# A NETWORK ANALYSIS OF OPEN INNOVATION IN DRUG DISCOVERY

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**Abstract**

*The purpose of this research is to classify the inter-organizational relationships in open innovation between pharmaceutical companies and to clarify quantitatively the relationship between each type and research efficiency. In terms of research methodology, a patent database of drug development was analysed using the technique of social network analysis. The study concludes that a significant difference in the research efficiency of the various types of inter-organizational relationships can be verified.*

**Keywords:** *open innovation, social network analysis, drug discovery, inter-organizational relationship*

## 1. INTRODUCTION

The purpose of this research is to classify the inter-organizational relationships in open innovation between pharmaceutical companies and to clarify quantitatively the relationship between each type and research efficiency. In the pharmaceutical industry, the research and development (R&D) model, hitherto based on the economies of scale associated with conventional large-scale corporations, is changing. It is difficult for a large-scale corporation to raise revenue using the vertical integration style of business model based on insourcing products within a company using large-scale internal R&D resources. The sizable technical transformation of biomedicines started with conventional low-molecule pharmaceutical products. It has become considerably more difficult to create large-sized blockbusters. Since the process for clinical trials has been tightened, the probability of success in launching a new drug is falling and the lead time to launch is becoming longer. Even if a new drug is launched successfully, manufacturers of generic products can enter the market after a patent expires and the recovery of the large investments required for development is difficult. Pharmaceutical companies always have to invest in pipelines with the advent of a new drug to sustain the vast corporate entity. For this reason, pharmaceutical companies are increasingly depending on external companies for the very uncertain R&D of a new drug. The risk can be reduced by buying a potential new drug for which the R&D process has been completed to some extent. The role of open innovation (Chesbrough, 2003) is thought to be important in such a transformation.

Open innovation has been researched for many years in the pharmaceutical industry compared to other industry segments. However, although there are various biotechnology industrial clusters in many parts of the world engaged in open innovation, there are few successful cases. Also, there are few examples of biotechnology ventures that have been successful and expanded widely. Rather, many biotechnology ventures have been unable to achieve the required outcomes and have been withdrawn; many other biotechnology ventures have barely been sustained through subcontracting work, rather than engaging in the primary business of the development of new drugs. While the development model for new drugs using the vertical integration mode and harnessing the economies of scale of large-scale corporations has not proved workable in the medical industry, in reality the horizontal specialization model of various ventures has also shown little growth.

On the other hand, in the IT industry, start-ups in Silicon Valley have repeatedly achieved considerable success. These ventures and others have greatly contributed to the promotion of innovation in the IT industry and the industry model has developed. In the IT industry, the open network type of many-to-many cooperation has been a prime mover in the industry's development through the adoption of a horizontal specialization style, whereby various companies share a value chain and

cooperate. In contrast, in the motor vehicle industry, enterprise groups that have adopted a vertical integration model have now gained strong competitiveness. For some motor cars (e.g. electric vehicles), the activity of venture businesses adopting a horizontal specialization style has also attracted attention. Strongly competitive company groups have adopted the vertical integration model with a huge finished car maker at the summit of the pyramid. Inter-organizational relationships are similar, not only in developed countries, such as Europe, the United States (US) and Japan, but also in companies in emerging countries, such as South Korea, China and India. It seems that the model of close inter-organizational relationships between individual firms fits the motor industry.

Therefore, it is considered that there is a strong relationship between business competitiveness and inter-organizational relationships. Moreover, it is thought that a desirable relationship changes with the industry, product characteristics and so on. It is important to consider what kind of relationship best suits each industry and product. Thus, the empirical study described in this paper aimed to examine what kind of inter-organizational relationships are best suited to the pharmaceutical industry.

As a method of determining the relationship between organizations, social network analysis was used in this research. As the object of research, data considered to be the result of open innovation were extracted from a database concerning intellectual property. From these data, various indicators were generated through network analysis showing the traits of relationships between organizations. Furthermore, the cause–effect relationship between each indicator and the productivity of R&D was verified.

## 2. PREVIOUS RESEARCH

First, previous research on inter-organizational relationships is considered; the studies are broadly divided into those concerning horizontal specialization (many-to-many open relationships) and those related to vertical integration (individual and close relationships).

### *2.1 Previous studies of horizontal specialization*

#### *2.1.1 Contingency theory*

One of the derivations of research on the relationship between R&D and an organization is contingency theory. The pioneering research on this framework for analysis was undertaken by Burns and Stalker (1961) and designated contingency theory by Fiedler (1971) and Lawrence and Lorsh (1967). Contingency theory inherited the dysfunction theory of bureaucracy (Merton, 1940), namely that a bureaucracy is not necessarily effective in an unstable environment. It is an analytic framework based on the presupposition that there is no perfect organizational structure, but that the outcome for an organization is improved by the contingent relationship between an environment and an organizational structure. That is, although a mechanistic system of management is effective under a stable environment, in an unstable environment, an organic system is more effective.

The value of this research is that it demonstrates the fit between the uncertainty of a market environment and the degree of integration of a management organization. However, the results of successive studies that have tried to verify this proposition have not been coherent as the objects of the analysis were various. In subsequent research, the need to take into consideration the influence of other variables was demonstrated.

#### *2.1.2 Product architecture theory*

It can be said that product architecture theory further elaborated the aforementioned research. The concept of product architecture was developed by Ulrich (1995). Product architecture has come to be recognized as the relationship or correspondence between the structural and functional elements of the internal structure of a product and the degree of standardization of an interface. Two typologies of product architecture have been used in the literature: (i) the integral style/modular style, according to

the complexity of the corresponding relationship between a structure and a function, and (ii) the closed style/open style, according to the degree of generalization of an interface that has been developed (Fine, 1998; Fujimoto, 2001; Morris & Ferguson, 1993; Ulrich, 1995; Ulrich & Eppinger, 1995).

In essence, product architecture is the basic design and is viewed in terms of the resolution and connection rules linking the components of a certain product. In integral architecture, the correspondence between a structure and a function is many to many and a close interaction arises between components. Thus, when adding a modification to a certain component, it is necessary to change other related groups of elements collectively. To develop a product in an integral manner, the integrity (Fujimoto, 2002) of the product needs to be ensured, based on successive design and development processes.

In modular architecture, the correspondence between a structure and a function is almost one to one and the interaction between the components is relatively low. If the degree of modularization is large, the influence which a modification of a certain component has on other groups of elements is slight. Although there is a closely interdependent relationship within an individual component, it is not necessary to take its influence on other components into consideration. In the case of modular products, a decent product is made simply by collecting and assembling commercial components (multiuse parts; Fine, 1998). However, to secure high merchantability, a refined prior design is indispensable and ingenuity in the combination is required (Fujimoto, 2002).

*2.1.3 The benefit of modularization*

Langlois and Robertson (1992) explained the benefit of modularizing a product and an industrial network from the viewpoint of organization economics. Making decisions regarding the insourcing or outsourcing of the components for a product is dependent on the relationship between the cost of internalization to the organization and the transaction cost (Langlois & Robertson, 1992). If the product is integrative, a company with a vertical integration mode of operation, in which it is easy to carry out coordination, will be at an advantage as the transaction cost within a market exceeds the internalization cost. However, if a product is modular, it is difficult to attain innovation only in a single firm without marring the interchangeability between modules; that is, the internalization cost exceeds the transaction cost. Therefore, in this situation, it is desirable to supply a component from the outside. Moreover, vertical specialization, which a modular style promotes, also encourages the construction of a manufacturer's network. In a non-centralized power network such as this, the manufacturer of a component, a user and an assembler can determine the standard required through the process of the market or negotiation. The horizontal network of such companies may actually bring an innovator a high profit than the monopolistic profit which an innovator can enjoy through patenting. The network realized by modularization can expand the overall market. Therefore, the profitability of the business concentrated on a specific component in an expanded market may be superior to the niche monopoly that is the exclusive business of a vertically integrated company.

Sanchez and Mahoney (1996) discussed modularization in relation to both products and the organization. According to Sanchez and Mahoney (1996), the product architecture and organization have a good fit because product design and product-design organization are closely related. The coordination activities in product design play a considerable role in specifying the design of a product or a productive apparatus. The tasks divided by modularization are performed autonomously and in parallel through the loosely coupled structure of a developing organization. In a modular organization, interdependence is reduced and a problem is continuously solved through the self-organization process. Standardizing the interface of various modular style systems may be the new dominant design, which leads to great flexibility and broad unity (Sanchez & Mahoney, 1996).

The economic efficiency of modularization has been demonstrated by statistical analysis. Worren et al (2002) analysed how modularization and strategic flexibility affected the performance of a US–British household electric appliance maker. They found that modular product architecture and modular organizational architecture had a positive correlation with the company's performance. The modularization of an organizational structure and a process had a direct correlation with performance.

Moreover, modular product architecture showed a positive correlation with product multiplicity and this multiplicity in turn was correlated with performance. On the other hand, there was no mutual correlation between the product architecture and the organizational architecture. Although many previous studies, including that by Sanchez and Mahoney (1996), have pointed out the conformance of the relationship between a product and organization, Worren et al's (2002) statistical analysis revealed no explicit relationship. It is therefore considered that the relationship between a product and organization is not simple and there is a room for a different explanation.

### *2.1.4 Open innovation*

Modularizing and opening up the product, the organization, or the business process in product architecture theory are connected to the discussion of open innovation in an industrial structure. According to Chandler (1977, 1990), important technology had been developed in the research sectors of large-scale European and American multimarket corporations by the middle of the 20th century. The large-scale corporations of those days yielded a scale and economy of scope through vertical integration from the R&D stage to distribution, and they established competitive advantage over small- and medium-sized enterprises or new-entry companies. However, Chesbrough (2003) argues that the vertical integration innovation model of Chandler (1977, 1990) had reached its limit, according to the empirical study of US industry, by the end of the 20th century. This is because, especially in high-tech companies, the liquidity of knowledge becomes greater if there is labour liquidity; venture funds helped to establish the new companies which utilized such knowledge. Moreover, according to Langlois (2003), as proof of the shift from the Chandler model, the work force was modularized and subdivided among companies as the need for vertical integration was lost. According to Grantstrand et al (1997), active learning processes, such as the acquisition of external technology and union of in-company technical capabilities, are needed in many cases to create competitiveness in a new field. Gulati (1998) gives an example in which a company strives for the absorption of knowledge through the exploitation of strategic alliances or complementary resources and further points out that such an alliance network approach is often observed in the bio industry, which especially needs advanced technology.

### *2.1.5 Exploitation strategy and pursuit strategy*

Dittrich et al (2007) describe the different approaches in a joint-research network as comprising an exploitation strategy and a pursuit strategy. In an exploitation strategy, an alliance partner has a funding relationship in general in the same technology or business field. It is rare for a new alliance partner to participate in a collaborative network and the speed at which an alliance partner changes is slow. An exploitation strategy is similar to a closed innovation in which a development is made in an originally outstanding field mostly with a specific partner. In a pursuit strategy, an alliance partner does not have a funding relationship and is in many cases in a different technological or business field. In the pursuit strategy, many new alliance partners participate in a collaborative network and alliance partners change rapidly.

In a pursuit strategy, the main purpose is the development of a new field of technology and a relationship with a specific company is insufficient. It is necessary to access an external open network and to find new alliance partners; in this case, the alliance partnership is also fluid. Therefore, it becomes close to an open innovation. The joint research in which International Business Machines (IBM) engages shifted from an exploitation strategy to a pursuit strategy from the mid-1990s. The turnover of the open innovation of IBM is apparent in the technical field and takes place in the style of joint research development. Moreover, although the alliance between IBM and its partners was primarily of a closed nature previously, alliances between multiple companies are increasing with the shift to an open style. On the other hand, the most important technology in an international strategy does not tend to be opened up before patenting. IBM is conjectured to have adopted a strategy that combines an open strategy and the conventional closed strategy.

*2.1.6 The depth of tangency or external relationships in pharmaceutical companies*

Several studies have considered tangential relationships with an outside company. Roberts and Hauptman (1986) examined a new biophysics company which was often in contact with external companies in developing a product involving more advanced technology. Henderson and Cockburn (1994) investigated 120 or more research projects for ten top European and US pharmaceutical companies. They found that the percentage difference in the number of patents and commercial production success in relation to research expenses was more than double for the successful company group than the ailing company group. The special features of the successful companies were as follows:

- They maintained a point of contact with a scientific field.
- Resources were allocated to a wide range of medical treatment fields and the companies aimed for the most advantageous project mix.
- The tension and friction generated by the matrix organization of a function and a product were tackled positively.

Moreover, according to Koenig (1983), there is a correlation between the number of clinical trials or theses cited within a medicinal or pharmaceutical academic community and the productivity of an area of investigation. According to Gambardella (1992), a company that has sufficient relationships with institutional science also has an excellent research programme.

*2.2 Previous studies of vertical integration*

While the trend towards the aforementioned open and modular approach has become strong, there is also a considerable body of research focused on internal managerial resources.

*2.2.1 Cooperation in R&D*

Cooperation in R&D is important for the component engineering of a research process to become a competitive product. According to Iansiti (1993), to take the plunge from component engineering into product development, it is desirable to for an integrated team. The conventional R&D style is a serial and continuous process involving basic research, applied research and product development. However, the lead time for product development can be shortened and costs can be kept down by composing a team consisting of scientists in an upper process, engineers in a lower process and managers who help them to generalize their work at the early stage of development. There are other merits in composing an integrated team. First, the frequency of communication between teams can be increased and the team members can share knowledge of fields other than their own specialty. Moreover, although existing and familiar technology tends to be selected at the site of product development, if there is a researcher who is well versed in component engineering in a team, various possible technologies may be offered. The merit of an integrated style of team is not limited to a single product development project: the tradition of sharing product information or technology is carried through efficiently to the development of other products.

*2.2.2 Exploration and exploitation*

According to previous studies, ‘exploration’ and ‘exploitation’ are contrasting styles of organizational learning and exploration tends to be neglected if the focus is put on exploitation (Levinthal & March, 1993; March, 1991; Stuart & Podolny, 1996). According to March (1991), exploration is an activity exhibiting characteristics such as the pursuit of diversity, risk taking, experimentation, the maintaining of margins and the preservation of flexibility. Radical organizational learning that is not influenced by existing knowledge or information remains concealed. On the other hand, the characteristics of exploitation are gradual learning, such as improvement or modification, the comparison or election of

alternatives, standardization, speeding up and cost cutting. For this reason, compared to exploitation, exploration is more uncertain, takes more time and the cause and effect relationship is also ambiguous. In other words, exploration is high risk compared to exploitation. As a result, the expected value of the economic performance of exploration is inevitably low and exploitation tends to be selected rather than exploration as a mode of operation.

Various operationalisations of exploration and exploitation have been tried in successive studies, for example related to the patent references of other companies, company patent exploitation (Sorensen & Stuart, 2000), the development of new drugs and indications (Cardinal, 2001) and so on. Moreover, Benner and Tushman (2003) discovered that the relationship between product innovation and process innovation (Abernathy & Utterback, 1978) is a relationship between exploration and exploitation. The isolation of the organizational structure has also been suggested in innovation research. For example, according to Christensen and Bower (1996), it is necessary to create a new business organization aimed at exploration that is separate from the existing business organization focused on exploitation to eliminate interference. However, according to Burgelman (1983), exploration and exploitation should be shared among the organizational hierarchies.

*2.2.3 Absorptive capacity*

According to Cohen and Levinthal (1990), absorptive capacity is the capability of carrying out a series of activities, such as the perception of new knowledge or information, evaluation, intake, assimilation and exploitation; it refers to the knowledge or information used as a source. Cohen and Levinthal (1990) further posit that this capability is born from the accumulation of continuous and gradual knowledge in an organization through fundamental R&D activity. It is necessary for a company to be conscious of the optimal external dependability in relation to the balance of exploration/acquisition capability and absorption/exploitation capability. External dependability involves sharing a proportion of R&D costs through an alliance. If external dependability is too low, information concerning the new knowledge gained from outside the company cannot be acquired quickly and efficiently. On the other hand, when external dependability is too high, the absorptive capacity for new knowledge decreases – even if new knowledge is acquired, it is hard for it to be exploited inside a company for product development and the acquisition cost is not harnessed sufficiently.

Van den Bosch et al (1999) argue that not only is the possession of related knowledge important as an organizational factor that influences absorptive capacity, but so is the structure of the organization and its combinative capabilities. The accumulation of knowledge in an organization is contained in the construct of absorptive capacity, together with the union and utilization of knowledge. The activities that constitute absorptive capacity are divided into ‘acquisition’, ‘assimilation’, ‘transformation’ and ‘exploitation’ (Zahra & George, 2002). Acquisition is an activity which recognizes and obtains new external knowledge or information. Assimilation analyses or understands newly acquired knowledge or information. Transformation promotes union between existing knowledge or information and the new knowledge or information. Finally, exploitation puts into practice the new knowledge for which the processes of acquisition, assimilation and transformation were carried out. According to Zahra and George (2002), acquisition and assimilation are the prerequisites of absorption and the absorption process is completed by transformation and exploitation.

Moreover, absorption is promoted on the basis of similarity and affinity (Lane & Lubatkin, 1998; Mowery et al, 1996). For example, Lane and Lubatkin (1998) show the correlation between similarity and affinity with a knowledge base, organizational structure, the knowledge-handling process, the dominant logic, etc. and the superiority or inferiority of absorptive capacity in the case of the alliance of R&D in the manufacturing of medicine and the biotechnology industry. Moreover, Levinthal and March (1993) argue that the fact that similarity and affinity promote absorption is related to organizational inertia.

*2.2.4 Integration capability*

Henderson and Clark (1990) defined two dimensions in technical innovation: innovation related to each component that constitutes the product system and innovation in terms of how to connect those components and collect them into a product. According to Christensen (2006), Prahalad and Hamel (1990) used the term 'core competence' to fulfil two meanings: one is the integrative capability necessary for innovation at the whole company scale and the other is a deep, narrow, special capability necessary for core component development.

Christensen (2006) defines organizational capability as comprising special technical capability and integration capability. Special technical capability is the team's basic capability to mobilize resources for a specific production activity. Integration capability is a high-level administrative ability which mobilizes, cooperates in and develops exchangeable resources or capability and is the capability to yield a value and competitive advantage at the system level. Special technical capability is a capability promoted with the resources inside an organization, whereas integration capability serves as the central resource of open innovation and organizational boundaries may differ according to managerial resources.

*2.2.5 An organizational capability approach to the medical industry*

Henderson and Cockburn (1994) classified R&D capability into local capability and architectural competence and explored the relevance of organizational capability and the outcome of research on pharmaceutical products in terms of the development of drugs for circulatory organs in a European and US pharmaceutical company. Local capability is the fundamental individual capability and knowledge for everyday problem solving. Architectural competence concerns the ability to use and unify local capabilities effectively and create new local capabilities that may be needed. They developed and tested four hypotheses: the first two hypotheses concern the relationship between local capability and productivity in the development of new drugs and the second two address the relationship between architectural competence and productivity in the development of new drugs.

- Productivity in the development of new drugs is an increasing function of the company's special professional knowledge in a specific field.
- Productivity in the development of new drugs is an increasing function of local capability in a specific disease field.
- A company with the capability to promote/sustain the flow of information, exceeding the boundaries of the company, has high productivity in the development of new drugs as long as other conditions are constant.
- A company with the capability to promote/sustain the flow of information, exceeding the scientific principle and the boundaries between medical treatment fields, has high productivity in the development of new drugs as long as other conditions are constant.

Based on analysing the number of patents as an indication of development performance, they found significant support for the first three hypotheses and demonstrated that local capability and architectural competence are related to productivity in the development of new drugs. Thus, the research claims that architectural competence, which is an organizational capability in connection with the integration and combination of information or knowledge from inside and outside an organization, is an important source of competitive advantage for a company.

Yeoh and Roth (1999) studied the source of sustainable competitive advantage for 20 US pharmaceutical companies and performed an empirical study using the resource-based view and organizational capability concepts. They showed that the cost of R&D was directly related to the component capabilities of the company and that the R&D expenses and the distribution of spending increased the company's integrative capabilities. Furthermore, an examination of the cause and effect relationship between local capability and the distribution of spending/integration capability showed variations between companies in the medical treatment field and that it yields new products at the

global level. Pisano (2006) has undertaken various case studies on science innovation in biomedicine in recent years, reaching the conclusion that vertical integration is suitable for a company attempting the development of epoch-making pharmaceutical products scientifically.

*2.2.6 Intermediate organization*

According to Imai et al (1982), the rationale for coordination in a market is primarily based on price, whereas the rationale in an organization is authority or the order of relationships based on a hierarchy. From the viewpoint of mutuality between participants, entry or withdrawal from a market is straightforward and an organization is characterized by being fixed and continuous. The market mechanism and the principle of organization each have a relative advantage according to the trade environment and the characteristics of the goods being traded. As an interim mode, there is an intermediate organization, which is the network type, such as keiretsu and strategic alliance. There are various types of networks which connect economic agents, reflecting the strength of the connection, duration and so on. An intermediate organization is considered an eclectic mode which addresses the weaknesses of the market or the business organization. According to Zenger and Hesterly (1997), the intermediate organizational mode of network type has increased in the information industry in recent years and the interpenetration of market and hierarchy has attracted attention in research.

*2.2.7 Supplier system*

Supplier system research started with the evaluation of the efficiency of the Japanese-style subcontract production system in the 1980s and has been extended by subsequent studies. Asanuma (1985, 1989) introduced the concepts which represent the beginnings of the study of supplier systems, based on research into the relationship between companies in the subcontracting system. Asanuma (1985, 1989) predominantly analysed the motor industry and evaluated the technical capabilities of the supplier, i.e. a subcontracting company. The long-term continuous dealing style of the motor industry in Japan can trigger investment in assets, which is dependent on special dealing with a supplier. Asanuma named such investment a ‘relation-specific skill’. A relation-specific skill is one required on the supplier side and concerns responding efficiently to the supply needs or requests of a core firm. To develop this skill, learning by repetitive interaction with a specific core firm is required, in addition to the existing fundamental technical competence of the supplier. Furthermore, Asanuma verified quantitatively the hypothesis that the core firm absorbs the risk of a supplier. A core firm directs care towards the growth of a supplier; considerable care is provided in the early developmental stages of a supplier and the level of care decreases with growth (Asanuma & Kikutani, 1992). For a core firm, the development of a relation-specific skill is indispensable in order for its productivity network to be adapted to the environment; therefore long-term continuous dealings are needed. The core firm provides strong protection for a small and weak supplier. This differs from the buffer exploitation of small- and medium-sized enterprises in times of economic fluctuation, as discussed in research on the conventional subcontracting system. Asanuma also developed the concept of the technical capabilities of a supplier in relation to the motor industry (e.g. the provided drawings system, the approved drawings system).

To analyse the growth of the Japanese motor industry in the 1980s, the US International Motor Vehicle Project investigated the source of competitive advantage of the Japanese motor industry from various perspectives. According to Womack et al (1990), it was shown clearly that Japanese producers of finished cars had higher productivity than European and US car manufacturers. One of the strengths of Japanese production was the effective use of components suppliers.

Clark and Fujimoto (1991) undertook a comparative study of the product development of 20 manufacturers of finished cars in Japan, the US and Europe, providing useful suggestions on the supplier system in the International Motor Vehicle Programme (IMVP) survey. According to Clark and Fujimoto (1991), the supplier system in the Japanese comprised a multi-storey business relationship structure in which the car manufacturer made direct transactions only with a small number of leading

suppliers and the leading suppliers then managed low-ranking suppliers. Furthermore, the leading suppliers were involved from an early stage in the car manufacturer's product development and close communications were exchanged. As part of the sourcing method of Japanese firms, there was a pattern of supply based on an approved drawings system, supply based on the provision of drawings and supply of proprietary parts.

According to Fujimoto (1997a, 1997b, 2001), the suppliers who took charge of each section of a technical system formed a hierarchical business relationship the shape of which overlapped exactly with that of a technical system. The Japanese-style supplier system for the motor industry was developed through an emergent process and evolutionary capability served as a key background concept. The following three points were made about the competitive advantage of the Japanese-style supplier system.

- It constituted a long-term continuing business relationship. As Asanuma (1985, 1989) also noted, long-term continuous dealings are indispensable so that a supplier may gain a relation-specific skill, thus accelerating promotion to an approved drawing supplier from a provided drawing supplier.
- There was keen competition between a small numbers of companies. In the narrow market managed by the car manufacturer, suppliers would engage in competition for orders received with their competitors and they would get to know each other well. The possibility that a car manufacturer could use the option of insourcing was also a factor that intensified competition.
- The approved drawing system gave manufacturers a competitive edge. In this system, the car manufacturer entrusted integration of mutually related tasks in alignment with the value chain collectively to a supplier through drawing approval. By accumulating integration capability on a long-term basis, a parts supplier could achieve cuts in costs and an increase in quality. The car manufacturer could concentrate resources in high value-added fields, such as engine or platform development. The supplier integrated and rationalized a series of processes, such as the development, production, or procurement quality assurance of its company components, so that these might optimized for the company. By using an autonomous supplier group extensively, it was possible to reduce lead times and promote productivity in both development and production throughout the motor industry.

*2.2.8 The organization of product development in the pharmaceutical industry*

In the pharmaceutical industry, a lightweight product management system has conventionally been adopted. According to Kuwajima (1999), as the product structure of a pharmaceutical product is very simple compared to that of a motor industry product, the development system of pharmaceutical products has not become an advanced division of the labour system as it has for the motor car. Thus, the need to achieve the integrity of a product through organizational integration involving coordination between sectors has been relatively low. However, as a variety of knowledge is needed in the product development of pharmaceutical products, the integration of knowledge concerning the effects of a drug, medicinal action and so on is important. It is possible for an individual researcher to undertake this knowledge integration, meaning that the need for integration between organizations or coordination between sectors tends to be low. As Kuwajima (1999) noted, the following aspects affect the product development performance for pharmaceutical products:

- The selection of a suitable search strategy.
- The researcher's motivation.
- Connecting the knowledge accumulated in each functional sector and the knowledge introduced from outside to knowledge of the project concerned.
- The optimal timing of judgment.

Kuwajima's (1999) points were derived from a survey of R&D projects involving conventional

pharmaceutical products. Possibly, in conventional pharmaceutical product development, there is little potential for a heavyweight product management system (Clark & Fujimoto, 1991), which achieves internal and external integration simultaneously, to affect product development performance. However, the conditions of R&D may differ in relation to the advanced and complicated biomedicine of the present time.

### *2.3 Social network analysis*

A social network is a social structure made up of a set of social actors (such as individuals or organizations) and a set of the dyadic ties between these actors. The social network perspective provides a set of methods for analysing the structure of whole social entities, as well as a variety of theories explaining the patterns observed in these structures (Wasserman & Faust, 1994). The study of these structures uses social network analysis to identify local and global patterns, locate influential entities and examine network dynamics.

Social networks are analysed at the scale relevant to the researcher's theoretical question. Although levels of analysis are not necessarily mutually exclusive, there are three general levels into which networks may fall: micro level, meso level and macro level. At the micro level, social network research typically begins with an individual, snowballing as social relationships are traced, or may begin with a small group of individuals in a particular social context. The smallest unit of analysis in a social network is an individual in their social setting, i.e. an 'actor' or 'ego'. Ego network analysis focuses on network characteristics, such as size, relationship strength, density, centrality and prestige, and roles, such as isolates, liaisons and bridges (Jones & Volpe, 2011). Such analyses are most commonly used in the fields of psychology or social psychology, ethnographic kinship analysis or other genealogical studies of relationships between individuals.

Ego density refers to the extent to which the alter organizations are linked to one another. Ego network density divides the total number of actual ties present by the number of possible ties. It depicts connectedness and cohesion within local structures. Degree centrality is defined as the number of links incident upon a node (i.e. the number of ties that a node has). Closeness centrality is the distance of an actor from all other actors in a network. Between centrality considers whether the actor is positioned on the shortest path between other pairs of actors in the network. These measures and their further elaboration into relevant statistics have conveniently been combined in the software package UCINET developed by Freeman and colleagues since the 1980s (Bonacich, 1987; Borgatti et al, 2002; Otte & Rousseau, 2002). A number of visualization programs for networks, such as Pajek and Mage, interface with UCINET. The visualization process and the statistics have become increasingly integrated. A structural hole is a relationship of non-redundancy between two contacts. Constraint is essentially a measure of the extent to which ego is invested in people who are invested in other alters of the ego (Burt, 2004).

## 3. DERIVATION OF RESEARCH HYPOTHESES

### *3.1 Hypotheses concerning horizontal specialization*

According to contingency theory, if the management environment is complicated, an organization will become diversified and organic; according to product architecture theory, the degree of divergence of an organization and the interface specification of each component that constitutes a product or a business process are related. A question here is whether the architecture of a pharmaceutical product is close to that of a modular style, like an electronic computer, or to an integral style, like a motorcar.

The business process style of the development of new drugs among pharmaceutical manufacturers is changing from a vertically integrated approach to an outsourcing model involving external companies. The cases in which biotechnology ventures have given rise to research processes, such as the finding of a new chemical compound, have increased. Moreover, outsource companies – contract research organizations and site management organizations – have taken on responsibility for development

processes such as clinical trials, which verify toxicity testing and the influence on the human organism. Furthermore, a contract manufacturing organization can take charge of production and a contract sales organization can take charge of marketing to hospitals and so on. Thus, there has been considerable progress in the horizontal specialization of the pharmaceutical manufacturing business process.

Based on the above, it can be said that the business processes for the development of new drugs are quite open and they are modularized. If it is assumed that the modular style fits the business processes for the development of new drugs temporarily, it is desirable to select and specialize in only some of processes that have an advantage for the company. The firm should cooperate with other companies as much as possible, rather than integrating various business processes within the company. With regard to the selected processes over which the company takes charge, the strategic goal is to form a strong industry horizontal platform by carrying out the intensive investment of resources more thoroughly. As competitive advantage is increased over a competitor by forming such a platform, more advantageous cooperation can be performed with the company which takes charge of other processes.

According to the previous research on open innovation, the R&D of pharmaceutical products is one of the industries in which open innovation is pioneering. In R&D, if it is assumed that the product architecture of a pharmaceutical product is close to a modular style, the company should not depend solely on innovation undertaken in one company. An open innovation strategy that exploits the innovation of various external companies fits well in the pharmaceutical industry. Moreover, it is desirable to supply and obtain revenue from the results of research that cannot be utilized in one company from an external company.

Based on the previous research on utilization and pursuit strategies, in current R&D, the skill employed in the utilization strategy plays an important role. Also, in the R&D of a pharmaceutical product, it is thought that the greatest chance for success and the generation of knowledge from R&D can be gained by the expansion of a utilization strategy rather than a pursuit strategy on the part of the company.

The following hypothesis can proposed from the above discussion:

Hypothesis 1: To promote the development of new drugs, having a broad network and engaging in positive participation in a community is useful.

### *3.2 Hypotheses concerning vertical integration*

According to previous research on the relationship between the research process and the development process, effects such as the cost reduction from communication or the shortening of lead times can be expected by integrating both processes. A biotechnology venture is an organization which primarily takes charge of the research process. By close cooperation with a pharmaceutical manufacturing company, which takes charge of the development process, the accumulation of the pharmaceutical manufacturer's abundant experience can be used and research may be promoted efficiently. Moreover, one of the objectives in the development of new drugs is to reduce the lead time from seed funding to the launch. Another important consideration is the lengthening the time period from the launch of a new medicine to the generic drug launch when the patent expires; this is in order to recover a large amount of the investment in R&D and to expand revenue. Therefore, for the growth of a biotechnology venture it may be useful for that venture to exchange information with a pharmaceutical manufacturer intensively from the early stage of the research process and to do a conformance test on the pharmaceutical manufacturer’s strategy.

Based on previous studies on exploration or exploitation and absorptive capacity and integration capability, it is apparent that an organizational capability is accumulated in the relationship between organizations. The development of new drugs generally takes a long period of time (10 to 15 years) from the early stages of research to the launch of a pharmaceutical product and the development of new drugs is a very uncertain operation – less than 1% of the early results of research become a finished product and almost all research leads to failure. Therefore, to tackle such long-term issues and address the uncertainty hanging over organizations, it may be desirable for the long-term relationship

to be fiduciary based, a relationship which permits such ambiguity.

According to previous research on the supplier system or intermediate organizations, we obtain a hypothesis concerning the sense of distance between organizations in R&D. In the case of a complicated artificial structure, such as a motor car, the inter-organizational relationship between the car manufacturer, which manages the whole supply chain, and the supplier, which offers components or technology, is neither completely unified nor completely separate and modular. In fact, interim inter-organizational relationships that carry out cream-skimming from both extremities have a competitive advantage.

If this relationship is transposed onto the relationship between a biotechnology venture and a pharmaceutical manufacturer, it may be a relationship in which the biotechnology venture is closely concerned with the R&D process within a particular pharmaceutical manufacturer; useful information exchange is carried out and a fiduciary relationship is also developed. It may be a relationship by means of which a considerable amount of free R&D activity on the part of the biotechnology venture is also collateralized simultaneously. As the venture business is outside the pharmaceutical manufacturer's organization, it may naturally be exposed to a competition and it may also stimulate venture growth. Such as relationship may be ideal for the growth of a biotechnology venture that is engaged in high-risk long-term R&D in that research can be undertaken with a high degree of freedom whilst it maintains a long-term relationship.

Until now, previous research has suggested that lightweight product management is suitable for the R&D of pharmaceutical products, in contrast to the situation outlined above. As conventional low-molecule pharmaceutical products have a simple product architecture, serious activity was necessary until the molecular structure was discovered, but the development or the manufacturing process following discovery was not so complicated. Therefore, rather than organizational effort, it may have been thought that trial and error on the part of an individual in the research process was the source of an enterprise's value. However, as has set out above, in the biomedical R&D process, especially today, the management of a long-term and uncertain process with the involvement of many external organizations is very much required. Thus, in the development of biomedicine, organizations should now rather consider whether the heavyweight product management is better fit for purpose.

Drawing on the above discussion, the following hypothesis can be proposed:

Hypothesis 2: To promote the development of new drugs, individual long-term relationships with various external organizations need to be built.

## 4. RESEARCH METHOD

The main objectives of this research do not entail psychological measures, such as questionnaire scale items, but quantitative analysis based on actual data concerning inter-organizational relationships in open innovation. Thus, social network analysis was chosen as the quantitative method for the analysis of inter-organizational relationships, using patent application data and performance data, as outlined below.

### *4.1 Data for analysis*

The data on open innovations were extracted from the patent database. In the case that the patent owner or assignee was a plurality, it was assumed that a partnership had been formed to undertake the open innovation. Joint application patents were extracted and classified according to the combination in the joint application. An adjacency matrix was created so that it might be applied to the software for social network analysis. The database used to collect patent information was Thomson Reuters Cortellis (Report Type: Patent). The top ten pharmaceutical companies in Japan were chosen for analysis: Takeda Pharmaceuticals, Otsuka Pharmaceutical, Astellas, Daiichi Sankyo, Eisai, Sumitomo Dainippon Pharma, Chugai, Tanabe Mitsubishi, Shionogi and Kyowa Hakko Kirin. In the case of mergers, all the names of the old company were transposed to that of the new company.

As already noted, the R&D of pharmaceutical products is a lengthy process and there is usually a long period between a patent application and the sale of a product. Thus, in this research, the time lag was set to five years. Specifically, data were extracted on patent applications from the fiscal year 2004 to the fiscal year 2008. In terms of firm performance, the financial data used were the amount of sale, business profit and R&D expenses for the period 2008–2013.

*4.2 Tools of analysis*

As mentioned above, the main hypothesis concerns the optimal inter-organizational relationship in open innovation, i.e. whether a 'broad' relationship is desirable or a 'deep' relationship. It is thought that the 'breadth' of an inter-organizational relationship can be measured by the number of partners. Of the indicators used in social network analysis, those used here for 'breadth' were degree centrality (standardization index) and closeness centrality (Freeman index). The 'depth' of an inter-organizational relationship is the concentration of a relationship with a specific partner and the indicator used in this study was ego network density. In addition, to take account of the weak tie hypothesis (bridge effect) in network analysis, the presence of structural holes (constraint) was measured. The network analysis software employed was UCINET.

## 5. VERIFICATION RESULTS AND DISCUSSION

Correlation analysis was conducted between each indicator in the output of UCINET and the financial results and the number of patent applications. The number of patent applications is a direct indicator of R&D. The results of the correlation analysis are shown in Table 1.

| Indicator | Sales amount/ R&D expenditure | Business profit/ R&D expenditure | Number of patent applications |
|---|---|---|---|
| Degree centrality | -.273 | -.288 | .935** |
| Closeness centrality | -.257 | -.378 | .776** |
| Ego network density | .775** | .531 | -.538 |
| Structural hole – constraint | .280 | -.176 | .013 |

Table 1. Results of correlation analysis (Note: ** indicates significance at the 1% level.)

From the results shown in Table 1, it is apparent that centrality – an indicator of breadth in open innovation – is correlated with the number of patent applications. On the other hand, density – an indicator of depth – is correlated with the operational efficiency of the expenditure on R&D. The bridge effect (structural holes) is correlated with none of the organizational measures.

These results show that broad open innovation with various players can be considered to contribute to a greater number of patents. Multiple linear regression analysis was used to ensure that the correlation was not spurious, mediated by the size of the firm: the analysis confirmed that the number of patent applications is a direct indicator of R&D. However, the number of patent applications in a broad relationship is not efficiently linked to either product launch or financial gain. On the other hand, R&D expenditure on pharmaceutical products can be linked effectively to product launch and financial gain through open innovation by cooperating in depth with a specific player.

An implication of this is that when the phases of development of new drugs differ, the effective roles required for open innovation may also differ. In the phase from discovery to patent application, encounters with various partners may provide opportunities in terms of discovery. On the other hand, in the phase in which a product is manufactured, it is necessary to collaborate over a very long period of time in the highly uncertain process peculiar to the development of pharmaceutical products.

Therefore, an accumulation of experience in cooperation and a mutual fiduciary relationship may improve productivity. These findings coincide with those of our earlier research (Isada & Isada, 2013), based on a survey of biotechnology ventures.

As case studies, Kyowa Hakko Kirin and Otsuka Pharmaceutical showed that the depth of inter-organizational relationships improves financial performance. In terms of a business model of pharmaceutical companies, these companies can be classified as speciality pharmaceuticals. The speciality pharmaceuticals model is one which narrows a product domain and concentrates resources on the business. On the other hand, Takeda Pharmaceuticals shows an increased number of patents through broad cooperation, but no link to financial performance. Making a comparison, for a drug manufacturing company to improve the financial productivity of R&D through open innovation, it may not be desirable to increase the number of partners excessively and to pursue an expansion in terms of scale or span. Rather, concentrating on the strong area of the company and engaging in deep cooperation with a specific partner may improve productivity. In addition, it appears that the development managers of drug manufacturing companies who undertake open innovation need the power and capability to build close relationships with an external company. Based on the results obtained here, hypotheses 1 and 2 were partially verified.

## 6. CONCLUSION

The aim of this research was to demonstrate a cause–effect relationship in terms of the mode of inter-organizational relationships and the results of research and development through open innovation for the pharmaceutical industry. In various previous studies on the development of new drugs, conclusions regarding the effects of open innovation have not necessarily been coherent. This study makes a contribution in verifying quantitatively that the depth and breadth of inter-organizational relationships could have a serious influence on the success or failure of an open innovation.

In terms of the implications of this research, the findings can contribute to managerial decisions in pharmaceutical companies which practise open innovation. As for the limitations of this research, as the object of analysis is limited to Japanese pharmaceuticals, it is possible that the results are specific to the management environment and conditions peculiar to Japan. Future research might include comparative study using an international sample.

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