21 The Effects of the Strength of Intellectual Property Rights Protection on Cooperative R&D between Vertically Related Firms

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This study considers two vertically related industries, intermediate goods producers and final goods producers, and makes an economic theoretical investigation of the effect that the strength of the protection of intellectual property rights (IPRs) has on cooperative R&D between final goods producers and intermediate goods producers. The focus is on the effects of IPRs on vertical cooperative R&D as strengthened IPR protection reduces the degree of R&D spillover. R&D spillover is the use of technology and knowledge by parties other than the inventor without payment of remuneration. The results supported the following conclusions. Vertical cooperative R&D promotes technological improvement regardless of the effectiveness of IPRs at ensuring the appropriability of the technology. However, when IPR protection is strong, R&D investment in vertical cooperative R&D may be excessive from the perspective of social welfare and joint profits of all firms in the two vertical industries. This means that when IPR protection is strengthened, conducting vertical cooperative R&D does promote technological improvement, but does not necessarily increase the joint profits and social welfare.

1 Introduction of this research

The purpose of this research is to investigate the impact of the strength of protection of intellectual property rights (IPRs) on cooperative R&D between vertically related firms using an economic theory approach. A vertical relationship between firms refers to the relationship between a producer of final goods that are sold to consumers and a producer of intermediate goods, such as components and materials required for production. For example, an automobile assembly manufacturer and an automobile parts manufacturer are vertically related firms.

The intellectual property (IP) system is a system that grants an exclusive right for use of technology in exchange for making the technology public. However, protection by an IPR is not perfect, and it is difficult to take exclusive possession of all benefits gained from the technology. The degree of appropriability afforded by an IPR depends on the strength of IPR protection. The strength of IPR protection is not simple, but involves various factors including the technical scope subject to protection, the length of the term of protection, and ease of enforcement (ease of demanding an injunction or claiming damages, the degree of penalties for infringement). Meanwhile, technologies outside the scope of IPR protection and know-how are also often useful for development of new products or new processes and bring benefits to other firms. Such a situation where technology or knowledge developed through R&D, whether or not protected by an IPR, is used by parties other than the inventor without payment of remuneration is called R&D spillover. R&D spillover occurs, for example, in the following five cases. The first is when a patented technology is published, other firms develop similar technologies that do not conflict with the patent right. These are called circumventing inventions. For the second case firms can learn about other firms' technology and knowledge by reverse engineering, meaning disassembling and studying new products. The third case occurs when research results published at an academic meeting or in a research paper serve as reference material for researchers of other firms. The fourth case occurs when intermediate goods users can utilize intermediate goods that embody other users' technology and knowledge by purchasing such intermediate goods as components and materials. The fifth type of spillover occurs when a researcher changes jobs and contributes to the new firm by using abilities developed at the previous firm. The degree of such R&D spillover will decline if IPR protection is strengthened. Therefore, this research focuses on the impact that the strength of IPR protection has on vertical cooperative R&D through changes in the degree of R&D spillover, and develops discussions based on the idea that the degree of R&D spillover declines if IPR protection is

strengthened[*1]. R&D spillover can be divided into four types: horizontal spillover between final goods producers; horizontal spillover between intermediate goods producers; vertical spillover from a final goods producer to an intermediate goods producer; and vertical spillover from an intermediate goods producer to a final goods producer. It is often pointed out that a close relationship between the final goods producer and intermediate goods producer is extremely important for success in technology innovation. For the intermediate goods producer, learning the needs of the final goods producer is useful for developing and producing components and materials. On the other hand, for the final goods producer, information on new components and materials is useful for introducing new intermediate goods at an early stage. Therefore, vertical spillover is likely to occur between a final goods producer and an intermediate goods producer that trade intermediate goods.

Cooperative R&D is most frequently observed between a final goods producer and an intermediate goods producer. This is because objectives and interests tend to coincide better between vertically related firms than between firms competing in a product market. Implementation of vertical cooperative R&D involves profits and risks. A final goods producer and an intermediate goods producer can internalize the externalities of vertical R&D by making decisions on R&D in concert, and can avoid redundant R&D by sharing useful knowledge. At the same time, the firms participating in vertical cooperative R&D fear horizontal spillover to rival firms, as well as the risk that rival firms will obtain a free ride by trading for intermediate goods from the R&D counterpart based on the R&D knowledge from the firm.

This research first theoretically analyzes the effects of vertical cooperative R&D in a case where R&D spillover occurs. Then, based on the analysis results, it examines the impact of the strength of IPR protection on vertical cooperative R&D.

2 Basic model

Section 2 introduces the basic model for theoretically analyzing the effects of vertical cooperative R&D in a case where R&D spillover occurs. Two industries having a vertical relationship are assumed. In each industry, there are two symmetric firms. Symmetric firms are firms that have the same cost structure for R&D and production. The firm in the downstream industry will be called a downstream firm and that in the upstream industry will be called an upstream firm. Both upstream firms produce an intermediate good that are required for producing a final good, and sell it to the downstream firms in the market. Both downstream firms produce the final good using the intermediate good, and sell it to consumers. The downstream firms use one unit of the intermediate good to produce one unit of the final good. The respective downstream firms are assumed to purchase the same quantity of the intermediate good from both upstream firms.

Firms conduct R&D in order to reduce the marginal production cost. The marginal production cost is the additional cost required for increasing the output level by one unit. R&D investment reduces the marginal production cost through an increase in the firm's knowledge stock. The knowledge stock includes technologies and information that are useful for reducing the marginal production cost. Since the respective downstream firms equally trade the intermediate good with both upstream firms, the same degree of spillover is assumed to occur from both downstream firms to both upstream firms, and the same degree of spillover is assumed to occur from both upstream firms to both downstream firms. Technologies of the rival firm are assumed to be beneficial knowledge, which is useful for accumulating knowledge stock, for the respective firms. This assumes a case in which firms in the same industry own different expert knowledge. The knowledge owned by the respective firms includes information that is required for efficiently developing and producing the intermediate good and the final good. This information is useful for R&D conducted by firms in vertically related industries.

(*1) There is also a contrasting idea that stronger IPR protection increases the degree of R&D spillover. This concept is based on an assumption that stronger IPR protection will, for example, increase the number of patented, published technologies, and promote new technology development inspired by those technologies. Indeed, this mechanism is also important considering the impact of IPRs. However, while stronger IPR protection may increase the number of published technologies, it may not necessarily promote creation of useful technologies (such as basic technologies) that will widely contribute to future technology innovations and increase the number of such patents. Moreover, the analysis will have to be dynamic (intertemporal analysis) and will involve extremely complicated models, if such a mechanism is also taken into consideration. Accordingly, this research will not consider the mechanism in which stronger IPR protection increases the degree of R&D spillover.

The firms compete in three stages. In the first stage, the firms forecast the equilibria of the second stage and the third stage, and strategically decide the level of R&D expenditure. In the second stage, upstream firms compete in the output level of the intermediate good (Cournot quantity competition). In the third stage, downstream firms compete in the output level of the final good, similar to the competition in the second stage.

Initially, two scenarios are assumed for firm behavior in the first stage. In the first scenario the respective firms conduct R&D without cooperating with the other firms. In this scenario, firms decide the level of R&D expenditure non-cooperatively so as to maximize their own profits. Such a mode of R&D will be called non-cooperative R&D. For the second scenario the firms in vertically related industries decide the level of R&D expenditure in concert. In this scenario, the downstream firm i and the upstream firm $i(i=1,2)$ decide the level of R&D expenditure so as to maximize the joint profits of both firms. Since the decisions on R&D are made in concert, this type of cooperative R&D will be called a vertical R&D cartel.

3   Equilibrium

Section 3 characterizes the equilibrium of the model introduced in Section 2. The three-stage game introduced in the previous section will be solved by backward induction, using subgame perfection as the equilibrium concept. Specifically, the equilibrium solution of this game is obtained by the following method. First, the equilibrium solution of the third stage (i.e., the optimum output level for the downstream firm) is obtained with the level of R&D expenditure chosen in the first stage and the output level of the intermediate good chosen in the second stage as given conditions. Then, the equilibrium solution of the second stage (i.e., the optimum output level for the upstream firm) is obtained based on the equilibrium of the third stage. Finally, the equilibrium solution of the first stage (i.e., the optimum R&D expenditure) is obtained based on the equilibria of the second and third stages.

After indicating the equilibrium outputs of the downstream firms and upstream firms in the second and third stages, the requirements met by the equilibrium R&D expenditure of the firms in the first stage are shown, both for non-cooperative R&D and a vertical R&D cartel. It is also demonstrated that an increase in the respective firms' R&D expenditure will increase the profits of the vertically related firms.

4   Comparison of equilibrium results

Section 4 compares the equilibrium results between non-cooperative R&D and a vertical R&D cartel. As a major result of this comparison, the section indicates that a firm's knowledge stock will be larger for a vertical R&D cartel than for non-cooperative R&D. In the model used in this study, a larger knowledge stock reduces the production cost, so technological improvements are likely to be promoted in such a case.

The reason that a vertical R&D cartel achieves higher technological improvement than non-cooperative R&D can be explained as follows. The R&D expenditure, which reduces the production cost for the respective downstream firms (respective upstream firms), not only expands the demand (supply) of the intermediate good, but also reduces the production cost for both upstream firms (both downstream firms) through vertical spillover. Therefore, it always has the effect of increasing profits for both upstream firms (both downstream firms). When conducting a vertical R&D cartel, firms spend a larger sum for R&D than when conducting non-cooperative R&D. As a result, a vertical R&D cartel has a larger effect of promoting technological improvement than non-cooperative R&D.

5   Vertical research joint ventures

Section 5 analyzes vertical research joint ventures as one mode of vertical cooperative R&D. Research joint ventures are cooperative R&D conducted by multiple firms through the establishment of an independent firm or research institute. The advantage of research joint ventures is that firms can avoid redundant R&D. By participating in a research joint venture, a firm will be required to provide its knowledge to the other participating firms for free, but it will be able to freely use the knowledge owned by the other participating firms. This study will focus on this point, and will call the sharing of knowledge that is useful for R&D among firms in vertically related industries a vertical research joint venture. A vertical research joint venture will be hereinafter referred to as a vertical RJV.

Two vertical RJV scenarios will be assumed as firm behaviors in the first stage. One is a case where a downstream firm i and an upstream firm i ($i=1$, 2) share all useful knowledge in order to avoid redundant R&D, but do not cooperate in deciding the level of R&D expenditure. Such cooperative R&D will be called a vertical RJV. The other is a case where a downstream firm and i an upstream firm i ($i=1$, 2) share all useful

knowledge as well as cooperate in deciding the level of R&D expenditure. Such cooperative R&D will be called a vertical RJV cartel. The non-cooperative R&D, vertical R&D cartel, vertical RJV, and vertical RJV cartel are all modes of R&D organization that can be adopted between vertically related firms, so they will be collectively called vertical R&D organizational modes in this analysis.

The characteristics of the equilibria are investigated for a vertical RJV and a vertical R&D cartel, and vertical R&D organizational modes are compared in terms of equilibrium knowledge stock and equilibrium joint profits. This comparison gave two results. A vertical RJV and a vertical RJV cartel increase the firms' knowledge stock and promote technological improvement. A vertical RJV cartel achieves the highest technological improvement and brings about the largest social welfare among the vertical R&D organizational modes, but it may not necessarily produce the largest joint profits that total the profits of all firms in the two vertically related industries (hereinafter referred to as the "joint profits").

A vertical RJV and a vertical RJV cartel have two opposite effects on R&D incentives. A downstream firm (upstream firm) participating in certain vertical RJV or vertical RJV cartel has stronger incentives for R&D investment, because it gains useful knowledge from the R&D counterpart. On the other hand, provision of knowledge to the R&D counterpart promotes production of rival firms through an increase in supply (demand) of the intermediate good, so it weakens the R&D incentives of this downstream firm (upstream firm). However, since the former direct, positive effect that vertical knowledge sharing has on R&D incentives is larger than the latter indirect, negative effect, a vertical RJV and a vertical RJV cartel promote technological improvement.

There are cases where high R&D incentives of the firms participating in a vertical R&D cartel depend on the degree of spillover and are not desirable from the viewpoint of joint profits and social welfare. If expenditure is marginally increased from the level of R&D expenditure paid by firms in a vertical RJV cartel when the degrees of horizontal and vertical spillovers are high, it not only eases the inefficiency of under-production caused by high market price, but also the inefficiency of under-investment caused by free-riding of knowledge. As a result, joint profits and social welfare will increase. On the other hand, if expenditure is marginally increased from the level of R&D expenditure paid by firms in a

vertical RJV cartel when the degrees of horizontal and vertical spillovers are low, the inefficiency of under-production is alleviated, but there is deterioration of the unprofitability of over-investment caused by efforts to win a high market share. As a result, joint profits decrease, but since the former easing effect is larger than the latter deteriorating effect, social welfare increases. Therefore, a vertical RJV cartel brings about the largest social welfare among the vertical R&D organizational modes because it achieves the highest technological improvement, but it may not necessarily produce the largest joint profits.

6 Vertical cooperative R&D and market concentration

Section 6 investigates the effects of vertical cooperative R&D by generalizing the model to two vertically related industries where there are n ($1 \leq n < \infty$) symmetric firms in each industry, in order to investigate the influence of the number of firms. In economics, a large number of studies have been made to verify the Schumpeter hypothesis, which hypothesizes that R&D is more actively conducted in a more concentrated market (i.e., a market with fewer firms) with regard to the relationship between market concentration (i.e., the number of firms that exist in a market)－a major indicator for the market structure－and R&D. The reason for anticipating a positive correlation between market concentration and R&D is that a firm that makes higher profits and has more internal funds is considered to be more capable of conducting R&D, because it is difficult to procure outside funds for R&D involving high uncertainties and risks.

It is assumed that n symmetric firms ($1 \leq n < \infty$) exist in both the downstream industry and upstream industry. The model is the same as the basic model in Section 2 except for the number of symmetric firms in the respective industries. Similar to the previous sections, four scenarios are assumed as firm behaviors in the first stage. The first scenario is a case where R&D is cooperatively conducted. In this case, the respective firms decide the level of R&D expenditure without cooperating with the other firms so as to maximize their own profits. The second scenario is a case where vertical R&D cartels are conducted. In this case, the downstream firm i and the upstream firm i ($i = 1, \cdots, n$) cooperatively decide the level of R&D expenditure so as to maximize the joint profits of both firms. The third scenario is a case where vertical RJVs are conducted. In this case, the downstream firm i and the upstream firm i ($i = 1, \cdots, n$) share useful knowledge for R&D, but do not cooperate in

deciding the level of R&D expenditure. The last scenario is a case where vertical RJV cartels are conducted. In this case, the downstream firm i and the upstream firm i ($i=1,\cdots,n$) share useful knowledge for R&D as well as cooperatively decide the level of R&D expenditure. When conducting vertical R&D cartels, vertical RJVs, and vertical RJV cartels, the number of vertical cooperative R&D projects will be n.

As a result of analyzing the model of industries with n symmetric firms, the following findings, which differ from those of a model of industries with two symmetric firms, were derived. When there are two symmetric firms in the respective industries, a vertical RJV cartel always brings about the largest social welfare among the vertical R&D organizational modes. However, if there are three or more symmetric firms in the respective industries and no spillover occurs, a vertical RJV cartel may not necessarily bring about the largest social welfare. The reason is as follows. If the number of firms in the respective industries increases, market competition will be intensified, so the market prices will decline and the output levels will increase. In other words, an increase in the number of firms has an effect of easing the inefficiency of under-production. Thus, if expenditure is marginally increased from the level of R&D expenditure paid by firms in a vertical RJV cartel when there are three or more firms in the respective industries and no spillover occurs, it lessens the unprofitability of over-investment more than it eases the inefficiency of under-production. As a result, social welfare will decrease. Therefore, since a vertical RJV cartel achieves the largest technological improvement even when n firms exist in the respective industries, if three or more firms exist in the respective industries and no spillover occurs, a vertical RJV cartel may not necessarily bring about the largest social welfare among the vertical R&D organizational modes.

7   Vertical R&D consortium

Section 7 analyzes the vertical R&D consortium conducted among all firms in two vertically related industries, and compares it with the vertical RJV cartel, which promotes technological improvement the most among the vertical R&D organizational modes. An R&D consortium is generally cooperative R&D conducted by the entire industry through the establishment of a firm or research institute. An R&D consortium is different from a research joint venture in that the R&D is conducted by the entire industry. The largest advantage of the R&D consortium is the ability to internalize the

externalities of technologies within the industry on potential beneficiaries and imitators. Therefore, an R&D consortium is often conducted for basic research or technology standardization, which involves large externalities. This research assumes a vertical R&D consortium in which not only rival firms in the same industry, but all firms in two vertically related industries participate.

This section uses the model of industries with n symmetric firms that was used in Section 6. The following first stage scenario is assumed for a case where a vertical R&D consortium is conducted. All firms in two vertically related firms (i.e., n downstream firms and n upstream firms) share useful knowledge for R&D and cooperatively decide the level of R&D expenditure so as to maximize the joint profits of all firms.

This section indicates that, irrespective of the degree of spillover, a vertical R&D consortium will promote technological improvement more and bring about larger joint profits and social welfare than a vertical RJV cartel. When a vertical R&D consortium is conducted, useful information is provided not only by vertically related firms, but also rival firms, so firms can accumulate the same level of knowledge stock at a lower cost than conducting a vertical RJV cartel. On the other hand, each firm's R&D expenditure will have an effect of increasing the profits of rival firms, because useful information will be provided to rival firms as well. In a vertical R&D consortium, however, all firms cooperatively decide the level of R&D expenditure, so such positive horizontal R&D externalities can be internalized. Therefore, a vertical R&D consortium increases the R&D expenditure more and achieves higher technological improvement than conducting a vertical RJV cartel. The R&D expenditure paid by firms in a vertical R&D consortium maximizes the joint profits, since the level of R&D expenditure is cooperatively decided by all firms. Therefore, when conducting a vertical R&D consortium, there is no inefficiency of under-investment or over-investment, though there is inefficiency of under-production. Accordingly, a vertical R&D consortium brings about more joint profits and social welfare than a vertical RJV cartel, because it promotes technological improvement more.

8   Discussions

Section 8 presents four conclusions as the impact of the strength of IPR protection on vertical cooperative R&D based on the analysis

results in the previous sections. First, vertical cooperative R&D promotes technological improvement irrespective of the validity of IPR on securing the appropriability of technology. This is because vertical cooperative R&D promotes technological improvement better than non-cooperative R&D, irrespective of the degree of spillover. When the IPR protection is weak, technological improvement is likely to be promoted by the R&D promoting effect of the vertical cooperative R&D, and when the IPR protection is strong, technological improvement is likely to be promoted even more due to the R&D promoting effects of the IPR and the vertical cooperative R&D.

Secondly, when IPR protection is strong, R&D investment in vertical cooperative R&D may become excessive from the perspective of joint profits and social welfare. This is because while a vertical RJV cartel achieves the highest technological improvement among the vertical R&D organizational modes, R&D investment in a vertical RJV cartel becomes excessive from the perspective of joint profits if the degree of spillover is low, and it becomes excessive from the perspective of social welfare if there are three or more firms in the respective industries and no spillover occurs. When IPR protection becomes stronger, R&D competition becomes intensified over the appropriability of technology. Moreover, if the number of firms within the respective industries increases, firms have a stronger inducement for R&D in order to capture the market from rival firms. Because of this, if IPR protection becomes stronger, R&D investment in vertical cooperative R&D may become excessive from the perspective of joint profits and social welfare.

Thirdly, if IPR protection is strong, vertical cooperative R&D may not necessarily increase joint profits and social welfare. This is attributable to the second conclusion. In other words, if R&D investment in vertical cooperative R&D becomes excessive from the perspective of joint profits and social welfare, vertical cooperative R&D may lower joint profits and reduce social welfare due to the inefficiency of this over-investment. Therefore, if IPR protection is strengthened, vertical cooperative R&D will promote technological improvement, but it may not bring benefits to firms or society. Because of this, the benefits of the pro-patent (patent-strengthening) policy would also be affected by whether or not vertical cooperative R&D is conducted and the status of market competition. IPRs do not only induce R&D, but also affect technology trading and the product market, so the IP system needs to be developed

in coordination with competition policy and industrial policy.

Fourthly, a vertical R&D consortium is beneficial both for the firms and consumers irrespective of the validity of IPRs on securing the appropriability of technology. This is because a vertical R&D consortium promotes technological improvement better and brings about larger joint profits and social welfare than conducting a vertical RJV cartel, which achieves the highest technological improvement in the vertical R&D organizational modes, irrespective of the degree of spillover. However, one must be careful about this result. Since rival firms also participate in a vertical R&D consortium, there is a risk that participating firms may be induced to free-ride on the technology of other participating firms without disclosing their own technology, or incentives for ardent engagement in R&D may be reduced due to lack of R&D competition. The analysis results may change if these effects are taken into consideration.

9 Conclusion

This study theoretically analyzed the impact that the strength of IPR protection has on vertical cooperative R&D through changes in the degree of R&D spillover. Three major results were obtained. Firstly, vertical cooperative R&D promotes technological improvement irrespective of the validity of IPRs on securing the appropriability of technology. Secondly, if IPR protection is strong, R&D investment in vertical cooperative R&D may become excessive from the perspective of joint profits of all vertically related firms and social welfare. Thirdly, as a result of the second result, if IPR protection is strong, vertical cooperative R&D promotes technological improvement, but it may not necessarily increase the joint profits of all vertically related firms and social welfare.

The results of this research indicate that, if IPR protection is strengthened, vertical cooperative R&D will promote technological improvement, but it may not necessarily bring benefits to the firms or society. Thus, the benefits of the pro-patent (patent-strengthening) policy will also be affected by whether or not vertical cooperative R&D is conducted and the status of market competition. In addition, since IPRs not only induce R&D, but also affect technological trading and the product market, the IP system needs to be developed in coordination with competition policy and industrial policy.

The above conclusion may rely on the following four points. The first point is that the

size of the final good market and the intermediate good market as well as the productivity of R&D (the R&D capacity of a firm) were considered as exogenous variables (given conditions) in the analysis models. These factors affect the efficiency of a firm's production and R&D. The second point is that the analysis models assumed that the firms of the respective industries competed not in price but in output level. This point should be noted, because price competition often derives results that are essentially different from production competition. The third point is that this research did not address the issue of whether or not firms will conduct vertical cooperative R&D. It would be necessary to consider the issue of profit distributions between the downstream firm and the upstream firm when conducting vertical cooperative R&D. The fourth point is that, while firms may license their technology to other firms, the analysis models did not take firms' licensing activities into consideration. Analysis of these factors will be considered in future research.

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