Selling Complementary Patents: Implications for Human Genome R&D

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# TABLE OF CONTENTS

Preface and Acknowledgements ........................................................................................................ iii
Executive Summary ................................................................................................................................. iv
1.0  Introduction ................................................................................................................................. 1
2.0  Theory ........................................................................................................................................ 2
3.0  Experimental Design and Hypotheses ....................................................................................... 5
4.0  Experiment Results ..................................................................................................................... 8
5.0  Conclusions and Discussion ..................................................................................................... 12
References .......................................................................................................................................... 13
Appendix 1: Simultaneous Royalties ................................................................................................. 14
PREFACE AND ACKNOWLEDGEMENTS

The Office Biological and Environmental Research within the Department of Energy’s Office of Science provided support for this paper. The paper is addressed to economists and other scholars and to policy officials concerned with intellectual property rights considerations surrounding the human genome. It deals with the ability of two patent holders to coordinate their choices in licensing patents that are strict substitutes to a downstream monopolist. The patent holders must choose between charging a fixed fee, a royalty fee, or a combination of the two.

The paper follows earlier work addressing what has become known as the tragedy of the anticommons, a situation that is asserted to occur when downstream activities require the licensing of complementary patents. The anticommons conjecture arose due to the potential for patents to be issued for multiple segments of individual genes sequenced as the “base genome.” Whereas there is reason to believe that the anticommons describes a valid behavior phenomenon (Stewart and Bjornstad, 2002), there may also be acceptable remedies (see Shapiro, 2001). Nonetheless, patenting in the context of strict complementarities raises any number of additional issues, and this paper raises one, the ability of patent holders to coordinate. Because policy choices often contain suggestions to redefine intellectual property rights conferred by patents, there is need for evidence as to the likelihood policies will succeed in the marketplace. This paper suggests that, whereas there is a clear ability for sellers to coordinate, behavior falls well short of theoretical optima.

We would like to take this opportunity to thank the many individuals who have contributed to this paper. In particular, our colleagues at Economics Science Associates gave many useful suggestions at their annual meeting in Tucson (November 2004), where an earlier version was presented. We also thank David Bruner, John Deskins, and Zach Richards for their diligence as research assistants on this project. Dan Drell of the Office of Science also provided support and advice. Sherry Estep of the Joint Institute for Energy and Environment edited the final manuscript and prepared the document for publication. The authors, of course, retain responsibility for any remaining shortcomings.
EXECUTIVE SUMMARY

Production often requires licensing groups of patents that allow firms to acquire and exercise unique technologies. If these patents are individually essential inputs, the producing firm treats them as strict complements, with the result that the bundle of patents has value only when purchased as a complete package. In this paper, we study the licensing choices made by patent-holding firms when patents are strict complements in downstream markets. We examine the case of a downstream monopolist who must license two exclusive patents, each of which is held by a separate patent holder announcing licensing terms simultaneously. Our intent is to discover the extent to which the patent holders can coordinate to capture optimal rents. Each patent holder knows the R&D costs of the other and the profits of the downstream monopolist. We allow each patent holder to set a fixed fee, a royalty, or both, the sum of which becomes the total cost to the firm for the technology. The theoretical argument shows that the optimal strategy for the patent holders is to set the royalty at zero and charge a fixed fee that exhausts monopoly rents. A series of laboratory experiments is run to test the theoretical predictions. In general, the players (patent holding firms) set the royalty higher than the theory predicts and the fixed fee correspondingly lower. The players do appear to learn over time and the behavior in the latter rounds is closer to the predictions of the theory. Cheap talk, a surrogate for time in the industry (learning), also generates behavior closer to the predictions of the theory.
1.0 INTRODUCTION

In many instances, the production of a particular item requires the use of two patented inputs or processes. Thus, the producer must obtain rights to both patents; either patent alone has no value to the licensee. If the producer does obtain rights to both, then it will be the sole producer in the final product market. Since each patent is an essential input, the licensing arrangements of the patent holders are perfectly complementary.

Each patent holder wishes to maximize the return from the R&D investment while ensuring that the downstream firm is able to earn profits sufficient to allow it to remain in business. The patent holders may charge a fixed fee for the use of the patent, a royalty for the use of the patent, or a combination of fee and royalty. Of course, the fee must be paid regardless of output, while the royalty is set as a per-unit-of-output charge.

In this paper we examine the behavior of the patent holders. In particular, we are interested in investigating the pricing strategy adopted by the patent holders in a setting where each patent holder sets the selling price simultaneously. In this setting, each patent holder knows the R&D costs of the other (set at zero for the experimental setting) and the profits of the downstream monopolist. We assume the patent holder may set a fixed fee, set a royalty, or use both. As the theoretical development shows, the optimal strategy for the patent holders is to set the royalty at zero and charge a fixed fee. A symmetric outcome has each patent holder charging a fee equal to one-half the monopoly profit.

The theoretical development of the equilibrium behavior in the patent setting is presented in the next section. Briefly, when the patent holders set their strategies simultaneously, the Nash equilibrium has both setting the royalty at zero and the fixed fee such that the sum of the fees is equal to the monopolist profit. A symmetric Nash equilibrium is a potential focal point.

A series of laboratory experiments is run to test the theoretical predictions and the results are reported in section 4.0 of the paper. In general, the players set the royalty higher than the theory predicts and the fixed fee correspondingly lower. The players do appear to learn over time, and the behavior in the latter rounds is closer to the predictions of the theory. Cheap talk, a surrogate for time in the industry (learning), generates behavior closer to the

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1 In some cases more than two patents are required, but we will confine ourselves to the case where it is two patents for this research.
predictions of the theory. Finally, the subjects appear to understand that the fee and the royalty are substitutes. When offered the opportunity to utilize both, the players set the royalty lower than when only the royalty is available.

2.0 THEORY

There are three players: Firm 1, Firm 2, and Downstream. Firms 1 and 2 hold patents, and the Downstream firm requires both patents in order to produce widgets. There are no other widget producers—Downstream will be a monopolist if it sells widgets. The inverse demand curve for widgets is

\[ P = a - b Q \]

where \( a, b > 0 \).

If Downstream has access to the patented technologies, it can produce widgets at a constant marginal cost: \( TC = cQ \). It is assumed that \( a > c \), implying that the monopolist should operate. It will be 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,

\[ Q^* = \frac{(a - c)}{2b} \quad \text{and} \quad \Pi^{\text{Max}} = \frac{(a - c)^2}{4b}. \]

Firms 1 and 2 can each charge a two-part tariff (a fixed fee and per-unit royalties) for the use of their patents. The reservation profit of each player is zero. Thus, if the fees set by the firms do not allow Downstream to earn non-negative 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 \((F_1, R_1)\) and \((F_2, R_2)\), where \(F_i \geq 0\) and \(R_i \geq 0\) for \(i = 1, 2\).

**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 non-negative profits after solving the following:

\[ \Pi = \max_{Q \geq 0} \left[ a - bQ - R_1 - R_2 - c \right] Q - F_1 - F_2 \]

At an interior solution, the optimum quantity is:

\[ Q^* = \frac{(a - R_1 - R_2 - c)}{2b} \]

Substituting this value into the expression for profits yields:

\[ \Pi(F_1, R_1, F_2, R_2) = \frac{(a - R_1 - R_2 - c)^2}{4b} - F_1 - F_2 \]

The profits of the downstream firm are:

\[ \Pi^*(F_1, R_1, F_2, R_2) = \max \{ 0, \Pi(F_1, R_1, F_2, R_2) \} \]

When there is no risk of confusion, the arguments of \( \Pi(F_1, R_1, F_2, R_2) \) and \( \Pi^*(F_1, R_1, F_2, R_2) \) will be suppressed. It will also be convenient to write \( \Pi(F_i, R_i, F_j, R_j) \) and \( \Pi^*(F_i, R_i, F_j, R_j) \), where \( i \neq j \). This should not cause confusion since \( \Pi(F_1, R_1, F_2, R_2) = \Pi(F_2, R_2, F_1, R_1) \).

Sub-game perfection requires that Downstream reject both offers if \( \Pi < 0 \), and accept both offers if \( \Pi > 0 \). It is assumed that Downstream accepts both offers when \( \Pi = 0 \), even though it is indifferent.

We can write the profits of Firm \( i \), denoted by \( \pi_i \), as a function of \((F_i, R_i, F_j, R_j)\). Specifically,

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

Firm \( i \)'s best response is the pair \((F_i^{br}(F_j, R_j), R_i^{br}(F_j, R_j))\) that maximizes \( \pi_i(F_i, R_i, F_j, R_j) \) while holding \((F_j, R_j)\) constant. When \( \Pi(0, 0, F_j, R_j) \leq 0 \), Firm \( j \)'s fees are so large that Downstream will necessarily reject the offers regardless of fees chosen by Firm \( i \) unless \( F_i = 0 \) and \( R_i = 0 \). So \( i \)'s best-response is not unique; however, we define \((F_i^{br}(F_j, R_j), R_i^{br}(F_j, R_j)) = (0, 0)\) whenever \( \Pi^*(0, 0, F_j, R_j) = 0 \).

**Lemma 1**—if either patent holder plays a best-response, then Downstream’s profits equal zero. Formally,
\( \Pi^*(F_1^{br}(F_2, R_2), R_1^{br}(F_2, R_2), F_2, R_2) = 0 \) for all \((F_2, R_2)\), and
\( \Pi^*(F_1, R_1, F_2^{br}(F_1, R_1), R_2^{br}(F_1, R_1)) = 0 \) for all \((F_1, R_1)\).

**Proof**—Suppose not, so that \( \Pi^*(F_1^{br}(F_2, R_2), R_1^{br}(F_2, R_2), F_2, R_2) > 0 \) which implies
\( \Pi(F_1^{br}(F_2, R_2), R_1^{br}(F_2, R_2), F_2, R_2) > 0 \). Then, Firm 1 could increase its payoff by increasing
its fixed fee by \( \epsilon = \Pi(F_1^{br}(F_2, R_2), R_1^{br}(F_2, R_2), F_2, R_2) > 0 \) without causing Downstream to
reject. It follows that the choice \( F_1^{br}(F_2, R_2), R_1^{br}(F_2, R_2) \) cannot be a best-response. The
argument for Firm 2 is identical.

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.

**Lemma 2**—Firm \( i \)'s best-response to any \((F_j, R_j)\) is to charge no royalty and a fixed fee that
leaves Downstream with zero profits. That is, for all \((F_j, R_j)\) we have \( R_i^{br}(F_j, R_j) = 0 \) and
\( F_i^{br}(F_j, R_j) = \Pi^*(0, 0, F_j, R_j) = \max \left\{ 0, \frac{(a - R_j - c)^2}{4b} - F_j \right\} \) for all \((F_j, R_j)\)

**Proof**—As discussed above, if \( \Pi^*(0, 0, F_j, R_j) = 0 \), then \( R_i^{br}(F_j, R_j) = 0 \) and \( F_i^{br}(F_j, R_j) = 0 \). If
\( \Pi^*(0, 0, F_j, R_j) > 0 \), Lemma 1 implies \( \frac{(a - R_i^{br} - R_j - c)^2}{4b} - F_i^{br} - F_j = 0 \). Therefore, we can
use this condition to substitute out the fixed fee from Firm \( i \)'s objective, which is then
\( \max_{k_i} R_i \frac{(a - R_i - R_j - c)}{2b} + \frac{(a - R_i - R_j - c)^2}{4b} - F_j \)

The first-order condition then implies a royalty rate of zero:
\[ -\frac{R_i}{2b} + \frac{(a - R_i - R_j - c)}{2b} - \frac{(a - R_i - R_j - c)}{2b} = 0 \]
\[ -\frac{R_i}{2b} = 0 \quad \Rightarrow \quad R_i^{br} = 0. \]

Using \( R_i^{br} = 0 \) along with Lemma 1 implies
\( F_i^{br}(F_j, R_j) = \frac{(a - R_j - c)^2}{4b} - F_j = \Pi^*(0, 0, F_j, R_j) \).
Proposition 1—\((F_1^*, R_1^*)\) and \((F_2^*, R_2^*)\) constitute a Nash Equilibrium if and only if
\[
\begin{align*}
\text{(i)} & \quad R_1^* = R_2^* = 0, \\
\text{(ii)} & \quad F_1^* + F_2^* = \frac{(a - c)^2}{4b} = \Pi^{\text{Max}}
\end{align*}
\]

Proof—

Necessity: The necessity of \(R_1^* = R_2^* = 0\) follows from Lemma 2. The necessity of \(F_1^* + F_2^* = \Pi^{\text{Max}}\) also follows from Lemma 2 and the definition of \(\Pi^{\text{Max}}\).

Sufficiency: First, note that Downstream accepts the offers since conditions (i) and (ii) imply \(\Pi(F_1^*, R_1^*, F_2^*, R_2^*) = 0\). Second, verify that \((F_1^*, R_1^*)\) is a best response to \((F_2^*, R_2^*)\). By Lemma 2, it is never a best response to charge a positive royalty, so if Firm 1 can improve upon \((F_1^*, R_1^*)\) it must do so by charging a different fixed fee. However, a decrease in \(F_1\) decreases the profits of Firm 1, while an increase in \(F_1^*\) would force the downstream firm to reject both offers since \(\Pi(F_1, R_1^*, F_2^*, R_2^*) < 0\) for all \(F_1 > F_1^*\). It follows that \((F_1^*, R_1^*)\) is a best response to \((F_2^*, R_2^*)\). Similar arguments verify that \((F_2^*, R_2^*)\) is a best response to \((F_1^*, R_1^*)\).

Thus, the equilibrium in the patent pricing game has each patent holder setting their royalty rate at zero and their fixed fees such that the downstream monopolist profit approaches zero.

3.0 EXPERIMENTAL DESIGN AND HYPOTHESES

A set of experiments was designed and implemented to provide a vehicle for testing the behavioral outcomes predicted by the theoretical development presented above. In the experimental setting, human subjects are assigned the role of patent holders and the behavior of the downstream firm is simulated. The assumption enforced by the simulated behavior is a simple profit rule. If the patent holders set their combined prices to the downstream firm such that its profits will be strictly negative, the monopolist firm does not purchase the patents and does not produce in this market. In this case, the patent holders earn zero income in that round. If the downstream firm does produce, the patent holder earnings consist of the fee and the royalty charges they choose to implement.
These are computerized experiments. Subjects interact with a computer interface that provides them with the necessary instructions and information and elicits their choices. The fixed fee is entered via a numeric keypad presented on the screen and the royalty is entered via the choice of a row or column in a game matrix. The interface allows the subjects to enter possible choices of the person they are paired with and observe the outcomes under different scenarios. The experiment implements the game of complete information as developed in the theory. Thus, the subjects are informed of the downstream monopolist’s profits for each possible combination of fixed fees and royalties. This information appears in the table denoting the payoffs to the players representing the patent holders. The game is symmetric—payoffs to each subject for a given fee and royalty are identical.

The experiment interface allows the subjects to input their choice of fee and royalty and then to input hypothetical choices of the player with whom they are paired. As these values are entered, the subjects are informed of the payoffs to themselves, the other patent holder, and the downstream monopolist that would result if they played their choice and the partner played the hypothetical choice. The subjects are free to investigate alternate strategies until they decide which one they wish to enter for themselves. The experiment interface does remind the subjects that they have a limited time to make a decision and provides a warning when 15 seconds remain. The interface allows subjects to review past performance by clicking on the appropriate button on the screen. The history presents all previous rounds and shows the decisions of the subject, the person they are paired with, and the resulting payoffs.

Within this simple setting, the experimental treatments are shown in Table 1. All instructions are provided on the subject computer screens. The subjects are told whether they will be paired with the same person each round or not (scrambled). They are not told the number of rounds in the session. In all sessions the subjects read through the instructions on the computer screen and are shown the interface with explanation of the operation of this interface. Subjects are given the opportunity to ask questions regarding the procedures and complete a number (three) of practice or training rounds.
Table 1—Experiment Treatments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Scramble</th>
<th>Cheap Talk</th>
<th>Fixed Fee</th>
<th>Royalty</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>U</td>
</tr>
<tr>
<td>2</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>U</td>
</tr>
<tr>
<td>3</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>U</td>
</tr>
<tr>
<td>4</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>U</td>
</tr>
<tr>
<td>5</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>U</td>
</tr>
</tbody>
</table>

In most treatments, subjects are allowed to enter both a fixed fee and a royalty. However, to test whether there is a focus on the use of one instrument, we conduct sessions (Treatment 4) in which the subjects may only select a royalty rate. Cheap talk (Treatment 3 and 5) is implemented in a manner similar to that employed by Alm and McKee (2004). Thus, the subjects are given time (four minutes) to discuss the experiment after the practice rounds have been completed. In the cheap talk setting, we provide seven practice rounds (only 3 in the other treatments) to allow the subjects considerable experience with the setting prior to the discussion period. The experimenter monitors this discussion only to provide reminders of time remaining. After this discussion, the subjects return to their carrels and the actual rounds of the session begin. There is no further opportunity for discussion. In a coordination game setting, there are several Nash equilibriums, but these can 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 agents to play the strategy that yields the equilibrium with the largest payoff.

Based on the theoretical development and the experimental implementation, we are able to formulate a series of behavioral hypotheses that we will test with the data from our experiments. The royalty is effectively a per unit excise tax—the effect is to increase the marginal cost of the downstream monopolist. This reduces profits and, hence, the amount the patent holders can earn from the sale of the patent rights. As the theoretical presentation above shows, it is optimal for the patent holders to set the royalty at zero and use the fixed fee to extract the monopoly rents. Thus, H1: The patent holders will set the royalty at zero.

Further, from the theoretical discussion it follows that the patent holders will set the fixed fees such that the sum of the fees will just exhaust the monopoly profits. In the
symmetric equilibrium, each fee will be set at one-half the monopoly profits. Since the downstream monopoly derives from the exclusive use of the patent rights, it follows that the patent holders will be able to extract the available rents—profits flow to the scarce resource—which is the patent right. Thus, H2: The patent holders will set the fixed fee such that the sum of the fees just exhausts the monopoly profit of the producer. A corollary, based on Schelling's focal equilibrium concept, is that a symmetric solution will result—each sets the fee at one-half the monopoly profit.

The pricing problem facing the patent holders is complex. However, at the simplest level, we have a coordination game in which there is a jointly optimal strategy. In the current setting, the coordination problem is complicated by the fact that there are two pricing vehicles and the players must overcome a natural tendency to wish to diversify by setting each vehicle at a positive value. Cheap talk has been shown to be useful in coordination games (see Alm and McKee). Thus, H3: Cheap talk will lead to improved coordination on the Pareto optimal outcome.

It is possible that subjects hedge by utilizing both of the pricing instruments when these are available. Alternatively, they may favor one instrument. To test this we conduct sessions in which the subjects can choose only the royalty rate to charge. Although the Nash equilibrium has the royalty set at zero, the desire to utilize a portfolio of pricing instruments means that subjects will not set the royalty at zero. However, if the subjects recognize the superiority of the fixed fee option, they will substitute toward the use of the fixed fee when this option is available. Thus, H4: Subjects will use the fixed fee option when it is available and will adopt lower royalty rates.

4.0 EXPERIMENT RESULTS

To date (10/20/2004), we have run 12 sessions involving 100 subjects making 20 or 25 decisions (rounds) each. The treatments were reported in Table 1. In Table 2 we report definitions of the variables to be used in subsequent analysis.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Royalty</td>
<td>Sum of the charged royalties divided by the maximal available royalty (the intercept of the monopolist’s demand curve).</td>
</tr>
<tr>
<td>Fixed Fee</td>
<td>Sum of the fees divided by the monopoly profit when the royalty is set at zero.</td>
</tr>
<tr>
<td>Efficiency</td>
<td>Sum of the payoffs to the patent holders and the monopolist divided by the theoretical optimum.</td>
</tr>
<tr>
<td>Monopolist Q</td>
<td>Quantity the monopolist produces divided by the output in the zero royalty case.</td>
</tr>
<tr>
<td>Round</td>
<td>Round or period of the experiment session.</td>
</tr>
<tr>
<td>No. Subjects</td>
<td>Number of subjects in the session.</td>
</tr>
<tr>
<td>Scrambled</td>
<td>Dummy for whether subjects were re-paired each round (=1 if yes).</td>
</tr>
<tr>
<td>Cheap Talk</td>
<td>Dummy for whether subjects were permitted to discuss experiment after completing practice rounds (=1 if yes).</td>
</tr>
<tr>
<td>Past Success</td>
<td>Dummy for whether the subject earned non-zero payoff in the previous round.</td>
</tr>
</tbody>
</table>

In Table 3 we report raw results for some aggregate metrics measuring behavior. The theory predicts that the royalty metric will be zero when fixed fees can be charged. The fixed fee metric and monopoly quantity metrics are predicted to equal one, as is the efficiency metric. Clearly, these predictions are not evident in the data when we look at all rounds of the experiment (as reported in Table 3). However, the results improve when we focus on the last 10 rounds. For the cheap talk treatment (3), the metrics all improve when we compare the last 10 rounds to the overall results. The royalty index declines while the fixed fee index increases and the monopolist’s output increases. The latter effect is due to the reduction in the royalty rate.
Table 3—Raw Results

<table>
<thead>
<tr>
<th>Metric—All Rounds</th>
<th>Treatment</th>
<th>Royalty</th>
<th>Fixed Fee</th>
<th>Efficiency</th>
<th>Monopolist Q</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>0.3331</td>
<td>0.1297</td>
<td>0.5670</td>
<td>0.4007</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.3631</td>
<td>0.2071</td>
<td>0.7221</td>
<td>0.5319</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.3225</td>
<td>0.2464</td>
<td>0.6491</td>
<td>0.4775</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0.5510</td>
<td>N/A</td>
<td>0.6630</td>
<td>0.4250</td>
</tr>
<tr>
<td>Metric—Last 10 Rounds</td>
<td>1</td>
<td>0.3140</td>
<td>0.1320</td>
<td>0.5242</td>
<td>0.3706</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.3854</td>
<td>0.2046</td>
<td>0.7175</td>
<td>0.5146</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.2583</td>
<td>0.3347</td>
<td>0.6753</td>
<td>0.5167</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0.6080</td>
<td>N/A</td>
<td>0.6090</td>
<td>0.3830</td>
</tr>
</tbody>
</table>

Since the data are generated by observations across a set of individuals over a number of rounds, we have a panel dataset. We estimate the models using a feasible generalized least squares estimator, which allows for corrections of panel-specific autocorrelation and heteroskedasticity (see Greene, 1993).\(^2\) We include the treatment factors in the estimation, a “history” variable (whether the monopolist produced in the previous round), and a control for the number of subjects in the session (ranging from 8 to 12). The results for models estimated to explain the performance metrics identified in our hypotheses and reported in Table 3 and shown in Table 4.

As expected from our discussion of the aggregate results in Table 2, we find that the behavior in the experiments does not generally support the hypotheses presented above. The royalty metric is affected by the treatments but the subjects never set this at zero—the intercept is positive and highly significant. Cheap talk does result in lower royalties (the coefficient on the treatment variable is negative and significant) and also higher fixed fees. Taken together, these results imply that the subjects in the cheap talk setting adopt strategies that are closer to the behavior predicted by the theory. However, hypothesis 1 is generally refuted by the data.

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\(^2\) We also estimate a subject fixed effects model. In general, the results for the FGLS estimations are superior.
Hypothesis 2 also does not fare well here. The patent holders are setting the royalty too high and the effect on the output of the monopolist leads to less than optimal rent extraction and less than optimal efficiency—the intercept is significantly less than 1.0.

Hypothesis 3 fares somewhat better. While the patent holders are unable to coordinate on extracting all of the rent, when they are offered the cheap talk opportunity they do capture more. The result is that the cheap talk does have a positive effect on the fixed fee metric, but not on any of the other measures reported in Table 4.

The subjects do appear to understand that the fixed fee and royalty must substitute for one another. When comparing the royalty metric in treatments 1 through 3 to that in treatment 4, it is seen that the royalty metric is closer to the optimum (zero) and the revenues to the patent holders are made up through the fixed fee.

The subjects in this setting face a complex coordination problem since they may set two components of the price in most treatments. When we scramble the subjects during the session, this coordination problem is exacerbated. As expected, scrambling has a negative effect on the efficiency metric and on the monopolist’s output. Scrambling increases the fixed fee metric, and this warrants some further study since this effect is not expected. Since

<table>
<thead>
<tr>
<th>Table 4—Panel Estimations Using Feasible Generalized Least Squares</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DEPENDENT VARIABLES</strong></td>
</tr>
<tr>
<td>Independent variables</td>
</tr>
<tr>
<td>-----------------------</td>
</tr>
<tr>
<td>Constant</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>No. Subjects</td>
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<tr>
<td></td>
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<td>Cheap Talk</td>
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<td>Scrambled</td>
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<td>Last Period Payoff</td>
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<td><strong>STATISTICS</strong></td>
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<td>Wald Chi Sq</td>
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<td>Log likelihood</td>
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<td>Significance levels: * 0.10, ** 0.05, *** 0.001</td>
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scrambling leads to an increase in the royalty metric the output falls and the efficiency effect must fall as well.

In the setting in which only the royalty is available (treatment 4) the subjects are generally able to reach the predicted outcome. In the Appendix we show that the Nash royalty rate is 2/3. Table 3 shows that for the last set of periods in the sessions, the subjects are quite close to this prediction.

5.0 CONCLUSIONS AND DISCUSSION

The experiment results show that the strict implications of the theory are not manifest in the experimental data. Specifically, the patent holders do not set the royalty at zero and extract the rents through the use of the fixed fee. Inspection suggests that the royalty rate is near the midpoint of the strategy space when the fixed fee option is available. It appears that the subjects are adopting “safe” strategies by using some royalty and some fixed fee in each round. When only the royalty is available the subjects actually do quite well in terms of the theory, and this tends to support our “portfolio hypothesis” as an explanation for the non-zero royalty rates that we observe.

Our limited look at feedback at this point focuses on simply whether the previous round resulted in a non-zero payoff or not. This is whether or not the patent holders set their total patent charge to the monopolist such that the resulting profit would be negative. This is an extreme test. A weaker test would look at specific elements of the prior behavior and results. This awaits subsequent analysis.
REFERENCES


APPENDIX 1: SIMULTANEOUS ROYALTIES

Here we consider the equilibrium outcome when firms are able to charge royalties, but not fixed fees. So firm $i$'s best-response solves

$$\max_{R_i} R_i \frac{(a - R_i - R_j - c)}{2b}$$

The first-order condition is

$$-\frac{R_i}{2b} + \frac{(a - R_i - R_j - c)}{2b} = 0$$

$$R_i^{br} = \frac{(a - c)}{2} - \frac{R_i}{2}$$

At a symmetric equilibrium we have

$$R^* = \frac{(a - c)}{2} - \frac{R^*}{2} \Rightarrow R^* = \frac{(a - c)}{3}$$

At these royalties, Downstream sells

$$Q^* = \frac{(a - c)}{2b} - \frac{2}{3} \frac{a - c}{2b} = \frac{(a - c)}{2b} - \frac{(a - c)}{3b} \Rightarrow Q^* = \frac{(a - c)}{6b}$$

Therefore, firm $i$ is predicted to earn

$$R^*Q^* = \frac{(a - c)}{3} \frac{(a - c)}{6b} = \frac{(a - c)^2}{18b}$$

We can normalize the equilibrium royalties as a function of the maximum royalty, $(a-c)$:

$$\frac{R_1^* + R_2^*}{a - c} = 2 \frac{a - c}{3} = \frac{2}{a - c}$$