Transaction Costs and Capabilities as Determinants of the R&D Boundaries of the Firm: A Case Study of the Ten Largest Pharmaceutical Firms in Japan

Hiroyuki Odagiri

Director of Research, National Institute of Science and Technology Policy

and Professor, Hitotsubashi University

September 2001

Correspondence Address:

National Institute of Science and Technology Policy (NISTEP)

Ministry of Education, Culture, Sports, Science and Technology

1-3-2 Kasumigaseki, Chiyoda-ku, Tokyo 100-0013, Japan

Tel: +81-3-3581-2396 Fax: +81-3-3500-5240

e-mail: odagiri@nistep.go.jp

JEL Classification Code: L22, L65, O31

Keywords:

Firm Boundaries, Pharmaceutical R&D, Research Alliance, Joint Research, Transaction Costs, Capabilities

The author wishes to acknowledge with thanks the able research assistance of Tadahisa Koga. He also wishes to thank a number of people in companies, universities, and public laboratories who provided valuable information through interviews. The remaining errors are of course all mine. Any opinion expressed in this paper is the author's alone and does not represent any of the institutions the author is affiliated with.

Abstract

The boundaries of the firm are an important issue in relation not just with the make-or-buy decision in production but also with research and development (R&D). Firms depend on universities to gain scientific knowledge, outsource some of their R&D works, purchase patented technologies, commission research, and participate in consortia. In this paper, we take the case of the ten major pharmaceutical companies in Japan and show that they employ various types of research alliances with various partners, domestic or foreign. Two major theories to explain the boundaries, the transaction-cost theory and the capability theory, are discussed and we argue that the observed pattern of research alliance is more consistent with the capability theory. Discussion is also made on the consortia and national projects these firms participate.

1. Introduction

The issue of the boundaries of the firm has been discussed most commonly in relation to make-or-buy decisions in the vertical chain of production. How much the supply of materials and parts is (and should be) integrated has been studied by a number of researchers, most often with the automobile industry and electric/electronic equipment industry.[1] The extent of transaction costs, particularly when relations-specific investment is needed, has been considered a major determinant of the boundaries of the firm (Williamson, 1975). Incomplete contracting has been also argued to be a major determinant of vertical integration (Hart, 1995).

Boundaries of the firm are an important issue in relation not just with production but also with research and development (R&D). In fact, no firm can complete the whole process of R&D by themselves. Every firm depends on universities, public laboratories, and other public institutions for the supply of basic scientific knowledge because such knowledge provides an indispensable basis on which the firm can develop commercially viable products. In addition, many firms outsource some of their R&D works, for instance, data collection, animal experiments, supply of order-made research tools, patent application, and product design. Many also form alliances with other firms to commission a certain part of R&D or to carry out joint R&D. They may also join research consortia that involve a number of firms and, probably, public institutions.

For firms in any industry but particularly in such high-technology industries as pharmaceuticals, chemicals, electronics, communication, automobile, and software, it is of the utmost importance to decide how much of the R&D they should make within themselves and how much they should outsource and collaborate with other firms. This decision must depend on a number of factors that define transaction costs and property rights on the one hand and, on the other, technological and organizational capabilities of the firm and its partners.

The advance of science and technology almost always change these factors. In the computer industry, IBM used to make all the computer-related R&D within the firm except only for the very basic academic research and, in the communication industry,

[1] In particular, the difference in this regard between Japanese firms and American or British firms has been documented by a number of authors: Asanuma (1989), Nishiguchi (1994), Odagiri (1992), and Sako (1992).

AT&T used to make all the communication-related R&D within the firm and its Bell Labs which were known for its high-level scientific research that produced a number of Nobel laureates. However, the introduction of new technologies, such as microprocessors, internet, and cellular phones, shifted the ownership of proprietary knowledge to independent firms, such as Intel. Furthermore, changing market and regulatory conditions made entry by non-integrated producers easier, reducing transaction costs of procuring from the market and changing the relative bargaining power between firms. The result was a more widespread use of market transactions in both products and technology.

Currently, the most profound change is taking place in the field of biotechnology. Here, the distance between academic research which is supposedly made by universities and development which is supposedly made by private firms has substantially narrowed, because outcomes from academic research, for instance, the invention of DNA-recombinant technology by Cohen and Boyer of Stanford and UCSF, respectively, became more commercially applicable. More recently, the development of research on genomic sciences and genetic engineering has been providing new techniques with which pharmaceutical firms can develop new drugs. The impact of this so-called biotechnology revolution on the R&D boundaries of the firm is most evident in the pharmaceutical industry.

This paper aims to discuss this issue of the R&D boundaries of the firm, taking the case of the pharmaceutical industry in Japan. In Section 2, we will discuss two major theories that explain the determinants of the R&D boundaries of the firm – the transaction-cost theory and the capability theory. In Section 3, we will discuss various types of procured R&D, that is, the means with which the firm utilizes outside resources in its R&D process. In Section 4, the pattern of procured R&D of the ten major pharmaceutical firms will be documented and, in Section 5, the above-mentioned two theories will be applied to discuss which of them explains the actual pattern better. Section 6 will discuss the extent of procured R&D using the patent application data, while Section 7 will discuss consortia and national projects these firms participate. Finally, Section 8 will conclude the paper with a summary and the discussion on the agenda for future study.

2. In-house R&D versus Procured R&D: Two Theories

For any firm, the purpose of R&D activity is to invent new products and new production processes or improve existing products and processes. For this purpose, the firm may undertake R&D in-house by hiring researchers and purchasing necessarily equipment, tools, and research material. Alternatively, it may procure all or parts of R&D from outside. The form of such procured R&D is diverse from purchasing the property right of completed invention, in which case the firm's in-house R&D can be minimal, to the purchase of more or less routine services, say, the input of data onto a digital file.

2.1. The Need for Both In-house R&D and Procured R&D

In-house R&D and Procured R&D are not exclusive and, in fact, virtually all the firms undertake some part of R&D in-house and procure the rest. The reason is that no firm can complete the whole R&D process in-house, because every firm relies on scientific knowledge supplied by universities and public laboratories. In addition, every firm purchases some equipment, material, or services from outside. Some of them are standardized and ready-made, such as personal computers and flasks, in which case it is perhaps inappropriate to call it procured R&D because it is just the purchase of a normal commodity. However, almost all firms also procure specific and custom-made goods and services, for instance, custom-made research equipment, custom-made computer software, and specific experiment or data-analysis services.

Neither can a firm procure all the R&D from outside. One reason is that the firm cannot just buy a technology and make profits out of it: it has to introduce the purchased technology to the process of manufacturing and marketing and, without a certain amount of own R&D, it can never exploit the imported technology successfully. Put it differently, if the firm can introduce a certain technology without any R&D of its own, any firm should be able to do so and, therefore, no opportunity is there for making profits.

The other reason is that the firm has to have certain technological capabilities to be able to assess numerous candidate technologies to be purchased, understand and learn from the acquired technology, apply it to manufacturing, and, if possible, to combine it with the firm's own technologies to achieve synergies. This capability, usually called *absorptive capacity*, is essential in the firm's exploitation of outside technological

sources and own R&D is needed to foster it (Cohen and Levinthal, 1989)[2].

Every firm, therefore, undertakes some part of R&D in-house and procures some of it from outside. When should it make it in-house and when should it procure from outside? Three explanations are appropriate.

2.2. Economies of Scale and Scope

The first, rather a technical one, is scale and scope economies. It is economical to produce a certain product or service in a large volume or jointly with other products/services. The firm, however, may need it only in a limited quantity or without any other products/services. It is then less costly for the firm to purchase them from those who specialize in producing them to achieve economies of scale and scope, and sell them to multiple customers. Such economies may arise in an inter-temporal sense if sunk investment has to be made and continuous production is economical because, once investment is sunk, the marginal cost from an additional use of the capital is minimal. Yet, the firm may need the product/service only once in, say, a year. In consequence, a specialist firm who sells to many customers can raise the utilization rate to spread the investment cost and, thus, set a lower price for the product and sell it to those customers who need it only occasionally. The capital may be an intangible one because training cost is sunk; for instance, the firm who needs trained engineers and technicians only infrequently would prefer to procure the service from a specialized firm who can employ such engineers and technicians full-time and have them produce the services demanded by multiple customers[3].

Aside from this consideration of economies of scale and scope, two theories explain why the firm undertakes R&D in-house in one instance and procures it from outside in the other. They are the transaction-cost theory, reinforced by the incomplete contract theory, and the capability theory, an extension of the resource-based theory of the firm. These theories have been often used in relation to the make-or-buy decision in the

---

[2] For the argument that the development of absorptive capacity was a major force behind Japan's industrial development since the mid-eighteenth century to the post-war high-growth era, see Odagiri and Goto (1996).

[3] Alternatively, the firm may wish to hire these trained workers temporarily for the period it requires for the work. Such temporal hiring is possible only when the required skill is general, that is, non-specific, and the cost of recruiting and laying-off is negligibly small, which is rare in reality.

vertical chain of production but they are equally applicable to the make-or-buy decision in R&D. In fact, I believe that the capability theory is even more relevant in the latter decision for the reasons to be discussed presently.

2.3. The Transaction-Cost Theory

As is well known, the transaction-cost theory has been advocated most strongly by Williamson (1975, 1985). Complexity and uncertainly are a common feature of market transaction as well as uneven distribution of information, which creates an advantage to one of the parties involved in the transaction. This party is then tempted to use this advantage in an opportunistic way. Rationality is bounded; hence, even though such an opportunistic behavior may result in a negative long-run consequence, this consequence cannot be fully predicted and is often ignored.

The cost of using market transaction arising from these aspects of imperfectness is the transaction cost in general and makes the use of internal transaction, through the mechanism of hierarchy and authority, less costly. On the other hand, the incentive mechanism that market competition is expected to provide may be lost in internal transaction. In addition, influence costs that arise when the players endeavor to influence others to gain a favorable internal bargaining position may be serious, and so is the agency cost that arises when the players pursue their own goals more than the goal of the organization, such as the firm they work for.

The issue of incentive is complicated because any contract is necessarily incomplete under the presence of uncertainty and the imperfectness of information. The ownership of property right has an important consequence on the provision of incentives because the owner can claim the residuals that have not been specified in the contract (Grossman and Hart, 1986; Hart, 1995). For instance, in a transaction between an upper-stream research unit (RU) and a customer of the research outcome (C), RU had better retain a property right for the research outcome because, then, it has an incentive to make efforts and maximize the probability of invention. On the other hand, if only C has the financial resource that is needed for the R&D, then, the property right should be held by C so that it has a sufficient incentive to invest in the R&D (Aghion and Tirole, 1994).

An appropriate organizational design, therefore, has to balance transaction costs with the provision of incentives. The firm is more likely to integrate the kind of R&D

activity where transaction costs are expected to be large, whereas it is more likely to procure where incentive is expected to be enhanced with market competition.

2.4. The Capability Theory

The capability theory starts from the fact that firms differ in their capability. The intellectual debt of this theory is to Schumpeter (1942) and Penrose (1959). It was Penrose who stressed the importance of viewing the firm as a collection of physical and human resources. This view became to be known as a resource-based view of the firm. Penrose, however, also stressed that these resources have to be accumulated for the firm to achieve growth. To her, the growth of the firm was the growth of its resources, both tangible and intangible, which enhances the capability of the firm. In this regard, she had much in common with Schumpeter who argued that innovation for new products, new technologies, new sources of supply, and new organizational forms is the source of competitive advantage and whose thought on innovation gave a deep impact on the evolutionary theory of the firm (Nelson and Winter, 1982). That is, resources are valuable only when they constitute capabilities which have to be enhanced through innovation and learning for the firm to grow. Similar views have been expressed by Chandler (1990) who used the word 'organizational capability' to emphasize the organizational aspect and Teece, et al. (1997) who used the word 'dynamic capability' to emphasize the dynamic nature. Also, Prahalad and Hamel (1990) used the concept of 'core competence' to discuss how and in what direction the firm should apply and extend its capability[4].

Firms have different capabilities and it takes time for them to create and enhance capabilities because experience, learning, investment, and innovation are needed. This fact implies that the firm may be able to fulfill a certain task cheaper and faster if it procures it from an outside firm who possesses more of the necessary capability than it conducts it within itself. In R&D, the firm often acquires scientific knowledge from an academic sector, procures certain services from specialist firms, and forms an alliance with another firm(s) who has different capability. The capability theory explains this behavior. Transaction costs may arise in the use of outside resources; yet,

[4] Odagiri and Goto (1996) used the word 'technological capabilities' to focus on the technological development of Japanese firms.

the advantage of utilizing the higher capabilities they possess may outweigh the transaction costs.

It should be also noted that, even if procuring the service from outside may be more efficient in the short run, it need not be so in the long run. The reason is that capability cannot be maintained and enhanced unless it is used. Complete reliance on outside suppliers may make the firm's own capability obsolete or may deprive the firm of a chance to create capability of its own. Furthermore, without maintaining a certain level of capability, the firm may lose an absorptive capacity discussed earlier and the capacity needed to monitor the activity of the suppliers and partners. It may also find its bargaining position weakening. Therefore, even if it is cheaper for the firm to outsource a certain work, it may find it rational to conduct it within itself. That is, a tradeoff may be there between a short-run efficiency that can be attained by procuring from outside the works for which the firm has a relatively low capability, and a long-run efficiency that requires nurturing or, at least, maintenance of a certain capability[5].

Economies of scale and scope, transaction costs, and capabilities are the three major determinants of the boundary of the firm, that is, of the boundary separating in-house R&D and procured R&D. In the next section, we will describe the process of R&D, taking the case of pharmaceutical research, and discuss various types of procured R&D.

3. Types of Procured R&D

We have been using the word 'procured R&D' to refer to any activity in the process of R&D that the firm uses to exploit external resources. However, the forms of procured R&D are diverse and it is useful to classify them. In the following, we take the case of pharmaceutical research.

3.1. The Process of Pharmaceutical R&D

Pharmaceutical research consists, basically, of three stages – discovery, pre-clinical tests, and clinical tests. Discovery is a process to find a drug candidate, usually a

[5] A good example is found in the case of firms that have transferred manufacturing facility to developing countries to exploit cheaper labor costs there. More and more of them are now finding it necessary to maintain at least one manufacturing plant within the home country, in order to find out any problems associated with manufacturing, to make protocols, and to experiment with new ideas for improving efficiency.

chemical compound, that is expected to be effective for a target disease. Scientific knowledge, biological and chemical in particular, is broadly applied and, with the progress of genomic science, more and more of such knowledge has started to be employed. In the pre-clinical stage, the safety and effectiveness of the candidate drug is tested with animals and the adequate dose level is investigated. Then, the firm conducts clinical tests to human bodies and, if successful, files for regulatory approval to, in Japan, the Ministry of Health, Labor, and Welfare.

In any of these three stages of pharmaceutical R&D, external resources are employed often and in various ways. In distinguishing the types of such procured R&D, the most important issues are how much the work to be procured can be 'defined' and 'specified' and, relatedly, how much of the outcome can be 'predicted'. We call the former the *definability* of work and the latter the *predictability* of outcome. They depend, most importantly, on the timing of contracting and the complexity of the work to be procured. Simply speaking, the earlier the contract is made relatively to the work to be done or the more complex the work, the less definable and the less predictable it is.

3.2. Outsourcing

The type of contract in which complexity is low and therefore the work can be relatively easily defined is *outsourcing*, which is a procurement of routinized service. Examples of frequently outsourced works are animal tests, data input, statistical analyses, and the preparation of application forms for regulatory approval. A large part of clinical tests are now often outsourced as well. In these cases, the outsourcer and the outsourcee agree on the specific details of the work to be outsourced, which will be written in the contract. The outsourcee conducts the stipulated work and all the output from the work is handed over to the outsourcer.

3.3. Technology Acquisition

Definability is also high with market transaction of a technology, which is a technology purchase or *technology acquisition* from the buyer's side and a technology sale or technology licensing from the seller's side. The technology to be traded has been already invented and patented before the contract; hence the object of the contract

can be clearly defined[6]. In a typical case, the invented technology is a complete one and the buyer can simply put it in its own manufacturing and marketing processes. There are also cases where the technology is yet incomplete and some R&D effort is needed on the buyer's side. In the pharmaceutical industry, this type of technology acquisition, which we call *acquisition for development*, is actually more common than the first type, to be called *acquisition for marketing*, in which virtually no R&D input is needed after the acquisition, as we will show later. There are two reasons.

The first, which is very much in accordance with the capability theory, is that the capability needed for discovery differs from the capability needed for clinical tests. Discovery is more research than development; hence, scientific knowledge and expertise are needed. By contrast, clinical tests are more development than research; hence, a capability to design and coordinate the tests to be conducted in a number of hospitals and to analyze the collected data is needed. As a result, discovery is often conducted by specialist research firms, some of which are spin-outs from universities, while clinical tests, as well as marketing, can be more easily done by established drug companies with the help of specialist contract research organizations (CROs).

The second reason is a geographical one; that is, clinical tests have to be conducted and application has to be made for regulatory approval in each country. Even though international harmonization of regulatory procedures has been fostered, there still remains (and is expected to remain in a foreseeable future) a need for local clinical tests. Thus, for example, the patent for a drug invented by an American firm may be licensed to a Japanese firm who makes a clinical test, applies in Japan, and then markets the drug there.

For these reasons, acquisition for development is more common in the pharmaceutical industry than acquisition for marketing, namely, a mere purchase of technology for manufacturing and marketing. Since the basic technology has been already invented, definability in the contract is high and the predictability of its commercial value is also high. This tendency is particularly strong with an acquisition for marketing whereas, in an acquisition for development, clinical tests may reveal that

[6] There may be also cases where the technology cannot be patented but still some form of appropriability has been established by the inventor. Technical knowhows are a good example.

the drug cannot be marketed because of unexpected side effects or insufficient effectiveness. Yet, even with an acquisition for development, the tendency is certainly stronger in comparison to commissioned research or joint research to be discussed below.

3.4. Commissioned Research and Joint Research

Definability and predictability are low in the cases of procured R&D where the contract has to be made before the main part of R&D process is started. These cases may be separated between *commissioned research* and *joint research*. In the former, research is mostly carried out by the commissioned party (say, Y), a pre-determined amount of the expenditure (possibly with a provision for re-negotiation) is paid by the commissioning party (say, X), and the property right for research outcomes belongs to X. Although in some cases X may dispatch one or two researchers to Y to learn from Y or to collaborate with Y's researchers, such dispatch is neither required nor in a significant scale (unlike the case of joint R&D to be discussed soon). In principle, Y supervises its own research activity and conducts it by itself within its own laboratory. The research theme may be determined by Y, to which X agrees, or is determined by agreement of the two parties.

Joint research, on the other hand, is conducted by the researchers of multiple organizations which may include firms, universities, and public laboratories. In principle, the research theme is determined by mutual consent, the expenditures are shared, researchers from all the participating organizations collaborate, and the property right to research outcomes is jointly held, although variation to this rule is found in several joint R&D projects. Most importantly, in a *national project* in which the government is the major source of fund, member firms may not financially contribute even if they dispatch their researchers to the project.

In either commissioned research or joint research, the partner may be another firm(s) and/or university(s) (or national laboratory(s)). In a commissioned research, the partner is likely single. In joint research, the partner may be single or multiple. In the case of the so-called *consortium*, the number of participants is large, say, more than ten. The typical example is the SNP Consortium (TSC) composed of Wellcome Trust and 11 American and European companies which are mostly pharmaceutical but also include IBM and Motorola. Another, similar one is the Pharma SNP Consortium

(PSC) composed of 43 pharmaceutical and chemical companies in Japan (including Japanese subsidiaries of American or European firms). In either of these cases, funding is made by the private sector (including a private foundation in the case of TSC) but actual research will be conducted at universities and the research outcome is to be put in the public domain.

Joint research is considered to be an efficient means of combining complementary capabilities of the participants. In addition, duplication of research among firms is expected to be avoided and yet the sharing of knowledge is fostered. However, transaction costs may be substantial because the activity of each participant cannot be fully monitored. As a consequence, each participant is tempted to free-ride on the contribution of other members. This free-rider problem, a typical example of opportunistic behavior, can be particularly serious in consortia and national projects where the number of participants is large and, therefore, each assumes that the performance of the consortium as a whole is insensitive to its individual behavior. In TSC and PSC, the free-rider problem does not arise because member firms only contribute in funding, which is easily monitored, whereas the research is carried out by universities. In national projects, on the other hand, a participating firm usually dispatches its researchers to the project's main laboratory or conducts a part of research allocated to the firm by itself. The firm may therefore be tempted to dispatch less capable researchers or make the allocated research half-heartedly. [7]

3.5. Summary and Reservations

The various types of procured R&D are summarized in Table 1. Three remarks are in order. First, the lines between different forms may be blurry. For instance, the use of an outside specialist to conduct a certain part of R&D will be regarded as outsourcing if the work is relatively small and clearly defined, for example, an animal test made in accordance with the outsourcer's clearly specified program, but will be regarded as commissioned research if the work is more comprehensive and the outsourcee has more say on the work to be done. The line between them can be thus unclear.

[7] The author has once studied the case of the Fifth-Generation Computer Project of Japan and examined how the project leaders tried to minimize the free-rider problem. See Odagiri, Nakamura, and Shibuya (1997).

Recently, many companies started using the services of the firms specialized in the provision of data, particularly genomic data, such as Celera Genomics and Incyte Genomics of the US. In a sense it is just a purchase of data, like the purchase of a weather forecast service. Yet, if the data to be supplied is tailored to the need of the user, then perhaps it should be considered an outsourcing or a commissioned research from the user's viewpoint. Furthermore, in some cases, the supplier retains the right to receive a royalty out of the sales of the drug that the user invents using the data supplied by these firms. Such cases have an element of joint research.

Second, the list is not exhaustive. For instance, mergers and acquisitions may be used as a means of procuring R&D because the technology of the acquired firm is also acquired with the M&A. M&A will not be emphasized in the following, mostly because the occurrence of M&A is infrequent in the Japanese pharmaceutical industry. Also, joint ventures may be established by two or more firms to pursue a certain R&D project. Such a case will be included in the category of joint research.

A more subtle form of procured R&D is the acquisition of technological knowledge through an informal network of researchers or by the advice of university professors. Spillovers through such channels are in fact an important source of technology acquisition for many firms; nevertheless, we will not discuss it in the following because we are more interested in the types of procured R&D that are made as market transactions.

Third, the extent of the definability of work, the extent of predictability of outcome, and the usual ownership of outcome shown in the table are for what we consider to be the typical cases and there may be exceptions. For instance, the work to be done in a joint research project may be clearly defined as in the case of the SNP consortia (TSC and PSC) where the work to be done, the analysis of SNPs, is basically definable. On the other hand, an outsourced work may produce an unexpected outcome; for instance, an animal test of a certain drug may indicate that it is ineffectual at all to the assumed disease or that it is effectual to an unexpected disease. Therefore, the discussion of definability and predictability in the table should be taken only as applicable to the majority, but not all, of cases.

As discussed earlier, the capability theory suggests that, in most cases, procuring the kind of R&D work for which the firm lacks sufficient capability is more efficient in the short run than making it in-house. Yet, if the firm is expected to need the capability

repeatedly in the future, it had better make it in-house to nurture the capability. The transaction-cost theory, on the other hand, suggests that, where transaction costs are expected to be large as in the case where the work to be contracted cannot be easily defined, the monitoring is difficult, and uncertainty is high, the use of market transaction is costly and in-house R&D is more likely economical.

Commissioned R&D and joint R&D are often made despite probable high transaction costs because, if the complementary capabilities of the participants are effectively combined, the benefit can outweigh the cost. The transaction cost of outsourcing, by contrast, is probably small. Hence, easily definable works had better be outsourced to take advantage of the capability of the outsourcee; yet, it is often desirable for the firm to conduct the work in-house to maintain a minimum level of capability which can be used to increase its bargaining power and to monitor the outsourcee's work.

With these views in mind, let us now investigate what is occurring in major Japanese pharmaceutical companies.

4. The Case of the Ten Largest Pharmaceutical Companies in Japan

4.1. Overview of the Ten Firms

Table 2 lists ten firms whose sales of pharmaceutical products in 1997 were the largest in Japan[8]. They are Takeda Chemical Industries (hereafter Takeda), Sankyo, Yamanouchi Pharmaceutical (Yamanouchi), Eisai, Daiichi Pharmaceutical (Daiichi), Fujisawa Pharmaceutical (Fujisawa), Shionogi, Tanabe Seiyaku (Tanabe), Chugai Pharmaceutical (Chugai), and Kyowa Hakko Kogyo (Kyowa). The pharmaceutical sales of these firms account for more than 80 percent of total sales except Takeda (74%) and Kyowa (40%).

Even the largest firm, Takeda, is small if compared internationally. The pharmaceutical sales of the world's largest company in 1999, Merck, was 17,482 million dollars which was more than threefold the pharmaceutical sales of Takeda, 5,129

[8] Actually, the sixth largest firm, Taisho Pharmaceutical, was eliminated from the list because its main products were over-the-counter (OTC) drugs whereas the main products of the others were ethical drugs. In its place, we included Kyowa who ranked eleventh in pharmaceutical sales and has a long tradition of biotechnological research because its technological root was fermentation.

million dollars (converted to dollars with $1=102 Yen, the average rate in 1999). Even though Takeda spent 11 percent of total sales and 16 percent of pharmaceutical sales on R&D, the amount is again internationally small since Merck spent 2,068 million dollars or 12 percent of pharmaceutical sales on R&D.

Takeda is also the winner in terms of pharmaceutical sales growth with an 11 percent annual growth between 1997 and 1999. By contrast, six of the ten firms experienced a decline of pharmaceutical sales. It should be noted, however, that this decline does not necessarily imply a decline in volume because the average list price of drugs, to be used by Japan's National Health Insurance scheme to reimburse drug expenses, was lowered by nearly ten percent in 1998.

Among the ten, the ratio of R&D expenditures to total sales was highest at 23 percent in Chugai and Shionogi and the lowest at 8 percent in Kyowa, although, since Kyowa's non-pharmaceutical sales (e.g., alcoholic drinks, food, and chemical products) outweighs pharmaceutical sales, the percentage is higher at 20% if divided by the pharmaceutical sales. The simple average among the ten firms is 16 percent, which is highest among manufacturing industries like in any other country. The average in the entire manufacturing industry was 3.7 percent in 1999[9].

Table 2 also shows the ratios of the number of patents and the number of new drugs to R&D expenditures. They are, admittedly, a poor measure of R&D productivity particularly because the timing is reverse (i.e., patents and invention should come after R&D expenditures). Yet, no correlation is found between them and the total or pharmaceutical sales, suggesting the lack of R&D-scale correlation that has been predicted by the so-called Schumpeterian hypothesis.

4.2. Increase in Research Alliances, 1989-1999

We will now investigate how often and in what way research alliances have been made by these ten firms. Among the several forms of procured R&D as shown in Table 1, outsourcing will not be discussed further, mainly because most of the outsourcing activities are not reported and, hence, no data can be found for the number of outsourcing cases or the amount spent on outsourcing. Exceptions are the contracts

[9] Somucho (Ministry of Public Management), *Survey on Research and Development, 2000* (http://www.stat.go.jp/data/kagaku/2000np/zuhyou/a110.xls).

made to get an access to genomic databases with such companies as Celera and Incyte, which may be considered a type of outsourcing or a type of commissioned research, as discussed in the previous section. These will be mentioned in the next subsection. With outsourcing excluded, let us hereafter call the various types of procured R&D under the name of *research alliances*, including technology acquisition, commissioned research, and joint research.

Table 3 shows that the number of these alliances increased by threefold during the ten-year period of 1989-1999. The basic source of data is a report titled *Bio Firms of the World* (in Japanese; BFW hereafter) published by Nikkei BP Co., an affiliate of Nihon Keizai Shimbun. BFW was published almost (but not always) bi-annually up to 1999 without any plan for a next issue at the time of my writing (i.e., September 2001). It lists all the activities of biotechnology-related firms that had been reported in the press, supplemented by those obtained through questionnaires. The accuracy and extent of the coverage of BFW may be questioned. Still I believe it to be sufficiently reliable, because all the alliances that the research managers mentioned when I interviewed several of the ten companies were included in BFW.

The alliances here include technology sales (i.e., opposite of technology acquisitions) and joint presentations at academic conferences besides technology acquisitions, commissioned research, and joint research. Although I gather that most of the presentations jointly made by, say, a company researcher and a professor are the results of joint research between the company and the university, there may be other cases; for instance, the presentation may be based on the research that the company researcher had made as a graduate student before he was employed by the company. Therefore, the alliances here may extend somewhat to the outside of those listed in Table 1[10].

Table 3 clearly shows that all the firms increased the number of R&D alliances during the 1990s. Eisai, who had just two alliances in 1989, increased by more than eightfold to 17 followed by Takeda and Chugai who increased by fourfold. Alliances increased with both domestic partners and foreign partners. The proportion between firms and universities (including public laboratories) was basically unchanged among domestic partners. The ratio of foreign new biotechnology firms (NBFs) was also

[10] For more detail on the data source, see Odagiri (2001).

rather stable, with about 40 percent, the highest among the five categories in the table. That is, both in 1989 and 1999, foreign NBFs were the most frequent alliance partners for Japanese pharmaceutical companies.

There was no case of alliance with overseas universities in 1989 but there were 17 cases in 1999. University-industry collaboration had always been active in the Japanese industry, particularly the pharmaceutical industry, although, because of miscellaneous regulations to national university researchers, such collaboration was often made in an informal and, sometimes, obscure manner (Odagiri, 1999). Therefore, I suspect that the actual number of alliances with domestic universities by these ten firms may have been much higher than these numbers imply. They may have been made with formal joint research agreements (*kyodo kenkyu*) or research commission agreements (*itaku kenkyu*). In addition, quite a few of them must have been made as donations (*shougaku kifukin*) most of which are not publicized and hence are not listed in BFW.

By contrast, collaboration with foreign universities appears to be a recent phenomenon. This fact is also consistent with the fact that most Japanese firms started to establish overseas laboratories only in the latter half of the 1980s (Odagiri and Yasuda, 1996, 1997). Through these laboratories, they could perhaps gain easier access to university professors to seek joint research. Alternatively, in a reverse causality, they may have been able to recruit talented foreign researchers to their new overseas laboratories as a consequence of joint research. Yet, even in 1999, the number of alliances with foreign universities, 13, fell far behind that with domestic firms, 49. Nevertheless, more and more Japanese firms are regarding foreign universities as suitable and indispensable research partners and, in fact, as we will see in the next subsection, there may be more instances of alliances with foreign universities than those (at least, formal ones) with domestic universities if we look at the most recent couple of years only.

The bottom row of the table shows the ratio of the number of alliances to R&D expenditures, which suggests that Kyowa was most active in alliances relatively to its size. Kyowa started in 1948 as a joint laboratory of three sake-making companies and thus had a long tradition of research in fermentation which is at the heart of the so-called 'old biotechnology'. It has been, therefore, active in maintaining relations with universities and other companies to maintain, apply, and expand this technological

capability.

4.3. Distribution of Recent Research Alliances

As mentioned earlier, BFW (*Bio Firms of the World*) has not been published since 1999. Yet, with the advance of genomic sciences, the two years since then have been the most interesting years. After the age of 'old biotechnology' just mentioned above and the age of 'new biotechnology' that Professors Cohen and Boyer started with their invention of recombinant DNA technique, the age of genome and post-genome seems to have started during this period. To re-direct their research towards this new field or, to be more precise, to add such research to their research portfolio, many firms have increased alliances and sought new partners.

To investigate the new development, I looked at the reports in *Nihon Keizai Shimbun* (NKS) from January 1999 to August 2001, and classified the relevant news by the type of alliances and the type of partners as in Table 4[11]. Unfortunately, the accuracy of the table is limited. For one thing, NKS may not have reported all the relevant news. For the other, it was often difficult to decide whether the reported case should be included in the table and to decide in what category of alliance it should be classified. I have basically classified according to the description of each category in Section 3; however, some of the cases were more or less at the border and hence the classification may not be free from my own subjective impression from the news report.

Outsourcing has been seldom reported and hence is not included in the table. An exception to this rule is the purchase of database access and, in one case, the purchase of DNA chips, if these should be considered a form of outsourcing. In the table, these cases are put under the category, 'database, etc'. Also excluded are research consortia and national projects, on which we will discuss in some detail later in Section 7.

There were 103 cases of R&D alliances during the period[12]. By company, Takeda

---

[11] *Nihon Keizai Shimbun* is a major economic journal of the country. One may consider it a Japanese counterpart to the *Financial Times* or *Wall Street Journal* but, in my view, NKS has more industrial news than FT or WSJ which are more biased toward financial news. For a comparison, see Odagiri (1992). Some of the alliance cases have been also taken from NKS's sister publication, *Nikkei Sangyo Shimbun*, but the number of such cases was rather small because not many cases were reported in the latter newspaper alone.

[12] It is misleading to compare this number with that in Table 3 because the coverage, I

and Sankyo, the largest two, had the largest numbers of cases and Shionogi, the fewest. Shionogi, in fact, had no case of alliance with domestic partners, making four alliances with foreign firms only. In all, there were 45 cases with domestic partners and 60 cases with foreign firms.

43 of the 103 cases were technology acquisition (for marketing or development); 34, joint research; and 16, commissioned research. In addition, there were 10 cases of 'database, etc'. All except one of them are with foreign partners. Most are with American genomics database firms, including Celera, Incyte, and HGS (Human Genome Sciences). Clearly, no Japanese firms possess comparable capability and, even if transaction costs are higher when dealing with foreign firms, the Japanese pharmaceutical firms had no choice but to utilize the American sources[13].

This choice of American partners to gain access to their databases was made for the reason consistent with the capability theory. Since this case was exceptional in that Japanese firms hardly had any other choice, a more systematic enquiry has to be made to assess the relative merit of the two theories, the transaction-cost theory and the capability theory. This enquiry will be made in the next section.

5. Transaction-Cost Explanation versus the Capability Explanation

5.1. The Transaction-Cost Explanation as Discussed by Pisano and Mang

Pisano and Mang (1993) inquired into 78 cases of contractual arrangements between new biotechnology firms and established pharmaceutical companies in the US during 1978-1990. They separated them to two categories, 'research agreements' and 'development agreements'. "We define a 'research' agreement as a relationship initiated before the product entered human clinical testing and a 'development' agreement as one initiated after the product has already begun human clinical trials" (*ibid*, p. 128). Commissioned research and joint research under our terminology are apparently research agreements whereas acquisitions for marketing are clearly development

---

estimate, is smaller, perhaps in a significant degree, in Table 4.

[13] The only one case of Japanese partner occurred between Yamanouchi and Hitachi in which Yamanouchi utilizes the data analysis service of Hitachi. It differs from other cases in that there is also an element of joint research between the two because Hitachi's work will be made in consultation with Yamanouchi.

agreements. The ambiguous case is acquisitions for development. If the technology was acquired from a foreign established pharmaceutical firm, it is likely that the foreign firm has started human clinical tests in its home country whereas, if it was acquired from a domestic non-pharmaceutical firm, this firm may not have started a human clinical test when the technology was transferred to its purchaser.

Pisano and Mang found that the proportion of development agreements has increased and, in 1988-1990, was exactly a half of all the agreements. In Table 4, if we exclude 'database, etc.', the proportion of acquisitions for both marketing and development is 46 percent (43 out of 93), which is close to the 50 percent found for the US, 1988-1990.

Another finding by these authors was the higher proportion of development agreements among the agreements with foreign firms in 1985-1990. This fact, they argue, is consistent with the transaction-cost theory for two reasons. The first is the higher transaction cost of research agreements because of "the difficulties in coordinating collaborations, particularly in the early stages of R&D." The second is that this higher transaction cost may be particularly damaging to non-American firms because "European and Asian pharmaceutical firms … may be at a relative disadvantage compared to their American counterparts when engaging in research agreements with American biotechnology firms, where contractual incompleteness requires extensive use of joint decision-making and on-going negotiations" (ibid, p. 129).

5.2. The Case of the Ten Japanese Firms

Our finding for the ten Japanese pharmaceutical firms not only fails to support this argument but actually contradicts it. See Table 5 which shows the distribution across types of partners for each category of alliance. The number of the cases of technology acquisitions, both for marketing and for development, is about the same between those with domestic partners and those with foreign firms. If this fact can be interpreted as implying that the pharmaceutical companies are indifferent in the choice between domestic and foreign partners, then, according to the Pisano-Mang story, they should prefer domestic partners to foreign partners when they need to commission research or make a joint research, because these activities, presumably, entail higher transaction costs and these costs are particularly higher when the partners are foreigners. For

instance, monitoring has to be made in the course of commissioned or joint research but the geographical distance and the language difficulty between the partners make this monitoring costly.

In fact, however, Table 5 reveals that the number of commissioned research is higher with foreign partners whereas the number of joint research is the same whether the partner is domestic or foreign. Therefore, the transaction-cost considerations appear unimportant in the choice of domestic versus foreign partners. This fact can be confirmed by Probit estimation results which will be discussed next.

5.3. The Probit Estimation Results

See Table 6. In Equation (1), the probability that the partner is foreign is explained by the dummy variables indicating the types of research alliance and company dummies. That the coefficient for 'acquisition for development' is negative indicates that the probability of the partner being foreign is lower for acquisitions for development in comparison to those for marketing, of which the dummy variable was omitted. Given that acquisitions for development would generally involve more transaction costs than acquisitions for marketing because the technology acquired for development must be still incomplete and subject to high uncertainty than that acquired for marketing, the result is consistent with the transaction-cost theory. The coefficient, however, is not at all significant. With similar seasoning, that the coefficient for 'commissioned research' is positive contradicts the transaction-cost theory whereas that the one for 'joint research' is negative is consistent with it. However, the coefficient for 'joint research' in its absolute value is smaller than that for 'acquisition for development', and this fact is inconsistent with the transaction-cost theory, because joint research must involve much more monitoring and other transaction costs than acquisitions for development. At any rate, none of these coefficients is statistically significant, suggesting that the transaction-cost theory lacks an explanatory power.

The results for company dummies indicate that Fujisawa has a higher inclination to choose a foreign partner in making a research alliance in comparison to Takeda, whose dummy is suppressed[14]. This result is not surprising because, among the 12 alliance

[14] The dummy for Shionogi is also omitted because Shionogi's four cases of alliance were all with foreign partners and, hence, were eliminated from the sample.

cases of Fujisawa's, only two are with domestic partners (see Table 4).

This Probit estimation is made on the presumption that the firm has a choice between a domestic partner and a foreign partner when it wishes to make a certain type of alliance. This presumption is perhaps unrealistic because, in view of the capability theory, a particular technology which the firm might wish to acquire through alliance must be held by a particular firm, domestic or foreign, alone. More reasonable choice, actually, might be on the timing of making the alliance, namely, whether the firm should acquire the technology at a finished stage just for marketing (or development), or get an access to the technology at a still infant stage by means of commissioned research or joint research. With this possibility in mind, we made a second Probit estimation in which the probability of an alliance being made as an acquisition (for marketing or for development) is dependent on the type of partners and company dummies. The result is shown as Equation (2) in Table 6.

The coefficient for 'foreign universities and public laboratories' is negative and significant, which implies that when the partner is either a foreign university or a foreign public laboratory, the alliance is more likely made as a commissioned or joint research in comparison to those alliances where the partners are domestic firms (including NBFs). In addition, all the alliances in which the partners are domestic universities or domestic public laboratories were made in the form of joint research (see Table 5) [15]. That is, when the firm makes an alliance with a university or a public laboratory, be it domestic of foreign, it will make it in the form of joint research (or, less frequently, commissioned research). This result is inconsistent with the transaction-cost theory but is consistent with the capability theory because these institutions possess competence in understanding basic science and making research in a more basic-oriented area. Since pharmaceutical companies, by comparison, possess competence in applying the technology towards clinical tests and commercialization, joint research between them is expected to enable their complementary capabilities to be combined and lead to a fruitful commercialization of basic technology.

The negative coefficient of 'foreign firms (including NBFs)' implies that the firm is less likely to choose a technology acquisition and more likely to choose commissioned or joint research when making an alliance with a foreign firm than when it makes one

[15] Because of this fact, these alliances (7 cases in all) were eliminated from the sample.

with a domestic firm. This fact, again, is inconsistent with the transaction-cost theory. The coefficient is insignificant, however.

5.4. Summary and Additional Remark

In summary, our findings disagree with Pisano and Mang who, among research contracts made with foreign partners, found a higher proportion of those initiated after the products have already begun human clinical tests. There is no such tendency at all among the research alliances made by the ten Japanese pharmaceutical firms. In fact, the tendency, though not statistically significant, seems opposite to that of these two authors. Consequently, we conclude that the transaction-cost theory cannot explain the observed distribution of research alliances.

On the other hand, the capability theory is consistent with this distribution. In particular, the frequent occurrence of joint research (or commissioned research) with universities and public laboratories, domestic or foreign, is interpreted as a result of firms' efforts to take advantages of the different capabilities that these universities and public laboratories are expected to possess. The same discussion has been made by many of the studies on university-industry collaboration: see Hall, Link, and Scott (2000) and the literature cited therein and, for the pharmaceutical industry in particular, Henderson, Orsenigo, and Pisano (1999).

It is also interesting to note that the Japanese pharmaceutical companies have been making as many alliances with domestic universities (and public laboratories) as with foreign universities. It has been often argued that the university-industry collaboration is weaker in Japan than in the U.S. In fact, however, such collaboration has been active in Japan in the past and at present, even though collaboration may have been on an informal basis in many cases (Odagiri, 1999). The evidence presented in this section supports this view.

6. Joint Application of Patents

We have also investigated the records of patent application of the ten firms made between January 1999 and July 2001. See Table 7. There were 62 cases of joint application[16]. The total number of applicants (besides the ten firms themselves) for

[16] Two additional remarks are in order. First, any application for patents in non-

these 62 applications was 92, indicating that many of the applications were made by three or more applicants together.

The table shows that joint application with foreign partner(s) account for less than ten percent, which is much smaller than the proportion of research alliances with foreign partners as shown in Table 5. There are several possible reasons. First, technology acquisitions may be just the licensing of already patented technologies and, hence, may not produce a new patent. Second, commissioned or joint research with foreign partners may produce research papers and foreign patents but not Japanese patents. Third, assuming that a lag of several years is common between the start of joint research and patent application, the difference may have occurred because joint research with foreign partners increased recently.

Most frequently, joint application was made with other domestic firms. They were mostly established firms in non-pharmaceutical industries, such as chemicals, cosmetics, food, and textiles. In only two cases did the same firm make joint applications with different firms among the ten: Ube Industries made a joint application with Sankyo and another with Tanabe, while Fuji Chemical made one with Yamanouchi and another with Chugai. I found no evidence indicating that Ube has had a lasting relationship with either Sankyo or Tanabe and neither did I find a similar evidence involving Fuji Chemical[17]. Therefore, joint patent applications appear to be the result of rather ad hoc joint efforts made for specific research projects.

The second most frequent was the joint application with university members (either as universities or as individual university professors). The names of the universities involved were also shown in the table. The members of the University of Tokyo made applications with four firms, which is not surprising in view of the size and quality of the university faculties. The university has not just a Medical School but also the Department of Pharmaceutical Sciences, the Institute of Medical Science, the Institute

---

pharmaceutical fields was omitted. Second, no case was found in which the application was made jointly by the two or more of these ten firms.

[17] Ube and Tanabe are members of the Sanwa Group, one of the six major business groups (i.e., the so-called horizontal keiretsu), which may explain the cooperative relationship between the two. However, Sankyo belongs to another group (DKB Group) and another pharmaceutical firm within the Sanwa Group, Fujisawa, has not made a joint application with Ube, suggesting that the common membership was not an important reason. See Odagiri (1992) for the discussion of business groups.

of Molecular and Cellular Biosciences, and others. Geographical proximity may be also important because each of Sankyo, Chugai, and Kyowa has its headquarters in Tokyo as well as one of its laboratories, whereas Takeda has the secondary headquarters in Tokyo[18]. The same can be said about Tsukuba because both Yamanouchi and Fujisawa have their laboratories in the so-called Tsukuba Science City Area. Tanabe has its headquarters and main laboratory in Osaka.

Even though the joint patent application data gives some useful information as discussed above, it need be taken with caution because joint research does not always lead to joint patent application. For instance, the research may produce only non-patentable information, such as basic scientific discovery or tacit knowhow. More importantly, the collaborating researchers may opt not to appear as joint applicants. Particularly in universities, professors are often said to relegate patent rights to companies in return for research grants from them. In view of this fact, it is desirable to inquire into the names of joint inventors than joint applicants. Unfortunately, however, the affiliation of inventors is not given in patent documents and, hence, it is extremely difficult to investigate the extent of joint invention.

7. Participation in Research Consortia and National Projects

Finally, let us investigate the extent that the ten firms participate in research consortia and national projects.

7.1. JPMA-Led Consortia

There are not many consortia of large scale that have been or are made with the initiative of the private sector alone. Exceptions are the two consortia organized with the initiative of the Japanese Pharmaceutical Manufacturers Association (JPMA)[19]. The first is the Pharma SNP Consortium (PSC) composed of 43 pharmaceutical and chemical companies which, as explained in Section 2, was formed following the example of the SNP Consortium (TSC) of the American and European firms. PSC is a three-year project to continue until March 2003 with the total budget of one billion yen

[18] Takeda's main headquarters is in Osaka.
[19] JPMA has 81 members including the Japanese subsidiaries of a number of American and European firms.

which is to be shared equally by the member companies[20]. The specific research themes of PSC are (1) location of single nucleotide polymorphism (SNP) in a pharmacokinetics-related gene, (2) frequency of SNP emergence in the general Japanese population, and (3) analysis of the expression and function of the mutation-type protein generated under the influence of SNP[21]. The research itself will be commissioned to Tokyo Women's Medical University and the SNP Research Center of Riken (the Institute of Physical and Chemical Research), a national research institute. A joint research project with Tokyo Institute of Technology is also planned. Basically, all the data to be gained from the project are to be put in the public domain.

The second is the Protein Structure Analysis Consortium (PSAC) composed of 22 pharmaceutical firms. Its aim is to build a special-purpose beamline within SPring-8, a third-generation synchrotron radiation facility, the largest of its kind in the world, that was constructed in Hyogo (in the western part of Japan) by two national research institutes, the Japan Atomic Energy Research Institute (JAERI) and Riken, jointly in 1991. The investment for this beamline is expected to reach a half billion yen to be shared by the member firms. After its expected completion in May 2002, the member firms plan to time-share the use of the beamline, with each firm pursuing its own project, such as structure-based drug design.

All the ten pharmaceutical firms in our sample are the major members of JPMA and participate in both PSC and PSAC. All of them also participate in Japan Bioindustry Association (JBA), an industrial association for 142 biotechnology-related companies (plus 103 companies as sub-members and 76 public members which include universities, public laboratories such as Riken, local governments, and even the embassies of the UK, Finland, Norway, and Sweden)[22].

7.2. METI-Based National Projects and Other Ministries

The ten firms also participate in the Japan Biological Informatics Consortium (JBIC) that consist of 75 corporate members, including informatics, electronics, and

[20] PSC actually received some fund from the government; however, it is just 40 million yen or 4 percent of the contribution of the member firms and is nearly negligible.
[21] http://www.psc.gr.jp/e02psc/index.html
[22] http://www.jpma.or.jp/12english/index.html

food-processing companies besides pharmaceuticals[23]. JBIC receives research grants from the government, mostly the Ministry of Economy, Trade and Industry (METI, formerly MITI, the Ministry of International Trade and Industry), for such projects as the 'preparation of bioinformatics-related intellectual bases,' 'development of SNPs-related technology,' and 'protein function analysis.' Research may be carried out within JBIC's laboratories, in which case most of the researchers are seconded from member firms, or may be commissioned to universities or public laboratories, such as Biological Information Research Center (BIRC), one of the laboratories founded by METI.

Biotechnology-related national projects are sponsored not only by METI but also by four other ministries, Ministry of Health, Labor and Welfare (MHLW), Ministry of Education, Culture, Sports, Science and Technology (MEXT), the Ministry of Agriculture, Forestry and Fisheries (MAFF), and the Ministry of Environment (MOE). Many firms and researchers I have interviewed argued strongly that this fragmentation of biotechnology policy is disadvantageous compared to the US where the National Institutes of Health (NIH) can plan and carry out a comprehensive and integrated policy to promote biotechnology and health-related sciences. In Japan, research budgets are allocated with only a limited coordination among the ministries, duplication of similar (if not exactly the same) research themes does occur, and each ministry requires different administrative procedures and different forms of papers to fill in.

7.3. MHLW-Based National Projects

Among the ministries, the one most closely related to the pharmaceutical industry is MHLW because it not only plans and executes health-related policies but also examines and approves drugs like Food and Drug Administration (FDA) of the US. MHLW has been basically a regulatory agency and, therefore, less active in industrial policy compared to METI. Still, it founded the Organization for Pharmaceutical Safety and Research (OPSR) whose original purpose was to support those patients who suffered from drugs' side effects. Since 1988, it also started helping industrial firms to set up research joint ventures (RJV) by providing 50 to 70 percent of the investment. The list of 15 such RJVs that have been started until now is given in Table 8. The circle in the table indicates that the firm was a member of the RJV. The ten firms have been

[23] http://www.jbic.or.jp/outline/english/index.html

involved in one to five of the RJVs per firm. In no case did all the ten firms participate in a single RJV together and in three cases none of the ten firms participated. The list also shows the names of participating firms other than the ten. Some of them are pharmaceutical firms but firms in other industries, such as chemicals, electronics, machinery, and steel, also participated. There are also cases where venture capitals (Jafco and Nikko Capital) joined.

Usually, for each RJV, one of the member firms acted as a leader, dispatching its senior researcher as the director of research. Most of the other researchers in the RJV's laboratories were also seconded by member firms and the research was conducted in a laboratory space set within the leader firm's laboratory or in a newly rented space. The performance of these RJVs is difficult to evaluate. One may say that at least some of them were successful because many patents have been applied. For instance, the DDS (for drug delivery system) Laboratory has applied for 63 patents. However, the commercial value of these patents are unknown and not all the RJVs has applied for a significant number of patents.

From a social viewpoint, the government investment to such an RJV can be justified only when the social benefit of the expected invention is high owing to widespread spillovers and yet, because of in-appropriability or uncertainly, private firms lack an incentive to invest in the R&D. With this view, the lack of patent application need not imply that the project was a failure, particularly if the RJV published its outputs in the form of papers. Yet, one company researcher who acted as an RJV's research director told me in an interview that MHLW often pressed the RJV to produce observable outcomes, such as patents. The paper work to comply with the ministry's formats and regulation was also heavy and this researcher in fact suggested that the company might have opted not to participate were it not proposed by MHLW who has a strong bargaining power over the pharmaceutical firms.

Therefore, it is ambiguous (and rather doubtful) that these national projects can be supported from a social viewpoint. The companies may have had an incentive to carry out the research by themselves and it might have been more efficient if they did so. Probably, the biotechnology projects supported by METI, such as those awarded to JBIC, were more justifiable because many of them focused on producing database that was considered necessary as infrastructure for industrial R&D. Research funds of MEXT mostly went to universities and public laboratories, Riken in particular, which

presumably conducted basic research. Some of them went to researchers on a competitive basis in the 'Grants-in-Aid' program, similarly to the NSF grants in the US. To the extent that they aim at promoting academic and basic research, they must be socially desirable, although complaint on the red tape is as common as in the OPSR RJVs cases.

8. Summary and Conclusion

This paper, it is hoped, has contributed in clarifying two issues. The first is the various forms of procured R&D, including outsourcing, technology acquisition, commissioned research, joint research, consortium, and national projects, that firms undertake. We took the case of the ten largest pharmaceutical firms in Japan and, using news report, the records of joint patent application, and various government sources, showed that these firms in fact carry out diverse R&D procurement activities. Certainly, there are inter-company differences, with some firms being more active than others and with some of them more inclined to form alliances with foreign partners. An inquiry into the causes and consequences of these inter-company differences will require more detail on the description of each alliance and its performance, which is one of our future research agenda.

The second is the relative explanatory power of the two factors that supposedly determine the extent, direction, and method of procured R&D. They are transaction costs and capabilities. The transaction-cost theory predicts that the firm will procure R&D if the transaction cost of using the market is smaller than the cost of using internal hierarchical organization in conducting the required R&D task. It also predicts that the firm will choose a partner with whom the necessary transaction cost is expected to be smallest. The capability theory predicts that the firm will procure R&D if the firm's own capability is inferior to that of a candidate partner or if its capability has been already fully utilized so that there is no room for starting a new R&D task. Also, if it should procure, it will choose as a partner the firm with the best capability available. Of course, this discussion is a gross simplification and the true implications of the two theories are more subtle. In addition, the two theories are not mutually exclusive and can be complementary.

If we can assume that commissioned or joint research requires more transaction costs than technology acquisition because the outcome is uncertain and more frequent

monitoring is needed, and that such transaction costs are particularly high when the partner is outside of the country, we can hypothesize that the firm would prefer domestic partners to foreign partners when it makes a commissioned or joint research in comparison to the case when it purchases technology that has been already invented, and that it would prefer technology acquisition to commissioned or joint research when the partner is foreign. The evidence from the ten firms does not support these hypotheses: in fact, the evidence, though insignificant, is rather contradictory. It is inferred therefore that the major determinant of the partner and of the mode of alliance is the distribution of various capabilities of the firms.

The interviews that this author conducted with a number of companies confirmed this conjecture. Any time I asked "why did you choose alliance over internal research?" and "why did you choose this particular firm as your partner?", the answer was almost always "because we lack the necessary capability", "they have more accumulated technologies and knowledge", or "they can do it more quickly than us"[24]. Apparently, the firms seek research alliances so that they can make the best use of the capabilities available outside of their own organizations.

However, under imperfect information and incomplete contracting, the free-rider problem can be serious. This problem is particularly serious when the participants are many, because monitoring is difficult and each participant assumes that the negative consequence of its not making a full contribution is small and hard to be detected. With this view, it is reasonable that a full-scale joint research effort is planned in neither of the two private-sponsored consortia, PSC and PSAC. In PSC, the firms contribute financially but the actual research work is to be done in universities and public laboratories. In PSAC, they collaborate only in the construction of a beamline while the research is to be done individually by allocating the usage time of the beamline across the member firms.

National projects are also joint research efforts involving a number of firms. In many of them, the outcomes have not been spectacular, to say the least. Partly the reason is that the projects are oriented more towards basic research. In addition, the

[24] Another frequent answer, particularly common in relation to outsourcing, was "because they have the equipment that is too expensive for my company alone to purchase and maintain", which suggests the presence of economies of scale.

free-rider problem may have occurred and administrative red tape aggravated the situation.

The present study is only a first step towards a better understanding of the R&D boundaries of the firm. What are the determinants of these boundaries? What is the optimal boundary for the firm? What can the government do to promote a better inter-company relationship? These are all relevant questions and more efforts are called for to investigate them.

References

Asanuma, Banri (1989) "Manufacturer-Supplier Relationships in Japan and the Concept of Relation-Specific Skills," *Journal of the Japanese and International Economies*, 3, 1-30.

Chandler, Alfred D., Jr. (1990) *Scale and Scope.* Cambridge, Mass.: Harvard University Press.

Cohen, Wesley M. and Levinthal, Daniel A. (1889), "Innovation and Learning: Two Faces of R&D," *Economic Journal*, 99, 569-96.

Grossman, Sanford and Hart, Oliver (1986) "The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration," *Journal of Political Economy*, 94, 691-719.

Hall, Bronwyn H.; Link, Albert N.; and Scott, John T. (2000) "Universities as Research Partners," NBER Working Paper, No. 7643, National Bureau of Economic Research.

Hart, Oliver (1995) *Firms, Contracts, and Financial Structure*. Oxford: Oxford University Press.

Henderson, Rebecca; Orsenigo, Luigi; and Pisano, Gary P. (1999) "The Pharmaceutical Industry and the Revolution in Molecular Biology: Interactions among Scientific, Institutional, and Organizational Change," in David C. Mowery and Richard R. Nelson [eds.] *Sources of Industrial Leadership*. Cambridge: Cambridge University Press, 267-311.

Nelson, Richard R. and Winter, Sidney G. (1982) *An Evolutionary Theory of Economic Change*. Cambridge, Mass.: Harvard University Press.

Nishiguchi, Toshihiro (1994) *Strategic Industrial Sourcing*. Oxford: Oxford University Press.

Odagiri, Hiroyuki (1992) *Growth through Competition, Competition through Growth: Strategic Management and the Economy in Japan*. Oxford: Oxford University Press.

Odagiri, Hiroyuki (1999) "University-Industry Collaborations in Japan: Facts and Interpretations," in Lewis M. Branscomb, Fumio Kodama, and Richard Florida [eds.] *Industrializing Knowledge: University Industry Linkages in Japan and the United States*. Cambridge. Mass: The MIT Press, 252-265.

Odagiri, Hiroyuki (2001) "Iyaku Kenkyu Kaihatsu ni Okeru 'Kigyo no Kyokai': Biotechnology no Impact" ['Boudaries of the Firm' in Pharmaceutical R&D: The Impact of Biotechnology], in Tsuruhiko Nambu [ed.] *Iyakuhin Sangyo Soshiki.* Tokyo: University of Tokyo Press.

Odagiri, Hiroyuki and Goto, Akira (1996) *Technology and Industrial Development in Japan: Building Capabilities by Learning, Innovation, and Public Policy*. Oxford: Oxford University Press.

Odagiri, Hiroyuki; Nakamura, Yoshiaki; and Shibuya, Minoru (1997) "Research Consortium as a Vehicle for Basic Research: The Case of a Fifth Generation Computer Project in Japan," *Research Policy*, 26, 191-207.

Odagiri, Hiroyuki and Yasuda, Hideto (1996) "The Determinants of Overseas R&D by Japanese Firms: An Empirical Study at the Industry and Company Levels," *Research Policy*, 25, 1059-1079.

Odagiri, Hiroyuki and Yasuda, Hideto (1997) "The Overseas R&D Activities of Japanese Firms," in Akira Goto and Hiroyuki Odagiri [eds.] *Innovation in Japan*. Oxford: Oxford University Press, 204-228.

Penrose, Edith T. (1959) *The Theory of the Growth of the Firm*. Oxford: Basil Blackwell.

Pisano, Gary P. and Mang, Paul Y. (1993) "Collaborative Product Development and the

Market for Know-how: Strategies and Structure in the Biotechnology Industry," *Research on Technological Innovation, Management and Policy*, 5, 109-136

Prahalad, C. K. and Hamel, Gary (1990) "The Core Competence of the Corporation," *Harvard Business Review*, May-June, 79-91.

Sako, Mari (1992) *Prices, Quality and Trust*. Cambridge: Cambridge University Press.

Schumpeter, Joseph A. (1942) *Capitalism, Socialism, and Democracy*. New York: Harper and Row.

Teece, David J.; Pisano, Gary; and Shuen, Amy (1997) "Dynamic Capabilities and Strategic Management," *Strategic Management Journal*, 18, 509-533.

Williamson, Oliver E. (1975) *Markets and Hierarchies*. New York: The Free Press.

Williamson, Oliver E. (1985) *The Economic Institutions of Capitalism*. New York: The Free Press.

Table 1. Types of Procured R&D

		Definability of work	Predictability of outcome	Ownership of outcome
Outsourcing		High	High to medium	This firm
Technology acquisition:	Acquisition for marketing	High	High	This firm
	Acquisition for development	High to medium	High to medium	This firm
Commissioned research:	Commissioned to universities (or public laboratories)	Low to medium	Medium	This firm (or joint)
	Commissioned to other firms	Low to medium	Medium	This firm (or joint)
Joint research:	Joint with universities (or public laboratories)	Usually low	Low to medium	Joint
	Joint with a limited number of other firms	Usually low	Low to medium	Joint
	Consortium	Usually low	Usually low	Joint (or public)
	National projects	Usually low	Usually low	Joint (or public)

Table 2. Ten Largest Pharmaceutical Firms in Japan

No.	Company name	Pharamaceutical sales, 1997	Pharamaceutical sales, 1999	Annual rate of growth of pharamaceutical sales, 1997-99	Total sales, 1999	R&D exp., 1999	No. of patents, 1980-99	Patents/R&D	No. of NCEs, 1980-98	NCEs/R&D
1	Takeda	469615	523179	11.4%	708470	77200	1472	1.91	25	3.24
2	Sankyo	419308	408091	-2.7%	450569	64432	978	1.52	24	3.72
3	Yamanouchi	313663	274888	-12.4%	278564	54821	694	1.27	27	4.93
4	Eisai	234093	203185	-13.2%	230597	46703	622	1.33	16	3.43
5	Daiichi	226367	242174	7.0%	247506	34204	519	1.52	15	4.39
6	Fujisawa	189135	176643	-6.6%	202061	45565	1090	2.39	17	3.73
7	Shionogi	181655	193103	6.3%	220743	27026	83 (see note)		30	11.10
8	Tanabe	163867	151168	-7.7%	185098	19475	519	2.66	16	8.22
9	Chugai	163129	174920	7.2%	176565	39993	478	1.20	8	2.00
10	Kyowa	160775	127149	-20.9%	316740	25010	640	2.56	NA	

Notes: 1. Sales, total and pharmaceutical, and R&D expenditures are in million yen.
2. No. of patents is the number of patents under IPC A61K (preparations for medical, dental, and toilet purposes) filed and publicized during 1980-99 except Shionogi (1991-99).
3. Patents/R&D is the number of patents (1980-99) divided by R&D expenditures (in 100 million yen) in 1999, and similarly for NCEs/R&D.
4. No. of NCEs is the number of new chemical entities (new drugs) approved by the Ministry during 1980-98.

Source: Japan Pharmaceutical Manufacturers Association (JPMA) *Data Book 2001*

Table 3. Increase in the Number of Research Alliances during 1989-1999

	Takeda	Sankyo	Yamanouchi	Eisai	Daiichi	Fujisawa	Shionogi	Tanabe	Chugai	Kyowa	Total	%
<1989>												
No. of alliances	6	7	10	2	7	4	6	6	7	10	65	
Types of partners												
Domestic firms	1	2	1		4	1		1	1	1	12	17.4%
Domestic univ. & public lab	1	1	2	1	1			1	3	5	15	21.7%
Foreign NBFs	2	3	4	1	4	3	4	2	2	3	28	40.6%
Other foreign firms	2	1	3				2	2	2	2	14	20.3%
Foreign univ. & public labs											0	0.0%
Total	6	7	10	2	9	4	6	6	8	11	69	100.0%
<1999>												
No. of alliances	25	23	27	17	9	12	10	13	29	24	189	
Types of partners												
Domestic firms	6	6	4	4	5	2		1	5	2	35	15.2%
Domestic univ. & public lab	6	3	2	7	6			3	9	13	49	21.2%
Foreign NBFs	7	15	13	5	3	7	8	7	11	8	84	36.4%
Other foreign firms	9	4	10	6		3	2	5	7	4	50	21.6%
Foreign univ. & public labs	3	1	2	1	1				1	4	13	5.6%
Total	31	29	31	23	15	12	10	16	33	31	231	100.0%
No. of alliances divided by R&D expenditures	3.3	4.4	7.1	4.1	3.0	3.7	3.9	6.3	8.8	10.7		

Notes: 1 Classified by the foreign parent when an alliance is made with its Japanese subsidiary.
2 Alliances with own foreign subsidiaries are excluded.
3 A few alliances involve multiple partners; hence, the total number of partners exceeds the total number of alliances.

Source: Compiled from "Sekai no Baio Kigyo" [Bio Firms of the World] (Nikkei BP, 1989 and 1999)
R&D expenditures (in million yen) are from company statements.

Table 4. Number of Research Alliances, Jan. 1999-Aug. 2001

	Types of Alliance					
	Database, etc.	Acquisition for Marketing	Acquisition for Development	Commissioned Research	Joint Research	Total
Takeda	2	5	7	1	4	19
Sankyo	4	2	4	1	8	19
Yamanouchi	2	0	1	1	2	6
Eisai	1	1	2	1	2	7
Daiichi	0	3	5	0	4	12
Fujisawa	0	2	3	3	4	12
Shionogi	0	1	1	1	1	4
Tanabe	0	0	2	5	2	9
Chugai	0	1	2	1	3	7
Kyowa	1	1	0	2	4	8
Total	10	16	27	16	34	103

	Types of Partners								
	Domestic				Foreign				Total
	NBFs	Other firms	Universities	Public Laboratories	NBFs	Other firms	Universities	Public Laboratories	
Takeda	0	8	2	0	4	5	0	0	19
Sankyo	0	7	0	1	7	2	2	0	19
Yamanouchi	0	2	0	0	1	2	1	0	6
Eisai	0	2	0	1	2	1	1	0	7
Daiichi	3	4	1	0	2	3	0	0	13
Fujisawa	0	2	0	0	5	4	1	0	12
Shionogi	0	0	0	0	1	3	0	0	4
Tanabe	2	2	1	0	3	1	0	0	9
Chugai	0	2	0	0	3	1	0	1	7
Kyowa	1	3	1	0	2	1	1	0	9
Total	6	32	5	2	30	23	6	1	105

Note: One alliance may involve more than two types of partners; thus, the total numbers differ between the upper and lower tables.
Source: Calculated by the author from Nihon Keizai Shimbun.

Table 5. Types of Research Alliance and the Types of Partners

	Types of Partners										
	Domestic				Foreign				Subtotal		Total
Types of Alliance	NBFs	Other firms	Universities	Public Laboratories	NBFs	Other firms	Universities	Public Laboratories	Domestic	Foreign	
Database, etc.	0	1	0	0	9	0	0	0	1	9	10
Acquisition for Marketing	0	6	0	0	2	8	0	0	6	10	16
Acquisition for Development	1	15	0	0	1	9	1	0	16	11	27
Commissioned Research	3	1	0	0	10	0	2	0	4	12	16
Joint Research	2	9	5	2	8	6	3	1	18	18	36
Total	6	32	5	2	30	23	6	1	45	60	105

Table 6. Probit Estimation Results

Equation No.	(1)		(2)	
Dependent Variable	Prob[Foreign Partner]		Prob[Technology Acquisition]	
	Coefficient	Std. Err.	Coefficient	Std. Err.
Constant	0.064	0.409	1.089	0.410 ***
Acquisition for Development	-0.588	0.436		
Commissioned Research	0.567	0.531		
Joint Research	-0.381	0.435		
Foreign Firms (incl. NBFs)			-0.473	0.319
Foreign Univ. & Pub. Labs.			-1.194	0.705 *
Sankyo	0.180	0.449	-0.936	0.513 *
Yamanouchi	0.886	0.775	-1.286	0.833
Eisai	0.184	0.616	-0.380	0.658
Daiichi	0.094	0.473	-0.268	0.565
Fujisawa	1.107	0.560 **	-0.860	0.537
Shionogi			-0.615	0.749
Tanabe	-0.321	0.597	-1.536	0.626 **
Chugai	0.401	0.544	-0.853	0.592
Kyowa	-0.563	0.677	-1.939	0.709 **
Pseudo R2	0.1283		0.1637	
No. of obs.	89		83	

Note: 1 ***, **, and * indicate, respectively, significance at 1%, 5%, and 10%.
2 4 cases by Shionogi are excluded from the sample to estimate Eq. (1) and 7 cases of joint research with domestic universities and public laboratories are excluded to estimate Eq. (2).

Table 7. Joint Application of Patents, January 1999-July 2001: By the Type of Joint Applicants

	By Partner						Total	
	Domestic				Foreign			
	Company	Private Laboratory	University	Public Laboratory	Company	University		Names of Domestic Universities
Takeda	4	1	3	1	1		10	Tokyo, Kobe, Okayama
	7	1	4	2	1		15	
Sankyo	2	3	1	1			7	Tokyo
	9	5	1	1			16	
Yamanouchi	3		1	1	1		6	Tsukuba
	4		1	1	2		8	
Eisai	4			1			5	
	5			1			6	
Daiichi	6	1	2	1			10	Setunan, Toyama M&P
	8.5	1	2	0.5			12	
Fujisawa	1		2				3	Tokyo PLS, Tsukuba
	1		2				3	
Shionogi	1			1			2	
	1			3			4	
Tanabe	4		1				5	Osaka
	9		3				12	
Chugai	2		1	2		1	6	Tokyo
	2		1	3		1	7	
Kyowa	2	1	3		1	1	8	Tokyo, TIT, Nagoya
	2.5	1	3.5		1	1	9	
Total	29	6	14	8	3	2	62	
	49	8	17.5	11.5	4	2	92	
Distribution	46.8%	9.7%	22.6%	12.9%	4.8%	3.2%	100.0%	
	53.3%	8.7%	19.0%	12.5%	4.3%	2.2%	100.0%	

Notes: The upper figures indicate the numbers of applicants and the lower, the numbers of applications. When an application is made by two applicants (besides the company in the far-left column), the application by each applicant is counted as 0.5. Toyama M&P = Toyama Medical and Pharmaceutical University, Tokyo PLS=Tokyo University of Pharmacy & Life Science, TIT=Tokyo Institute of Technology

Table 8. Research Joint Ventures Invested by the Organization for Pharmaceutical Safety and Research (OPSR) of the Ministry of Health, Labor, and Welfare

Name of the Laboratory Founded by Each RJV	Period	Membership									
		Takeda	Sankyo	Yamanouchi	Eisai	Daiichi	Fujisawa	Shionogi	Tanabe	Chugai	Kyowa	Others
DDS	1988-1995				○	○		○	○			Asahi Kasei, Ajinomoto, Meiji Seika
Bio-Sensor	1988-1995									○		Kuraray, Toso, Hamamatsu Photonics
Cyto-Signal	1989-1996		○									Kirin Beer, Mitsubishi Chemical
Artifical Blood Vessel	1989-1996					○						Sumitomo Electric
Bio-Function	1990-1996	○					○		○			Sumitomo Heavy Ind., Nihon Mediphysics, Wako Junyaku, Yoshitomi Pharm.
Advanced Skin Research	1990-1997									○		Shiseido, Nihon Yushi
Vessel Research	1991-1998										○	Terumo
Anti-Virus Drug	1992-1999			○								Kuraray, Sanwa Chemical Lab., Toso, NKK, JT, Yamasa, Intelligent Cosmos Research Inst.
Cardiac Pacing	1992-1999											Terumo, Yuasa, NTT Electronics
HSP	1993-2000											Sumitomo Pharm., JT, Hayashibara, Mochida Pharm.
Agene	1994-2001				○							Japan Roche, Kissei Pharm.
Dnavec	1995-2002		○	○				○	○		○	Hisamitsu Pharm., Sumitomo Pharm.
Genox	1996-2003		○	○	○				○		○	Olympus, Hamamatsu Photonics, Kirin Beer,
BF	1997-2004	○	○		○			○	○			Suntory, Jafco
RRF	1998-2005											Hisamitsu Pharm., Nikko Capital

Source: http://www.kiko.go.jp/Kenkyuu/Invest.html (in Japanese)