Optimal Cross-Licensing Arrangements: Collusion vs. Entry Deterrence

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Abstract

This paper analyzes optimal cross-licensing arrangements between incumbent firms in the presence of potential entrants. The optimal cross-licensing royalty rate trades off incentives to sustain a collusive outcome vis-a-vis incentives to deter entry with the threat of patent litigation. We show that a positive cross-licensing royalty rate, which would otherwise relax competition and sustain a collusive outcome, dulls incentives to litigate against entrants. Our analysis can shed light on the puzzling practice of royalty free cross-licensing arrangements between competing firms in the same industry as such arrangements enhance incentives to litigate against any potential entrants and can be used as entry-deterrence mechanism.

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1 Introduction

This paper analyzes optimal cross-licensing arrangements between incumbent firms in the presence of potential entrants. It is increasingly common in today's high-tech industries that commercialization of new products requires applications of multiple technologies. In addition, these technologies are often proprietary and patented by different patent owners. As a result, firms often need to engage in cross-licensing arrangements to successfully market the products without infringing other firms' intellectual property (IP) right. In such a case, it is a well-known result that firms have incentives to sustain a collusive outcome by including a positive royalty rate to soften competition in the market (Shapiro, 1985; Jeon and Lefouili, forthcoming).[1] However, we often find that direct competitors engage in royalty-free cross-licensing contracts, sometimes called "IP for IP" arrangements, contrary to the prediction of economic theory (Shapiro, 2004). We resolve this discrepancy by considering a situation in which the incumbent firms with IP face potential entrants. We find that the optimal cross-licensing royalty rate trade-offs incentives to sustain a collusive outcome vis-a-vis incentives to deter entry with the threat of patent litigation. We show that a positive cross-licensing royalty rate, which would otherwise relax competition and sustain a collusive outcome, dulls incentives to litigate against entrants when IP is probabilistic and litigation entails the risk of IP being invalidated. Our analysis thus can shed light on the puzzling practice of royalty free cross-licensing arrangements between competing firms in the same industry as such arrangements enhance incentives to litigate against any potential entrants and can be used an entry-deterrence

[1] Eswaran (1994) also explores how cross-licensing arrangements can be used as a "facilitating device." However, his mechanism is very different as he considers cross-licensing between substitute patents rather than complementary ones. In addition, he adopts a repeated game framework which generates the usual "topsy-turvy" results.

mechanism.

To illustrate the mechanism, we analyze a set-up in which two incumbent firms, A and B, compete in a common market (market C), but they also have their own respective captive markets (market A and market B, respectively). In the benchmark case of no potential entrant, we first establish that the optimal cross-licensing contract is characterized by a positive royalty rate to sustain a collusive outcome. We then consider a situation in which there is a potential entrant that can enter one of the two captive markets. This is to abstract from a potential free rider problem in entry deterrence when the entry is into a common market, which is addressed later. We show that a positive royalty rate dulls litigation incentives of the incumbent facing entry in its captive market. The reason is that a potentially negative litigation outcome for the incumbent would invalidate its IP and put it at a disadvantageous position against the other rival incumbent in the common market: it needs to continue to pay a positive royalty rate to the rival firm whereas the rival firm now is able to use its invalidated IP without paying a positive royalty rate. As a result, we may have a situation in which the incumbent may not have a credible threat against an entrant if the cross-licensing royalty rate is set at the level to sustain collusion. In that case, the incumbent may prefer to set the royalty rate at a lower level to maintain incentives to litigate and restore the credibility of litigation threats against the potential entrant.

We then consider optimal cross-licensing between incumbents when there is potential entry in their common market. In this case, infringement litigation becomes a free-rider problem. One successful lawsuit prevents entry and preserves both incumbents' market power. However, litigation implies the risk of having the patent invalidated which would put the firm in a disadvantaged position in the marketplace. The higher the cross-license fee the incumbents set, the higher the potential loss from an invalidated patent and the larger the free rider problem. The incumbents thus face a trade-off between collusive cross-licensing and maintaining a credible litigation threat by alleviating the free rider problem with low cross-license fees. We show that the incumbents optimally set their cross-license fees below the collusive level. If the incumbents' patents are weak, the optimal cross-license is low and deters entry completely. With stronger patents, the optimal license fee is higher. This induces entry which followed - with some probability - by infringement litigation.

There is a small literature on cross-licensing.[2] However, the focus of the existing literature is very different from ours. Fershtman and Kamien (1992), for instance, consider the case where the introduction of a new product requires the development of two distinct complementary technologies as in our paper. Their focus is on the interdependence between the innovation race and the cross licensing game. In particular, they analyze how the possibility of cross-licensing affects the pace of the innovation race and how the potential continuation of the innovation race affects the terms of cross licensing contracts. In contrast, we take the developments of complementary technologies with dispersed ownership as given, and analyze implications of cross-licensing for competition in the product market. Shapiro (2004) discusses the role of patents in the semiconductor industry in his analysis of the FTC's antirust case against Intel. He argues that Intel's cross-licensing policy of "IP for IP" is an efficient way to navigate patent thicket and protect it from the hold-up problem and afford "freedom to design."

Jeon and Lefouili (forthcoming) analyze the competitive effects of cross-licensing arrangements as in our paper. They generalize the standard result on the collusive effects of a positive royalty rate (Shapiro, 1985) to a setting with more than two firms. The extension from duopoly to more than two firms is straightforward with a multilateral bargaining involving all of them. Their contribution is to show that

[2] In contrast, the literature on licensing in general is very extensive. For an excellent survey on licensing, see Kamien (1992).

bilateral cross-licensing agreements can lead to the monopoly outcome in a setting with many competing firms. However, their analysis assumes iron-clad patents owned by all incumbent firms. In contrast, we consider probabilistic patent rights and the threat of potential entry. In our framework, the incumbents need to balance the benefits of collusion against maintaining incentives to litigate against an entrant to protect the market.

The remainder of the paper is organized in the following way. In Section 2, we set up a simple model of patent cross-licensing between two incumbent firms facing a potential entrant. We show that in general the optimal cross-licensing running royalty rate among competitors is less than the one that sustains the collusive outcome in face of entry threat. In section 3, we do a comparative statics exercise with respect to litigation costs to explore implications of escalating litigation costs on entry dynamics. We show that the effects of an increase in litigation costs can be asymmetric and beneficial to the incumbents. In section 4, we extend the analysis to consider an entrant whose cost is unknown when the incumbents set a cross-licensing royalty rate and show that royalty-free licensing contracts can naturally rise in such a situation. Section 5 discusses implications of our analysis for patent pools which can be an alternative to cross-licensing arrangements. In section 6, we consider various extensions including entry into the common market. Section 7 closes the paper with concluding remarks. The omitted proofs for lemmas and propositions are relegated to the Appendix.

2 Model

Consider two incumbent firms, A and B, who are monopolist in a captive market (market A and market B, respectively) and compete in a common market (market C). Demand in the common market is given by $D(p)$ while the size of the captive market for each firm is $sD(p)$. The parameter $s \geq 0$ represents the relative size and importance of the captive market for each firm compared to the common market C in which they compete. As s increases, the relative importance of the captive market increases vis-a-vis the competitive market. For instance, if $s = 0$, there is no captive market and they are direct competitors. If s is very large, the overlap in their product markets is negligible and the firms essentially operate in different markets.

Firms A and B have their own intellectual property (IP) that which is required to produce in both the captive market and the common market. The product in the common market needs to incorporate both firms' IP. This means that it requires a cross-licensing arrangement between firms A and B for them to produce in the common market without infringing on each other's IP. To simplify our analysis, we assume that the product in captive market i only requires firm i's IP, where $i \in \{A, B\}$.[3] This would be the case if the different markets use different application of the technology covered by the incumbents' IP.

We further assume that the two incumbents have the same production technology. The constant marginal cost of production for both firms in each market is identical and given by c. Let $q^m(c)$ be the monopoly output associated with an inverse market demand of $P(q) = D^{-1}(q)$ when the monopolist's marginal cost is c, that is, $q^m(c)$ $= \arg\max_q (P(q) - c)q$. When firms compete, we use a reduced form approach rather than assuming any specific duopoly model. More specifically, let $q^d(a, b)$ denote the equilibrium output when its cost is a and the rival firm's cost is b. The associated profits are denoted as $\pi^d(a, b)$. When both firms have the same marginal cost of c, we denote the symmetric equilibrium duopoly output and profit as $q^d(c, c) = q^d(c)$ and $\pi^d(c, c) = \pi^d(c)$, respectively. We make the following standard assumptions about

[3]This assumption is not crucial. We can alternatively assume that the product in each firm's captive market also requires the other firm's IP without changing any of qualitative results. We comment on this possibility in the analysis below.

the duopoly equilibrium outcomes.

Assumption 1.

$$(i)\frac{d\pi^d(c)}{dc} < 0, \frac{dq^d(c)}{dc} < 0,$$
$$(ii)\frac{\partial\pi^d(a,b)}{\partial a} < 0, \frac{\partial\pi^d(a,b)}{\partial b} > 0, \frac{\partial q^d(a,b)}{\partial a} < 0, \frac{\partial q^d(a,b)}{\partial b} > 0.$$

Assumption 1*(i)* states that the symmetric equilibrium profits and outputs are lower as both firms' marginal costs are increased by the same amount. Assumption 1*(ii)* states that when a firm's marginal cost is unilaterally increased while the rival firm's marginal cost stays the same, its equilibrium profit and output decreases whereas they increase if the rival firm's marginal cost is increased while its cost stays the same.

We consider a situation in which there is a potential entrant that can enter one of the captive markets protected by IP. There is uncertainty about the entrant's capability that will determine which market the entrant will enter. Ex ante, entry is equally likely for each captive market. The assumption of entry to only one captive market is for expositional simplicity. We can easily incorporate entry to both captive markets in a straightforward manner without any changes in the qualitative results. In section 6, we also entertain the possibility of entry to the common market. We assume that there is a fixed cost of entry $K \geq 0$. Once the entrant is established in the captive market, it competes with then incumbent using a technology that involves a marginal cost of production of $\gamma \geq 0$.

Once there is entry in captive market $i \in \{A, B\}$, incumbent firm i can decide whether to litigate the entrant for the infringement of its IP. We assume that the patent rights of the incumbents are probabilistic in the sense that they can be invalidated in court. This means that in case of litigation, the entrant contests the validity of the patent in question. Let θ be the probability that the court will uphold the validity of the patent. This parameter reflects the strength of the incumbents' patent portfolios. By contrast, if the patent is invalidated, the rival incumbent and the entrant can practice the covered technology at no further cost. Additionally, we denote L as the exogenous litigation costs for both the incumbent and the entrant. Section 3 explicitly introduces these litigation costs to explore their implications for the entrant's incentives to enter and the incumbents' incentives to deter entry. However, as the main focus of the paper is on the endogenous cost of litigation via cross-licensing, we will abstract from exogenous litigation costs (i.e. $L = 0$) in other parts of the analysis.

The model set-up is summarized in FIGURE 1 below.

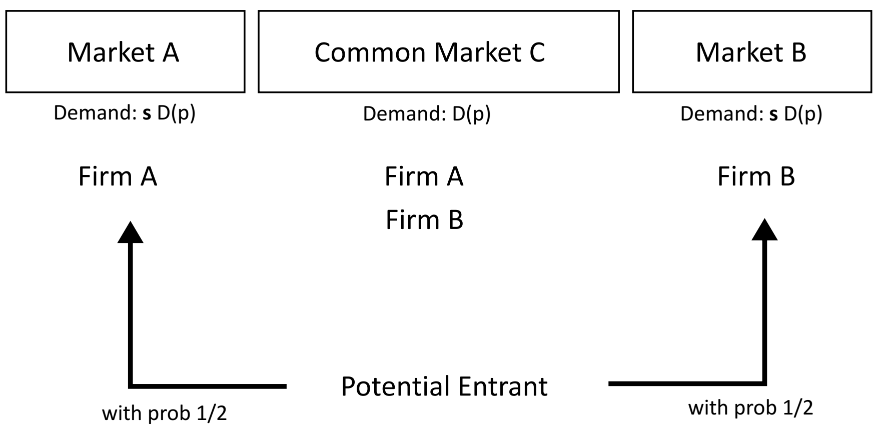

FIGURE 1: *Set-up with Entry in Captive Markets*

We consider the following timing of the game:

1. Incumbents A and B agree on a per-unit cross-licensing royalty rate r for the common market.

2. Nature picks a captive market for entry. The entrant decides whether to sink a fixed cost K to enter the captive market or not.

3. If there is no entry, the captive market remains monopolistic. If there is entry in captive market i, firm i decides whether or not to litigate against the entrant. If firm i does not litigate, the captive market with entry becomes duopolistic.

4. If there is litigation, its outcome is revealed. If the incumbent wins, there is an injunction against the entrant, and the captive market becomes monopolistic. If firm i's patent is found to be invalid, the captive market with entry remains duopolistic. In addition, firm i loses its royalty revenue from firm $j(\neq i)$ in the common market while firm i continues to pay the royalty rate of r to firm j.

In what follows we first consider cross-licensing in the absence of a threat of entry as a benchmark. This is followed by an analysis of the case where the entrant's cost γ is known to the incumbents.

2.1 Benchmark Case: No Potential Entrant

As a benchmark case, we first consider a situation in which there is no threat of entry for any of the markets served by firms A and B. In this case there is no linkage between the captive markets and the common market. Each incumbent makes a profit of $s\pi^m(c)$ in its captive market. Given a cross-licensing royalty rate of r for outputs in the common market C, each firm's equilibrium profit in this market is given by

$$\Pi^C(r) = \pi^d(c+r) + rq^d(c+r).$$

The first term is the profit from selling the product in market C, the second term are the royalty revenues due to the sales of the rival incumbent. The optimal royalty rate in the absence of potential entrants (r^m) aims to sustain a full collusive outcome in the competitive common market

$$\frac{d\Pi^C(r)}{dr} = \frac{d\pi^d(c+r)}{dr} + q^d(c+r) + r\frac{dq^d(c+r)}{dr} = 0$$

and we get the following result.

Lemma 1. *In the absence of potential entry, the optimal cross-license fee is* $r^m > 0$*, which induces the fully collusive outcome in the common market.*

Proof. Note that

$$\frac{d\pi^d(c+r)}{dr} = \frac{\partial \pi^d(c+r,c+r)}{\partial a} + \frac{\partial \pi^d(c+r,c+r)}{\partial b} = -q^d(c+r) + \frac{\partial \pi^d(c+r,c+r)}{\partial b}$$

by the envelope theorem. As a result, we have

$$\frac{d\pi^d(c+r)}{dr} + q^d(c+r) = \frac{\partial \pi^d(c+r,c+r)}{\partial b} > 0$$

by Assumption 1*(ii)*. This implies that

$$r^m = -\frac{\frac{\partial \pi^d(c+r,c+r)}{\partial b}}{\frac{dq^d(c+r)}{dr}} > 0.$$

□

Throughout the analysis, we use the Cournot model with homogenous products and linear demand to illustrate the results. In this benchmark case, we get the following result.

Example (*Cournot Model with Linear Demand*)**.** *Suppose the two incumbents compete as Cournot competitors with homogeneous product and constant marginal costs. Let the inverse demand function be* $P = 1 - Q$*, where* $Q = q_A + q_B$*. It holds that*

$$q^m(c+r) = (1-c-r)/2, q^d(c+r) = (1-c-r)/3,$$
$$\pi^m(c+r) = [q^m(c+r)]^2, \pi^d(c+r) = [q^d(c+r)]^2$$

and the optimal cross-licensing rate satisfies

$$2q^d(c+r) = q^m(c)$$

which yields $r^m = (1-c)/4$.

For simplicity, we have assumed that each firm only needs its own IP to produce in its captive market. Our result above would not change even if they need each other's IP for captive markets as long as they can set different royalty rates across markets. They would agree to set zero royalty fees for each other's captive market to eliminate any distortion associated with positive rates whereas they would set r^m in the common market. If they cannot set different royalty rates and are constrained to set the same royalty rate across markets, the optimal royalty rate depends on the relative size of the captive market vis-a-vis the common market with $r^*(s)$ decreasing in s with $\lim_{s\to 0} r^*(s) \to r^m$ and $\lim_{s\to\infty} r^*(s) \to 0$.

2.2 Cross-licensing when cost of entrant is known

Suppose that there is a potential entrant who can enter one of the two captive markets. Let the potential entrant's marginal production cost be γ. There is an entry cost of K for the potential entrant. By assuming negligible litigation costs, we can define two threshold values of γ, $\underline{\gamma}$ and $\overline{\gamma}$, where $\overline{\gamma} > \underline{\gamma}$:

$$s\pi^d(\overline{\gamma}, c) - K = 0$$

$$(1-\theta)s\pi^d(\underline{\gamma}, c) - K = 0$$

Potentially, there can be three types of entrants. Entrants whose cost is sufficiently low ($\gamma \leq \underline{\gamma}$) will enter the market regardless patent litigation by the incumbent. Entrants whose cost is sufficiently high ($\gamma > \overline{\gamma}$) will never enter the market because their expected profit never justifies their entry cost of K. For the entrants whose cost is intermediate ($\underline{\gamma} < \gamma \leq \overline{\gamma}$), entry is profitable if and only if it is accommodated without any patent litigation. To analyze the possibility of limiting entry through a strategic choice of cross-licensing royalty rate, we focus on the intermediate cost type case where $\underline{\gamma} < \gamma \leq \overline{\gamma}$.

Now consider the subgame in which entry has taken place in the captive market for firm A. Suppose that firms A and B have a cross-licensing arrangement with a royalty rate of r. If firm A litigates against the entrant (with cost γ) its expected payoff is given by

$$\Pi^L(r) = \theta[s\pi^m(c) + \Pi^C(r)] + (1-\theta)\left[s\pi^d(c,\gamma) + \pi^d(c+r,c)\right].$$

With probability θ, firm A prevails in the court, imposes an injunction against the entrant and maintains its monopolistic position in market A. However, with a probability of $(1-\theta)$, its patent is invalidated. In this case, the captive market becomes duopolistic with the entrant. In addition, there are collateral damages in the common market C. First, the incumbent cannot collect any royalty revenues from firm B because it does not have any valid IP. Moreover, it now faces a stronger competitor as the rival incumbent firm's marginal cost is reduced from $c+r$ to c. This reduces its profits in the common market further.[4]

In contrast, if it does not litigate and accommodate entry, its payoff is given by

$$\Pi^{NL}(r) = s\pi^d(c,\gamma) + \Pi^C(r)$$

Thus, firm A litigates against the entrant if and only if $\Pi^L(r) \geq \Pi^{NL}(r)$ or

$$\theta s[\pi^m(c) - \pi^d(c,\gamma)] \geq (1-\theta)[rq^d(c+r) + \pi^d(c+r) - \pi^d(c+r,c)], \tag{1}$$

The LHS of inequality (1) are the incumbent's expected benefits of litigation against the entrant. With probability θ, the incumbent gains monopoly rather than duopoly profits in the captive market of size s. The RHS represents the potential loss of

[4]After its patent is invalidated, firm A may have an option to try to invalidate firm B's patent not to pay royalty payments in the common market. However, this strategy runs the risk of its sales being enjoined in the common market if B's patent is validated. We assume that this risk is too large for A to challenge B's patent.

profits in the common market when initiating patent litigation against the entrant. With probability $1-\theta$, the incumbent's patent is invalidated. In this case, it loses its license revenues from the rival incumbent and makes lower product market profits as it faces a more efficient competitor in the common market. Notice that the RHS is increasing in r for at least $r \in [0, r^m]$. The higher the cross-license fee, the more the incumbent stands to lose in the common market in terms of lost license revenues and lower product market profits due to facing a more efficient competitor. By contrast, for $r = 0$, the RHS is zero and there is no potential loss from litigating against the entrant.

Moreover, note that the RHS is independent of the entrant's marginal cost while the LHS is decreasing in γ. This implies that the more efficient the entrant is, the more incentives the incumbent has to exclude the rival from the market. In particular, let $\gamma^L(r)$ be the value of the entrant's cost such that condition (1) holds with equality. We get the following result.

Lemma 2. *After entry, the incumbent litigates against the entrant if and only if* $\gamma \leq \gamma^L(r)$. *It holds that* $d\gamma^L(r)/dr < 0$ *for all* $r \in [0, r^m]$.

The incumbents gain more from litigating and excluding low-cost entrants. A higher cross-licensing royalty rate in the common market reduces the incumbent's incentives to litigate and accommodates entry by the marginal, low-cost entrant.

For any entrant type γ, there are two cases to consider. If $\gamma \leq \gamma^L(r^m)$, the incumbents have an incentive to litigate against the entrant even if they set the fully collusive royalty rate in the common market. Entry is blocked for this type of entrant. By contrast, if $\gamma > \gamma^L(r^m)$, the incumbents do not have a credible threat to litigate against the entrant if the royalty rate is set at the fully collusive level. In this case, the incumbents have two choices. They can either set the cross-licensing rate at r^m and accommodate entry or set the rate at the entry-deterring level $\hat{r} < r^m$ that satisfies

$\gamma^L(\hat{r}) = \gamma$, that is, $\hat{r} = \gamma^{L^{-1}}(\gamma)$. Deterring an entrant of type γ in the captive market is optimal for the incumbents if and only if

$$s\frac{1}{2}[\pi^m(c) - \pi^d(c,\gamma)] \geq \Pi^C(r^m) - \Pi^C(\hat{r}). \tag{2}$$

The incumbents face a trade-off between collusion in the common market and entry deterrence in the captive market. The LHS is the potential benefit from entry deterrence in the captive market. This benefit is strictly positive and decreases in the marginal cost of the entrant γ. The RHS is the relative gain from colluding and accommodating entry in market C. A higher γ requires a lower limit cross-license $\hat{r}$ to maintain litigation incentives. Hence, the RHS is zero at $\gamma = \gamma^L(r^m)$ and increasing for higher cost levels of the entrant. As a consequence, incumbents are better off deterring entrants less who are not too much more inefficient than $\gamma^L(r^m)$. We thus get the following result.

Proposition 1. *Suppose that $\gamma \in (\underline{\gamma}, \overline{\gamma})$ and $\gamma > \gamma^L(r^m)$. There exists a critical level of the entrant's cost $\gamma^* \leq \overline{\gamma}$ such that if and only if $\gamma \leq \gamma^*$, then the incumbent deters entry with a royalty rate $\hat{r} < r^m$.*

The proposition states that for intermediate values of the entrant's cost, the incumbents optimally deter entry by reducing their cross-licensing rate in the common market. For more efficient entrants, $\gamma < \gamma^L(r^m)$, the incumbents have an incentive to litigate at the fully collusive cross-license rate. For less efficient entrants, they accommodate entry as the required reduction in the cross-license fee to induce litigation makes deterrence too costly.

Example (Cournot Model with Linear Demand, continued)**.** *Consider the above example with $\theta = 1/2$, $s = 1$, $c = 0$ and $\gamma \in [0, 1/2]$.*[5] *We then have*

$$\pi^m(c=0) = 1/4, \pi^d(0,\gamma) = (1+\gamma)^2/3, \Pi^C(r) = \frac{1}{9}(1+2r)(1-r).$$

[5] The values of $\underline{\gamma}$ and $\overline{\gamma}$ depend on the entry cost satisfying $0 \leq \underline{\gamma} \leq \overline{\gamma} \leq 1/2$ for any $K \geq 0$.

From (1), it can be easily verified that

$$\hat{r} = \begin{cases} r^m = 1/4 & \text{if } \gamma \lesssim 0.173, \\ \gamma^{L^{-1}}(\gamma) = (5 - \sqrt{24(1+\gamma)^2 - 29})/12 & \text{if } \gamma \gtrsim 0.173. \end{cases}$$

It also follows from (2) that if $\gamma \gtrsim 0.414$, then the condition can be written as

$$\hat{r} \geq \frac{1 - \sqrt{5 - 4(\gamma^2 + 2\gamma)}}{4}$$

Otherwise, entry deterrence always dominates. These two conditions are illustrated in Figure 2 where the blue line represents condition (2) and the red line is the optimal royalty rate.

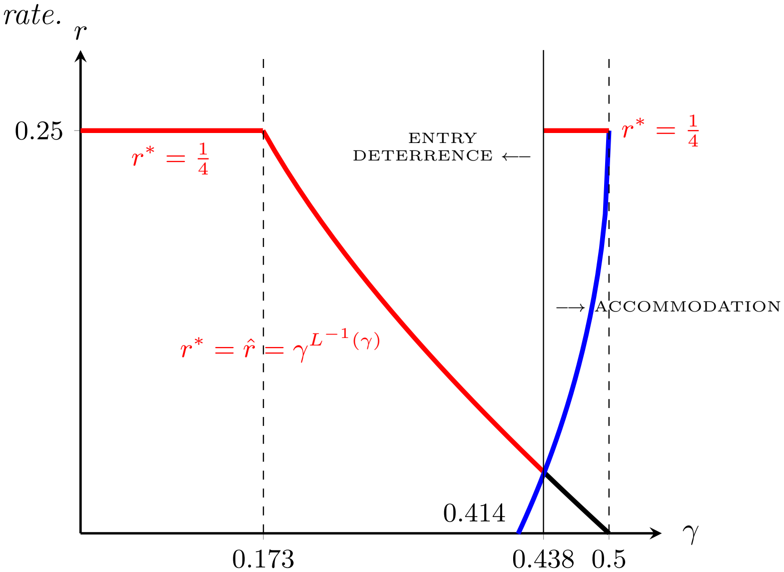

FIGURE 2: *Collusion vs. entry deterrence with limit royalty rate*

In this example, the incumbents deters entry if $\gamma \leq \gamma^* \approx 0.438$. When the entrant's cost is low (i.e., $\gamma \lesssim 0.173$), the incumbents have incentives to litigate against the entrant even at the fully collusive royalty rate of $r^m = \frac{1}{4}$. However, for higher values of $\gamma > 0.173$ they need to reduce the cross-licensing royalty rate to $\hat{r} = \gamma^{L^{-1}}(\gamma)$, which is decreasing in γ. For intermediate values of $\gamma \in (0.173, 0.438)$, entry deterrence with a royalty rate of $\widehat{r} = \gamma^{L^{-1}}(\gamma)$ yields higher profits for the incumbents *than accommodating entry. However, for a very inefficient entrant with $\gamma > 0.438$, entry deterrence is not worthwhile because it is too costly for the common market as it requires a very low royalty rate to maintain incentives to litigate. In addition, the profit loss in the captive market is minimal when the entrant is very inefficient. Thus, the optimal royalty rate reverts back to the fully collusive level of $r^m = \frac{1}{4}$, introducing a non-monotonicity in γ and a discrete jump of the royalty rate.*

Let us briefly discuss the optimal royalty rate from the perspective of second-best social welfare with all other decisions (i.e., entry, litigation, and pricing decisions) left to market participants. The social planner faces a similar trade-off between competition in the common market versus promotion of entry into the captive market. However, the incentives for the social planner with regard to entry are diametrically opposite to the incumbent firms. As discussed, the incumbents choose a royalty rate to deter entry if the potential entrant's cost is low while they accommodate entry with $r = r^m$ when γ is high. For the social planner, in contrast, entry is more desirable whenγ is low whereas entry is mostly an inefficient business stealing when γ is high. This implies that the optimal second-best royalty rate for high values of γ would be the lowest royalty rate that would deter entry, which is $\hat{r}{=}\gamma^{L^{-1}}(\gamma)$. If γ is very low and the incumbents have incentives to litigate against the entrant even with the collusive royalty rate r^m, it is impossible to induce entry into the captive markets. Thus, the optimal royalty rate would be zero in order to promote competition in the common market. For intermediate value of γ for which the incumbents need to set a royalty rate of $\hat{r} = \gamma^{L^{-1}}(\gamma)$ to deter entry, the second-best socially optimal royalty rate can be $\hat{r} + \varepsilon = \gamma^{L^{-1}}(\gamma) + \varepsilon$, the lowest royalty rate that would eliminate the incumbents' incentives to litigate and induce entry. In such a case, the second-best socially optimal outcome in the common market would be essentially the same as the market equilibrium, but would induce entry in the captive markets.

In this section, we have assumed that the incumbents know the entrant's cost. As a result, the incumbents can tailor its cross-licensing royalty rate just enough to make their litigation threat credible when they adopt the strategy of entry deterrence. Thus, a royalty-free cross licensing can take place as a knife-edge case in the current set-up.[6] In section 4, however, we show that a *royalty-free* contract can emerge as a generic case when the incumbents face an entrant with unknown costs.

3 Litigation Costs and Entry Deterrence

In our model, credible litigation threats can serve as an entry barrier. In order to focus on the endogenous cost of litigation in the form of lost licensing revenues, we have so far abstracted from any exogenous litigation costs. In this section, we explore the role of litigation costs on the credibility of litigation and entry incentives. In particular, we show that the incumbents' ability to set a royalty rate to maintain litigation incentives can generate a paradoxical result. An increase in litigation costs may benefit the incumbents by changing the equilibrium configuration from entry met with litigation to entry deterrence.

To explore such a possibility, consider a situation in which the entrant's cost is sufficiently low and entry cannot be deterred even when the incumbent responds with litigation in face of entry. In other words, consider a case where there is "slack" z_E

[6]However, we can think of other reasons that would favour royalty-free cross licensing arrangements. For instance, if the limit royalty rate is positive, but close to zero, they may prefer a royalty-free contract if there are administrative costs in enforcing the contract with a positive royalty rate such as monitoring each other's outputs.

in the entry constraint and slack z_L in the litigation constraint of the incumbents,

$$z_E \equiv (1-\theta)s\pi^d(\gamma, c) - K - L > 0,$$
$$z_L \equiv \theta s[\pi^m(c) - \pi^d(c,\gamma)] - (1-\theta)[\Pi^C(r^m) - \pi^d(c + r^m, c)] - L > 0.$$

Let $r^D \in [0, r^m)$ be the royalty rate at which the incumbents are indifferent between entry deterrence and accommodation if entry can be deterred with $\hat{r} = r^D$, that is,

$$\frac{s}{2}[\pi^d(c,\gamma) + \pi^m(c)] + \Pi^C(r^m) = s\pi^m(c) + \Pi^C(r^D)$$

As the entry deterrence profits on the RHS are increasing in $\hat{r}$, the incumbents prefer entry deterrence if entry can be deterred at any royalty rate $\hat{r} \geq r^D$. Note that the RHS always dominates accommodation profits on the LHS at $\hat{r} = r^m$. Therefore, $r^D < r^m$. If the RHS exceeds the LHS for all $\hat{r} \in [0, r^m]$, we set $r^D = 0$.

Suppose that $z_L > z_E$. Then, it is evident that an increase in litigation costs by $\Delta L \in (z_E, z_L)$ can be beneficial to the incumbents as the incumbents still maintain credible litigation threats whereas the expected profit from entry becomes negative when entry is met with litigation for certain. What is interesting is that even if litigation costs increases more than z_L or there is a more slack in the IC constraint for entry, i.e., $z_L < z_E$, an increase in litigation costs can still be beneficial. The reason is that the incumbents can adjust their cross-licensing royalty rate to relax the litigation IC constraint further. As the incumbents are willing to reduce its royalty rate down to r^D, we can define an enlarged slack

$$z_L' \equiv \theta s[\pi^m(c) - \pi^d(c,\gamma)] - (1-\theta)[\Pi^C(r^D) - \pi^d(c + r^D, c)] - L > z_L$$

We can thus conclude that if $z_L' > z_E$, then an increase in litigation costs by $\Delta L \in (z_E, z_L')$ can be beneficial to the incumbents.

Example. *Consider our earlier example with $\theta = 1/2$, $s = 1$,and $c = \gamma = 0$ and $r^m = 1/4$. We compare how equilibrium changes when the litigation costs increase* *from L to L', where $\Delta L = L' - L > 0$ and*

$$z_E = (1-\theta)s\pi^d(\gamma, c) - K - L = \frac{1}{18} - K - L > 0$$

Thus, entry cannot be deterred because the expected profit for the entrant is positive even in the face of certain litigation. In this example, it can be shown that entry deterrence always dominates for all $\hat{r}$, that is, $r^D = 0$. Note that

$$z_L = \frac{1}{2}[\frac{1}{4} - \frac{1}{9}] - \frac{1}{2}[\frac{1}{8} - \frac{1}{36}] - L = \frac{5}{72} - \frac{7}{144} - L = \frac{1}{48} - L$$

while

$$z_L' = \frac{1}{2}[\frac{1}{4} - \frac{1}{9}] - 0 - L = \frac{5}{72} - L > z_E = \frac{1}{18} - K - L > 0$$

This implies that if the litigation costs increase by $\Delta L \in (1/18 - K - L, 5/72 - L)$, the incumbent can deter entry.

This result is in contrast to cases where the patent holder is a non-practicing entity, or both the patent holder and the alleged infringer are practicing entities already in the market. In such cases, an increase in litigation costs can only hurt the patent holder because the litigation incentive constraint is more difficult to satisfy with higher litigation costs (Choi and Gerlach, 2017). Our analysis thus reveals that the effects of litigation costs may differ depending on whether the infringing firm is already active in the market or a potential entrant.

4 Optimal Cross-Licensing with Cost Uncertainty

We now consider a situation in which the potential entrant's cost is unknown to the incumbents when they set a cross-licensing royalty rate. The potential entrant's marginal cost γ is drawn from a distribution function $F(.)$ on $[\underline{\gamma}, \overline{\gamma}]$. To reduce the number of cases to consider and without sacrifice of any insights, we make the following parameter assumption:

$$(1-\theta)s\pi^d(\underline{\gamma}, c) - L < K < s\pi^d(\overline{\gamma}, c) \tag{3}$$

This ensures that the highest cost entrant has an incentive to enter without any litigation threat whereas the lowest cost entrant will not enter if its entry is met with litigation.

When the incumbent firms set a royalty rate of r, they have ex post incentives to litigate against the entrant if and only if its cost is lower than the critical value $\gamma^L(r)$. In this case, the threat of litigation is credible and entry is deterred. If the entrant's cost is above $\gamma^L(r)$, the threat of litigation is not credible and entry is accommodated. Ex ante, the probability of entry deterrence is given by $F(\gamma^L(r))$ whereas with the remaining probability entry occurs and is accommodated. The incumbents maximize their expected profits and set a cross-license fee of

$$r^* = \arg\max_r \quad \Pi^C(r) + F(\gamma^L(r))s\pi^m(c) + \int_{\gamma^L(r)}^{\overline{\gamma}} [s\frac{1}{2}(\pi^d(c,\gamma) + \pi^m(c)]df(\gamma),$$

which yields the following first order condition

$$\frac{d\Pi^C(r)}{dr} + \frac{s}{2}[\pi^m(c) - \pi^d(c, \gamma^L(r))]\frac{d\gamma^L(r)}{dr}f(\gamma^L(r)) = 0. \tag{4}$$

The first term is the marginal effect of the cross-license rate on collusion in the common market. The second term is the effect of a higher cross-license on the profits from the marginal entrant. Since $d\gamma^L(r)/dr < 0$ by lemma 2, this term is negative. A higher r reduces ex post litigation incentives and allows entry which leads to duopoly instead of monopoly profits in the captive market. Hence, incumbents to trade-off collusion incentives in the common market against probabilistic entry deterrence in the captive market. It is clear that the optimal cross-license rate always satisfies $r^* < r^m$. As the entry deterrence motive becomes more important, the optimal cross-licensing rates need to be reduced further. If the first order condition is negative for all r, a corner solution with $r^* = 0$ obtains; the optimal licensing arrangement is *royalty-free* cross-licensing.

Example (Cournot Model with Linear Demand, continued)**.** *As in the earlier example, assume that $\theta = 1/2$, $s = 1$,and $c = 0$ with $r^m = \frac{1}{4}$. It can be shown that given a cross-licensing royalty rate of r, the incumbents have incentives to litigate against the entrant if*

$$\gamma \leq \gamma^L(r) = \sqrt{\frac{9}{4} + 6r^2 - 5r - 9L} - 1$$

In this example, let $L = \frac{14}{225} \simeq 0.0622$ and assume that γ is uniformly distributed on $[0.2, 0.3]$. This implies that $r = 0$ is required to have incentives against all types of entrant. We further assume that $K < \frac{4}{225}$, which ensures that the highest cost type entrant has incentives to enter the market if there is no litigation. Then, it can be verified that the optimal strategy for the incumbents is to set $r^* = 0$ and deter all types of entrants.

In the analysis above we assume that an entrant's marginal cost is exogenously given and cannot be changed. However, we can imagine a situation in which the entrant engages in "Judo economics" (Gelman and Salop, 1983) and adopts a puppy dog strategy by entering the market with a deliberately inefficient technology to deter litigation. We show that our qualitative results are robust to this possibility. To account for this possibility, let us assume that an entrant endowed with a marginal cost of γ can enter the market with any cost higher than or equal to γ. If this were the case, given a cross-licensing royalty rate of r between the incumbents, any entrant whose marginal cost is below $\gamma^L(r)$ will enter the market with the technology of $\gamma^L(r)$ to eliminate incentives to litigate by the incumbents. As a result, the incumbent facing such an entrant has a profit of $s\pi^d(c, \gamma^L(r))$ rather than monopoly profits $s\pi^m(c)$ when

$\gamma < \gamma^L(r)$. With such judo strategies, the incumbents solve

$$\max_r \quad \Pi^C(r) + F(\gamma^L(r))s\frac{1}{2}[\pi^d(c,\gamma^L(r)) + \pi^m(c)] + \int_{\gamma^L(r)}^{\overline{\gamma}} [s\frac{1}{2}(\pi^d(c,\gamma) + \pi^m(c)]df(\gamma),$$

which leads to

$$\frac{d\Pi^C(r)}{dr} + \frac{s}{2}\frac{\partial \pi^d(c,\gamma)}{\partial \gamma}\frac{d\gamma^L(r)}{dr} f(\gamma^L(r)) = 0 \tag{5}$$

as the first-order condition. As we have $\partial \pi^d(c,\gamma)/\partial\gamma > 0$ and $d\gamma^L(r)/dr < 0$ by Lemma 2, we can again conclude that the optimal cross-licensing rate for the incumbents is less than the royalty rate that sustains a fully collusive outcome in the common market. With this Judo strategy, the incumbents are unable to deter entry. However, by lowering, the royalty rate r, the entrant needs to raise γ to avoid litigation which increases the incumbents' duopoly profits in the captive market.

5 Policy Implications for Patent Pools

Incumbent firms with IP can use per-unit royalty rates to trade off collusion motives against entry-deterrence. When they lack incentives to litigate against a new entrant with a fully collusive royalty rate, they need to sacrifice full collusion in the common market by setting a lower royalty rate. However, *if* they are able to write a licensing contract that stipulates continuation of royalty payments even for invalidated patents, they can achieve both goals of fully collusive outcome in the common market and credible threat of litigation against an entrant in the captive markets. Current competition policy would not allow such a contract. Moreover, if one of the incumbents litigates against the entrant and loses in court with invalidation of its patent, the rival incumbent firm may have no incentive to honor the original contract as it would not be enforceable in court.

Patent pools may be a vehicle for incumbents to circumvent this problem and sustain full collusion in the common market while maintaining credibility of litigation threat against the potential entrant. Consider a scenario in which the incumbents contribute their respective patents and set up a patent pool with equal revenue sharing. The patent pool retains the full ownership of all patents contributed by member firms who pay a royalty rate of r for the use of the whole patent portfolio in the pool. When there is entry in a captive market, the patent pool initiates litigation against the entrant as a proxy on behalf of its member firms. In such a scenario, it can be easily verified that

$$\begin{aligned}\tilde{\Pi}^L(r) &= \theta[s\pi^m(c) + \Pi^C(r)] + (1-\theta)[s\pi^d(c,\gamma) + \Pi^C(r)] \\ &= \Pi^C(r) + \theta s\pi^m(c) + (1-\theta)s\pi^d(c,\gamma)\end{aligned}$$

while $\tilde{\Pi}^{NL}(r) = \Pi^{NL}(r)$.[7] Thus, we always have $\tilde{\Pi}^L(r) > \tilde{\Pi}^{NL}(r)$ for all r. The patent pool will license its patents to member firms with a royalty rate of $\tilde{r}^* = r^m$ to sustain full collusion in the common market, but still maintain a credible litigation threat against the potential entrant. Note that in such a scenario, it may backfire if the competition authority imposes a non-discriminatory licensing rule on the patent pool to allow the entrant to receive licenses and insulate the entrant from litigation threat. The reason is that the patent pool in the presence of such a rule may then set a royalty rate even higher than r^m to discourage entry by raising the entrant's costs (Salop and Scheffman, 1983). As a result, we may end up having monopoly outcomes in both the common and captive markets.

As in Lerner and Tirole (2004), requiring pool members to be free to independently license their patents outside the pool can be used as a screening mechanism to prevent welfare-reducing patent pools in our set-up. Lerner and Tirole (2004) consider patent pools when patent owners are not downstream users and therefore not potential licensees. In such a setting, they show that independent licensing by

[7] Variables associated with patent pools are denoted with a tilde (˜).

pool members creates competition and undermines patent pools that would elevate prices with substitute patents. In contrast to Lerner and Tirole (2004), we consider vertically integrated firms that are potential licensees. In our set-up, independent licensing implies that each patent holder can use its own technology for free. Thus, when the other firm's patent is invalidated, there is no need to license from the patent pool any more. Thus, we restore the endogenous cost of litigation as in the case of cross-licensing. As a result, the patent pool needs to reduce its royalty rate to restore incentives to litigate against the entrant.

6 Entry into the Common Market

For analytical simplicity and to develop basic intuition, we have considered entry into only the captive markets. With potential entry into the common market, we need to consider entry deterrence as a public good (Gilbert and Vives (1986) and Waldman (1987)); successful litigation against an entrant benefits both incumbents, but the litigation cost and the potential cost associated with losing patents due to invalidity judgements are incurred solely by the litigating firm. In this case, royalty-free licensing agreements or patent pools can be a commitment mechanism to mitigate this free-rider problem.

Gilbert and Vives (1986) analyze the potential free-rider problem in entry deterrence in an oligopolistic industry and show that underinvestment in entry-deterrence never occurs in equilibrium. Waldman (1987) further shows that the same conclusion obtains in the presence of uncertainty. In these models, the incumbents make an *ex ante* decision concerning entry deterrence before the potential entrant makes an entry decision. In our model, we consider a situation in which the incumbents make an ex ante strategic decision which changes the incentives to litigate ex post entry.

Consider the following framework. The two incumbents only operate in a common market C, that is, $s = 0$. There is a potential entrant in this market who might infringe on the intellectual property of the two incumbents in the same way as in the previous sections. If the entrant's technology is found infringing on a valid patent, the entrant is unable to compete in the market. This means that successful exclusion requires exactly one incumbent to win infringement litigation. To shorten exposition, we focus on the endogenous cost of litigation in the form of patent invalidation and assume that any other litigation related costs are negligible relative to the expected profits in the marketplace (that is, $L = 0$).

We further assume that the incumbents and entrant produce at $c = 0$ and $\gamma = 0$, respectively. Let $q^t(a, b)$ and $\pi^t(a, b)$ be an incumbent's market quantity and profit in a triopoly when it has a marginal cost of a while the rival incumbent has a cost of b. Similarly, the entrant's quantity and profits are given by $q^t_e(a, b)$ and $\pi^t_e(a, b)$. Moreover, let $\Pi^t(a, b)$ be the total profit of an incumbent inclusive of licensing revenues when it pays royalty a to its rival incumbent and receives a royalty b from that same firm. We again assume that all market quantities and profits decrease in own cost and increase in the cost level of the competitor.

Assumption 2.

$$(i) \quad \frac{dq^t(a,b)}{da} < 0, \frac{dq^t(a,b)}{db} > 0, \frac{d\pi^t(a,b)}{da} < 0, \frac{d\pi^t(a,b)}{db} > 0,$$

$$(ii) \quad \frac{dq^t_e(a,b)}{da} = \frac{dq^t_e(b,a)}{da} > 0, \frac{d\pi^t_e(a,b)}{da} = \frac{d\pi^t_e(b,a)}{da} > 0.$$

$$(iii) \quad \frac{\Pi^t(a,0)}{da} + \frac{\Pi^t(0,a)}{da} < 0, \frac{\Pi^t(a,a)}{da} < 0$$

Point *(ii)* makes sure that both incumbents' cost levels enter symmetrically into the entrant's quantity and profit. The last point states that the joint profits of the incumbents in a triopoly decrease in any license fee. This assumption holds, for example, if competition is in quantities and strategies substitutes.[8] We consider the following timing of the game:

1. Incumbents jointly set the cross-licensing rate $r \geq 0$.

2. Entrant decides whether to enter at a sunk cost of K.

3. When there is entry, the incumbents simultaneously choose whether to litigate or not.

4. If the incumbent wins the infringement litigation, the duopoly persists. Otherwise the incumbents can renegotiate the cross-licensing fee and firms compete in a triopoly.

This set-up reflects a situation with a continuous threat of entry for the duopoly. The incumbents commit to a cross-licensing rate as long as they are able to exclude other competitors. If an entrant is able to establish itself in the market, either due to the absence of a litigation challenge or due to a win in court, the incumbents renegotiate their cross-license arrangement and accommodate entry.

When there is entry into the common market, the incumbents simultaneously decide whether or not to initiate legal action against the entrant, $l_i \in \{L, N\}$. Let Π^{xy} denote an incumbent's expected profits when it picks $x \in \{L, N\}$ while the other incumbent chooses $y \in \{L, N\}$. For simplicity we assume that if both initiate legal

[8] We make this assumption for analytical simplicity. If competition is in prices and strategic complements, higher prices by the incumbents with a positive royalty could invite a higher price from the entrant. In this case, positive royalty fees may increase the incumbents' joint profits (see Deneckere and Davidson (1985) for a discussion in the context of mergers). While this would add an effect on the incumbents' ex ante profits, it would not interfere with the free-rider problem of patent litigation and the qualitative results of this section.

action, one of the two incumbents is randomly drawn to litigate against the entrant.[9] This assumption also reflects the war of attrition nature of the entry deterrence free-riding problem. Given the rival incumbent takes the case to court, an individual incumbent has a strict incentive to wait for the litigation outcome. Moreover, if after initiating, an incumbent decides not to act on its threat, its inaction may be interpreted as a tacit withdrawal of the patent claims. This can imply that the patent holder is barred to bring an infringement suit later on based on equitable estoppel.[10]

We look for a subgame perfect equilibrium of this game. Consider the last stage when the incumbents engage in Nash bargaining to renegotiate their cross-license agreement. First suppose there is entry and the incumbents are not litigating or the incumbent has lost the infringement case. In both cases, the entrant is able to establish itself in the market. The incumbents then engage in renegotiating their cross-licensing agreement. Under assumption *2 (iii)*, any cross-licensing fee is a transfer between the incumbents and reduces their joint production level and profits. Hence, the incumbents always have an incentive to eliminate any licensing arrangement once entry has occurred. This implies that in the absence of litigation each incumbent gets $\Pi^{NN} = \pi^t(0,0)$. Similarly, suppose the litigating incumbent loses in court against the entrant. In a triopoly, the pair of incumbents is better off removing any license fees. In this case, under Nash bargaining with equal bargaining power, the losing incumbent pays $\Delta(r)/2$, where

$$\Delta(r) = \Pi^t(0,r) - \Pi^t(r,0),$$

[9] Allowing for two litigation cases simultaneously or sequentially would not change the qualitative nature of the results in this section.

[10] See, for example, Aspex Eyewear Inc. v. Clariti Eyewear, Inc., Nos. 09-1147, -1162 (Fed. Cir. May 24, 2010).

to the rival incumbent and they both make profits of $\pi^t(0,0)$ in the marketplace. Hence, $\Delta(r)$ is the difference in profits between a litigating and non-litigation incumbent or the potential gain from free riding on the rival incumbent's entry deterrence efforts. Note that with a zero cross-licensing fee there is nothing at stake for a litigating incumbent in case of losing the infringement case. This means there is no free-rider problem. However, strictly positive cross-licensing fees drive a wedge between the profits of a litigating and non-litigating incumbent.

Note that from a joint perspective, each incumbent can gain as much as

$$B(r) = \Pi^C(r,r) - \pi^t(0,0)$$

from a successful exclusion of the entrant. This benefit is strictly positive and increasing in the cross-licensing fee r. We make the following assumption on the above profit functions:

Assumption 3. *For all $r \leq r^m$ it holds that*

$$\frac{d\Delta(r)/dr}{\Delta(r)} > \frac{dB(r)/dr}{B(r)}.$$

The elasticity of the gain from free-riding with respect to the cross-licensing fee is higher than the elasticity of the overall benefit. In other words, the gains from free-riding are more responsive to the cross-license fee than the incumbents' collusive duopoly profits. This seems natural and holds, among others, in our leading example with Cournot competition and linear demand.

We can thus write the ex post payoffs for the incumbents as

$$\Pi^{LN} = \Pi^{NN} + \theta B(r) - (1-\theta)\frac{1}{2}\Delta(r)$$
$$\Pi^{NL} = \Pi^{NN} + \theta B(r) + (1-\theta)\frac{1}{2}\Delta(r).$$

Successful litigation increases both incumbents' profits by the difference between duopoly and triopoly profits, that is, $B(r)$. At the same time, litigation is costly as the litigating incumbent stands a chance of losing and having its patent invalidated. In this case, the losing incumbent pays $\Delta(r)/2$ to the rival incumbent in exchange for a zero-fee cross-license in a triopoly.

Now consider the litigation initiation subgame after entry. We focus on the symmetric, mixed-strategy equilibrium of this game.[11] Let λ be the probability that a given incumbent initiates legal action. In a mixed-strategy equilibrium, the expected payoff from litigation has to be equal to the expected payoff from waiting, that is,

$$\lambda(\Pi^{LN} + \Pi^{NL})/2 + (1-\lambda)\Pi^{LN} = \lambda\Pi^{NL} + (1-\lambda)\Pi^{NN}$$

or

$$\lambda(r) = \frac{\Pi^{LN} - \Pi^{NN}}{(\Pi^{LN} + \Pi^{NL})/2 - \Pi^{NN}} = 1 - \frac{(1-\theta)\Delta(r)/2}{\theta B(r)}.$$

The first expression states that the litigation probability for an individual incumbent is given by the ratio of private gains over the average joint benefit from litigation. The second expression describes the probability of initiating litigation as a function of $\Delta(r)$ and $B(r)$. What is the effect of the cross-licensing fee r on litigation incentives? First note that in the absence of a free-rider problem, that is, for $\Delta(r=0) = 0$, litigation always occurs with probability 1. Higher cross-licensing fees increase the gains from free-riding $\Delta(r)$ which lowers the probability of litigating. At the same time, more collusive fees increase the potential reward from preventing entry $B(r)$. However, the first effect dominates and we get the following result.

Lemma 3. *For all $r < r^m$, it holds that $d\lambda(r)/dr < 0$.*

[11] There also exist two asymmetric pure-strategy equilibria, one for each incumbent litigating. We find the symmetric, mixed-strategy equilibrium a better representation of the war of attrition aspect of the free-riding problem in entry deterrence. Using public randomization over the two asymmetric pure-strategy equilibria would yield similar qualitative results in stages 1 and 2 of the game.

Like in the benchmark model, cross-licensing arrangements have the potential to dull litigation incentives of incumbents. In this set-up, cross-licensing exacerbates the free-rider problem in litigating against an entrant in the common market. Note that the incumbent's individual litigation probability implies an overall litigation probability of $\Lambda(r) = 1 - (1 - \lambda(r))^2 \geq \lambda(r)$ which also decreases in r and increases in θ. Intuitively, the probability of litigation increases in the perceived strength of the patent case θ.

At stage 2, the entrant decides whether to enter or not, anticipating the litigation behavior of the incumbents. To make the analysis meaningful, we restrict ourselves to situations where entry is profitable without litigation but could be deterred with a credible threat of litigation, that is,

$$(1-\theta)\pi_e^t(0,0) < K < \pi_e^t(0,0).$$

The entrant prefers to enter the marketplace and sink the cost if and only if

$$[1 - \Lambda(r)\theta]\pi_e^t(0,0) \geq K.$$

A higher cross-license royalty rate reduces the threat of litigation and increases the entrant's expected profits. Vice versa, at r=0, post-entry litigation occurs with probability one and entry is always deterred. Let us define $\hat{r}$ as the maximum royalty that deters entry from the competitor. For higher values of r, the entrant invests the entry cost and then faces potential litigation that could exclude the firm from the marketplace. In other words, the incumbents can either use the mere threat of litigation to prevent entry or exclude firms in case they win litigation following entry. Note that a higher θ raises the probability of litigation and the entrant's chance of losing in court. This implies that the limit royalty fee $\hat{r}$ increases in the strength of the incumbents' patent case θ.[12]

Now consider the choice of the ex ante optimal cross-licensing arrangement at stage 1. The maximum profit an incumbent can earn without inducing entry is given by a collusive cross-license arrangement at the limit entry fee, that is, $\Pi^C(\hat{r})$. For higher values, $r > \hat{r}$, the entrant incurs the entry cost and faces litigation with probability $\Lambda(r)$. In this case the optimal royalty rate for the incumbents solves

$$r' = \arg\max_{r} \quad \Lambda(r)\theta\Pi^C(r) + [1 - \Lambda(r)\theta]\pi^t(0,0)$$
$$\text{subject to } r > \hat{r}$$

The first-order condition for an interior solution is given by

$$\Lambda(r)\frac{d\Pi^C(r)}{dr} + \frac{d\Lambda(r)}{dr}[\Pi^C(r) - \pi^t(0,0)] = 0. \tag{6}$$

Ex post, the cross-license rate only matters in case the incumbents win litigation. Hence, the success rate θ cancels out. The first term in condition (6) is the marginal potential gain in collusive cross-license profits in a duopoly weighted with the probability that litigation takes place. The second term is the marginal potential loss from reducing the litigation intensity by increasing the royalty rate r. It follows straight that marginal profits are always smaller than $d\Pi^C(r)/dr$ for any $r < r^m$. Thus, any interior solution - if it exists - has to satisfy $r' \in (\hat{r}, r^m)$.

The incumbents prefer complete entry deterrence over accommodation and litigation if and only if

$$\Pi^C(\hat{r}) \geq \pi^t(0,0) + \Lambda(r')\theta[\Pi^C(r') - \pi^t(0,0)] \tag{7}$$

It is clear that there must exist parameter values such that entry deterrence is optimal for the incumbents. As the incumbents' patent case θ becomes weaker, the threat

[12] Moreover, note that, for its feasible values, the entry cost parameter K increases the limit royalty rate from $\hat{r} = 0$ to $\hat{r} = r^m$.

of litigation goes down and the RHS of condition (7) approaches triopoly profits. This must be dominated by entry deterrence as the LHS yields at least (royalty-free) duopoly profits. Vice versa, there are also situations where entry accommodation and litigation is optimal. As θ increases towards 1, the probability of litigation goes towards 1 and r' gets closer to r^m. Hence, the RHS approaches the fully collusive duopoly profits. Since $\Pi^C(r)$ is increasing for $r \leq r^m$, the interior solution r' must yield higher profits than $\Pi^C(\hat{r})$. We can summarize as follows.

Proposition 2. *When incumbents face entry in a common market, the optimal cross-licensing fee r^* satisfies $0 \leq r^* < r^m$. If the incumbents' patent protection is weak, the optimal cross-licensing arrangement induces complete entry deterrence. Otherwise, entry occurs and the incumbents try to exclude the competitor through patent litigation.*

Like in the model with entry in the captive markets, we find that the optimal cross-license fee is bounded away from the fully collusive fee r^m. With entry in the common market, reducing the cross-license fee alleviates the free-rider problem of post-entry litigation. To which extent the cross-license is reduced depends on whether it is optimal to deter entry completely or allow entry followed by some litigation. The former strategy implies a low fee (and a high threat of litigation) whereas the latter uses an intermediate fee with less post-entry litigation. If the incumbents' IP is strong, they rather face litigation then reducing the cross-license fee.

To illustrate the above analysis consider again our example with Cournot competition and a linear demand function. Below we graph the LHS and RHS of condition (7) for $\theta = 0.75$ and $\theta = 0.9$, respectively. The incumbents trade off the possibility of deterring entry entirely by setting a low limit cross-license $\hat{r}$ against the expected profits from setting higher fees and facing entry and litigation. If the patent protection is sufficiently strong, the incumbents prefer the latter strategy and choose the interior maximizer of the expected litigation profits, r'. If patent protection is weak, the incumbents optimally choose $\hat{r}$ and prevent entry.

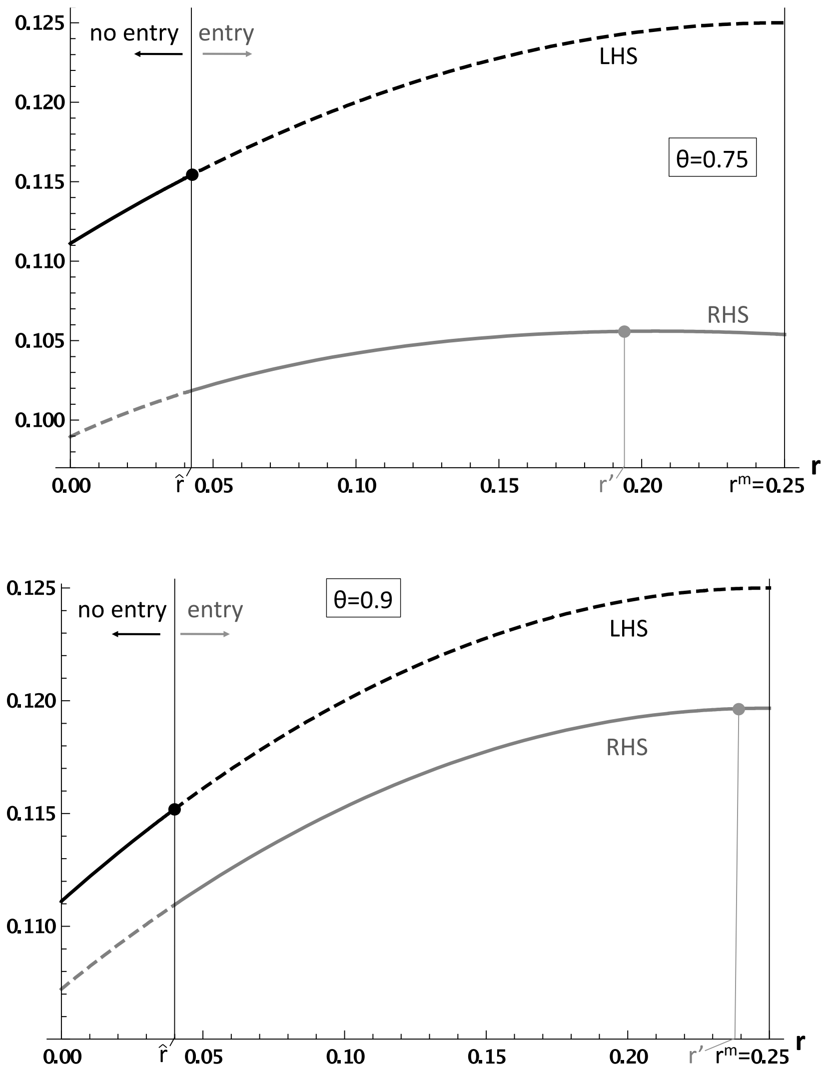

FIGURE 3: *Optimal cross-licensing with entry in common market*

Finally, consumers are again stuck between two evils, collusive cross-licensing fees and entry deterrence. For a given cross-license rate, consumer are better off in a tri-opoly and they strictly prefer entry and less litigation. However, higher cross-licensing rates induce entry and lower the probability of litigation and possible exclusion of the entrant due to patent infringement. Are consumers better off with lower or higher cross-license rates? The answer depends on the strength of the incumbents' patent case. For example, suppose the incumbents' patent protection is weak and the optimal cross-license rate is the limit entry license $\hat{r}$. It follows straight from the above analysis that, in this case, a per se prohibition of positive cross-licensing rates would improve consumer surplus. By contrast, note that at $r = \hat{r}$, consumer surplus has a discrete jump upwards as the expected surplus with entry and a potential triopoly always dominates entry deterrence. This implies that cross-license rate that maximizes consumer surplus can be strictly positive. This is, in particular, more likely if $\hat{r}$ is sufficiently small or K close to the entrant's profits with certain litigation.

7 Conclusions

This paper analyzes optimal cross-licensing arrangements between incumbent firms in the presence of potential entrants. We show that the privately optimal cross-licensing royalty rate trade-offs incentives to sustain a collusive outcome vis-a-vis incentives to deter entry with the threat of patent litigation. As acknowledged by the U.S. Department of Justice and the Federal Trade Commission Report (2007), cross-licenses can be pro-competitive by allowing firms operating within a patent thicket to use each other's patented technology without the risk of litigation and affording them the design freedom to design new products without fear of infringement (Shapiro, 2004). This is especially so in high-tech industries such as the semiconductor and smartphones, which is characterized by a plethora of overlapping patent rights. The Report (2007, pp. 61-62) also expresses competitive concerns associated with cross-licensing agreements. In particular, an elevated royalty rate that intends to relax competition and facilitate collusion can be a major concern. In addition, it points out the possibility of cross-licensing agreements posing a barrier to entry to outsiders. We present a unified theory to capture both of these two concerns. In this framework, a cross-licensing arrangement with a very low royalty rate (or even a royalty-free contract) may not be as benign as it appears if it is used as an entry deterrence mechanism.

As in Jeon and Lefouili (forthcoming), our analysis provides some caution against simplistic rules regarding cross-licenses. In particular, their analysis does not support the policy of granting a safe harbor to cross-licensing agreements between competitors based on their joint market share.[13] Our analysis adds another layer of subtlety to competition policies concerning cross-license agreements if we consider potential entry. In fact, Jeon and Lefouili points out the possibility that constraining cross-licensing royalties may lead to the exclusion of some firms from the market. We formalize this idea in the context of entry deterrence.

Appendix

Proof of Lemma 3

We get

$$\frac{d\lambda(r)}{dr} = \frac{(1-\theta)[\Delta(r)d\Pi^C(r)/dr - [\Pi^C(r) - \pi^t(0,0)]d\Delta(r)/dr]}{2\theta[\Pi^C(r) - \pi^t(0,0)]^2}$$

[13] Both the European Commission and US DOJ/FTC grant antitrust exemption to cross-licensing agreements if their joint market share is below 20%.

which is negative if and only if

$$\Delta(r)\frac{d\Pi^C(r)}{dr} < [\Pi^C(r) - \pi^t(0,0)]\frac{d\Delta(r)}{dr} \quad \text{or}$$
$$\frac{dB(r)/dr}{B(r)} < \frac{d\Delta(r)/dr}{\Delta(r)}.$$

This condition is always satisfied under Assumption 3. To show that Assumption 3 holds in the Cournot model with linear demand, check that $\pi^t(0,0) = 1/16$, $\Pi^t(0,r) = 1/16 + r(6-11r)/16$ and $\pi^t(r,0) = (1-3r)^2/16$. This yields $\Delta(r) = r(3-5r)/4$ and $B(r) = (1+r-2r^2)/9 - 1/16$. Assumption 3 holds if and only if

$$\frac{d\Delta(r)/dr}{\Delta(r)} = \frac{3-10r}{r(3-5r)} > \frac{dB(r)/dr}{B(r)} = \frac{16(1-4r)}{7+16r(1-2r)}$$

or

$$\frac{21-2r(35-8r)}{r(3-5r)[7+16r(1-2r)]} > 0.$$

The denominator is always positive for $r \leq r^m = 1/4$. The numerator is concave and takes values of 21 and 9/2 at $r = 0$ and $r^m = 1/4$, respectively. Hence, the condition is always satisfied. □

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