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Patent Pools as a Solution to Efficient Licensing of Complementary Patents? Some Experimental Evidence

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Abstract
Production requiring licensing groups of complementary patents implements a coordination game among patent holders, who can price patents by choosing among combinations of fixed and royalty fees. Summed across patents, these fees become the total producer cost of the package of patents. Royalties, because they function as excise taxes, add to marginal costs, resulting in higher prices and reduced quantities of the downstream product and lower payoffs to the patent holders. Using fixed fees eliminates this inefficiency but yields a more complex coordination game in which there are multiple equilibria, which are very fragile in that small mistakes can lead the downstream firm to not license the technology, resulting in inefficient outcomes. We report on a laboratory market investigation of the efficiency effects of coordinated pricing of patents in a patent pool. We find that pool-like pricing agreements can yield fewer coordination failures in the pricing of complementary patents.

1. Introduction and Literature

In some research and development (R&D) areas, technical advances have resulted in the issuance of numerous patents, each constituting an essential element of a larger information base. Consequently, obtaining access to innovations requires licensing increasingly larger sets of intellectual property rights. To commercialize an innovation may well require simultaneous dealings with as many different agents as there are patented elements.1 Requiring multiple patent rights to produce a product creates two sets of issues: the potential for holdup problems (a patent holder refusing to license) and the potential compounding effect of multiple license fees set as royalties. Obtaining numbers of essential patents could lead to higher prices and/or reduced access to upstream information bundles, owing to increased transactions costs. It could also reallocate rents among individual elements of the larger information package required to bring biomedical products to market, leading to reduced incentives for downstream research.

Royalty fees are an inherently inefficient mechanism for pricing patents. In effect, such fees constitute an excise tax on downstream production, shifting the marginal cost of the good upward and resulting in higher prices and lower quantities for the consumers of the final product. The problem is compounded when a set of patents is required to produce the good. Each patent holder sets a use fee (a royalty), and since each of these acts as an excise tax on the downstream producer, the cumulative effect of several fees being charged (what Lemley and Shapiro [2007] refer to as "patent stacking") is a higher cost of producing the good and a smaller quantity of output. The welfare losses consist of the sum of the patent holder's lost returns, the lost profits of the downstream firm, and the consumers' loss of surplus from the final product.

When there is a single downstream purchaser of the technology, or when patent holders can price discriminate, one solution to this dilemma is for patent holders to charge fixed fees rather than royalty rates for the use of the patents. Such fixed fees will not affect the marginal cost of the downstream firm, and so the welfare losses enumerated by Shapiro (2006) will not arise. In this case, the existence of multiple patent holders would introduce coordination problems, but the pricing mechanism itself would not introduce inefficiencies. Coordination, however, may prove difficult, and if the patent holders are unable to coordinate strategies, at least two types of inefficiency may result. The first type arises if the combined fees are sufficient to discourage the downstream firm from purchasing the technology. Here potential consumers of the final product fail to realize the resulting surplus, and the firms (including those holding the patents) fail to realize potential profits. The second type can arise if the patent holders anticipate the inability to coordinate on their pricing and, therefore, invest fewer resources attempting to innovate.

It is clear (see Merges 1996, 2004a, 2004b; Lerner, Tirole, and Strojwas 2003) that successful pools for the purpose of licensing intellectual property rights (IPR) have emerged over time. As Merges (2004a) suggests, repeat players learn to develop strategies and take steps that allow business to be transacted, and within a dynamic marketplace, excessively rigid rules and institutions reduce efficiency unnecessarily.

Bittlingmayer (1988) describes a case (aircraft manufacturers in 1917) in which the industry was encouraged to form a pool to facilitate the development of aircraft needed for World War I. The open question is whether the pools that have emerged achieve efficient pricing of the IPR. This question can be resolved only through empirical investigation because it is inherently behavioral. While there are case studies of patent pools, there are few studies reporting the terms of these agreements.

A solution to the potential coordination problems arising from complementary patents in current technology might be to encourage the formation of patent pools or other collective property rights organizations. While this solution has the obvious advantage of speeding the learning process discussed above, such organizations by themselves can easily slip into collusive practices if they serve as a means to reduce competition and could fall victim to antitrust proceedings. However, many analysts (for example, Kato 2004; Shapiro 2001) believe that allowing holders of complementary patents to undertake monopoly pricing practices through pooling or other arrangements would result in lower prices for the package of complementary patents and therefore lead to welfare gains. Current policy appears to endorse this approach (Clark et al. 2001). Patent pools may also allow the avoidance of various holdup problems. Merges (2001, 2004a, 2004b), Gilbert (2004), and Lerner and Tirole (2004) describe the history of patent pools and analyze their impact on competition among patent holders. Bessen (2004) and Shapiro (2006) provide discussion of the holdup problem.

To investigate the scope for pools to avoid potential coordination failures in the complementary patent setting, we begin by constructing a three-player game. The game consists of two profit-maximizing upstream holders of strictly complementary patents and a downstream firm that requires the technology to produce a final product. The patent holders choose a combination of fixed and royalty fees in a full-information environment. In equilibrium, the patent holders forgo use of the royalty, which would distort the downstream firm's output, extracting rents through the use of fixed fees. As such, all rents theoretically accrue to the patent holders, leaving the downstream monopolist with only sufficient incentives to produce. Multiple equilibria exist because only the sum of the fixed fees matters to the downstream firm. Each Nash equilibrium is equally efficient and identical to the solution arrived at by a patent pool that successfully emulates the behavior of a single upstream seller. This simple game captures the essential elements of the licensing of perfectly complementary patents and yields testable predictions.

In the absence of sufficient field data, we test the predictions of our model with data from a laboratory experiment designed to investigate the occurrence of coordination failures and options for improving efficiency. The patent holders are allowed to price their patents using fixed fees or royalties, and the information exchange among patent holders, a surrogate for public policy toward collusive behavior, is varied as experimental treatments. Patent holders choose patent prices that, when added together, become the cost to a buyer of a bundle of essential patents. A downstream buyer then compares the cost of the bundle with expected revenues and determines whether or not to produce the final product the patent bundle enables.

We find that players generally are not able to improve their pricing strategies over time and continue to coordinate poorly in the absence of facilitating mechanisms. The players set the royalty higher than the theory predicts and the fixed fee correspondingly lower. The result is that the patent holders earn suboptimal rents. The subjects obtain more efficient outcomes in the cheap-talk (information-sharing) regime and do best in our simplified pool regime, although in no circumstance do they fully achieve the theoretical (Nash) outcome. The class of failures arising when the monopolist rejects the patent offers because of violation of the nonnegative profit constraint is also affected by the treatment variables. Ours may be the first empirical evidence of the desirability of patent pools in a setting in which the patent holders are unable to coordinate their fees to maximize the return to R&D activity.

2. Theory

There are three players: Firm 1, Firm 2, and Downstream. Firms 1 and 2 hold patents, and Downstream requires both patents in order to produce widgets. There are no other widget producers—Downstream will be a monopolist if it sells widgets, and entry is precluded through enforcement of exclusive patent rights.9 The inverse demand curve for widgets is

$$P = a - b \times Q, \quad \text{where } a,\ b > 0.$$

Given that Downstream has access to the patented technologies, it can produce widgets at a constant marginal cost: TC p *cQ*. It is assumed that *a* 1 *c*, which implies that the monopolist should operate. It is convenient to have notation for the profits that would be earned if Downstream did not have to pay for either patent. Straightforward calculations show that the standard monopoly quantity and profits are, respectively, *Q* p (*a* _ *c*)/2*b* and Pmax p (*a* _ *c*)2/4*b*.

Firms 1 and 2 can each charge a two-part tariff (a fixed fee and per-unit royalties) for the use of their patents.10 The reservation profit of each player is zero. Thus, if the fees set by the firms do not allow Downstream to earn nonnegative profit, then Downstream will not purchase access to either technology. The timing of the game is as follows:

Stage 1. Firms 1 and 2 simultaneously set fixed fees and royalties. That is, Firms 1 and 2 simultaneously choose (*F* , *R*) and (*F* , *R*), where *F* ≥ 0 and 1 1 2 2 *I R* ≥ 0 for *i* p 1, 2.

Stage 2. Downstream either accepts both offers or rejects both offers.

Stage 3. If Downstream rejects both offers, then each player earns a reservation profit equal to zero. If Downstream accepts both offers, it must decide how many widgets to produce.

It is optimal for Downstream to accept the offers as long as the fees for the patents allow it to earn nonnegative profits after solving the following:

$$\max_{Q \geq 0} [a - bQ - R_1 - R_2 - c]Q - F_1 - F_2.$$

At an interior solution, the optimum quantity is *Q** p (*a* _ *R* _ *R* _ *c*)/2*b*. 1 2 Substituting this value into the expression for profits yields

$$\Pi(F_1,\ R_1,\ F_2,\ R_2) = (a - R_1 - R_2 - c)^2/4b - F_1 - F_2.$$

The profits of the downstream firm are P*(*F* , *R* , *F* , *R*) p max{0, P(*F* , *R* , 1 1 2 2 1 1 *F* , *R*)}. When there is no risk of confusion, the arguments of P(*F* , *R* , *F* , *R*) 2 2 1 1 2 2 and P*(*F* , *R* , *F* , *R*) are suppressed. It is also convenient to write P(*F*, *R* , *F*, 1 1 2 2 *i i j R*) and P*(*F*, *R* , *F*, *R*), where *i* (*j*. This should not cause confusion since *j i i j j* P(*F* , *R* , *F* , *R*) p P(*F* , *R* , *F* , *R*).

Subgame perfection requires that Downstream reject both offers if P ! 0 and accept both offers if P ≥ 0. It is assumed that Downstream accepts both offers when P p 0, even though it is indifferent.

We can write the profits of Firm *i*, denoted p, as a function of (*F*, *R* , *F*, *i i i j R*). Specifically,

$$\pi_i(F_i,\ R_i,\ F_j,\ R_j) = \begin{cases} R_iQ^* + F_i & \text{if } \Pi(F_i,\ R_i,\ F_i,\ R_i) \geq 0, \\ 0 & \text{if } \Pi(F_i,\ R_i,\ F_i,\ R_i) < 0. \end{cases}$$

Firm *i*’s best response is the pair (*F*br(*F*, *R*), *R*br(*F*, *R*)) that maximizes p(*F*, *i j j i j j i I R* , *F*, *R*) while holding (*F*, *R*) constant. When P(0, 0, *F*, *R*) ≤ 0, Firm *j*’s fees *i j j j j j j* are so large that Downstream will necessarily reject the offers unless Firm *I* charges no fee. It follows that *i*’s best response is not unique: Firm *i* will earn no profit regardless of the fees it charges. However, for concreteness, we define (*F*br(*F*, *R*), *R*br(*F*, *R*)) p (0, 0) whenever P*(0, 0, *F*, *R*) p 0.

Lemma 1. If either patent holder (or both) plays a best response, then Downstream’s profits equal zero.

Proof. Suppose not, so that (br(,), br(,), ,) 1 0, which P* *F F R R F R F R* 1 2 2 1 2 2 2 2 implies that (br(,), br(,), , . Then Firm 1 could increase P *F F R R F R F R*) 1 0 1 2 2 1 2 2 2 2 its payoff by increasing its fixed fee by _ p ((,), (,), ,)1 br br P*F F R R F R F R* 1 2 2 1 2 2 2 2 0 without causing Downstream to reject. It follows that the choice *F*br(*F* , *R*), 1 2 2 *R*br(*F* , *R*) cannot be a best response. The argument for Firm 2 is identical. In other words, Lemma 1 shows that it is never optimal to leave rents on the table. As long as Downstream is capable of earning positive profits, one of the patent holders would be better off charging a larger fixed fee.

Lemma 2. Firm *i*’s best response to any (*F*, *R*) is to charge no royalty and *j j* a fixed fee that leaves Downstream with no profit. That is, for all (*F*, *R*), we *j j* have *R*br (*F* , *R*) p 0 and *F*br (*F* , *R*) p P* (0, 0, *F* , *R*) p max {0, (*a* _ *R* _ *i j j i j j j j j c*)2 /4*b* _ *F*} for all (*F*, *R*).

Proof. As discussed above, if (0, 0, ,) p 0, then br(,) p 0 and P* *F R R F R j j i j j F*br(*F*, *R*) p 0. If P*(0, 0, *F*, *R*) 1 0, lemma 1 implies that (*a* _ *R*br _ *R* _ *c*)2/4*b* _ *F*br _ *F* p 0.

Therefore, we can use this condition to substitute out the *i j* fixed fee from Firm *i*'s objective, which is then

$$\max_{R_i} R_i \frac{(a - R_i - R_j - c)}{2b} + \frac{(a - R_i - R_j - c)^2}{4b} - F_j.$$

The first-order condition reduces to _*R* /2*b* p 0, which implies that *R*br(*F* , *i ij R*) p 0:

$$\frac{-R_i}{2b} = 0 \rightarrow R_i^{\mathrm{br}}(F_j, R_j) = 0.$$

Using *R*br(*F* , *R*) p 0 along with lemma 1 implies

$$F_i^{\mathrm{br}}(F_j, R_j) = \frac{(a - R_j - c)^2}{4b} - F_j = \Pi^*(0, 0, F_j, R_j).$$

Given that royalties (further) distort the output decision of Downstream, they are an inefficient means of extracting surplus. Hence, is not surprising that it is never a best response to choose a positive royalty. We do not prove the next proposition, as it follows immediately from lemmas 1 and 2.

Proposition 1. The terms (*F**, *R**) and (*F**, *R**) constitute a Nash equilib- 1 1 2 2 rium if and only if (i) *R** p *R** p 0 and (ii) *F** _ *F** p (*a* _ *c*)2/4*b* p Pmax.

According to proposition 1, there exist a multiplicity of equilibria. Furthermore, the equilibria cannot be Pareto ranked since in any equilibrium in which Firm 2 receives a higher fee, Firm 1 receives a lower fee since *F** p Pmax _ 1 *F**. Facing such settings, the players are often depicted as utilizing focal points 2 to select outcomes from the set of Nash equilibria (Sefton 1999). Given the symmetry of the patent-pricing game, one such focal equilibrium is the symmetric one in which each firm extracts half of Downstream's profits via the fixed fee (*F** p *F** p Pmax/2).

Whether or not firms can coordinate on a given equilibrium, symmetric or other, is ultimately an empirical question. The discontinuity of the payoff functions potentially makes the coordination failures very costly. For any given *F*, *j* the payoff to both firms is zero if firm *i* charges *F* 1 Pmax _ *F* since Downstream *i j* will not purchase either technology in this case. Similarly, if the fixed fees charged are such that *F* p *F* p Pmax, any positive royalty drives the profits of the patent 1 2 holders down to zero. Hence, even the slightest coordination failure or mistake can have dramatic consequences.

3. Experimental Design and Hypotheses

The task of the patent holders is to choose patent-pricing strategies that achieve two ends: provide the necessary incentive for the monopolist to produce an optimal quantity by forgoing the use of a royalty and choose the fixed fees such that their sum exhausts monopoly rents. In our experimental setting, human subjects were assigned the role of patent holders, and the behavior of the downstream firm (the monopolist) was simulated. The assumption enforced by the simulated behavior was a simple profit rule. If the patent holders set their combined prices to the downstream firm such that its profits would be strictly negative, the monopolist did not purchase the patents and did not produce. In that case, the patent holders earned no income in the round. If the downstream firm did purchase the patents and produce the final product, the patent holders' earnings consisted of the fixed fee and the royalty charges they chose to implement. All of this information was conveyed via the instructions provided to the subjects through several computer screens.

As these were computerized experiments, subjects interacted with a computer interface that provided them with the necessary instructions and information and elicited their choices. The fixed fee was entered via a numeric keypad presented on the screen, and the royalty was entered via the choice of a row or column in a game matrix. The interface allowed the subjects to enter the potential choices of the person with whom they were paired and to observe the outcomes under alternative scenarios. As these scenario values were entered, the subjects were informed of the payoffs that would result if they played their choice and their partner played the hypothetical choice. The subjects could also observe the resulting profits to the downstream monopolist for each scenario. This feature of the experimental design reinforces the interdependence that exists in the naturally occurring setting. The subjects were free to investigate alternative strategies until they decided which one they wished to choose. The interface reminded the subjects that they had limited time (3 minutes) to make a decision and provided an on-screen warning when 15 seconds remained in the round. The software imposed a zero-price outcome on a subject who did not submit a decision prior to time expiring.

The experiment implemented a game of complete information, as developed in the theory. Thus, the subjects were informed of the downstream monopolist's profits for each possible combination of fixed fees and royalties. The game was symmetric—payoffs to each subject for a given fee and royalty were identical. The subjects were told that they would be paired with the same person each round. Subjects were not told the number of rounds in the session. In all sessions the subjects read through the instructions on the computer screen, which showed the interface and an explanation of its operation. Subjects were given the opportunity

Table 1 Experimental Treatments

		Additional Condition Imposed			
Treatment	Subjects	Royalty	Fixed Fee	Cheap Talk	Pool
T1 Royalty	20	Y			
T2 Fixed Fee	24	Y	Y		
T3 Cheap Talk	30	Y	Y	Y	
T4 Pool	28	Y	Y		Y

to ask questions about the procedures and to complete a number of practice or training rounds, after which further procedural questions were addressed. Each subject participated in only one session (treatment). The interface allowed subjects to review past performance, including the decisions of the subject, the person with whom they were paired, and the resulting payoffs.

The experimental treatments in this simple setting are shown in Table 1. Since the subjects faced a potentially difficult coordination problem, to provide a baseline setting we ran our first treatment, T1 Royalty, in which the subjects could choose only a royalty to license the patent. The second treatment, T2 Fixed Fee, introduced the fixed fee along with the royalty.

In a coordination game setting, such as this one, there are several Nash equilibria, which cannot be Pareto ranked. Since the players can benefit from coordinating strategies, there is the potential for cheap talk to improve the outcome by providing opportunities for informing strategy choices and encouraging the players to play the strategy that yields the equilibrium with the largest payoff. This raises the potential for communication to facilitate coordination on pricing even though such communication is not binding on the parties. The third treatment, T3 Cheap Talk, allows for this possibility.

We implemented cheap talk in a manner similar to that used in other experiments (see, for example, Sefton 1999; Alm and McKee 2004). After six nonpayment practice rounds were completed, the subjects were given 4 minutes to discuss the experiment among the entire group. Since subjects were never informed of the identity of the person with whom they were paired, the discussion could inform the subjects of general principles of the decision task but could not facilitate explicit agreements. Six practice rounds allowed the subjects considerable experience with the setting prior to the discussion period. The experimenter monitored the subjects' discussions only to provide reminders of time remaining. After this discussion, the subjects returned to their carrels, and the actual rounds of the session began. There was no further opportunity for discussion.

Finally, formal coordination among patent holders (for example, through the formation of a patent pool) would be expected to lead to efficient patent pricing. That is, the logical next step beyond cheap talk is a joint decision setting. We implemented this as the fourth treatment, T4 Pool, where the subjects were paired and the pairs assigned to a single carrel. The subjects each had their own terminal in the carrel in which they entered their patent-pricing decisions. The subjects had full view of each other's computer screens and could discuss strategies and easily monitor the decisions of the person with whom they were paired for the session.

4. Results

A total of 102 subjects participated, with each making 20 or 25 decisions (rounds). In Table 2 we provide definitions of the variables used in subsequent analysis, and in Table 3 we report raw results for the behavioral metrics we constructed. We predict that each metric will improve as we introduce coordination-facilitating mechanisms as treatments (T3 Cheap Talk and T4 Pool). The simplest setting, T1 Royalty, serves as a benchmark of the subject's understanding of the decision setting. Here, the players coordinated on strategies yielding results quite close to the Nash equilibrium. The predicted royalty rate (index) is .67 (see note 10), and we see that in the last 10 rounds the subjects achieved an average royalty index of .61 for each pair of patent holders.

Royalties are inefficient means of pricing patents, and this is demonstrated by the relatively low scores for the efficiency index in T1 Royalty.

Introducing the fixed fee option has the potential to generate efficient pricing, and we examine in detail the results from those experimental settings in which both a fixed fee and a royalty could have been charged. The costliest coordination failure has the monopolist buying neither patent, the result being zero profits to each patent holder. This class of failure arises when the combined price of the two patents is such that the downstream firm incurs a loss by purchasing the patents. The failure rate is highest for the treatment in which nonbinding discussion was allowed (T3 Cheap Talk). As expected, the failure rate is lowest for the collusion setting (T4 Pool), which may suggest that the failures in T3 Cheap Talk are not due to a failure to understand the pricing setting. Rather, it

Table 2 Variables and Definitions

Variable	Definition
Failure Rate	Failures (patents not used) divided by the number of decision rounds
Royalty Index	Sum of the royalties charged divided by the maximal available royalty (the intercept of the monopolist's demand curve less the marginal cost)
Fee Index	Sum of the fees divided by the monopoly profit when the royalty is set at zero
Efficiency Index	Sum of the payoffs to the patent holders and the monopolist divided by the theoretical optimum
Monopolist Q	Quantity the monopolist produces divided by the output in the zero royalty case
Monopolist Rent Share	Monopolist profit as share of maximal rents from patents
Round Number	Round of the experiment session
Fixed Fee	Equals one if subject was permitted to choose a fixed fee, and zero otherwise
Cheap Talk	Equals one if subject was permitted to discuss the experiment after completing practice rounds, and zero otherwise
Pool	Equals one if subjects were able to coordinate their joint decisions prior to entering them into the computer, and zero otherwise

is plausible that these failures are due to the inability to enforce the agreements that emerged through cheap talk.

It is optimal for the patent holders to set the royalty at zero and use only the fixed fee to extract the monopoly rents. The Nash equilibrium has a zero royalty being charged by both patent holders (a royalty index equal to zero). Examination of the aggregate results (Table 3) shows that the royalty index is greater than zero for all four treatments but decreases as we provided opportunities for the patent holders to communicate (T3 Cheap Talk) and to collude (T4 Pool). The index is bounded at zero, the predicted value, so errors can occur in only one direction. The performance in T4 Pool can be judged to be quite good in light of the theory.

The downstream monopoly right derives from the exclusive use of the patent rights, and it follows that the patent holders will be able to extract the available rents—profits flow to the scarce resources, the patent rights. The patent holders are predicted to set the fixed fees such that the sum of the fees will just exhaust the monopoly profits.20 Thus, theory predicts that the fixed fee and the efficiency index will each equal 1.0. Examination of the data reported in Table 3 clearly shows that this is not observed. The fixed fee index is below .5 for all but the T4 Pool treatment. Similarly, the efficiency index is well below 1.0 except for the T4 Pool treatment. The indices improve as the experimental treatments

Table 3 Results for Performance Indices

Treatment	Failure Rate	Royalty Index	Fee Index	Efficiency Index	Monopolist Q	Monopolist Rent Share
All rounds:						
T1 Royalty	.008	.555	N.A.	.652	.425	.213
T2 Fixed Fee	.089	.344	.229	.755	.566	.148
T3 Cheap Talk	.119	.260	.352	.779	.620	.108
T4 Pool	.032	.167	.591	.909	.800	.068
Last 10 rounds:						
T1 Royalty	.007	.609	N.A.	.622	.395	.178
T2 Fixed Fee	.074	.380	.220	.749	.545	.140
T3 Cheap Talk	.142	.257	.396	.766	.617	.098
T4 Pool	.043	.158	.597	.902	.799	.066

successively introduce facilitating mechanisms, but we do not observe the levels required for efficient pricing.

The coordination problem facing the patent holders is complicated by the fact that there are two pricing vehicles. Players must also overcome a natural tendency to seek to diversify by setting each vehicle at a positive value. Cheap talk has been shown to be useful in coordination games, and we expect that it is useful here. The results in Table 3 provide some support for this conjecture. With the opportunity to engage in cheap talk, the patent holders were better able to coordinate on the equilibrium predicted by the theory. However, T3 Cheap Talk does not fare as well in comparison with T4 Pool. As we would expect, collusion among the patent holders provides the best opportunity for the coordination on the optimal joint fixed fee and royalty in order to exhaust the monopoly profits. The aggregate results in Table 3 suggest that the sort of collusion associated with a patent pool may be able to resolve the coordination problem. The royalty index approaches zero in this treatment, while the efficiency and monopolist quantity indices approach one. The fixed fee index falls short of the predicted level even in the presence of the facilitating opportunities. We check whether the results improve if we focus on the last 10 rounds of the session. In general, the results are unchanged. Learning through repeated play does not, in itself, facilitate coordination.

We can learn more about individual behavior from econometric investigation of the data. Since the data are generated by observations across a set of individuals over a number of rounds, we have a panel data set. We analyze the data using a generalized equation estimation model (see Liang and Zeger 1986). Our model uses the probit link function and binomial distribution family, which constrains predicted values for the dependent variable to be in the [0, 1] interval defined by our construction of the indices. We include as regressors in the model dummy variables corresponding to treatment conditions and round-specific indicator variables. The errors are corrected for clustering on subjects. The results for the

Table 4 Panel Estimations

	Royalty Index	Fee Index	Efficiency Index	Monopolist Q
Constant	−.2460**	−.5646**	1.0836**	.3802*
	(.0943)	(.1106)	(.1307)	(.0974)
Cheap Talk	−.2645**	.4353**	.1094	.1574
	(.0884)	(.1274)	(.1282)	(.1060)
	[−.0877]**	[.1677]**	[.0266]	[.0558]
Patent Pool	−.5867**	1.0539**	.7794**	.7398**
	(.1251)	(.1552)	(.1318)	(.1342)
	[.1708]**	[.4000]**	[.1661]**	[.2426]**
Wald χ^2	312.67**	264.97**	269.19**	196.12**

models estimated to explain our performance metrics are reported in Table 4, with coefficients corresponding to the round-specific indicator variables suppressed for compactness.

The regression results presented in Table 4 provide a more comprehensive look at the effects of the cheap-talk and pool settings on patent-pricing behavior and market efficiency. For this analysis we include only the data from those treatments in which the subjects could set both a royalty and a fixed fee. The coefficients on both Cheap Talk and Patent Pool are generally significantly different from zero. The more interesting comparison is the relative effects of the treatments. The marginal effects of the pool setting are uniformly greater, and these differences are statistically significant at the .10 level, or better, for all indices. While cheap talk may facilitate coordination, introducing the pool is the only treatment that yields noticeable effects on the efficiency in the market for intellectual property rights. Our cheap-talk setting is comparatively weak in that no further opportunities for discussion were offered during the progress of the experiment. The effect is smaller than expected when compared with results in prior applications in coordination games. It is also possible that cheap talk is simply insufficient in more complex settings such as one requiring multiple (royalty and fixed fee) decisions.

5. Discussion

It may be argued that our patent pool setting is contrived. All players knew the potential profits of the downstream firm, a situation unlikely to arise in the naturally occurring setting. Second, the size of our patent pool was exogenous and relatively small. Third, the patent holders were identical in terms of their investment in R&D (here normalized to zero). Fourth, our downstream market was extremely simplified; there was no value added at the downstream end. We address these points.

It is not necessary that the players know the profits of the downstream firm for the patent holders to coordinate on the use and size of the fixed fees. It is necessary only that the parties agree as to the assessment of these profits. Overestimating the rents that can be extracted may lead the upstream firms to charge fees that are rejected by the downstream firm. However, this would be true for a single upstream patent holder and is not specifically a coordination failure.

The size of the patent pool is an important issue not addressed here but is a worthy topic for future research. A larger number of complementary patent holders should have greater difficulty coordinating in the absence of a patent pool. Even with complementary patents, the most favorable argument for pools, the potential exists for the pool to exert monopoly power through the use of tie-in sales and full-line-forcing contracts (Burstein 1960).

Unequal levels of investment can further complicate the coordination problem that is at the heart of the pool's task. In a formal patent pool with multiple players, there must be a set of fairly rigid rules. A necessary rule governs the division of the revenues from patent licensing. As Libecap and Wiggins (1985) show, disagreement over division of the rents severely compromises agreements even when substantial private inefficiencies could be avoided. In the patent pool, a potential principle might be to divide the rents equally since each patent is an essential input—all have equal value at the margin. However, the R&D costs may differ substantially, and a revenue-sharing rule that ignores the differential investment will not encourage R&D in the costly complements. Such division will be more likely agreed upon in the presence of a patent pool.

Finally, in our market, the downstream firm served merely as a distributor of the technology embedded in the patents, with no distinct contribution to command rents. In the Buchanan and Yoon (2000) and Shapiro (2001) models, the downstream firm was constructed differently, implying multiple uses for the technology, such that adding access to the technology led to a welfare gain. It would be interesting to expand the role of the downstream firm or firms such that this market can add to social welfare in a manner similar to the model in Buchanan and Yoon (2000).

6. Conclusion

Academics and policymakers alike have suggested that increased coordination among holders of complementary patents, including the formation of patent pools, can improve welfare. Our experiments provide empirical evidence supporting this view. In particular, we find that coordination failures can greatly decrease efficiency and that institutions improving coordination can help combat this problem.

Our observed coordination failures in the setting where communication was not permitted raise concerns regarding the two classes of inefficiency noted in our introduction. First, setting positive royalties results in distortions in the downstream market. Second, suboptimal rent extraction implies a lower return to R&D and less investment. Subsidies to R&D activity may be viewed as a correction of the latter, but such policy responses will be second best in that the initial distortion remains. A first-best solution would facilitate coordination among patent holders. As such, our results provide evidence in support of permitting collusion among patent holders such that coordination failures are avoided. Our experimental investigations demonstrate the difficulty that holders of complementary patents have in coordinating their pricing strategies. Such difficulties can be overcome through the use of collusion on pricing. To the extent that a patent pool can facilitate such collusion, the pools would provide a benefit.

The “patent race” stage game has been extensively analyzed (see Taylor [1995], Fullerton et al. [1999], and Zizzo [2002] for the case in which a single patent is sufficient for production of a good). Solving the sequential game by backward induction to determine the best-response investment in R&D requires that the prospective patent seekers know the yield (expected value) from the resulting patent. The yield depends on the full license price for the patent. Absent the ability of patent holders to set their prices to maximize profits, the level of R&D activity will be reduced. Finding that patent holders are unable to jointly arrive at rent-extracting patent prices calls into question whether the results of the single-patent literature can be extended to the case in which patents are complements. As our experimental results demonstrate, coordination failures are less likely to arise when patent holders can jointly set use fees as they would, for example, if they belonged to a patent pool. This institutional structure would help the patent holders achieve the sorts of payoffs available in the single-patent case. Thus, one possible policy response to this coordination problem is to facilitate coordination among the holders of complementary patents by allowing them to form patent pools.

While our empirical evidence is obtained from the decisions of subjects in a laboratory setting, the basic decision making is not dissimilar from that encountered in the naturally occurring setting. Our interface provided subjects with the ability to investigate outcomes under alternative scenarios of conjectures of the behavior of the other patent holder. In particular, the interface reminded our subjects of the consequence of setting the joint fee for the use of the complementary patents so high that the downstream monopolist does not license the patents and so the return is zero.25 However, this is the patent-pricing setting faced in the field where patent holders have different means of licensing intellectual property, including fixed fees and royalties. Our laboratory experiments suggest that profit-seeking agents can coordinate licensing arrangements in complicated situations fairly effectively with the opportunity to set prices jointly. In the case of strictly complementary patents, the gains arising from permitting collusion (measured as market efficiency) appear to be substantial, and the extreme examples of coordination failure are avoided.

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