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The Consortium Standard and Patent Pools[1)]

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1. Introduction

In this paper we examine the current practices of a patent pool that is part of a consortium standard. A consortium standard is a collaborative venture of firms to promote a new technical standard. It can eventually be adopted by national or international standard setting bodies (a *de jure* standard) or become the *de facto* standard after winning the competition with other possible standards. A collaborative approach to standardization has become essential in the information and communication technology areas where speed of innovation and the world wide reach of the technologies have made compatibility and early establishment of a standard critical. Consortium standard is distinguished from a standard sponsored by a single firm in the following two respects. First, it involves multiple firms with different interests. Second, it often adopts open licensing policy through its commitment to standard bodies such as ITU and ISO. Since a majority of the recent standards involve proprietary technologies, patent pools have become an essential feature of consortiums. We look at the two sides of a patent pool : interactions among members and with users of the technology. A list of recent prominent consortiums is provided in Appendix 2.

Since such a consortium often involves collaboration among competitors, there is the question of how such collaboration can be designed to avoid becoming an anti-competitive device. The critical rule in this respect is whether it is for combining complementary patents or not (see Lerner and Tirole (2004) for the analysis of competition rules for a patent pool, such as the freedom of bypassing the pool). The Cournot effect (Shapiro (2001)) means it is socially beneficial to bundle complementary patents. Recognizing this fact, the U.S. antitrust authority has stated that a patent pool of essential patents are not anticompetitive[2)]. A patent is essential to a standard if the standard is not possible to implement without infringing it. Thus essential patents for a particular standard are always complementary, implying it is socially desirable to have the set of patents form a pools and be licensed as a bundle.

Bundling essential patents has additional dynamic beneficial properties. Bundling improves not only consumer welfare but also the competitive position of a consortium standard relative to the standard controlled by a single firm. (See Nalebuff (2000) for a potentially huge competitive disadvantage of uncoordinated pricing of complements.) Second, the joint profit of firms is larger when the patents are bundled, since the unbundled prices exceed the profit maximizing price. Thus return from R & D investment will be greater when patents are bundled.

In spite of these beneficial properties, such collaboration does not necessarily occur. An outsider of the patent pool can emerge, who does not join in the pool and licenses an essential patent independently from the pool. Although such a licensor may be still subject to the RAND (reasonable and non-discriminatory) conditions when it has participated in the standard development, his licensing term is not bound by the licensing policy of the patent pool. In the worst case, a "submarine" patent may emerge after the adoption of the standard. The outsider who suddenly surfaces can charge whatever the market bears, causing the hold-up problem in addition to double marginalization. Another possibility is that a patent pool for a single standard may split, so that a licensee must obtain licenses separately from two or more group of the patentees. In the case of the DVD patent pool, a firm must obtain at least two independent licenses, one each from the 3C group and the 6C group. Such breakdown of an integrated patent pool not only raises the total price to be paid by licensees but also reduces the joint profit of the patentees.

The question is why we see the emergence of an outsider and the split of the patent pool. In the next two sections we identify two major sources: free rider problem and bargaining failure due to heterogenous membership.

In Section 4 we focus on how a patent pool interacts with its users. In particular we examine the effectiveness of RAND as part of the consortium standard. Standard setting organizations which are willing to accommodate standards with non-free patents require the firms to commit themselves to licensing under RAND conditions (i. e., licensing under reasonable and non-discriminatory terms) for members of the organizations and often for the general public[3]. However, the economic rationale of RAND conditions has not been explicitly specified and there are many ambiguities on what they mean. We analyze whether non-discriminatory licensing ensures ex-post efficiency and whether there are any good grounds for the government (e. g., competition policy authority) to control the level of royalty.

2. The Free Rider Problem

First we introduce the basic framework. A firm that receives the licenses of all the patents necessary to implement the technology for royalty c_i for i-th patent will pay total of $\sum_i c_i$, Firm k's optimal output $q_k(\sum_i c_i)$ maximizes its profit[4]. That is, it solves,

$$\max_{q_k} q_k\left(P_k(q_k, q_{-k}) - \sum_i c_i - \gamma\right),$$

where γ is the non-license marginal cost and $P_k(q_k, q_{-k})$ is k's inverse demand function given other firms are producing $q_{-k}=(q_1,\cdots, q_{k-1}, q_{k+1},\cdots q_n)$[5] when there are n licensees in total. The total demand for licenses will be,

$$q\left(\sum_i c_i\right) = \sum_k q_k\left(\sum_i c_i\right).$$

Because the patents are essential, this is also the demand for any one of the essential patents as well as demand for the bundle if the patents are bundled. We assume that $q'<0$ and $q'+cq''\leq 0$. When the patents are priced as a bundle by the patent pool, demand for the bundle will be function of the single bundle price c_0 instead of $\sum_i c_i$.

The incentive to remain an outsider or split away from a pool can be illustrated using Figure 1 where c_0 represents the license royalty set by a pool and c_1 the royalty set by an outsider. The reaction curve $R_0(c_1)$ shows how the pool's profit $(c_0(q(c_1+c_0)))$ maximizing royalty changes as the outsider's royalty changes. Since $q'+cq''\leq 0$, it satisfies the first-order condition,

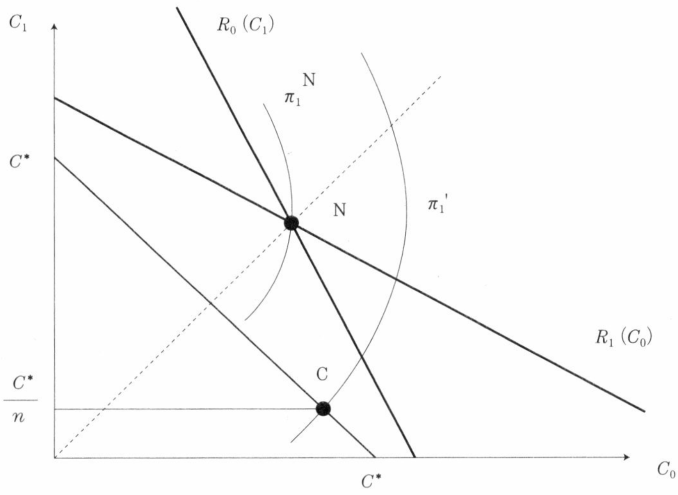
$$q(c_0+c_1)+c_0 q'(c_0+c_1) = 0. \qquad (1)$$

The reaction curve is negatively sloped since the patents are complementary. Similarly, the reaction curve $R_1(c_0)$ shows how the royalty of the outsider changes as the pool royalty changes. This satisfies

$$q(c_1+c_0)+c_1 q'(c_1+c_0) = 0. \qquad (2)$$

Since all patents (pool's and outsider's) are essential, two curves are entirely sym-

Figure 1. Patent Pool and Outsider



metric, irrespective of the relative number of the patents held by the pool and the outsider. The intersection is a Nash equilibrium (c_1^N, c_0^N) (Point N in Figure 1.), which gives the outsider and the pool equal revenues since $c_1^N = c_0^N$. The iso-profit curve for the outsider at the Nash equilibrium is denoted π_1^N.

If the outsider joins the pool, the new pool royalty c^* that maximizes pool revenue, $cq(c)$, satisfies the following first-order condition,

$$q(c^*) + c^* q'(c^*) = 0.$$

Equations (1) and (2) implies $q(c_1^N + c_0^N) + (c_1^N + c_0^N) q'(c_1^N + c_0^N) = c_0^N q'(c_1^N + c_0^N) < 0$ from which we have the Cournot effect,

$$c^* < c_1^N + c_0^N.$$

We can find the outsider's iso-profit curve when it becomes a pool member by identifying the appropriate point on the line $c_0 + c_1 = c^*$. If there are n members (including the outsider) in the pool, the relevant point is C where $c_1 = \frac{c^*}{n}$ since the outsider's share of pool revenue is $\frac{1}{n}$. The corresponding iso-profit curve is π_1' in Figure 1 (assumes $n \geq 3$). As a result of the integration of the outsider, royalty would fall and the joint profit would rise. However, if the pool's profit is distributed equally among its members, the profit of the outsider is most likely to fall significantly, especially when the number of the pool membership is large. (The point C moves south east along $c_1 + c_0 = c^*$ as n increases).

Thus, not joining the pool is profitable as a unilateral conduct. The disincentive for joining the pool increases as the number of complementary patents increases, since the profit share of a particular member of the patent pool declines while what it can collect as an outsider increases with the value of the standard[6].

The incentive to license independently as identified above is due to the free rider problem. Free rider problem arises when access to the good is not excludable, that is, it is a public good. In the case of a standard specification patent pool, the public good is not the technology, since they are patented and access to them can be controlled. The public good is the demand for the standard. The outsider which has an essential patent related to the standard does not need permission from the other suppliers of the standard technologies to impose royalty on the users of the standard technology. If the outsider is also a user of the standard technology, his access to the demand can be controlled indirectly through licensing policy of the pool members. That is, the pool members can demand reciprocity in licensing to the outsider firm. It is important to note that the DOJ explicitly allows such clause as a device to support the viability of a patent pool against outsiders in its business review letter. However, such a clause is not effective at all on those outsiders who are specialized in licensing with respect to that standard.

3. Heterogenous Membership

In this section we analyze the bargaining failure inherent in patent pools and explore possible solutions. Coalition formation literature has shown that even with open membership, the grand coalition may not form in equilibrium when there is asymmetry among firms (Belleflamme (2002)). We do note that the premises of his analysis is quite specific (firms are Cournot competitors and coalitions reduce marginal costs), not applicable to extent of asymmetry in our analysis. A simulation analysis by Axelrod *et. al* (1995) of the UNIX operating standard also suggests fragmentation from heterogeneity. Together with the Belleflamme result, we suspect a similar heterogeneity from preventing some firms to join the patent pool.

To demonstrate we extend the basic model to three types of firms that differ by vertical structure: insider manufacturing V-firm (vertically integrated firm), outsider manufacturing M-firm, and insider research R-firm. Insider means a firm in the patent pool, which collects specific royalty c from licensees. The patent pool has only 2 members, V and R firms, each of which has an essential patent. There are two licensees, V and M firms which produce very different products: each firm produces as a monopolist in respective separate but identical markets. This allows us to focus only on significance of vertical structure of firms[7]. Using the initial basic formulation, firm k's inverse demand is,

$$P_k(q_k, q_{-k}) = P(q_k),$$

for any k. When the (total) royalty is c, M-firm always produces the monopoly output when marginal cost is c, denoted $q_M(c)$.

Patent Pool and Independent Licensing

When there is a patent pool charging the bundle price c, V-firm chooses output q to maximize,

$$(P(q)-c)q+\frac{q+q_M(c)}{2}c.$$

Reorganizing, we get

$$\left(P(q)-\frac{c}{2}\right)q+\frac{q_M(c)}{2}c.$$

The V-firm produces as if the marginal cost were $\frac{c}{2}$. We denote the maximum profit achieved with $q=q_V(c)$ by $\pi_V(c)$.

When V- and M-firms are producing optimally given c, R-firm's profit is,

$$\pi_R(c) = \frac{q_V(c)+q_M(c)}{2}c.$$

The pool sets royalty to maximize pool revenue $c(q_V(c)+q_M(c))$. This also maximizes patent R-firm's profit.

When firms license independently, V-firm chooses c_V and q simultaneously to maximize its profit. It is equivalent to maximizing[8]

$$\pi_V = (P(q_M(c_R))-c_R)q_M(c_R) + q_M(c_V+c_R)c_V,$$

and R-firm chooses c_R to maximize

$$\pi_R = (q_V(c_R)+q_M(c_R+c_V))c_R.$$

This is a non-cooperative game where the firms choose royalty (firm's strategy) simultaneously.

The following proposition characterizes the relationship between royalty set by a patent pool and royalties set independently.

Proposition 1. *When c^*, π_R^*, π_V^* are the patent pool revenue maximizing royalty and profits, and $\hat{c}_R, \hat{c}_V, \hat{\pi}_R, \hat{\pi}_V$ are equilibrium royalties and profits when R- and V-firms set them independently, then*

(*i*) $c^* < \hat{c}_R + \hat{c}_V,\ \hat{c}_R > \hat{c}_V,\ \hat{c}_R > \frac{c^*}{2},$

(*ii*) $\hat{\pi}_R + \hat{\pi}_V < \pi_R^* + \pi_V^*,\ \hat{\pi}_V < \pi_V^*.$

The proposition is summarized in Figure 2. (The proof is in Appendix 1.) β_V and β_R are best-response correspondences and are downward sloping since the royalties are strategic substitutes. R-firm's response correspondence is steeper because its royalty effects outputs of both

M- and V-firms. V-firm only gets revenue from M-firm. Thus for the same increase of rival royalty, R-firms reduces its royalty less. Both firms charge the same royalty, c_m, if it were the sole licensor, equivalent to 0 rival royalty[9]. This implies the Nash equilibrium (point IE) must be under the 45 degree line ($c_R = c_V$), i. e., $\hat{c}_R > \hat{c}_V$. In addition, the sum of the royalties at point IE exceeds the pool revenue maximizing royalty, since each firm does not internalyze the negative spillover of its own royalty increase on each other (Cournot effect). This implies $c^* < \hat{c}_R + \hat{c}_V$.

Since R-firm's profit is proportional to that of the patent pool revenue, the highest level along 45 degree line is at c^* (as drawn in Figure 2). V-firm's profit decreases monotonically in total royalty along the 45 degree line and with rival royalty, c_R, along its own best-response correspondence. This implies $\hat{\pi}_V < \pi_V^*$. The sum of R-firm and V-firms profits is

$$(c_R + c_V)\, q_M(c_R + c_V) + P(q_V(c_R))\, q_V(c_R) \tag{3}$$

The first term is decreasing in total royalty in the relevant region and thus is higher with patent pool royalty c^*. The second term is also decreasing in c_R. Thus aggregate profit will be larger with patent pool royalty c^*. R-firm's profit may be higher or lower by licensing independently. In Figure 2, R-firm is better-off (as in the following case of linear demand). But the equilibrium IE may be on a lower iso-profit line. R-firm always has incentive to deviate from a patent pool but independent licensing may make it worse off.

Bargaining Failure

We investigate the relationship further by assuming the product market has linear demand $P(q) = 1 - q$. Profits with patent pool royalty c are,

$$\pi_V(c) = \frac{1}{4} - \frac{3c^2}{16}, \quad \pi_R(c) = \frac{c}{2}\left(1 - \frac{3}{4}c\right),$$

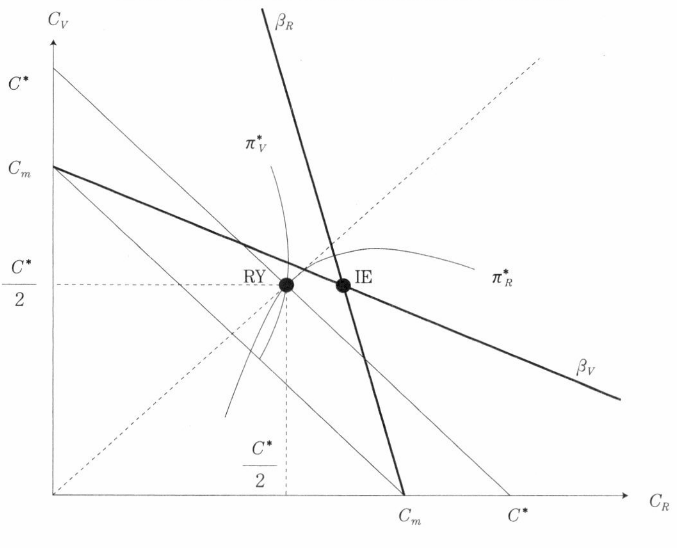
$$\pi(c) = \frac{1}{4} + \frac{c}{2} - \frac{9}{16}c^2,$$

where $\pi(c) = \pi_V(c) + \pi_R(c)$. Note that the V-firm has the same incentive as the M-firm in that it wants c to be as low as possible. Of course this will not be desirable for the R-firm. Although the R-firm would not like the royalty to be too high since it reduces demand, it finds its profit increasing in c when c is small. That is, $\pi_R(c)$ is increasing in c for $c \leq \frac{2}{3}$ and decreasing for larger c's.

We can highlight the trade-off by drawing a curve in (π_R, π_V) space by plotting $(\pi_R(c), \pi_V(c))$ for $0 \leq c \leq 1$. We will refer to this as the frontier (Figure 3). The frontier is on the vertical axis when $c = 0$ since $\pi_R(0) = 0$. Raising royalty benefits R-firm and hurts the V-firm. However the trade-off is not one to one because the V-firm will adjust output. It is downward sloping until $c = \frac{2}{3}$. Then it is upward sloping until the curve ends at $\left(\frac{1}{8}, \frac{1}{16}\right)$ corresponding to $c = 1$. Making royalty too high is not good for both firms.

If the pool sets royalty to

Figure 2. Patent Pool and Independent Licensing



maximize revenue, then the royalty should be $c^*=\frac{2}{3}$. In this case,

$$\pi_V^* = \pi_V\left(\frac{2}{3}\right) = \frac{1}{6}, \pi_R^*$$
$$= \pi_R\left(\frac{2}{3}\right) = \frac{1}{6},$$
$$\pi^* = \pi\left(\frac{2}{3}\right) = \frac{1}{3}.$$

Outputs will be $\frac{1}{6}$ for M-firm and $\frac{1}{3}$ for V-firm. This would be most desirable royalty for the R-firm. The frontier is vertical at this point. (This is point RY in Figures 2 and 3).

If the pool sets royalty to maximize the joint profit of the V-and R-firms, $\pi(c)$, then the royalty is $c^{PF}=\frac{4}{9}$. Profits are,

$$\pi_V^{PF} = \pi_V\left(\frac{4}{9}\right) = \frac{23}{108}, \quad \pi_R^{PF} = \pi_R\left(\frac{4}{9}\right) = \frac{4}{27},$$
$$\pi^{PR} = \pi\left(\frac{4}{9}\right) = \frac{13}{36}.$$

This is the point farthest from the origin on the frontier. (This is point PF in Figure 3).

If the firms license independently, the Nash equilibrium royalties are,

$$\hat{c}_V = \frac{2}{7}, \quad \hat{c}_R = \frac{3}{7}.$$

Recall that royalty rates are strategic substitutes for essential patents. The equilibrium profits are,

$$\hat{\pi}_V = \frac{6}{49}, \quad \hat{\pi}_R = \frac{9}{49}, \quad \hat{\pi} = \frac{15}{49} < \pi^*.$$

The point is marked IE in Figures 2 and 3. V-firm has lower profit than the R-firm. R-firm is better off than the patent pool.

If R-firm moves first, then it will set royalty level $c_R^S=\frac{1}{2}$. V-firm chooses $c_V^S=\frac{1}{4}$. Profits are,

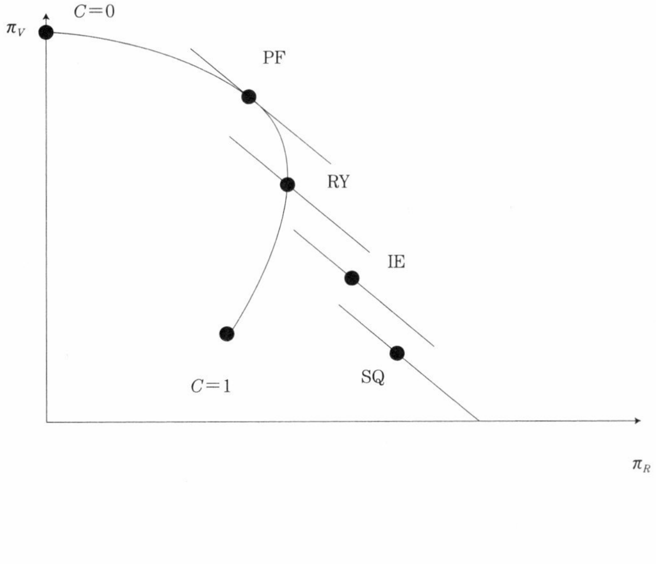
$$\pi_V^{SQ} = \frac{3}{32}, \quad \pi_R^{SQ} = \frac{3}{16}, \quad \pi^{SQ} = \frac{9}{32}.$$

R-firm's profit increases but V-firm loses out. This corresponds to point SQ in Figure 3.

Both points IE and SQ are outside the frontier. Independent licensing is more attractive to the R-firm than a patent pool while the V-firm always prefers the pool. We also note that revenue maximizing is not the best option for the patent pool as a whole.

The aggregate profit is largest when $c=c^{PF}$. Both simultaneous independent and R first mover licensing result in smaller total profit. The total profits are even lower than with the revenue maximizing royalty, c^*. This means that the V-firm would be better off if it give what R-firm would achieve as a first-mover to induce R-firm to join the pool. Because point SQ is outside the frontier, this allocation that guarantees R-firm enough to join cannot be achieved by splitting the pool revenue according to patents. It must be achieved in form of a transfer payment.

Figure3. Patent Pool Frontier



Discriminatory Licensing Rule

The pool frontier is constrained by the non-discriminatory licensing rule. Without this constraint, it is possible to increase joint profit even more. Specifically, the pool chooses two royalty rates, c_M and c_V, cooperatively to maximize joint profit (3). This is achieved with $c_M^C=\frac{1}{2}$ and $c_V^C=0$. The insider (V-firm) pays zero royalty. The joint profit achieved is $\frac{3}{8}$. The Nash Bargaining Set (feasible set) is,

$$\left\{(\pi_R, \pi_V)\,|\,\pi_V+\pi_R\leq\frac{3}{8}\right\}.$$

The disagreement point is the independent licensing point $(\hat{\pi}_R, \hat{\pi}_V)$. Then the Nash Bargaining Solution is,

$$\pi_R^{NB}=\frac{171}{784},\quad \pi_V^{NB}=\frac{123}{784}.$$

This allocation is acceptable to the R-firm. But can be achieved only by having the pool charge different prices. This is very attractive to the R-firm but not to the V-firm since $\pi_V^{NB}<\pi_V^*$.

Note that $c^*>c_R^C+c_V^C$. Discriminatory treatment of R and V firms result in lower royalty than the revenue maximizing non-discriminatory royalty payment. However it is higher than the non-discriminatory profit maximizing royalty. With discriminatory royalty, V firm pays no royalty. With non-discriminatory royalty, burden is shifted from M firm to V firm[10].

4. Analysis of RAND Conditions

In this section we explore what the RAND condition achieves, given that the cooperation among firms for a standard is secured.

We start with the model with three types of firms: V, M and R. We now assume the number of firms of each type are v, m and r respectively. Both V and M-firms must obtain a license from the pool to produce. We denote T-firm's output by q_T, price by p_T, and profit by π_T. Vertical firm's profit comes from both royalty and production:

$$\pi_V=(p_V-c)\,q_V+\frac{cQ}{v+r},$$

where $Q=vq_V+mq_M$ is the total output. M-firm has no royalty revenue:

$$\pi_M=(p_M-c)\,q_M,$$

while R-firm has only royalty revenue:

$$\pi_R=\frac{cQ}{v+r}.$$

We assume the same type of firms behave identically.

We consider a two stage game: the royalty fee c is set by the pool in the first stage. In the second stage, firms that manufacture choose prices (outputs) non-cooperatively. We assume zero manufacturing cost so that the only cost will be the license royalty, c. We consider two extreme cases: when products are perfect substitutes (homogeneous product) and when each firm is a local monopolist. The first case would correspond to the case where the firm specific complementary assets, i.e. assets complementary to the standard technology such as manufacturing know-how, are not important. The second case would correspond to the case where the standard can support a number of applications for which each firm develops specialized complementary assets[11].

Perfect competition in manufacturing

Here we assume that there is no vertically intetrated firm ($v=0$) for simplicity. In this case, Bertrand competition with homogeneous goods results in marginal cost pricing,

$$p_M=c.$$

Given marginal cost pricing in manufacturing, there is no markup so that there is no inefficiency due to double marginalization when a patent pool is successful in bundling all complementary patents. The profit of a research firm is given by,

$$\pi_R=\frac{cQ}{r}.$$

The pool chooses the royalty rate (c^*) to maximize Q_c subject to competition with alternative standards. The RAND conditions require the pool to apply the rate c^* to all licensees. In the case of Bertrand competition in manufacturing, this nondiscriminatory application of the royalty rate insures the efficient manufacturing. Only a firm with the lowest manufacturing cost serves the market. It also generates the maximum profit for R & D. Thus, non-discrimination is feasible and efficient.

Let us go back one step further and consider the member firm i's R & D investment decision (k_i). We assume that such investment improves the quality of the standard. Each firm has the following ex-ante profit :

$$\max \frac{Q(k_1, k_2, \cdots, k_r)\, c}{r} - k_i.$$

Under the revenue sharing scheme where revenue is divided equally among members, each firm can obtain only one r-th of the increased licensing revenue from quality improvement of the standard as result of investment. Thus such a scheme causes a large scale underinvestment in R & D compared to what is collectively optimal[12]. The degree of underinvestment will be very large when the pool membership is large. This inefficiency obviously handicaps the consortium standard relative to a closed standard sponsored by a single firm. The only solution is to allocate pool revenue according to contribution to the pool revenue. Some scheme to evaluate the contribution of each patent must be devised to address this underinvestment problem. Given such an underinvestment problem, there is no economic ground for a government to suppress the royalty rate agreed by the pool[13]. Such intervention only exacerbates the underinvestment problem.

Local monopoly

Assume that each firm serves its own market, i.e., each firm is a monopolist in its own market. Each firm chooses the profit maximization price, for a given royalty c. Thus there is a positive markup for a manufacturing firm and for a manufacturing operation of a vertically integrated firm. Any positive per use charge causes the problem of double marginalization.

In this case, non-discriminatory licensing does not ensure ex-post manufacturing efficiency. The perceived marginal cost is lower for an insider vertically integrated firm than the outsider manufacturing firm, since it perceives the gain from output expansion both from its sales of output and through royalty income :

$$\frac{\partial \pi_V}{\partial q_V} = \frac{\partial}{\partial q_V}(P(q_V)\, q_V) - \left(1 - \frac{1}{v+r}\right)c.$$

Thus, the non-discriminatory application of royalty in fact does not insure the efficient entry in manufacturing. However, the advantage of being an insider becomes smaller as the number of the members of the patent pool increases. In the case where a number of firms supplying technologies to a patent pool is large, this effect can be negligible.

Let us look at the determination of the level of royalty. As analyzed in Section 3, three types of firms have different interests regarding the level of royalty, c. Since price is chosen optimally for each c, by the Envelope Theorem, we have,

$$\frac{\partial \pi_V}{\partial_c} = -q_V + \frac{1}{v+r}\frac{\partial (Q_c)}{\partial c}.$$

We can make several observations. First the outsider manufacturing firm wants the minimal price, since the second term does not exist. The insider research firm wants a higher price, since there is no first term. The vertically integrated firm is in the middle ground. It wants to balance its production profit and royalty revenue. The outcome would mainly depend on the negotiations between insider manufacturing firms, and insider research firms, as well as on competition with the other standards.

Secondly, higher royalty increases reward to R & D but exacerbates the problem of double marginalization. The zero price for technology is the most efficient price ex-post but it gives no return on R & D by research firms. Thus, there is a clear trade-off between ex-post efficiency and ex-ante incentive. Given the dilution problem of R & D incentive identified above, there seems to be no good ground for a government to suppress the royalty even though it is high due to double marginalization. The solution to the tradeoff cannot come from the government intervention in pricing. Instead, a lump-sum payment to the insider research firm may alleviate the above inefficiency. Buy-out of the IPR of the research firms would be an alternative, although such financing scheme may not be easily available for a technology coalition.

While we discussed the effect on manufacturing efficiency of non-discriminatory licensing policy, we have not discussed why this might be beneficial in the context of dynamic competition. Carlton and Gertner (2003) have argued that one advantage of an open source system to a proprietary system is that it makes it possible for anyone to make improvements. The system is able to improve or permutate according to needs more easily. Although a consortium standard depends on patented technology, its commitment to give access to anyone who requires at a "reasonable" price allows outsiders to improve the technology as with the open system.

5. Conclusion

We have identified two possible obstacles to a successful implementation patent pools : free riding and bargaining failure. Once the standard has been established, it is not possible to exclude a firm with an essential patent from accessing the demand for the standard (i. e. collecting royalty from the users of the patent). Patents can only be used to control access to the technologies implementing the standard. We have also shown that the noncooperative outcomes of licensing are not achievable by transfer of rents by per patent split. This is because the royalty alone cannot both increase patent revenue and allocate rents among heterogeneous members at the same time. Thus, while it is easy to argue why a patent pool bundling complementary patents are socially desirable, the reality is that patent pools can be difficult to organize and to maintain.

Our results suggest that both the RAND licensing scheme and the way to allocate rents among pool members need to be changed to accommodate the heterogeneous membership. The heterogeneity of membership makes the "reasonable" royalty policy more difficult to implement. This is because the relationship between royalty rate and revenue differs between research firms that only have patent revenue and vertically integrated firms that also have production profit as well as patent revenue. One might think that charging sufficiently high royalty will transfer production profit from vertical firms to research firms in addition. Unfortunately this transfer also reduces the size of the total pool revenue by compounding the harm of double-marginalization. Thus it is impossible to transfer enough revenue to make it profitable for a research firm to join a pool instead licensing independently. This result suggests that there should be extra distribution to research firms to compensate for the lack of production profits. Requiring all members of the pool to be treated equally could be a source of patent pool's failure.

The system of allocating pool rents according to patent numbers is also detrimental to innovation. Firms may significantly underinvest in quality of the standard since it is unable to obtain appropriate return on its R & D investment. Improving the dynamic incentive of the consortium standard will be important, since it may have to compete with a closed proprietary standard, which may have a handicap in innovation but has an clear advantage in appropriation.

Finally let us turn to policy issues. Although it is very important for a competition authority to deter the formation of a pools which are anticompetitive, it would be detrimental to competition and innovation for a government to condition the approval of the pool on low royalty rate. Once the pool is judged to be a bundle of complementary patents, it should be free to set the royalty rate. On the other hand, a government intervention may be warranted to prevent the free riding on the pool by an outsider which surfaces after the standard is set.

(The Institute of Economic Research, Hitotsubashi University, and Department of Economics, University of Auckland ／Institute of Innovation Research, Hitotsubashi University)

Appendix 1 : Proof of Proposition 1

Propotition 1. *When* c^*, π_R^*, π_V^* *are the patent pool revenue maximizing royalty and profits, and* $\hat{c}_R$, $\hat{c}_V$, $\hat{\pi}_R$, $\hat{\pi}_V$ *are equilibrium royalties and profits when R- and V-firms set them independently, then*

$$(i)\ c^* < \hat{c}_R + \hat{c}_V, \quad \hat{c}_R > \hat{c}_V, \quad \hat{c}_R > \frac{c^*}{2},$$

$$(ii)\ \hat{\pi}_R + \hat{\pi}_V < \pi_R^* + \pi_V^*, \quad \hat{\pi}_V < \hat{\pi}_V^*.$$

Let the inverse demand be $P(q)$. We denote by $q_m(\gamma)$ the monopoly profit when marginal cost is γ. That is, it is the solution to the first-order condition,

$$\max_q (P(q) - \gamma) q.$$

We denote by c_m, the royalty rate that maximizes revenue $\gamma q_m(\gamma)$. We assume that the second-order condition,

$$2cq_m'(c) + q_m''(c) \leq 0, \qquad (4)$$

so that it satisfies, the first-order condition,

$$q_m(c_m) + c_m q_m'(c_m) = 0. \qquad (5)$$

The profits of R- and V-firms when they constitute the patent pool are,

$$\pi_R(c) = \frac{c}{2}\left(q_m(c) + q_m\left(\frac{c}{2}\right)\right),$$

$$\pi_V(c) = \frac{c}{2} q_m(c) + \left(P\left(q_m\left(\frac{c}{2}\right) - \frac{c}{2}\right) q_m\left(\frac{c}{2}\right)\right).$$

Royalty c^* maximizes pool revenue and satisfies,

$$c^*\left(q_m'(c^*) + \frac{1}{2} q_m'\left(\frac{c^*}{2}\right)\right) + q_m(c^*) + q_m\left(\frac{c^*}{2}\right) = 0. \qquad (6)$$

Claim 1.

$$c_m < c^* < 2c_m.$$

Proof. It follows from (5) and (6). □

The profits when the two firms set royalties independently are,

$$\pi_R^I(c_R, c_V) = c_R(q_m(c_R + c_V) + q_m(c_R)),$$

$$\pi_V^I(c_R, c_V) = c_V q_m(c_V + c_R) + (P(q_m(c_R)) - c_R) q_m(c_R).$$

Denote by $\beta_R(c_V)$ and $\beta_V(c_R)$ the best-response correspondences when firms set royalties independently. They are solutions to the two first-order conditions

$$\frac{\partial \pi_R^I}{\partial c_R} = c_R(q_m'(c_R + c_V) + q_m'(c_R)) + q_m(c_R + c_V) + q_m(c_R) = 0, \qquad (7)$$

$$\frac{\partial \pi_V^I}{\partial c_V} = c_V q_m'(c_R + c_V) + q_m(c_R + c_V) = 0.$$

Claim 2.

$$-1 < \beta_R'(c_V) < 0, \quad -1 < \beta_V'(c_R) < 0.$$

Proof.

$$\frac{\partial^2 \pi_R^I}{\partial c_V \partial c_R} = q_m'(c_R + c_V) + c_R q_m(c_R + c_V) \leq 0,$$

$$\frac{\partial^2 \pi_R^I}{\partial c_R^2} = c_R q_m''(c_R + c_V) + 2q_m'(c_R + c_V) + c_R q_m''(c_R) + 2 + 2q_m'(c_R) < 0.$$

The inequalities follow from (4). Since

$$\beta_R' = -\frac{\partial^2 \pi_R^I}{\partial c_V \partial c_R} / \frac{\partial^2 \pi_R^I}{\partial c_R^2},$$

and $q_m'(c_R + c_V) < 0$, so that the ratio must be greater than -1. □

Claim 3.

$$\beta_V(0) = c_m, \quad \beta_R(0) = c_m.$$

Proof. Substituting $c_R = c_m$ and $c_V = 0$ into (7) yields

$$2q_m(c_m) + c_m 2q_m'(c_m).$$

This is zero from (5) implying $\beta_R(0) = c_m$. Similarly for β_V. □

Claim 4. *(i)* $c_R = \beta_R(c_V)$ *intersects the line* $c_R + c_V = c^*$ *below the line* $c_R = c_V$ *(45 degree line).*

(ii) $c_V = \beta_V(c_R)$ *intersects the line* $c_R = c_V$ *above* $c_R = c_V = \frac{c^*}{2}$.

(iii) Intersection of $c_R = \beta_R(c_V)$ *and the line* $c_R = c_V$ *is northeast (higher along the 45 degree line) of intersection of* $c_V = \beta_V(c_R)$ *and the line* $c_R = c_V$.

Proof. We first show

$$\frac{\partial \pi_R^I}{\partial c_R}\Big|_{c_R = c_V = \frac{c^*}{2}} = c^* q_m'(c^*) + \frac{c^*}{2} q_m'\left(\frac{c^*}{2}\right) q_m(c^*) + q_m\left(\frac{c^*}{2}\right) - \frac{c^*}{2} q_m'(c^*) = -\frac{c^*}{2} q_m'(c^*) > 0.$$

The last inequality follows from (6). This implies part (i).

Denote the intersection of $c_R = \beta_R(c_V)$ and line $c_R + c_V = c^*$ by $(\bar{c}_R, c^* - \bar{c}_R)$. Since this is on β_R,

$$q_m(c^*) + \bar{c}_R q_m'(c^*) + \bar{c}_R q_m'(\bar{c}_R) + q_m(\bar{c}_R) = 0.$$

Since $\bar{c}_R < c_m$, the sum of the last two terms is positive from (5). The sum of the first two terms must be negative and we have

$$\bar{c}_R < -\frac{q_m(c^*)}{q_m'(c^*)}.$$

Since $\frac{c^*}{2} < \bar{c}_R$, we have

$$\frac{\partial \pi_V^I}{\partial c_V}\Big|_{c_R=c_V=\frac{c^*}{2}} = q_m(c^*) + \frac{c^*}{2} q_m'(c^*) > 0.$$

This implies part (ii).

Suppose $c_R = \beta_R(c_V)$ intersects line $c_R = c_V$ at $c_R = c_V = z$. It must satisfy (7) :

$$q_m(2z) + zq_m'(2z) + q_m(z) + zq_m'(z) = 0.$$

The sum of last two terms must be positive since $z < c_m$. Thus we have

$$\frac{\partial \pi_V^I}{\partial c_V}\Big|_{c_R=c_V=z} = q_m(2z) + zq_m'(2z) < 0.$$

This shows part (iii). □

The proceeding claims are summarized in Figure 2. The part (i) of the proposition follows: Nash Equilibrium lies below the 45 degree line, it is above the line $c_R + c_V = \frac{c^*}{2}$, and to the left of the point RY.

To show part (ii) of the proposition, we first calculate the total of the firm profits:

$$\pi_R(c^*) + \pi_V(c^*) = c^* q_m(c^*) + P\left(q_m\left(\frac{c^*}{2}\right)\right) q_m\left(\frac{c^*}{2}\right),$$

$$\pi_R^I(\hat{c}_R, \hat{c}_V) + \pi_V^I(\hat{c}_R, \hat{c}_V) = (\hat{c}_R + \hat{c}_V) q_m(\hat{c}_R + \hat{c}_V) + P(q_m(\hat{c}_R)) q_m(\hat{c}_R).$$

Since $c^* < c_m$, the first term is an increasing function on the interval $(\hat{c}_R + \hat{c}_V, c^*)$. The second term is a decreasing function and $\hat{c}_R > \frac{c^*}{2}$. This implies $\pi_R(c^*) + \pi_V(c^*) > \pi_R^I(\hat{c}_R, \hat{c}_V) + \pi_V^I(\hat{c}_R, \hat{c}_V)$. This implies first inequality of proposition's part (ii).

To show the second inequality, first we note that $\pi_V^I\left(\frac{c}{2}, \frac{c}{2}\right)$ is decreasing in c :

$$\frac{\partial \pi_V^I\left(\frac{c}{2}, \frac{c}{2}\right)}{\partial c} = \frac{1}{2}\left(q_m'(c)c + q_m(c) - q_m\left(\frac{c}{2}\right)\right) < 0.$$

This implies $\pi_V^I(c_R, c_V)$ is decreasing along $c_R = c_V = \frac{c}{2}$ (45 degree line). So profit is lower at the intersection of 45 line and β_V than at $c_R = c_V = \frac{c^*}{2}$. Since $\pi_V^I(c_R, c_V)$ is decreasing in c_R along β_V, profit is lower at IE than at the intersection. Thus we have the second inequality.

Notes

1) We are indebted to comments from Yoshihito Yasaki, Akira Okada and other participants of "IT Innovation Workshop," Hitotsubashi University, March 2004, and Institute of Economic Research Seminar as well as research assistance of Naotoshi Tsukada.

2) See Klein (1997) for the recent articulation of the policy of the US antitrust authority toward patent pools. See Gilber (2002) and Priest (1977) for a historical overview of the U. S. policy toward patent pools.

3) There is an example of a standard body which maintains free IPR policy such as W3C. See Lemley (2002) for a comprehensive review of licensing policies of standard bodies.

4) For instance, if the product market is a Cournot duopoly with linear demand $1-Q$, Q, total output, then $q_k(\sum_i c_i + \gamma) = (1 - \sum_i c_i - 2\gamma + \gamma')/3$ where γ and γ' are this firm and rival's respective firm specific non-license marginal costs.

5) We write $P_k(q_k, q_{-k})$ for generality, including heterogenous goods. If firms produced homogenous goods, then $q_{-k} = \sum_{j=1, j\neq k}^{n} q_j$.

6) The above analysis assumed the Nash equilibrium of simultaneous pricing by the pool and the outsider. It is possible that the outsider moves first in price setting, since there is a first mover advantage. This is explored in Section 3.

7) There is no market interaction between M and V firms: V-firm has no incentive to raise royalty to raise rival's cost. See end of this section for details.

8) V-firm's royalty revenue comes only from the M-firm and does not include own output. So V-firm chooses output equal to the monopoly output when marginal cost is c_R, i. eo, $q_M(c_R)$ and not $q_V(c_R)$.

9) Exact definition is in the proof.

10) Of course these trade-offs will differ when there is downstream market interaction. For a discussion of downstream oligopoly, see ?

11) Remarks regarding the case of downstream oligopoly at end of previous section would apply here also.

12) The benchmark is the investment when the standard is controlled by a single firm. Such firm may overinvest or underinvest in the quality of the standard, depending on the relationship between the valuation of a marginal consumer and that of a average consumer.

13) Note that any dynamic concern of pricing, such as penetration pricing for promoting the diffu-

Appendix 2: Recent Standard Patent Pools

Name, Year	Admin.	Members	Licensing Policy	Patents	Other Info.
MPEG 2, 1997	MPEG LA	Originally 13 firms, 1 university; And any firm that has an essential patent can participate; currenlty 22 firms, 1 univ.	1. The contract term is from 10 and a half to 15 and a half years. 2. For MPEG-2 decoding products, the royalty is US $4.00 for each decode unit. A royalty of US $6 per unit applies to Consumer Products having both encoding and decoding capabilities. (Both of which prior to Jan. 1, 2002, and $2.50 from Jan. 1, 2002.) Etc. 3. Licensees have the right to renew for successive five-year periods for the life of any MPEG-2 Patent Portfolio Patent, subject to reasonable amendment of royalty terms and rates (not to increase by more than 25%). 4. New Licensors and essential patents may be added at no additional cost.	Originally 27 patents; currently over 640.	1. Each firms can license independently. 2. The allocation of royalties depends on the share of patents contributed to the pool.
DVD (3C), 1998	Philips	Philips, Sony, Pioneer	1. The contract term is 10 years. 2. Commitment to royalty (royalties of 3.5% of the net selling price for each player sold, subject to a minimum fee of $7 per unit, which drops to $5 as of Jan. 1, 2000 and $.05 per disc sold.) 3. A most favorable conditions clause. 4. An obligation for licensee to grant-back any essential patent on fair, reasonable and non-discriminatory terms.	115 patents for the manufacture of DVD players, 95 patents for the manufacture of the discs. Future essential patents	1. Each firms can license independently. 2. The allocation of royalties is not a function of the number of patents contributed to the pool.
DVD (6C), 1998	Toshiba	Hitachi, Matsushita, Mitsubishi Electric, Time Warner, Toshiba, Victor Company of Japan	1. The contracts run until Dec. 31, 2007 and renew automatically for 5-years terms thereafter. 2. Commitment to royalty (royalties of $.075 per DVD Disc and 4% of the net sales price of DVD players and DVD decoders, with a minimum royalty of $4.00 per player or decoder) 3. A most-favored-nations clause 4. An obligation for licensee to grantback any essential patent on fair, reasonable and non-discriminatory terms.	All the present and future essential patents	1. Each firms can license independently. 2. The allocation of royalties depends on the share of patents contributed to the pool.
3G Platform[14]	3G Patent Ltd[15]	19 firms (8 operators, 11 manufacturers)	1. Maximum Cumulative Royalty is 5%. 2. Standard Royalty Rate per certified essential patent is 0.1% (However, the option to negotiate a bilateral agreement is available)	All the essential patents of the member firms	1. Members able to by-pass and license independently with mutually agreeable terms. 2. The allocation of royalties depends on the share of patents contributed to the pool.

Source: Nagata (2002); *http://www.3gpatents.com*; *http://www.mpegla.com*; DOJ Review Letter from Joel Klein to Carey R. Ramos, June 10, 1999; DOJ Review Letter from Joel Klein to Gerrard R. Beeney, December 16, 1998.

sion of a standard, can be internalized by a patent pool.

14) The licensing of certified essential patents will be undertaken by separate licensing companies ("Platform Companies") which are specific to a particular radio access technology e. g. W-CDMA, cdma 2000, TD-CDMA, etc. The members of the Platform Companies are the owners of certified essential patents.

15) The Platform Company for the 3G systems based on the W-CDMA technology was formed in September 2003 (PlatformWCDMA Limited or "Platform WCDMA"). Platform WCDMA will offer licenses under the W-CDMA Patent Licensing Programme which was launched officially on the 24 March 2004. The W-CDMA Patent Licensing Programme became effective 1 January 2004.

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