different types of innovation (Abernathy, 1978, P172). As for the fluid stage, impetus is typically provided by the users' new needs out of the established market. Additionally, the most radical innovations are generated by a more flexible organization as an entrepreneurial act, but less by the established large firms, which are major in the specific stage, stimulated by competitive pressure on prices and the need for greater efficiency and market scale, and quality standardization in the product and manufacturing process.

To further develop this model, Abernathy and Clark (1983, 1985) classified in detail innovation into architectural innovation, niche creation, regular innovation and revolutionary innovation, based on the concept of "transilience"—the capacity of innovation to influence the established systems of produc-

1) Certainly, whether basic research in a firm is necessary remains a controversial. The arguments of potential competence from basic research are persuasive and practicable, like Rosenberg(1989), Pavitt(1990). And, there are still many large established corporations holding their way.(Rosenbloom & Spencer, 1996, P.5) in America, especially Japan and so on.

tion and marketing. When the development of industry comes to the regular phase and niche creation phase, in which production and market are maturity and less innovation is generated, it is necessary for the established firms to "de-mature", that is to shift to the revolutionary phase, which is dominated by "technology push". From one stage transiting to another, it is evident experience that "originating firms exit and are replaced by new firms better able to manage in the new mode (Abernathy & Clark, 1985)."

From other perspectives, Henderson and Clark (1990) defined innovation by core concepts of the modality and the linkages between core concepts and components into four types—incremental innovation, radical innovation, modular innovation and architectural innovation. They focused on architectural innovation that reconfigures an established system to link together existing components in a new way, and has a significant effect on corporation strategy. They emphasized communication channels, information filters, and problem-solving strategies embody an organization's architectural knowledge of the linkages between components that are critical to effective design. Then the established organizations perhaps mainly focus on the innovation based on their embedded architectural knowledge, so that it's more difficult to move their attention for the new emergent architectural innovation than the new entrants which are "not handicapped by a legacy of embedded and partially irrelevant architectural knowledge" (Henderson & Clark, 1990). In other words, the new entrants may exploit the potential new architectural innovation more effectively.

Christensen (2002) explained why the textbook examples of good practice in firms fail in the new market by studying the hard disk drive industry. He divided innovation into sustaining innovation in which technology improves the performance of the established products, and disruptive innovation which instead results in worse product performance but cheaper, simpler, smaller and frequently more convenient (Christensen, 2002). As in the hypothesis of Christensen, the leading firms can manage the sustainable innovation in the mainstream market but always show not enough attention to the newly emerging one, so they fail in the new market which is thought to be created by the disruptive innovation. Therefore Christensen argued the way to solve the dilemma is through a "spin-out" organization formation, because of disadvantage as well as advantage of leading firms, such as resource dependent, limited organizational capabilities, established value network, existing customers-focusing, and ignoring the unattractive new markets.

By the analysis of the characteristics of innovation, the changing stages and stimulus in the process of innovation, the influence of the established knowledge and resource dependant, and the existing market focus, new start-ups instead of the existing firms, should be an ideal way for the radical innovation. Additionally, during the process of

innovation of an industry, there is a well defined complementary relation of competition and cooperation between the established firms and new start-ups. However, why can new start-up ventures without the cumulative core competence (Prahalad & Hamel, 1990; Miyazaki, 1994), an existing value network (Christensen, 2002), and lack of management resources (Penrose, 1959; Barney, 1991, 2001), defeat the well-managed companies ? What are the source of innovative technology and the information source of market needs ? How can they further develop and recreate them ? These questions should be discussed further.

1.3 Modularity and New Start-ups

The evolution of the design of production triggers the revolution in corporation strategies and competitive and cooperative relationship in industry. At the heart of the remarkable advance is modularity—"building a complex product or process from smaller subsystems that can be designed independently yet function together as a whole (Baldwin & Clark, 2000)." Based on the theory of Adam Smith's division of labor, the development of modularity makes the decentralized "design and industry revolution (Baldwin & Clark, 2000)" possible. Decentralized design of products makes organizations more flexible and closes the gap between the established firms and start-ups as well. It empowers the individual organization and frees them from the passive subcontract positions (Baldwin & Clark, 1997).

In order to co-exist and co-develop, it is necessary for firms to cooperate with organizations inside and outside in a certain form[2]. Thus modularity fosters the development of the technology-based startups and boosts the rate of innovation (Baldwin & Clark, 1997; Ando & Hashimoto, 2002). The most obvious example is the computer industry developing from the opening System/360 and the rapid development of Silicon Valley—a "cluster of modules" (Baldwin & Clark, 1997; Ando & Motohashi, 2002), where information and communication industry rapidly developed and was prosperous.

However, the forming and developing of the "cluster of modules" is not only based on the internal elements—design and industry revolution, but also depends greatly on the environmental support, including government supporting policy and service, cooperation from universities, substantial venture capital, mobile and rich human resources, entrepreneurship spirit and open-minded culture and so on. Therefore, in order to understand the development of technology-based start-ups and their process of innovation as a whole, the view of the social innovation in a country is indispensable, besides the general innovation theory analyzed above.

2 . The High Performance of University Spin-offs

It seems common sense that the new technology-based start-ups are so highly

2) The obvious case of Japan automobile industry is analyzed by Fujimoto (2002).

risky that the operational rate of them should be very low. As for university spin-offs, some of the founders are students and faculties in non-profit organizations, who are usually considered not good at doing business. Moreover, the technology from a university is always apt to be so basic, theoretical or even state-of-the-art over the need, that is easy to fall into the "Dead Valley" when transferred. Therefore, it is normal to consider the performance of university spin-offs should be by far lower.

However, to the contrary, the fact is reversed. As an innovator to translate new ideas and potential technology from a university, university spin-offs have a high performance in some places around the world. Shane (2003) reported that through analyzing the 134 spin-offs from Massachusetts Institute of Technology (MIT) from 1980 to 1996, only 20 percent had failed by 1997, and 24 of the new ones or 18 percent experienced an initial public offering (IPO), which was over 257 times the rate of initial public offering for typical start-up companies in the United States (Shane, 2003, pp30-32)[3]. According to the survey 2002-2004 of AUTM, which undertakes a survey every year from 1993 in United States, reported that 2741 start-ups still operational is 63.4% of 4320 in 2002, which have been formed since 1980, and 55.8% in 2003, 58.8% in 2004[4]. So it concluded that the survival rate of university spin-offs is quite high, approaching the rate experienced by the venture capital industry overall.

There is no exact data about the operational rate of university spin-offs in China. However, according to the report of university spin-offs in 2004 by Ministry of Education, the sales of the total university spin-offs in China were up to 96.93 billion Yuan, compared with 33.5 billion dollar in America in 1999 (Cohen, 2000). (Compared with thatin America, the total performance of university spin-offs in China was not had.) And since the development of university spin-offs is far later than America and there is not enough data available about the university spin-offs in Japan, it is difficult to made a whole analysis of the situation of Japan. However, from table 1, the data of 2003-2006 of Japan[5], which made a great effort to develop university spin-offs from 2002[6], the number of nonoperational university spin-offs is small

3) "During the 1980-1996 period, 111274000 companies were founded in the United States, and 7456 companies went public, or 7/100ths of 1 percent of the number of companies founded. A comparison of the proportion of companies that were founded to exploit MIT assigned inventions between 1980 and 1996 that went public with the proportion of all companies founded during the same period that went public indicates that the ratio is 257 to 1… Unfortunately, no information is available on the average level of capital gain on MIT spinoffs that go public, so it is not possible to compare this level of capital gain on the average level of capital gain on an IPO." (Shane, 2003, p38.)

4) As Shane indicated, the number of the surviving firms that may be dormant without having legally dissolved, is not clear. So it is possible to understate the failure rate of university spinoffs (Shane, 2003, P38).

5) The survey on university spin-offs over the whole country in Japan was taken from 2000 by Chiba University and others.

6) "A Plan for 1000 University Spin-offs" was implemented from 2002. At that time, the number of university spin-offs in Japan was no more than 387.

and 1% of total in the survey of 2004 took IPO. Besides America, China and Japan, there is a similar tendency of high survival rate of university spin-offs in France, Sweden, and Holland as well (Shane, 2003; METI, 2006).

The reason that university spin-offs have a high performance can be interpreted in the framework of national innovation system (Figure 1). Compared with non-university spin-offs, university spin-offs have some important support from universities, which is considered especially important for starting up in the early stage. It includes ① in the figure 1, direct resources supporting, like human resources, technology, capitals, reputation, materials and so on; and ② the indirect support like benefit from support to affiliated university by government and the cooperation of affiliated university and specific industry; finally ③ strategic alliance with the affiliated university.

Table 1 The operational number of university spin-offs in Japan 2003-2006

	2003	2004	2005	2006
Total	799	1099	1503	1677
The non-operational	16	28	40	87

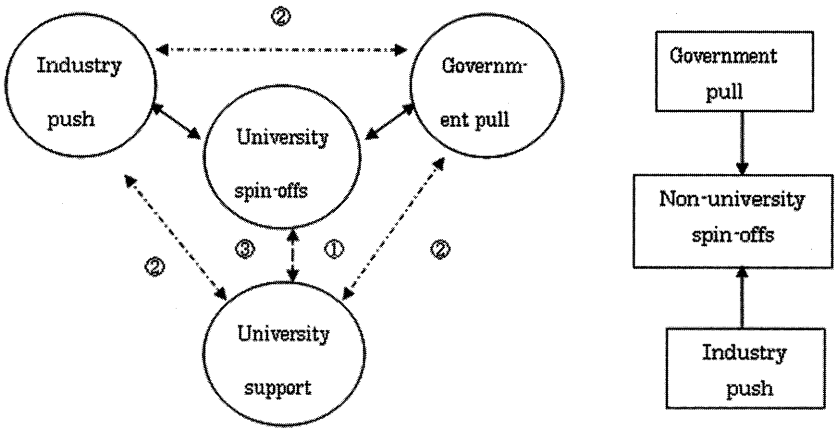
Note: The nonoperational refer to the ones which went out of business, the ones which were merged so that no longer exist, and the likes.
Source: METI 2003-2006.

3. Comparison with University Spin-offs among America, China and Japan

3.1 The Development of University Spin-offs in America, China, and Japan

Since the last part of the nineteenth century, universities have become an increasingly important part of the capitalist engine (Nelson, 1986). The mission of university is also changing and increasing all the time. While the mission of a university is from education to education and research, and now "the third mission"—a contribution to society (Etzkowitz, ect, 2000)[7] is highly expected

Fig. 1 Comparison between the university spin-offs and non-university spin-offs



(Miyata, 2002), the linkages of universities and industry are gradually stronger and stronger. And the methods used to transfer techndogy and ideas are from individual-level to organization-level contracts during the changing relationship between universities and industry (Mitchell, 1990).

While for a long time publication and training remains the major way (AUTM, 1998), joint research and contract research with corporations, applying for the patent and translating, jointly establishing science and industry park are greatly encouraged by the university-industry liaison offices, which are formed by many universities engaged in the cooperation between universities and industry. Besides, starting up new companies to directly translate the potential technology to market is now a highly expected and effective way, practiced by most of those universities. What is more, university spin-offs are now developed in unprecedented numbers around the world (Figure 2).

Many governments are engaged in promoting the linkages of universities and industry, and the development of small-medium size enterprises and university spin-offs. They provide subsidies for start-ups and kinds of services like consulting, execute deregulation for starting up, and invest to build kinds of clusters like biotechnology and software, especially to incubate university spin-offs and so on. An environment easier for the new starting up is being built around the world. From figure 2, it is obvious that there are numbers of university spin-offs that are founded in both the developed countries and developing country like China.

Surprisingly, however, the gap of the cumulative numbers is extremely large. Take America, China and Japan for examples (Figure 3, 4, 5). Although the numbers of university spin-offs were gradually increasing both in America and Japan, the total numbers were quite different and obviously the number in Japan was very small. Both the totals of America and China were about 5000 recently, but instead of being in an increasing rate like that of America, the total of China declined gradually, whereas the number of high-technology university spin-offs was increasing slowly. However, the fact that can not be disregarded, is that the data is from surveys based on separate standards, taken by organizations in each country.

3.2 The Different Views of University Spin-offs in America, China and Japan

University spin-offs are global phenomenon and not new any more, but the definition what is a university spin-off is still ambiguous and lacks of discussion. As analyzed above, there is a great gap of development of university spin-offs in different countries. It is because the definitions, background, ranges are extremely different among America, China and Japan.

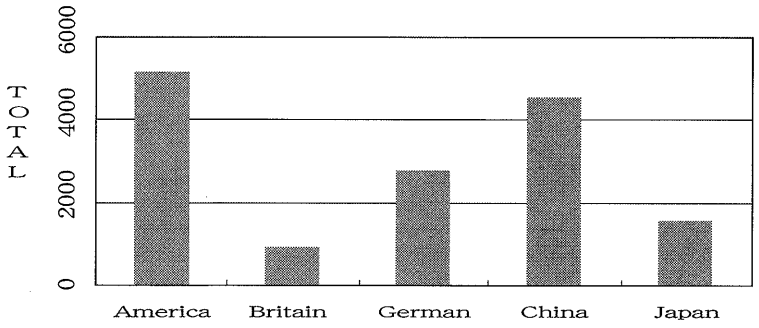
There are 5171 university spin-offs in total founded in the United States from 1980 and

7) Etzkowitz etc. proposed the role of entrepreneurial university in their model of "triple-helix" (Etzkowitz & Leydesdorff, 1995).

2005 (AUTM, 2005). On averages these companies were successful and technology-oriented as well (Shane, 2003). AUTM defined "start-up companies are ones that were dependent upon licensing the institution's technology for initiation". Shane also argued that a university spin-off should be "a new company founded to exploit a piece of intellectual property created in academic institutions," and criticized that "companies established by current or former members of a university, which do not commercialize intellectual property created in academic institutions, are not included in the definition of a spin-off (Shane, 2003, P4)."

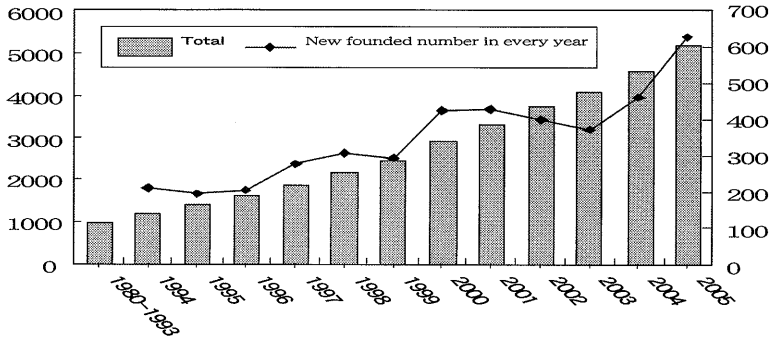
Obviously the definition of Shane and AUTM focus mainly on intellectual property. It implies that a university spin-off is a technology-translating agency between academic and private organizations. To do one's own business is not anything new and special in the nation like America that is rich

Fig. 2　International comparison with university spin-offs



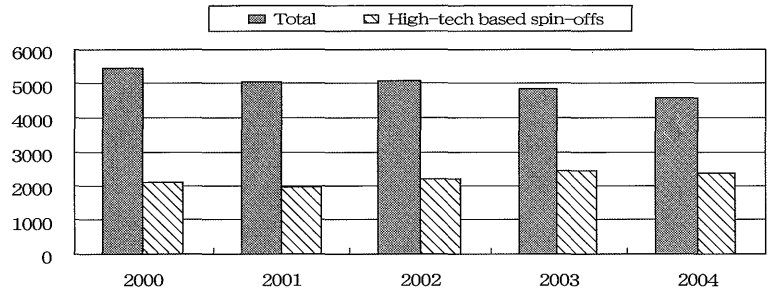
Note: The data of Japan was about 2006, and America 2005, German 2000, China 2004, Britain 2002. All of those were cumulative.
Source: AUTM 2005; NISTR 2006;
Ministry of China 2004; Science and Technology Academic Council 2007.

Fig. 3　The number of university spin-offs in America



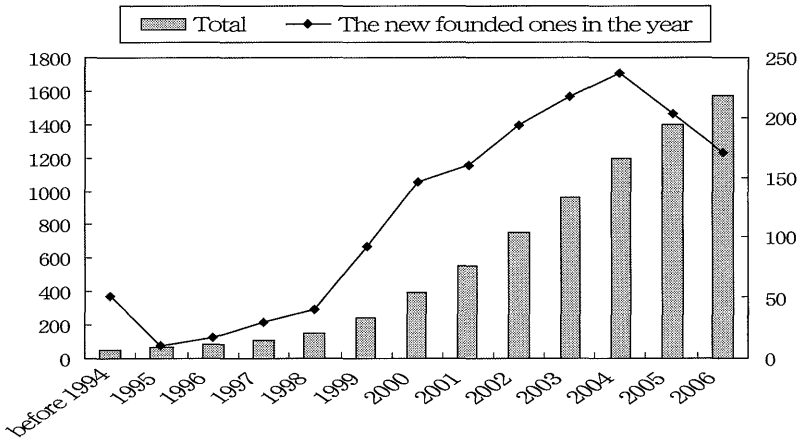
Source: AUTM 1993-2005.

Fig. 4 University spin-offs in China



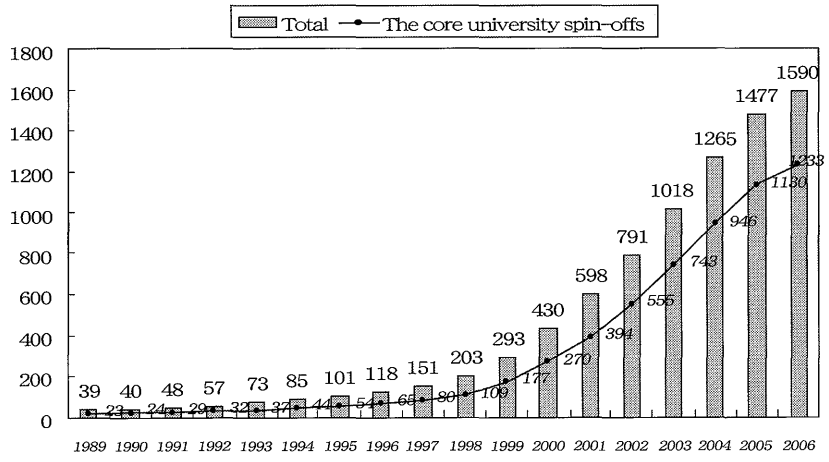
Source: Ministry of Education, China 2004.

Fig. 5 University spin-offs in Japan



Source: NISTR 2006.

Fig. 6 University spin-offs in Japan



Source: MIET 2006.

in entrepreneurship. The focus on the value of university spin-offs in America is obviously not whether any new more companies are created by faculties or students, but if any potential technological resources have been translated and commercialized. Therefore, in the world is there only one unique Silicon Valley formed by tens and thousands of spin-offs, which are considered as the very economic engine to save the American economy from stagnation of the 1990s.

As for China which is thought to develop in a unique way, there were more than 5000 university spin-offs in 2000. However there is no any formal definition about university spin-offs when surveyed. A university spin-off in Chinese is "*Xiao Ban Qiye*[8]". "*Xiao*" means educational institutions. "*Ban*" means to found, operate and manage. And "*Qiye*" means firms. It implies that university spin-offs are owned and operated by educational institutions, but not necessarily technology-orientated, according to (the meaning of Chines expression and) the publication and reports of Ministry of Education as well. Actually, "Xiao Ban Qiye" is not anything new in China and familiar to many education institutions, because not only universities but also most vocational schools and high schools also have their own "Xiao Ban Qiye" as well. Therefore, no wonder there were such a total amount in China, it includes such kinds of firms engaging in real estate, trade, Dublishing and so on.

The reason that total number was decreasing while that of high-tech start-ups was increasing, is that the government of China has started to lead the "Xiao Ban Qiye" back to the "traditional way" and contribute to the development of high-tech industry and innovation (Pan, 2007). Noreover the total number of high-tech firms was just about 50% of the total, but the sales of them accounted for more than 80% in 2004 (Furuta & Pan, 2007).

It seems that this kind of organization structure in China has much more closed linkages between the universities and industry on one hand, the vague ownership between university and spin-offs, the overall trend of commercialization of academy, and the possible financial risk are problems confronting universities on the other. Moreover, since the total economic reform from 1978 and the reform of Science and Technology Institution in 1985, both of which have encouraged and accelerated the private economic development, the period of a university going into market directly and indirectly has been inaugurated, and university spin-offs have been one of the most important ways. In a word, it was such a period in China that it needed very badly to develop, in any possible ways by trial and error, in order to emerge out of poverty and the state falling behind (Pan, 2007).

A university spin-off in Japanese is "Daigaku Hatu Bentya.[9]" "Dayigaku" means a university. The nuance of a "Bentya", as a Japanese English word of "venture", is that this kind of firms is possibly filled with risks

8) In Chinese, 校办企业.

and adventures[10], and also some kind of boom characteristics, so that it is easily led to the tendency to be highly considered of quantity (Shiotsugu, 1997; Maeda, 2001).

There was ambitious policy A plan for "1,000 university spin-offs" during 2002-2004 in Japan and actually it was well accomplished. According to the METI 2007, the total amount went up to 1590, steadily increasing every year (Figure 6). However the definition in Japan is by far wider, and different between some ministries. Ministry of Education, Culture, Sports, Science and Technology (MECSST) classified them into four types. They are (1) the ones based on patents, (2) the ones exploiting the research result, (3) the ones founded by teachers, technology staff and students of universities, and (4) the ones invested by universities or TLO.

Then METI which promoted the policy mentioned above broadly divided university spin-offs into two kinds. One kind is named "the core university spin-offs" which refer to the new founded ones on the purpose of commercializing patents, new technology and business ideas created in universities" and "the ones founded by students who have a deep relationship with universities" (METI, 2007). And the other kind involves (1) the ones which are founded within 5 years taking some joint research with universities, on the purpose of commercializing the technology of the founders; (2) the ones which are founded within 5 years, having ever translated technology from universities, in order to develop and sustain the existing business; (3) the rest which have some kind of deep relationship with universities, such as the ones invested by a university (METI, 2007).

Obviously, the definitions in Japan are very wide and ambiguous, especially that of METI. Compared with figure 5[11] and figure 6, the data is different. Certainly, the wider range of the definition, the bigger number of university spin-offs results in. From the view of resources, university spin-offs are considered as resource-translating agencies of universities—resource-creating factories. Besides patented and non-patented technology, the promising human resources, unemployed capital, intangible relation network and any other dormancy resources in universities are also filled with expectations. However, there is also reasonable doubt that the quantities rather than qualities were pursued, particularly in the period of 1000 university spin-offs plan[12].

Some characteristics of Japan's innovation

9) In Japanese, "大学発ベンチャー"."ベンチャー" is katakana, directly translated "venture" into from 1970 by some government officers and scholars. But they used "venture" in a form of "venture business"(ベンチャービジネス"), means the special kind of start-ups (Maeda, 2001; Furuta, 2005).

10) According to my interview with some entrepreneurs of university spin-offs, they said "it is difficult for us to find trading partners, because people consider our firm is a 'venture', which is unstable." (Interview in Jan., 22nd, 2008).

11) The definition of university spin-offs in figure 5 is based on those of MESST.

12) In an interview with a coordinator in the local science park of X, he said actually at the very beginning, there was tendency and pressure to incubate more spin-offs, however, now government has recognized that it is quality rather than quantity that is more significant (Jan., 24th, 2008).

system are always considered as the central role and independent principle of the giant corporations, the weak cooperative linkages between universities and industry, the non-mobile human resources (Motohashi, 2001; Ando & Motohashi, 2002). Therefore, the government of Japan and some researchers expect the new start-ups as a leading role to contribute to the new development and growth of Japanese economy and help to go out of the "Lost Decade". Thus, starting up is greatly encouraged by building both the hard and soft environment easier for starting up recently. Particularly university spin-offs receive a nationwide attention.

From the discussion above, the development of university spin-offs is quite different in America, China and Japan. And the differences in the three countries, in one hand, reflect the characteristics of the separate innovation system of them; on the other, it is the differences in an innovation system that lead to the differences of the development of university spin-offs.

4. Discussion: National Innovation System and University Spin-offs

4.1 A Dynamic and Systemic View

The one who first analyzed a nation from a systemic view is Friedrich List (List, 1841; Freeman, 1995). List (1841) analyzed the development of a nation not simply from the immediate benefit. Rather, he argued that it should stand on the systemic view of the economy and politics of a nation by persuadably analyzing ten countries.

A system is a complex elements of which have such characteristics that cannot be explained by any disperse single one, since they are dependent on each another by a specific relation (Ludwig von, 1968; Takahashi, 2002 pp.224-226). Different from the view of a network, in which elements are in certain arbitrary relation, the view of a system focuses on the specific relation, which restrains its elements, as well as characterizes the system itself. List considered a nation from a network to a system.

Schumpeter proposed innovation can be created by five cases of new combination. They are (1) production of new types of goods, or change of properties of the existing goods; (2) introduction of a new method of production that may be based on the new scientific discovery; (3) opening of a new market; (4) use of new sources of raw materials and intermediate goods; (5) new organization of production. From the resources-based views (Penrose, 1959; Barney 1991, 2001; Yitami, 2004), where is the source of the resources that foster firms' competitiveness, especially for new start-ups ? What is the process that leads to innovation of a new combination ? Instead of focusing on the resources of the internal structure of a firm as discussed above, the resources from the external combination of the organizations are possible and essential. The combination of the public, academic, private organizations is possible to help generate innovation, especially for new start-ups.

Table 2 The changing functions of the public, academic, private organizations

		Public	Academic	Private
Typical organization		Central and local government	Universities and similar institutions	Business firms
Regular functions		Public policy and central control	Basic research and human-educating	Production, serving and distribution
Inter-functions	Academic	Public research (military relation, etc.)	Applied research	Basic research and human-training
	Private	State-owned companies (public business)	University spin-offs	Corporation spin-offs
New-born Connected organizations		Supporting organizations for combination and transferring.	TLO and the similar institutions	A joint research program and lab, etc.

When government, university, industry are taken as disaggregated elements, and the relations among them are arbitrary, the inter-organizational relations are no more than a network relationship (Aldrich & Whetten, 1981). However, when the specific relation is defined and they constitute a complex based on the relations, through which they interact and cooperate with each other rather than a lone wolf separately, then "the whole is more than the sum of parts", and it forms a "system" (Ludwig von, pp.54-55). It is the systemic relation that initiates, modifies, diffuses, accumulates resources, makes the actors flexible, and stimulates the linkages of actors to generate the innovation in a nation, therefore, defined as a "nation innovation system".

An innovative chaos is on the way among the public, academic and private organizations. While some of the functions among them become interchangeable, the boundaries among them are indistinguishable (Table 2). Among them, a university spin-off is to an extent an innovative organization to create a new window for university potential resources. While the organizational rigidities are dissolved, a new organization mode is being created and developed. While cooperation and competition operate simultaneously, the incentive construct is reconstructing. They come closer and closer from the state of differentiation to integration as the expectation, interaction and communication among them are being vigorous, as well as the human, capital, material and information, technology resources are recursively mobilized, increasingly accumulated, widely diffused.

Rather than follow a global tendency, a new order should be established based on one's own dynamic national system of the human resources subsystem, the technology and knowledge accumulated subsystem, the incentive structures, and the linkages of the institutions.

4.2 Learning Process of Innovation and University Spin-offs

Another problem needed to be discussed is the process of combination to generate innovation. As many scholars proposed, the process of innovation is a knowledge accumulated (Pavitt, 1984; Tidd, Bessant, & Pavitt, 2005) and learning process (Kline & Rosenberg, 1986, Goto, 2006), not only inside a single organization, but also with the external environment. Freeman (1987), as the first one to use national innovation system to analyze how Japan's government and industry to combine as an integral to initiate, import, modify, and diffuse technology and build the competitiveness. Odagiri and Goto (1993), in historical perspectives, analyzed the Japan's innovation system from Meiji Era to present by technology advancing process, the evolutional educating system, and the management system and so on. The catching-up, advancing and innovating process of a nation, in this point, are an integrated learning process in a whole, including all the tangible and intangible elements and players. Therefore, the essence of national innovation system, is an interactive, cumulative and creative learning process.

If ultimate purpose of organization is long term survival and growth (Fiol & Lyles, 1985), technology-based start-ups have to at first pass the barrier to survive in their infancy. Organizations which discover new environmental niches, which promote the environmental discontinuities, are unlearning old behaviors, and learning new ones (Hedberg, 1981). In this kind of view, the process of innovation is to create, manipulate and adapt their changing environments with sustainable competence. And thus, "to learn, unlearn, and relearn is the organizational walk" (Hedberg, 1981) —the ability that leads to innovation.

Learning as a continuous genesis, and a creating and recreating process is to cumulate, maintain, and restructure knowledge (Hedberg, 1981). Generally, two levels of learning are discussed: one is the low-level learning (Hedberg, 1981; Fiol & Lyles, 1985), or to say single-loop learning by Aryris (1976), which is the repetitive behavior based on the routine (Fiol & Lyles, 1985). This level of learning is to accumulate and maintain knowledge. The other is the high-level learning (Fiol & Lyles, 1985), or to say "metalevel" learning by Hedberg (1981), the double-loop by Aryris (1976), which is a more cognitive process (Foil & Lyles, 1985) to change and create something (Hedberg, 1981). This level of learning is somewhat to restructure and create knowledge. Both of the two levels are on-going in the process of organizational learning.

In addition, Hedberg (1981) argued that to understand and adapt the environment involves both learning new knowledge and discarding obsolete and misleading knowledge. Unlearning is the discarding activity, which is also a part of adding new knowledge, because unlearning makes way for the new knowledge and responses, and relearning is also ongoing. Therefore, the knowledge

in the organization is in the creating, discarding, recreating process by organizational learning, unlearning and relearning. But unlearning is difficult, which is considered as the crucial weakness of many organizations. It is the inclination to avoid relearning new knowledge and discarding the obsolete but to stick on it, that is the main obstacle to innovation (Christensen, 2002).

Fiol & Lyles (1985) proposed that "learning is the development of insights, knowledge, and associations between past actions, the effectiveness of these actions, and future actions". Levitt and March (1988) also discussed the organizational learning as routine-based, history-dependent, and target-oriented by encoding inferences from history into routines that guide behavior. They proposed that the paucity of experience problems of learning could be ameliorated by augmenting direct experience through the diffusion of routines.

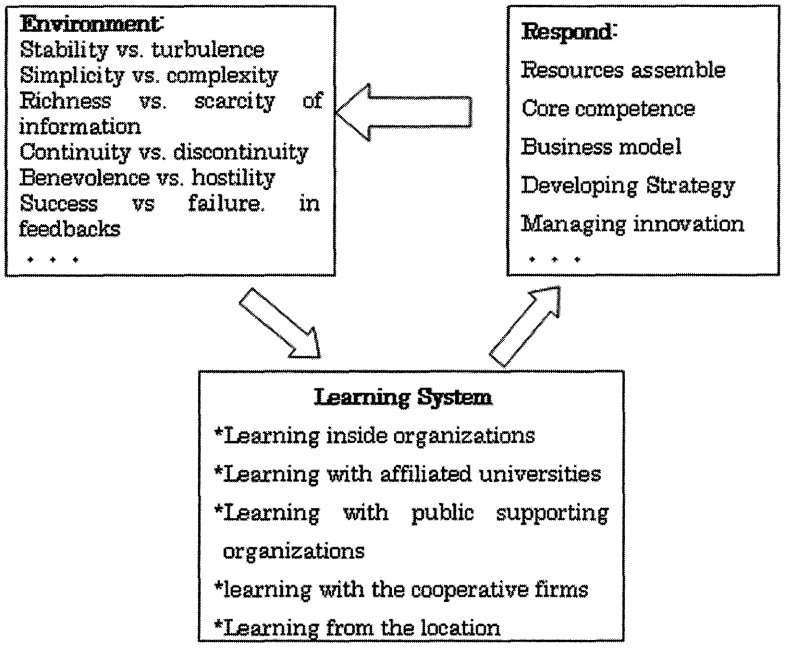
However, as far as the learning of technology-based start-ups, instead of learning from the past, they learn from the present action and augment their routines from the extemal environment and heterogeneous co-operators. In the case of university spin-offs, they learn from both of the insiders and outsiders, the homogenous and heterogeneous organizations. Thus the learning system of university spin-offs includes learning with cooperative firms, the affiliated university (a specific researcher or institution), the public supporting organizations, and the environment they choose and endeavor to adapt.

As well as too much stability, too much turbulence in an environment can frustrate organizational learning (Hedberg, 1981). But organization can choose and effect their environment in a certain extent. University spin-offs as new comers, which are considered in a turbulent market environment, can choose a "warning house"—a specific cluster or near their affiliated university. In different environment, like stability vs. turbulence, simplicity vs. complexity, richness vs. scarcity of information, continuity vs. discontinuity, benevolence vs. hostility, success vs. failure in feedbacks (Hedberg, 1981), organizations receive different stimuli and threats. Different from the stimulus-response model that organizations will not react to learn and respond until receive the stimuli, instead, learning in the university spin-offs born with high risk and threat is the spontaneous behavior and necessary tool to survival. So university spin-offs have to learn actively inside and outside to develop their potential technology, to assemble resources, to foster their core competence, to design and test business model and strategy, so that they can correspond to their unstable and changing environment (Figure 7).

5. Conclusion

This paper studied the process of innovation of university spin-offs in a national innovation system. The development of university spin-offs, which have been encouraged by many countries, can reflect the innovation

Fig. 7 The process of learning and innovation of university spin-offs



system of a nation in a whole. On the other hand, in the view of national innovation system, university spin-offs can possibly have a high performance by the support of public, academic and private organizations as a system. Innovation is a knowledge accumulated and learning process. The process of innovation by university spin-offs is the one that they learn, relearn and unlearn interacting with their affiliated universities, industry, and public supporting organizations in the specific chosen environment. During this process, they develop their potential technology, assemble resources, foster their core competence, design and test business model and strategy. Therefore, perhaps it is the open interactive learning system that leads the university spin-offs to the road to radical innovation, contrasted with the established corporations as closed system in some extent.

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