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Presented to the Conference on IT Innovation, Tokyo, December 2004.

IIR Working Paper WP#05-01

February 2005

Institute of Innovation Research
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Tokyo, Japan
http://www.iir.hit-u.ac.jp

Coalition formation for a consortium standard through a standard body and a patent pool: Theory and evidence from MPEG2, DVD and 3G

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February 2005

Abstract

We examine why cooperation among essential patent holders for a standard may not occur, despite significant gains for patent holders and users of the standard. Utilizing Maskin's (2003) framework, we show that a grand coalition can be implemented only if the number of patent holders (n) is small. When n is large, emergence of an outsider is inevitable, so that voluntary sequential negotiation cannot secure the socially efficient outcome. We also show that a firm specialized in research is more likely to become an outsider. We discuss the MPEG2, DVD and 3G patent pools in light of these results.

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[‡]We would like to thank for the informative seminars by Hisashi Kato of Mitsubishi Electric, Yoshitaro Shimanuki of NTT Docomo and Yasuo Nishioka of Toshiba for the research project on essential patents in technical standard in Hitotsubashi University. We benefitted from comments by Suzanne Scotchmer, Hideshi Itoh and other participants of "IT Innovation Conference", Hitotsubashi University, 13-14 December 2004. We would also like to thank excellent research assistance by Naotoshi Tsukada, Tomoyuki Shimbo and Kazuyoshi Taniguchi in this research project. Their support was essential for us to develop the empirical section of this paper (section 6). The responsibility of all errors rests with us. Aoki is grateful to financial support of Japan Center for Economic Research.

1 Introduction

In this paper we examine whether firms with essential patents to a particular standard can voluntarily cooperate for efficient licensing of their technologies. There is a concern that a growing number of patents granted globally may stifle innovation by creating the "tragedy of anticommons"(see Heller and Eisenberg (1998)). That is, individual assertion of a patent right by many patentees over a given technology might make its price prohibitively high and causes the massive underutilization of technology. This significantly reduces the return from the technology, thus harming the ex-ante incentive for developing such technology, and if the technology is a research tool, it also harms down-stream R&D. Such concern can be especially serious in a cumulative technology area such as information and communications technology, where there are many patents and patentees involved in a particular technology. For example, in the case of MPEG2 standard, there are more than 600 certified essential patents and at least 23 organizations are the patentees (see table2). If each of these firms sets its royalty freely, the total royalty to be paid by a licensee will become astronomical so that the use of the technology will be seriously hampered. We have the inefficiency of double marginalization first pointed out by Cournot (see Shapiro (2001)).

On the other hand, a conventional view based on the "Coase theorem" suggests that such problem can be solved by a voluntary cooperation among firms. Since collaboration among firms for controlling the total royalty benefits not only consumers but also patentees themselves, that is, a coordinated reduction of individual royalty increases the total royalty revenue available for the patentees, they would have an incentive to cooperate in the pricing of technology. The existence of such incentive guarantees the efficient coordinated outcome according to an optimistic Coasian view. In fact, we can think that a standard body and a standard-specifying patent pool (a collective licensing scheme of the patents essential to a particular standard) have played a role in facilitating such collaboration. A standard body asks the submission of patent statement by the firm with an essential patent before adopting a standard. The patent statement obliges the firm to commit itself to either royalty free licensing or licensing under RAND (reasonable and non-discriminatory conditions) on the reciprocity basis. Thus, when a standard is adopted, a firm presumably commits itself to the price reasonable from the view point of standard as a whole. Since the standard body itself usually does not get involved in royalty determination, except for the case when patentees commit to free royalty licensing, some institutional mechanism to implement licensing on the reasonable term is necessary. The collective licensing through a patent pool of essential patents is exactly the facility to perform this function. Firms can avoid the problem of royalty accumulation by delegating the decision of royalty determination to a single licensing body. Given such efficiency improving nature of the collaboration, antitrust authorities have approved the standard-specifying pool under the conditions of establishing the safeguard mechanism against anticompetitive abuse, such as the restriction of the scope of licensing to essential or complementary patents and the guarantee of the freedom to bypass the pool[1].

However, we observe that such collaboration does not necessarily occur in reality. 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 is 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. Since the standard body does not specify the level of total royalty, without saying the level of royalty which can be collected by each patentee, the commitment to licensing under RAND leaves a large discretion for each patentee in royalty determination. 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 paten-

[1]See Klein (1997) for the recent articulation of the policy of the US antitrust authority toward patent pools. See Gilbert (2004) and Priest (1977) for a historical overview of the U.S. policy toward patent pools. See also Tirole and Lerner (2004) for the effect of the patent pool on competition, in particular, the role of the freedom to bypass.

tees. The 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 such emergence of an outsider and the split of the patent pool. In the next four sections we analyze this issue from the perspective of coalition formation problem. Recently, Maskin (2003) pointed out the externalities among coalitions as an important source of the failure of forming a grand coalition, and proposed to approach this problem from the perspective of a non-cooperative implementation or bargaining. We adopt his framework to analyze the coalition formation problem of standard-specifying patent pool (i.e. the pool of the patents essential to a specific standard). In section 2 and 3, we present an analysis of the coalition formation problem when all patentees are research only firms[2]. In section 4 we will see that the situation is similar when all patentees are vertically integrated so that they all produce, i.e., all are both licensor and licensees. In section 5 we present the analysis of the case where there are heterogeneous members: two vertically integrated firms and one research only firm. In section 6 we discuss three cases of patent pools: MPEG2, DVD and 3G, to see how the experience of these cases can be interpreted in light of the analytical results and what we miss in our theory. In section 7 we conclude.

The economic literature on patent pools has developed and changed as the legal, particularly the anti-trust, views have. Typically, a patent pool has been characterized as a device for extending and possibly abusing market power of patents (Gilbert (2004)). For this reason, interest in patents pools such as standard specification pools, which have been sanctioned by the Anti-trust Division (Klein (1997)) has been limited. The recent extensive examination of patent pools by Lerner and Tirole (2004) focuses on trade-off between market power and efficient use of patents by introducing partial substitutability and addresses foreclosure and raising costs. Our interest is not this trade-off. We argue that given the trade-off is in favor of pooling, potential efficiency

[2]We can interpret this analysis to cover also the case of vertically integrated firms which however face Bertrand competition in manufacturing.

may not always be realized. Our approach and interest is closer to issues related to the American Society of Composers, Authors and Publishers (Scotchmer (2004) Chapter 6), an organization where not all potential members join. We are concerned about the relationship between benefit to pool members and stability of membership.

2 Effects of the coalition by the holders of essential patents to a particular standard

In this section, we consider the case where all firms with essential patents are specialized in research. We will clarify the following two major features of coalition formation in this context. Coalition generates positive externality to outsiders. That is, an outsider firm gains from the coalition. In addition, a coalition is super-additive only if its size is more than a critical level. That is, the member of a small coalition loses and only a grand coalition is super-additive when the number of firms independently collecting royalties (n) is small.

We consider the following simple set-up. There are n research only firms (R-firm), each of which has an essential patent to the standard. The per unit royalty of firm k is given by r_k. The market demand for the standard technology (we can consider this as either the number of licensees or the quantity of sales incorporating the standard, we adopt the first interpretation) is given by

$$q = 1 - \sum r_i. \tag{1}$$

The profit for firm k is given by

$$\pi_k = qr_k.$$

The marginal profit with respect to royalty for firm k is given by

$$\frac{\partial \pi_k}{\partial r_k} = q - r_k. \tag{2}$$

Using (1), we have

$$r_k = \frac{1 - \sum_{i \neq k} r_i}{2}. \tag{3}$$

Equation (2) shows that royalties are strategic substitutes (i.e. reduction of royalty by the other firms increases the incentive of firm k to increase its royalty). Reflecting this, equation (3) shows a negative relationship among the royalties of the firms.

Since the model is symmetric, we can focus on the following symmetric equilibrium: $r = r_k$ for all k. From (3), we have

$$r = \frac{1}{n+1}. \tag{4}$$

Given this, we can get the total royalty (R) and the number of licensees of the standard technology as follows:

$$\begin{aligned} R = nr &= \frac{n}{n+1}, \\ q &= \frac{1}{n+1}. \end{aligned} \tag{5}$$

The profit of each firm and consumers surplus (CS) are given respectively by

$$\begin{aligned} \pi &= \frac{1}{(n+1)^2}, \\ CS = \frac{1}{2}(1-R)q &= \frac{1}{(n+1)^2(\frac{1}{2})}, \\ W = n\pi + CS &= \frac{n + \frac{1}{2}}{(n+1)^2}. \end{aligned} \tag{6}$$

As the number of firms independently collecting royalties (n) increases, the price of technology increases, the number of licensee declines, and the welfare declines uniformly to zero, due to royalty accumulation.

Based on the above results, we can establish the above two features of coalition making in standard. First, as shown in equation (6), the reduction of the number of firms (n) increases the profit of the remaining firms. Formation of a pool, which is a coalition, of essential patent holders results in the reduction of the number of firms who independently collect royalty. Thus the outsider gains from such coalition. As equation (4) shows, such coalition causes the outsider to increase its royalty reflecting the strategic substitute relationship in the pricing of the essential patents, even though the total royalty falls due to the coalition as shown in equation (5). Thus, coalition generates positive externality to outsiders.

Lemma 1. *There is a positive externality of a coalition by the firms having essential patents with respect to a standard.*

Let us then see the effect of a coalition on its members. Let us consider m-firm coalition. If m firms cooperate and form a patent pool, the number of firms who independently imposes royalty declines from n to $(n - m + 1)$. The gain or loss for the member of coalition is given by

$$\pi(n-m+1) - m\pi(n) = \frac{1}{(n-m+2)^2} - \frac{m}{(n+1)^2}$$
$$= \frac{\{n+1+\sqrt{m}(n+2-m)\}(\sqrt{m}-1)\left\{\sqrt{m}+\frac{1}{2}\sqrt{n+\frac{5}{4}}\right\}\left\{\sqrt{m}+\frac{1}{2}-\sqrt{n+\frac{5}{4}}\right\}}{(n-m+2)^2(n+1)^2}.$$

Thus, the coalition is super-additive only if

$$m > m_{cr} = (\sqrt{n+\frac{5}{4}} - \frac{1}{2})^2. \qquad (7)$$

That is, the size of a coalition has to be larger than a critical size (m_{cr}), in order for it to be super-additive. On the other hand, a coalition of small size which is less than the critical size is sub-additive. The basic reason is the following. If the outsiders of a coalition do not change their royalties in response to the coalition, even a small coalition can gain by eliminating double marginalization among the members. However, outsiders will increase their royalties in response to the coordinated reduction of the royalties by the members of the coalition, due to the strategic substitute nature of pricing in this case. This latter effect reduces the profit of the insiders. When the coalition size is small, the first effect is small but the second effect is large. Thus, small coalition is sub-additive, while a large coalition is super-additive.

The critical size coincides with the number of essential patent holders n, allowing the integer constraint, when n is small. According to equation (7), the critical size coincides with n for $n \leq 4$. The critical size of a coalition increases as n increases. In terms of the coverage ratio (m_{cr}/n), the minimum coverage approaches 100% as the number of the firms n. Thus, we have the following Lemma 2.

Lemma 2. *A coalition is super-additive only if its size is more than a critical level. Such coalition can only be a grand coalition when the number of firms independently collecting royalties (n) is small. Such critical size increases with n and the necessary coverage for a super-additive coalition approaches 100% as n becomes indefinitely large.*

Figure 1 illustrates the basic results thus far obtained. The horizontal axis (n) measures the number of firms which have essential patents and collect royalties independently. As n increases, the price of technology increases and the welfare declines uniformly to zero, both due to worsening problem of royalty accumulation. Only the grand coalition is super-additive if n is less than or equal to 4. The coalition with only one outsider or less is super-additive if n is more than 4 but less than or equal to 10. A two-firm coalition is profit-making only if it is a grand coalition.

3 Coalition formation problem among research firms

Let us consider whether the grand coalition can be formed in the above model. It critically depends on the number of firms. As shown above, when n is small, there is no coalition other than the grand coalition which is super-additive. In this case we show that there is an implementation which achieves the grand coalition even if the coalition has a free rider problem, due to the sub-additive nature of smaller coalitions. On the other hand, when n is large, there is a coalition other than the grand coalition which is super-additive. In this case, we show that the grand coalition does not form.

For the sake of simplicity, we consider two cases: $n = 3$ (firm a, b and c) and $n = 5$ (firm a, b, c, d, and e). The payoff relevant for the coalition decisions is shown in Table 1. In the latter case of 5 firms, the coalition of 4 firms breaks even. We assume that firms prefer a coalition when it breaks even with non-coalition, assuming that a coalition per se generates a small extra value ($\epsilon > 0$). We denote the payoff for a coalition C in the case of N firm independent pricing by $v(C \mid N)$. Thus, the payoff for the coalition, or the value of the coalition, of firm b and c when two firms (firm a and the coalition bc) independently collect royalties is given by $v(bc \mid 2)$.

3.1 Case of three firms(a, b, c)

Let us consider the order of arrival is a, b, and then c. In this case of three firms, two-firm coalition is sub-additive. That is,$v(bc \mid 2) = 0.1111 < v(b \mid 3) + v(c \mid 3) = 0.1250$. This means that if one of the firms commits not to joining the coalition, the other firms will not form a coalition. Thus, the first firm a can foresee that he gets only $v(a \mid 3) = 0.0625$ if he commits not to joining the coalition. On the other hand, he can be sure that his offer of a coalition with b will be accepted. Because if b refuses it, b is sure that no coalition will be made (so that he payoff is 0.0625). Thus, we have a coalition ab as a team for further negotiation with firm c.

This coalition ab can increase the value by expanding the coalition firm c, since the grand coalition is super-additive. That is, while c can enjoy a relatively high payoff ($v(c \mid 2) = 0.1111$) even if the grand coalition is formed, the coalition ab can offer firm c more than this payoff with a positive residual remaining for itself:

$$v(abc \mid 1) - v(c \mid 2) = 0.25 - 0.1111 = 0.1399 > v(ab \mid 2) = 0.1111.$$

Thus, we expect that the grand coalition or the patent pool with full members can be formed based on the voluntary negotiations.

The final payoff allocation is the following: $v_F(a) = 0.0764$, $v_F(b) = 0.0625$ and $v_F(c) = 0.1111$.[3] The last firm c which enters into the negotiations obtains the most, since the formation of the coalition ab for a negotiation makes his potential profit when he stays an outsider to the pool large. Thus, there is no first mover advantage in initiating the negotiations for the grand coalition. Thus, unless some firm is compelled to initiate the process, we may have the inefficient delay due to the war of attrition.

3.2 Case of five firms (a, b, c, d, e)

Let us consider the order of arrival is a, b, c, d and then e. We consider the question of whether firm a should start negotiation for the coalition or commit itself to being an outsider. In this case of five firms, both the grand coalition and four -firm coalition is super-additive, given our assumption that a coalition generates a small extra value ($\epsilon > 0$). That is, $v(bcde \mid 2) = 0.1111 + \epsilon > v(b \mid 5) + v(c \mid 5) + v(d \mid 5) + v(e \mid 5) = 0.1111$. The rest of smaller coalitions are sub-additive.

If the first firm a commits not to joining a coalition, the other firms will form a coalition of four members. This is because if the second firm b decides not to form a coalition, he can expect that no coalitions will be formed since the remaining coalitions have only the size of less than four. Thus, he can expect only the payoff of $v(b \mid 5) =$

[3] We denote by superscript F that it is the final allocation. Although not explicitly stated, the final allocation depends on the final coalitions formed, as well as structure of the coalition formation, in particular the order in which firms move.

0.0278. Thus, the second firm will move to initiate the coalition formation process. The rest of the firms will follow the initiative, since if any one of the firms refuses to do so, the coalition will not be formed. Thus, the coalition of $bcde$ will be formed. Thus, in this scenario, the final payoff allocation is :$v_F(a) = v(a \mid 2) = 0.1111$ and $v_F(b) + v_F(c) + v_F(d) + v_F(e) = v(bcde \mid 2) = 0.1111 + \epsilon$.

Let us consider the second scenario where firm a offers a coalition for b. In this case, firm a has to make a large payment to firm b so as to make him to participate in the coalition, since the refusal by firm b will put the rest of the firms (including firm a) to form a coalition, based on the same reasoning as that of the above paragraph, and firm b can get the payoff of being outsider (0.1111). This threat leaves firm a very little of the surplus from the grand coalition, since the rest of the firms have to get the minimum (0.0278) for joining in the grand coalition. That is

Payoff for firm a if he offers a coalition to firm b

$$= 0.25 - 0.1111 - 3 \times 0.0278 - = 0.0555.$$

This payoff is clearly smaller than the case where firm a commits not to joining in the coalition.

Thus, we can expect that the grand coalition will not be formed in this case. The equilibrium partition is $\{a, bcde\}$: one outsider firm and the coalition of the rest of the firms. The first firm a gets 0.1111, the second firm gets $0.0278 + \epsilon$ and the rest of the firm gets 0.0278. In this case there is a first mover advantage but it is negative in a sense that he can gain only by committing to not to joining the coalition. Why does not the outsider a and the coalition $bcde$ negotiate ex-post for the grand coalition, despite the fact that it is Pareto-improving? This is because it is against the commitment of firm a not to joint in the coalition. Firm a can achieve the above payoff only if it can force the rest of the firms to form a coalition without firm a, and this is possible only if it can credibly commit not to joining in the coalition.

What makes the different outcome between the two cases? In the latter case, the number of firms with essential patents is large, so that the problem of double marginalization is more serious. Thus, even one firm staying out of the coalition still makes the rest of the firms willing to form a coalition. In the former case there is no such profitable coalition less than the grand coalition. Thus, we have the following proposition.

Proposition 1. *A grand coalition can be implemented only if the number of essential patent holders (n) is small. When n is large, the emergence of outsider is inevitable, so that the voluntary negotiation cannot secure the socially efficient outcome.*

4 Only Vertically Integrated Firms

Let us examine the situation when all the patent holders are all vertically integrated, i.e., they also produce. We refer to such a firm as a V-firm. Decisions are made sequentially: licensors (independent firms and patent pool) will respective royalty rates, then firms decide on output, taking royalty as given. In particular, pool member firms choose outputs independently, for antitrust reasons. For simplicity we assume that products are perfectly differentiated so that each firm is a monopolist in its own market, each with demand $q = 1 - p$, where q is the output and p is price of the good.[4] The only marginal cost is the license royalty. When it pays total royalty r to licenses, firm i chooses the monopoly output when marginal cost is r, $q(r) \equiv (1 - r)/2$.

With vertically integrated firms, there is a question of if the pool should charge royalty to its members or not. A royalty rule where a pool charges the same rate to its members as non-members is called *non-discriminatory licensing*. If a pool charges a different royalty to members, then it is *discriminatory licensing*[5] and it will be optimal to charge nothing to its members, i.e., cross-license. Our analysis will focus on

[4]Thus there is no strategic interaction among patent holders in the final goods market even when vertically integrated, unlike Lerner and Tirole (2004). This assumption also makes collusion of outputs useless.

[5]If the licensees are heterogeneous, then discriminatory licensing may also entail different rates among non-members.

discriminatory licensing.

Let us see what the allocations are with n V-firms. When there are no coalitions, each firm charges r_i to the other firms and pays r_j to firm j, ($j = 1, \cdots, i-1, i+1, \cdots, n$). Firm i chooses r_i to maximize,

$$\pi_i = \left(\frac{1 - \sum_{j \neq i}^{n} r_j}{2} \right)^2 + r_i \left(\sum_{\ell \neq i}^{n} \frac{1 - \sum_{j \neq \ell}^{n} r_\ell}{2} \right).$$

The first term is profit from production, the second term is the licensing revenue. Since all firms are identical, all firms charge the same equilibrium royalty,

$$r_n^* = \frac{1}{n},$$

and firm output and profit are,

$$q((n-1)r_n) = \frac{1}{2n},$$
$$\hat{\pi}_n^* = q((n-1)r_n)^2 + (n-1)r_n q((n-1)r_n) = \frac{2n-1}{2n} q(\frac{n-1}{n}) = \frac{2n-1}{4n^2}. \quad (8)$$

Now consider the case where m ($< n$) firms form a pool. There are $k \equiv n - m$ independent firms. The total number of licensors is $k+1$ (one pool and k firms) and there are n producers. The pool members' profit is,

$$\pi_0 = m \left(\frac{1 - \sum_{j=1}^{k} r_j)}{2} \right)^2 + r_0 \left(\sum_{\ell=1}^{k} \frac{1 - \sum_{j \neq \ell}^{k} r_j - r_0}{2} \right).$$

The first term is the production profit of its m members and the second term is the revenue from licensing to k independent firms. Pool members pay royalty to non-members and the pool collects royalty from the non-members. The non-member (independent) firm i's profit is,

$$\pi_i = \left(\frac{1-\sum_{j\neq i}^{k} r_j - r_0}{2}\right)^2 + r_i \left(\sum_{\ell\neq i}^{k} \frac{1-\sum_{j\neq \ell} r_j - r_0}{2} + m\frac{1-\sum_{j=1}^{k} r_j}{2}\right).$$

The firms and the pool set their royalties to maximize respective profit but the only part that matters is the licensing revenue. The royalty rate is determined by the number of licensors, which is $k+1$ for all producers. The equilibrium royalty is,

$$r_0^* = r_k^* = \frac{1}{k+1}.$$

An independent firm pays total royalty $(k-1)r_k^* + r_0^* = k/(k+1)$ and a pool member pays $kr_k^* = k/(k+1)$ in royalties. Respective profits are,

$$\begin{aligned} \pi_k^* &= q(\frac{k}{k+1})^2 + \frac{k}{k+1}q(\frac{k}{k+1}) = \frac{2k+1}{4(k+1)^2}, \\ \pi_0^* &= mq(\frac{k}{k+1})^2 + \frac{k}{k+1}q(\frac{k}{k+1}) = \frac{2n-m}{4(n-m+1)^2}. \end{aligned} \tag{9}$$

As in the previous sections, we will use $v(k|m)$ to denote allocation of firm k (or coalition kj with members k and j) when the size of the pool is m. (We do not consider configuration with two or more pools each with more than two members). The values for general m and n are given by (8) and (9):

$$v(1\cdots m|m) = \pi_0^*, \quad v(1|1) = \hat{\pi}_n^*.$$

To check super-additivity, we inspect

$$\delta(m) \equiv v(1\cdots m|m) - mv(1|1) = \frac{2n-m}{4(n-m+1)^2} - m\frac{2n-1}{2n}q(\frac{n-1}{n}). \tag{10}$$

We used $k = n - m$. We note that,

$$\delta(1) = 0, \quad \delta'(1) = -\frac{(n-1)^2}{2n^3} < 0, \quad \delta''(m) = \frac{4n - m - 2}{2(n - m + 1)^4} > 0,$$

and

$$\delta'(n) = \frac{2n^3 - n^2 - 2n + 1}{4n^2}, \quad \delta(n-1) = \frac{n^3 - 7n^2 + 12n - 4}{16n^2},$$

are positive for sufficiently large n. This implies that for sufficiently large ne, there is a $\hat{m}(n) < n$ such that,

$$\delta(m) \lesseqqgtr 0 \quad \Leftrightarrow \quad m \lesseqqgtr \hat{m}(n).$$

In particular, we can make the following claim.

Lemma 3. *When there are only V-firms, there will be a sub-coalition that is super-additive when n is sufficiently large.*

The explanation for this is the same as for coalitions of when there are only research firms. Larger pools mean less double marginalization but outsider's royalty becomes larger. When the latter effect dominates, coalition reduces profits.

5 V and R firms

We now show that there will be super-additive sub-coalition of V firms for sufficiently large number of firms even when there is an R firm. There are n V-firms and one R-firm. If all n firms are independent, every producer (V-firm) pays royalty to n firms. Royalty rate charged by all firms is $1/(n+1)$ each. Each independent firm's profit is,

$$\hat{\pi}^R = q(\frac{n}{n+1})^2 + \frac{n}{n+1} q(\frac{n}{n+1}) = \frac{2n+1}{2(n+1)} q(\frac{n}{n+1}).$$

When m V-firms form a coalition, there are $k = n - m$ independent V-firms. Each producer pays royalty to $k+1$ firms, either the pool, R-firm and $k-1$ independent firms or R-firm and k independent firms. Equilibrium royalty is $1/(k+1)$. Pool profit is,

$$\pi_0^R = mq(\frac{k+1}{k+2})^2 + \frac{k}{k+2}q(\frac{k+1}{k+2}) = \frac{2n-m+2}{2(n-m+2)}q(\frac{n-m+1}{n-m+2}),$$

using $k = n - m$. As with the case with only V-firms, super-additivity means

$$\delta^R(m) \equiv \pi_0^R - m\hat{\pi}^R > 0.$$

This must be true for sufficiently large n since the first term is convex, the second term is linear in m and

$$\delta^R(n) = \frac{n(n^2-6n+5)}{16(n+1)^2}.$$

We can define a similar measurement of super-additivity when there are $n+1$ V-firms using (10). We define as $\delta^V(m)$ the value of $\delta(m)$ when total number of firms is $n+1$ instead of n. One can show

$$\delta^R(n) > \delta^V(n).$$

This means whenever n V-firms are super-additive when ($n+1$)-th firm is a V-firm, it is also super-additive when ($n+1$)-th firm is a R-firm.

Now we ask the question, which outsider is more likely to occur, R-firm or V-firm. Think of the situation where there are $n+1$ firms: $n+1$ V-firms or n V-firms and one R-firms. We have verified that sub-coalition can form for sufficiently large n for both cases. First we claim the following:

Lemma 4. *A coalition of $n-1$ V-firms will bid more to V-firm to join than to R-firm to join its coalition.*

Proof. Independent of which firm joins the coalition, there will be 2 licensors. Thus equilibrium royalty and outputs do not differ according to which firm joins the pool.

The pool's license revenue which only comes from the outsider will be the same. But if V-firm joins the coalition, there will be production profit. There will be no production profit if R-firm joins the coalition. $\square$

When any firm, V-firm or R-firm, joins a pool, it reduces inefficiency of double marginalization for other members. Because a V-firm pays royalty, itself benefits by joining the pool since it eliminates double marginalization. There is no such benefit to a R-firm from joining.

We know now that if there are sufficiently many firms, a coalition of n V-firms will form, instead of coalition with one R, if both firms are willing to join. However a coalition of $n-1$ V-firms and R-firm will form if one V-firm has *committed not to negotiate*. Similarly if R-firm commits not to negotiate, then a coalition of n V-firms will form. Which firm has more to gain from making such a commitment? In answer to this question, we claim that,

Lemma 5. *R-firm's profit as an outsider is greater than that of a V-firm.*

Proof. With one outsider and one pool, the equilibrium royalty is $1/2$ and output is $1/4$. Profits of the pool and R-firm when the R-firm is an outsider are,

$$\pi_0^R = n(\frac{1}{4})^2 = \frac{n}{16}, \quad \pi_R = n(\frac{1}{2} \times \frac{1}{4}) = \frac{n}{8}.$$

When V-firm is the outsider, the pool and outsider profits are,

$$\pi_0^V = (n-1)(\frac{1}{4})^2 + \frac{1}{2} \times \frac{1}{4} = \frac{n+1}{16}, \quad \pi_V = (n-1)(\frac{1}{2} \times \frac{1}{4}) + (\frac{1}{4})^2 = \frac{2n-1}{16}.$$

$\square$

Suppose pool revenue is allocated proportional to number of patents. Then the marginal gains from being an outsider are,

$$\pi_R - \frac{1}{n}\pi_0^V = \frac{2n^2 - n - 1}{16n} > \pi_V - \frac{1}{n}\pi_0^R = \frac{2n-2}{16}.$$

That is, R-firm has more to gain. If there are n V-firms and one R-firm, and if firms can compete for a chance to commit not to negotiate, then the R-firm will bid higher and will actually commit not to negotiate and becomes an outsider. This is consistent with the emergence of research only firms as an outsider.

It is important to note that this result is independent of how pool profits are distributed among members. Thus it is not only the distribution rule that prompts an R-firm not to join a patent pool as was suggested by Aoki and Nagaoka (2004).

6 Some evidence from MPEG, DVD and 3G standard

In this section, we review the experiences of three standard-specifying patent pools from the viewpoint of coalition making. In particular, we would like to see how the process of coalition making worked in light of the above analytical results, and what we miss in our theory. The above analysis suggests that outsiders are more likely to emerge, that is, the grand coalition is less likely to be achieved, when the number of firms having the essential patents is large, essentially because the defection of a few firms still keeps the pool of the rest of the member worthwhile, and that a firm specialized in research is more likely to become an outsider than a vertically integrated firm.

(1) MPEG2

In the case of MPEG2, the number of the member firms of the patent pool was originally 8 organizations, including one university, when it started licensing in September 1997. The number of the members expanded to 23 organizations as of April 2004. The members include both manufacturers (17 firms) who are also licensees but also pure licensors, including complementors (telecommunications firms), firms specialized in licensing and a University. In terms of the coverage of essential patents, the share of the original members accounts for 60% of the patents which are being offered by the MPEG patent pool in 2004. Thus, there was a significant expansion of the membership in terms of the patent coverage since the establishment of the pool. According to an industry expert, the MPEG patent pool now covers more than 90% of the essential patents for the MPEG2 standard. There are two important non-members of the patent pool: IBM and Lucent Technology. However, IBM is engaged in extensive cross-licensing contracts with many licensors who participants in the MPEG2 pool, and it is not a licensee of the pool.

The case of MPEG2 in successfully expanding the coalition suggests that there may be important advantages of a pool, besides the control of royalty accumulation. First, the pool offers the advantage of ”one-stop shopping”. The number of licensees in the case of MPEG2 reaches 734 firms. Negotiating a contract with all of these firms could be expensive for an individual licensor and a licensee. Second, the pool may have the economy of scale in verifying the essentiality of the patents. Such certification is critical for a patentee to be able to collect royalty. Certification of the essential patents is a highly complex task, which requires the detailed knowledge of the standard specification. Hiring a common third party expert may be able to reduce the overall cost of such certification. In addition, the pool has a mechanism to allow the other members of the pool to challenge the essentiality of the patents. This ”opposition ”system may increase the credibility of the evaluations of the essentiality of the patents by a pool. A firm with an essential patent can exploit these advantages of a pool only if it participates in the pool. That is, in our framework, the “epsilon” is quite large, making some coalitions actually super-additive.

We may also point out the fact that a licensor seeking an independent licensing for high royalty would face the resistance by a licensee, since independent licensing only increases the total cost of technology for the licensee. On the other hand, the expansion of the member firms of the pool means no additional cost for the licensees, since the pool commits to the fixed ceiling of the total royalty to be paid by a licensee for all essential patents offered by the pool.

(2) DVD

Let us turn to the case of DVD. 10 firms agreed to the DVD standard in December 1995. While they originally aimed at providing a one-stop shopping facility for licensing the standard information, essential patents, and logo, Thomson decided to license its patents independently.[6] Following this, three firms (Sony, Philips and Pioneer) also decided to choose independent licensing but collectively (the formation of 3C group). The rest of the firms (six companies: 6C) decided to collectively license its technology through a patent pool. Thus, even the firms which participated in the standard development could not form a single patent pool and got split into the three licensing parties. Both groups widely license its technology (179 licensee in the case of 3C and 245 firms in the case of 6C for hardware, see Table 2). As a result, a manufacturer of DVD players has to currently pay royalties to each of three parties (5 dollar per unit for 3C, 4 dollar per unit for 6C and unknown amount to Thomson). We understand that the disagreement among the firms with respect to the distribution formula of the royalty was behind the split of the pool. 6C adopted the formula, which distributes the royalty revenue of the pool to a participant based on the number of its essential patents, in the same way as MPEG2. 3C and Thomson look to be unsatisfied with such pro-rata formula.

It is important to note that a firm can increase its profit by moving to independent licensing by defecting the patent pool using the pro-rata formula for royalty distribution, if its patent share is significantly less than half and it can expect that the rest of

[6]Thomson is a licensee of 4C.

the firms will stick to the patent pool (it can be so for whatever the level of royalty, see Aoki and Nagaoka (2004)). This is because the party can aim at collecting the half of the total royalty paid by the licensees through independent licensing and the total royalty will not significantly decline as long as the rest of the patent pool does not disintegrate (see the analysis in the above theoretical sections). In the case of DVD, it is estimated that the patent share of 3C group is about 42% of the total patents owned by 3C and 6C for a DVD player based on US patents, while the royalty share of 3C group is 56%(=5$/(5$+4$)). Thus, the pool adopting the pro-rata formula is vulnerable to the defection of a firm who claims that their contribution of technology is more than the number of the essential patents.

(3) 3G(W-CDMA)

Let us finally cover 3G. There are 5 standards (W-CDMA, cdma2000, TD-CDMA, EDGE and DECT) which were approved by the ITU. 3G patent platform for collective licensing was proposed and approved by the DOJ on the condition that the essential patents of each standard will be independently licensed. The patent platform began to evaluate essential patents of the participating firms in order to start the collective licensing of the essential patents for W-CDMA standard. The platform has the policy of committing to the maximum collective royalty rate of 5% and each essential patent is allocated 0.1% royalty until the collective royalty reaches this maximum value. Thus, the distribution of royalty follows the pro-rata formula as in the case of MPEG2 and 6C.

According to the declarations to the ARIB (Association of Radio Industries and Businesses, Japan), there are more than 30 firms who have self-declared essential patents (not certified by a third party), and the number of the candidates for essential patents amount to more than 950 in terms of the number of patent families. Qualcomm alone accounts for about half of the essential patents declared to ARIB in terms of patent families. There are 14 firms which have more than 4 families of patents. On the other hand, the members committing to the collective license for W-CDMA are limited to 7 firms (four Japanese firms, two European firms and one Korea firm) up to now, although there are more firms who support the 3G patent platform per se. Qualcomm, Motorola, Ericsson and Nokia, which would have substantial essential patents, are not the members of the pool.

Whether a single patent platform can be formed in the case of W-CDMA is still uncertain. One of the key issues is whether the pro-rata formula rewards adequately the firm which has many important patents, such as Qualcomm. A firm with important technology contribution would choose independent licensing especially if the pro-rata formula significantly under-rewards such firm, as noted earlier. Second, a pure license firm gains more from being an outsider to the pool, as shown in section 5. Third, a firm has strong patent positions both in W-CDMA technology and in cdma2000. Fourth, the cooperation by the other firms through a 3G platform will actually make it more attractive for a firm to stay as an outsider.

7 Conclusions

We have analyzed why cooperation among essential patent holders does not necessarily occur in reality, despite its significant gain for them and for users. Based on the analytical framework of Maskin (2003) on sequential negotiation for a coalition formation, we have shown that a grand coalition can be implemented only if the number of essential patent holders (n) is small. When n is large, the emergence of an outsider is inevitable, so that the voluntary sequential negotiation cannot secure the socially efficient outcome. There are two reasons for this outcome. First, a firm can gain by becoming an outsider and such gain increases as the coalition of the other firms expands. Second, the rest of the firms want to have a coalition, even if there is an outsider, when the number of firms is large so that the cost of double marginalization is high. Thus, there is indeed a risk of the tragedy of anti-commons.

In addition, we have also shown that even in the case where a grand coalition can be formed, the initiator of such firm can not gain much, since the other firms can gain from being an outsider. Thus, there is a risk of delay due to war of attrition, since each firm wants other firms to take the initiative to develop a patent pool for a standard. Furthermore, we have shown that a firm specialized in research is more likely to become an outsider than a vertically integrated firm, since such firm has the first mover advantage in setting the price of its technology. Thus, as technology market develops and the number of firms specialized in research increases, the collaborative venture for a standard setting may become more difficult.

The actual experiences of the standard-specifying patent pool indeed show that the grand coalition is not easy to achieve. In the case of the DVD reader there are at least three groups of essential patent holders which provide the licensing of technologies. The 3G patent platform could start only in a small coalition. On the other hand, the MPEG2 case suggests that the standard-setting patent pool may have the substantial coalition benefits such as the low cost of one-stop shopping, besides the gain from avoiding royalty accumulation. In this case, the coverage of the coalition has significantly expanded over time. However, this case may be more an exception.

How can we improve the situation? There may be several policy options to consider. We focus what standard bodies may undertake, since this is more a market-base solution. First, a standard body may wish to clarify the basic principles which help the licensor and the licensee to determine what RAND conditions imply, in particular, what the reasonable royalty of each patent is. Such clarification will reduce the gain from being an outsider. The reasonable royalty of a patent cannot be individually negotiated if it is one of the patents essential to the standard. The price of each patent has to be reasonable in light of the total royalty for the technology as a whole. Second, a standard body may wish to ask the group of the firms sponsoring the standard to announce not only the technology specifications of a standard but also the maximum price of the standard. Such requirement will force the essential patent holders to focus on the pricing of the standard itself and to commit to it before the adoption of the standard. Third, a standard body may prepare the following option of the patent statement in addition to the existing statements: a patentee is wiling to provide a license under RAND, and to do so collaboratively if and only if his patent is a part of the essential patents to the standard.

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Table 1: Nash pricing and effects of coalition

(A)Profit of each firm when n firms engage in independent pricing

	Number of firms(n)				
	1	2	3	4	5
p	0.5	0.3333	0.2500	0.2000	0.1667
$P = np$	0.5	0.6667	0.7500	0.8000	0.8333
$\prod$	0.25	0.1111	0.0625	0.0400	0.0278
total $\prod$	0.25	0.2222	0.1875	0.1600	0.1389

(B)Payoff to a coalition

		Number of firms			
		2	3	4	5
Size of a coalition	2	0.0278	-0.0139	-0.0175	-0.0156
	3		0.0625	-0.0089	-0.0208
	4			0.0900	0.0000
	5				0.1111

Table 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*	3G Patent Ltd**	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 bi-lateral 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.

Figure 1 ″Tradegedy of anticommons″ and the effect of coalition