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Japanese Retro-Modern Engines of Innovation

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This paper highlights the important role played by central research institutes, also known as "corporate R&D," in acquiring external knowledge and expanding the scope of the application of research outputs in Japanese electronics companies. To illustrate this, the paper uses six mini cases as examples to prove that Japanese retro-modern engines of innovation continue to work and contribute to business growth.

While R&D in the U. S. can be categorized as market-oriented, that in Japan is organization-oriented. Further, this paper discusses the pros and cons of the open innovation model. It can be stated that the advantage of the market-oriented open innovation model is that it enables a search of various technologies, but it falls short in terms of its ability to integrate them. On the other hand, the organization-oriented model is advantageous because it enables the integration of various technologies, but it is deficient with respect to the promotion of conducting research to search various technologies.

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1. Introduction

When the reputable publication, *Engines of Innovation: U. S. Industrial Research at the End of an Era*, edited by R. S. Rosenbloom and W. J. Spencer (1996), was translated into Japanese, it was given a more straightforward title which, if retranslated into English, would resemble the following: *The Era of the Central Research Institute Is Ending: The Future of Research and Development*. The book's messages may be more clearly reflected in the Japanese title than in the original English one. The book implies that "engines of innovation" will no longer be the central research institutes, particularly in the industrial sectors. This might

be true in the U. S., and perhaps in Europe, but how about in Japan? Is there any evidence that some Japanese companies have been maintaining and renovating old central research institutes into retro-modern engines of innovation?

In the rest of this section and the next, we will review many of the preceding studies, which collectively contain a wide variety of discussions. The primary perspective that we will try to stress is as follows. Today, every single company has the opportunity to "buy a technology" from the market, which is open to the world[1]. However, in terms of the R&D process, Japan and the U. S. seem to be in clear contrast: the U. S. is market-oriented while Japan is organization-oriented. Thus, this paper determines the degree of difference between the experiences of the two countries in combating the challenges of technology development in recent decades by exploring various studies.

The complicated nature of contemporary technological development has required the acquisition of diverse technical knowledge. Indeed, the development of high technology products demands knowledge acquisition. Apt examples can be found among electronics products: leading-edge rechargeable battery technology requires knowledge of the ingredients of the lithium cathode and the material of the carbon anode, knowledge of the chemical reactions that occur at the electrodes of a charged battery, and knowledge of cathode/anode production and processing with regard to miniaturization and thinning processes. However, the management styles used for diverse technologies vary from country to country. Further, as mentioned above, recently, companies have had to introduce an increasing amount of technology into their products. In this section of the paper, we briefly introduce the differences between Japan and the U. S. in terms of technology management, and next, open innovation, which companies need in order to adapt to the current business environment.

Granstrand et al. (1992) investigated the differences between the most prominent technology management issues among Japanese companies, U. S. companies, and others. The finding is that Japanese companies tend to focus on the development of diverse technologies within their organizations, while American companies tend to focus on the acquisition of external knowledge.

It can be said that Japanese companies are organization-oriented and tend to develop diverse technologies at their own expense. However, with regard to R&D in Japan, academic research systems such as university laboratories are undeveloped and inadequate. Although Japanese companies are confronting the problems associated with this unfavourable research system, thus far, they have yielded high technology products effectively. Therefore, it can be conclusively

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[1] Examples of the companies that "sell technology" to the open market are Fraunhofer, a German company (http://www.fraunhofer.de/EN/index.jsp), and NineSigma, a Japanese firm (http://www.ninesigma.co.jp/english/innseekers/index.html). They are essentially promoting "R&D as a shared service."

stated that although there are fewer research outputs at the basic research level in Japan, these outputs are effectively employed for product development through the applied research phase.

In the U. S., the situation is completely different. Academic research is highly productive, and many universities and venture companies produce multifarious research outputs such as academic papers. Nonetheless, much of the research and forefront technology remain unused. While the U. S. is far ahead of Japan in terms of researching forefront technologies, American companies are lagging behind in terms of product development. This is why, in contrast to the situation in Japan, many research outputs in the U. S. do not lead to or contribute toward product development.

In order to survive in the current business environment, which necessitates the acquisition of diverse technical knowledge, specifically in the so-called hi-tech industries that include the electronics industry, it seems that American companies seek the open innovation of the market function, whereas Japanese companies seek the closed innovation that can ideally treat all of the diverse technologies at their central research institutes. In this context, "central research institutes" refer to corporate level entities rather than those at the divisional level. More detailed definitions will be discussed later. However, Japanese companies do not conduct research to develop all of their various technologies by themselves, as is the case in a closed innovation model. While the Japanese research system as a whole can still be regarded as unfavourable, Japanese companies seek to utilize external forefront technologies. Although it may appear as though both American and Japanese companies utilize an open innovation approach, the dissimilarity between their intentions is substantial. Thus, we can state that both of these nations aspire for open innovation, which is based on an organization-oriented model in Japan and a market-oriented model in the U. S. In this paper, we define open innovation as the utilization of external unused technologies, the enlargement of their application, and the combination of various technologies (Chesbrough, 2003).

2. Analytical framework

2. 1 Theoretical background

There has been a great deal of discussion concerning the following notion: Japanese companies consider organizational capacity as an important matter, whereas American companies regard transactions as important. Some research suggests that these differences between the two countries are due to the differences between their cultures (e.g., Abegglen, 1958; Pascale and Athos, 1981), and many researchers have been discussing these different management styles over a long period of time.

Since the 1950s, comparative analyses have been conducted on Japanese and American management systems (e.g., Abegglen, 1958; Kagono et al. 1985). In particular, Jacoby (2005) presented one of the most interesting studies and

discovered the fact that Japanese companies tend to function on the basis of an organization-oriented model and American companies on the basis of a market-oriented model[2]. Japanese high-performance companies have powerful headquarters, which implies that the headquarters have the authority to make decisions regarding the management of personnel (Kono, 1999). Miyamoto (2007) pointed out that personnel management such as the rotation of engineers plays the important role of knowledge management in Japanese manufacturers' R&D organizations. On the other side of the Pacific Ocean, Hounshell (1996) asserted that after the 1980s, American R&D companies began to develop technologies from a market-oriented approach, which implies selling and buying technologies in the intermediate market. It can be considered that the conclusive notion of these analyses is that Japanese companies seek organization-oriented models, especially with regard to personnel management, while companies in the U. S. seek market-oriented models (Jacoby, 2005).

This dichotomy can also be applied to various management systems such as the supply chain system of the automobile industry. Cusumano and Takeishi (1991) asserted that Japanese automobile companies have long term relations with a relatively smaller number of suppliers, evaluate these alliances on the basis of long term trust, and involve these parties in product development. On the other hand, American companies tend to sign contracts with a relatively larger number of suppliers and evaluate them on the basis of short term transactions. Thus, Japanese automobile companies seek suppliers with whom they can form partnerships, like colleagues of the organizations, while American automobile companies tend to seek market-oriented relationships.

Aoki (2001) pinpointed the reason for this dichotomy by employing evolutionary game theory and asserting that the differences between Japanese and American economic institutions are the result of their historically accumulated assets, transaction rules, and systems such as governance and coordination. Japanese companies socially accommodate these economic institutions that adopt an organization-oriented philosophy.

The difference between Japanese and American companies with regard to their intentions in the adoption of organization-oriented or market-oriented approaches affects their R&D activities. According to Ulrich (1995), products are divided into two technology typologies based on the products' architecture from the viewpoint of the standard interface of their components; one is a modular product that represents interface-standardization technology, and the other is an integral product on which interface technologies have yet to be standardized. Fujimoto (1993) asserted that Japanese companies are superior in terms of integrating various

[2] Note that although Jacoby's primary concern might be human resource management rather than R&D, his comprehensive insight on Japan's administration methods should be applicable to various aspects of management.

complex technologies, and this strength in integration yields architectural innovation. On the other hand, American companies are superior at developing modular technology products.

In recent times, both Japanese and American companies have faced a challenging business environment that demands forefront and diverse technical knowledge. For example, the development of the mobile phone necessitates high-technology such as software, communications equipment, and liquid crystal. While American companies excel at researching high-quality modular technologies, they experience difficulty in determining how to integrate many modules during the product development stage. Conversely, while Japanese companies excel at integrating diverse technical knowledge during the development stage, they experience difficulty in determining how to enhance forefront technologies.

Thus, companies in the U. S. have tried to utilize external technologies as a means of open innovation in intermediate markets (Chesbrough, 2003). This fact is theoretically based on the interface-standardization approach (Baldwin and Clark, 1997). Interface-standardization enables many players to easily combine many modules from the intermediate market. Although American companies are still inefficient at integration, by utilizing the market function, they can adapt to the prevailing business environment, in which the acquisition of diverse technical knowledge is essential. However, the issue examined in this paper is how Japanese companies have adapted to the recent changes in the business environment. This paper discusses open innovation from the perspective of Japanese companies' execution using organization-oriented functions and not market-oriented functions (Table 1).

The discussion of this section can be summarized as the following two notions: (1) there is a difference between Japanese and American companies in terms of the intention of their R&D, because their capabilities vary and (2) as a vehicle of survival in today's environment, we are focusing on open innovation based on intention and capability, especially in Japanese companies. This paper's research question concerns the second notion: Why do Japanese companies, particularly in the electronics industry, still have central research institutes in the current

Table 1. Difference between R&D Activities in Japan and the U. S.

	Japan	The U. S.
Intention	Organization-oriented	Market-oriented
Capability	Integral development	Modular development
Method adopted to cope with recent changes in the business environment	Research question of this paper	Open innovation, standard interface, and their combination

environment?

2. 2 Methodology

First, we review the definitions of R&D as proposed by the Organisation for Economic Co-operation and Development (OECD) and the National Science Foundation (NSF). The OECD defines three types of R&D: basic research, applied research, and experimental development. Basic research is defined as the experimental or theoretical work that is undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without considering any particular application or use. Applied research is defined as the original investigation that is undertaken in order to acquire new knowledge; however, it is directed primarily toward a specific, practical aim or objective. Experimental development is systematic work that draws on existing knowledge gained from the research and/or practical experience that is directed to produce new materials, products, or devices; to install new processes, systems, and services; or to substantially improve existing goods or installed systems.

The NSF has a slightly different definition of the three types of R&D: basic research, applied research, and development. Basic research aims at acquiring comprehensive knowledge or an understanding of the subject being studied, rather than a practical application of it. As it is applied in the industrial sector, basic research is defined as research that advances scientific knowledge but does not have specific commercial objectives, though such an investigation may be conducted in the fields that are of present or potential interest to the company. Applied research is directed toward gaining knowledge or an understanding of the concepts that are necessary for determining the means by which a recognized and specific need may be met. In the industry, applied research includes investigations directed toward the discovery of new knowledge, keeping in mind specific commercial objectives with respect to products, processes, or services. Development refers to the systematic utilization of the knowledge or understanding gained from research toward the production of useful materials, devices, systems, or methods, including the design and development of prototypes and processes.

Now, this paper defines the three stages of R&D as follows. Basic research institutes are in charge of academic research, and their main output is in the form of papers published in academic journals. Applied research institutes are in charge of adapting basic and academic research studies to industrial technology, which is concerned with the development of the applied areas of basic and academic research, development of the specifications of technology, and the development of components and devices. The product development departments of each enterprise unit are in charge of industrial design, preparation of production, and so on.

To investigate the concrete state of recent Japanese technological developments, based on a case study method (Yin, 1994), we conduct an analysis of the development of advanced Japanese technologies, which are considered to possess high integration capabilities but are confronted with the problem of how to

obtain diverse technological knowledge. Essentially, Japanese electronics companies are the subject of the research in this paper, because the development of technologies in the electronics industry necessitates the acquisition of diverse knowledge from most industries. Further, this study focuses on the Japanese open innovation approach.

Prior to the analysis, we conducted a pilot research project covering all of the major Japanese electronics companies (N = 9). Among them, five companies have basic research institutes, and all companies have applied research institutes. Further, basic research institutes and applied research institutes, which are controlled by the headquarters (e.g., "corporate R&D"), are independent from the product development department of the enterprise unit and can concentrate on their own R&D activities. Thus, in Japan, basic and applied research institutes are called "central research institutes."

Now, we can summarize that in Japan, all the major electronics companies have central research (basic or applied research) institutes whose headquarters control them separately from their enterprise units. However, not all companies have basic research institutes. This paper analyzes two specific companies: "A co.," which has both basic and applied research institutes, and "B co.," which has only applied research institutes. Note that our definition of central research institutes includes both basic and applied research institutes.

We have two reasons for selecting these two companies. First, many of the other electronics companies are not as diversified as these two are. One of the other major companies is highly acclaimed as a worldwide audio visual brand, but does not manufacture home appliances. Likewise, another one has a prestigious display device and various types of applications for home use, but does not have any product for an industry section. However, the two companies examined in this paper are general, highly diversified electronics companies. Both A co. and B co. deal with various technologies such as home appliances, display devices, mobile phones, and industrial machinery. Thus, our view is that in order to analyze various R&D activities, these two companies are the most appropriate ones among them.

Second, the central research institutes of these two companies are relatively smaller than those of the other major companies. Inevitably, these two companies have to and tend to utilize external knowledge and technologies as open innovation. Thus, to focus on open innovation, these two companies are more appropriate than the others.

With regard to these companies, we conducted field research, especially focusing on the role and function of their central research institutes and how they have coped with the recent changes in the business environment, which demands forefront and diverse technical knowledge. We interviewed the R&D chief of A co. and the R&D director of B co. to learn about the functioning of their central research institutes.

3. Analysis

As mentioned above, A co. and B co. were selected because the scope and scale of their R&D organizations were most appropriate. Yet, in certain aspects, the research institutions of the two companies demonstrate a clear contrast. The following paragraphs exemplify the facts[3].

Case 1: In A co., while the basic research institute researches issues related to physics, such as the arcs of a gas circuit breaker (GCB), the applied research institute conducts research on designing an application for a consumer product called a "gas clean heater." The application then becomes the final product in the engineering department of the product division.

Case 2: Unlike in A co., in B co., the applied research institute conducts some basic research as well. An example of basic technology is an electrolytic conduction that was originally developed for rechargeable batteries. The applied research institute developed a completely different application of air and water purifying technology as a derivative of that basic technology. The manufacturing division developed it as a new application for washing machines.

Case 3: Another example of the research conducted at B co. pertains to some technologies related to the base stations of mobile phone systems. One of the applied research institutes and a product division closely collaborated to develop the system and finally achieved a profitable business venture. Moreover, the same applied research institute is attempting to lead the industry to deploy next generation mobile phone systems as well as wireless communication systems.

Thus, in Japan, even a manufacturer that cannot afford to maintain a basic research institute utilizes an applied research institute to conduct some portion of its basic research. This is primarily because the basic research conducted at universities and venture companies in Japan may not be sufficiently diversified or intense. In practical terms, even if a Japanese consumer electronics manufacturer does not have a basic research institute, it possesses the basic research function in practice at its applied research institute.

As shown in Case 1, regarding a GCB, central research institutes develop new applications of forefront technologies. In addition to developing new applications, central research institutes have the important task of acquiring external knowledge (e.g., university laboratories) and in the process, adding product value from basic research to product development. Here, we present the following examples.

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[3] Some of the cases here were already stated in Miyamoto and Maegawa (2008).

Case 4: A university developed a turbine; however, the turbine failed to qualify as an industrial product because of its cost, size, and the loud noise that it produced. The university faculty was inclined to believe that there would be no problem regarding industrial quality simply because a development was well-done to write a paper. However, to employ an application as a product, critical factors including but not limited to cost and size should comply with manufacturing standards. Therefore, the turbine remained unused and idle in the basic research phase. However, the central research institutes in A co. developed this turbine technology into industrial products.

Case 5: After completing a wind tunnel experiment that was essential to verify a theory, scientists at a university would not revise it because a "task" concerning industrial use would not contribute to enhancing the value of their paper. Nonetheless, there would be no industrial value without the completion of that task. Again, it is the central research institutes in A co. that developed this wind tunnel technology into industrial products.

Case 6: This case is based on a statement made by one of the managers at the applied research institute in B co. Unlike other managers of R&D organizations, this manager is more committed to creating a new business than to developing a technology by himself or by the team that he is supervising. He visited a start-up company outside of Japan. After a discussion and demonstration of image processing, he concluded that the company's technology was more advanced than what his team was developing. Furthermore, the technology of the start-up appeared ready for mass production at anytime. These facts influenced the manager's decision about how to proceed:

> *I would go for the start-up's candidate simply because it is better than ours. But obviously, one of the engineers who reports to me regarding this technology would be disappointed. In the worst case scenario, he would probably resign from the company that we work for. Even if that is the case, I would still not change my decision, again, simply because the start-up's solution would be more beneficial to our company.*

The outcome of his decision has not yet been revealed. His statement certainly illustrates how the applied research institute in B co. contributes to promote production for tomorrow rather than for the next generation.

As mentioned above, central research institutes have the important task of absorbing external knowledge (e.g., university laboratories) and in the process, enhancing the industrial quality from basic research to product development.

4. Discussion

The basic research function enables companies to access and evaluate various external research outputs such as academic papers (Rosenberg, 1990). The central research institutes in Japan also have the function of accessing this external

knowledge and integrating these phases of knowledge to enable their use in the industry.

The course of actions described in section 3 can be summarized as a knowledge transfer process that may provide a clear reasoning. The phases in this process should be search and transfer (Hansen, 1999). Transfer is solidly bound to integration, which is related to the organization-oriented process. Further, search is closely linked to the market-oriented process. This way, the Japanese R&D methodology can be summarized as an organization-oriented approach that is closely associated with integration as a knowledge transfer process.

Therefore, in central research institutes, research outputs are absorbed and their scope is enlarged through an adequate knowledge transfer process. In central research institutes, research outputs are accessed and evaluated, these forefront technologies are developed, and their scope is enlarged to enable industrial use. In terms of the knowledge transfer process, central research institutes have the important function of searching unused forefront technologies and integrating them with a variety of technical knowledge.

Moreover, through this process, central research institutes enhance the industrial quality of various technologies. As previously mentioned, the basic research of university faculties tends to focus on the quality of an academic paper. Therefore, central research institutes should enhance the different type of quality of these papers so that these technologies can be manufactured. Due to the work of central research institutes, industrial quality is easily improved at the product development stage.

Central research institutes search for forefront technologies and evaluate and integrate their own companies' technologies with them. Through this process, some forefront technologies researched at universities are developed as marketable products or they are employed to invent some new business applications. This is why research and development are effectively integrated in Japan. Indeed, in Japan, the research system for developing forefront technologies is inadequate; however, the research outputs effectively lead to development. Thus, Japanese companies possess high performance manufacturing quality (Clark and Fujimoto, 1991). The cutting edge R&D products described above, such as the arcs of a GCB, air and water purifying technology derived from electrolytic conduction, mobile phone systems or wireless communication systems, and a turbine system, boast high-quality manufacturing systems that yield high value.

Therefore, organization-oriented open innovation means that Japanese companies absorb various external technologies either from academia (universities) or from business (other companies), enlarge their applications, and develop them for industrial use through central research institutes. Conversely, market-oriented open innovation means that American companies do this by utilizing the intermediate market. Compared to the market-oriented open innovation system in the U. S., the open innovation system in Japan may be

relatively less efficient at searching external technologies. Organization-oriented research offers a narrower scope than what is available in the market because (1) internal research is prioritized above external research (this is not a written rule, but the actual thinking is in line with this), (2) searching the technology market either in academia or business is not done companywide but is left to the central research institute, (3) a technology with room for improvement and with the potential of more value added in-house is preferable to one that can be mass produced as it is. This way, it can be said that the scope of the Japanese organization-oriented open innovation approach is limited and narrower than the American market-oriented approach. Yet, Japanese open innovation based on organization is relatively more efficient at integrating R&D than what is accomplished in the market.

The typology of technologies is an important matter for these two models. As highly complicated technology is difficult to transfer (Hansen, 1999), organization-oriented open innovation is effective for complicated technologies. On the other hand, interface-standardization technology is easy to integrate (Baldwin and Clark, 1997); thus, market-oriented open innovation is effective for this technology. For example, the transaction of medicine patents in the intermediate market is effective (Hippel, 1988) because it is easy to integrate as an interface-standardization technology (Hara, 2003). Therefore, more companies should search many medical technologies and combine them in the intermediate market by trial and error, similar to the American open innovation approach. This way, it could be said that even the American approach to open innovation is not borderless neither. An easy-to-transfer technology such as one with a standard interface should be selected and studied. Further, since many candidates should be investigated concerning whether they can be mass produced virtually as they are, there will be a certain amount of trial and error.

5. Conclusions and implications

This paper's research question was why do Japanese companies, particularly in the electronics industry, still have central research institutes in the current environment? Now, the answer to this question should be clear: central research institutes undertake the important task of searching and integrating forefront technologies in terms of the knowledge transfer process. Moreover, organization-oriented Japanese companies seek openness through central research institutes.

The market-oriented R&D in the U. S. can be summarized as committing to "search" or "explore" technology in the market while, in terms of technology "transfer," being limited to technologies with a standard interface. The organization-oriented R&D in Japan is the opposite: it is committed to technology "transfer" while, in terms of "searching" or "exploring" technology in the market, it is left to a business-academia partnership, government owned consortium, or a private network of engineers. As mentioned in the previous section, both sides of open innovation have challenges. Japan's domain covers only what is within the

reach of the engineers' network, but a smooth transition from research to development can be expected. The U. S.' domain may have more breadth and depth in terms of technology selection, but a standardized interface and a certain amount of trial and error is required.

One of the most important statements that this paper makes is that having a central research institute should not be directly associated with closed innovation or the NIH (not invented here) syndrome (Katz and Allen, 1982). Central research institutes in Japan have been flexible enough to modify and open themselves up to adapt to the competitive environment.

As implied in the introduction of this paper, Hounshell (1996) pointed out that decades ago, when heavy electronics, heavy chemical, and aerospace led the industries, central research institutes made significant financial contributions. However, due to some unfortunate cases in the late twentieth century, like those of IBM, Lucent, and PARC of Xerox, which are collectively cited in Chesbrough (2003), American companies have lost the incentive to maintain a central research institute and vertical integration, specifically in the computer, software, and IT industries, which are the symbolic industries of American recovery in the current century. Thus, particularly in the U. S., central research institutes have been losing the function of engines of innovation inside profit organizations. Managers who pursue immediate financial gain prefer purchasing technology from the open market.

At the same time, Japanese companies have accumulated integrative capability based on their organization-oriented approach. They have never jumped into the new concept of a market-oriented approach; rather, they seek to improve their integrative capability and adopt open innovations based on an integrative capability that suits their economic institutions. The central research institutes, which conduct basic and applied research, play an important role in facilitating various processes, particularly the knowledge transfer process. This discussion is consistent with Aoki (2001), which states that "differences between Japanese and U. S. economic institutions were a result of their historically accumulated assets, transaction rules, and systems such as governance and coordination."

As a complement to the Chesbrough (2006) model, we refer to another model of open innovation. Chesbrough (2006) refers to open innovation based on the function of intermediate markets as market-oriented open innovation. However, we have revealed another model of open innovation based on the function of organizations called organization-oriented open innovation (Figure 1). In terms of the knowledge transfer process, market-oriented open innovation, which is promoted by Chesbrough, considers the searching process of external technologies as important, while the organization-oriented open innovation approach considers the integration process as important. Moreover, suggesting which model of open innovation should be adopted should depend on the historically accumulated capability of institutions and the typology of technology.

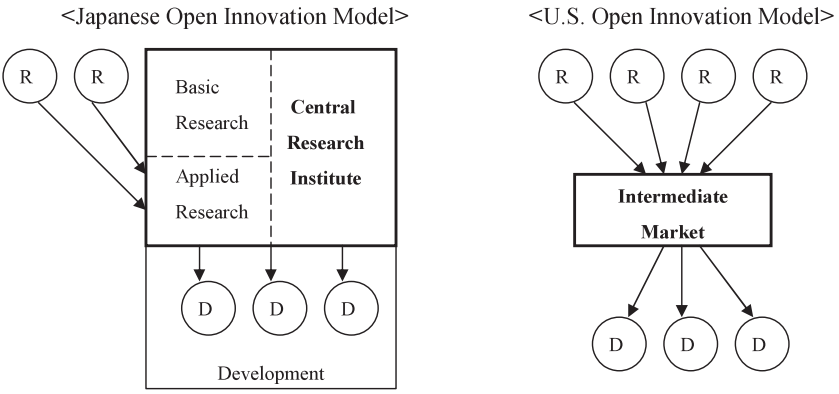

Figure 1. Japanese and U. S. Open Innovation Models

Until the 1980s, it could be said that central research institutes in Japan were old fashioned and afflicted with the NIH syndrome. However, throughout the slow, sagging 1990s, referred to as the "lost decade" in Japan, central research institutes redefined themselves to gain adaptability to environmental change. Even if maintaining a central research institute and conducting research in-house may seem antiquated or outdated, today, it certainly contributes to the promotion of open innovation. The essential issue is that electronics companies in Japan, which are organization oriented, modify central research institutes to fit today's business environment and manage them flexibly. Certainly, Japanese retro-modern engines of innovation still work and contribute to business growth.

The last concern of this paper is that the following potential problems might remain. Indeed, Japanese companies have been yielding high-quality products, but manufacturing high-quality products does not always lead to a competitive performance. According to Nobeoka (2006), Japanese companies are good at accessing and integrating diverse technical knowledge, as the term "value creation" suggests, but they are not as good at gaining profits in the "value capture" phase. As the model of this paper sheds light on the process from research into development, we were not able to cover activities such as sales, the operation of factories, and investment decision-making, which as the total process, lead to value capture. Therefore, with our current model, we are unable to discuss the profitability of the companies. The purpose of this paper is to reveal the model of open innovation based on the organization-oriented approach.

Therefore, although we introduce a different model from that of Chesbrough, we do not reveal how to manage central research institutes in adequate depth. With regard to this point, Miyamoto et al. (2008) points out the importance of the rotation of engineers.

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