Patent Licensing and Entry Deterrence: The Role of Low Royalties

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Patent Licensing and Entry Deterrence: The Role of Low Royalties

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We study how an incumbent patent holder can use licensing strategically to reduce the threat of further entry, through a low royalty. This licensing strategy deters entry by making the terms of future licensing agreements less favourable to potential entrants. Strategic licensing induces a trade-off between a more concentrated market and a lower price. When this strategy is profitable for the patent holder, it is welfare enhancing if and only if the entry cost is high, or the efficiency edge of the technology is significant. Our analysis yields new policy implications (e.g. royalty floor) with respect to strategic licensing.

INTRODUCTION

The past two decades have witnessed an important growth of technology licensing in high technology industries. Nearly 60% of semiconductor firms voluntarily engage in licensing, and other industries have also adopted it as a standard practice (Cohen et al. 2000). Although often considered as a revenue-generating device, technology licensing—in particular horizontal licensing, between rivals—may also be used for strategic reasons. Specifically, licensing can be used by patent owners to deter or limit competition.

Most licensing contracts involve a royalty and a fixed fee.¹ Unlike the fixed fee, which is simply a transfer from licensee to licensor, the royalty can affect the market price by modifying the licensee’s marginal cost. A patent holder may be inclined to reduce the market price by making the licensee more efficient through a lower royalty in order to deter unlicensed potential entrants. In the US chemicals industry, where average royalty rates have been historically low, Du Pont used this strategy in the 1950s for its polyester patent. By licensing only to Fiber Industries, Du Pont was able to limit entry by non-licensees, and the two firms dominated the market until 1970.² Another example is meprobamate, which is used as an anxiolytic drug (see Comanor 1964). Right after the issue of its patent in 1955, Carter licensed its main competitor, the American Home Products Corporation, with a 5% royalty rate, and they both enjoyed market dominance until 1960.

This paper considers the possible anticompetitive effects of such licensing arrangements. We analyse the licensing strategy of an incumbent innovator of a non-drastic technology in a duopoly market with potential entry. In particular, the patent holder may choose to decrease licensing revenues from its competitor through a low royalty, in order to discourage further entry.³ Thus on the one hand entry deterrence results in a less competitive market structure in the form of a duopoly rather than a triopoly (market structure effect), but on the other hand it yields a lower royalty and hence increased efficiency of the incumbent licensee (price distortion effect). Whether entry deterrence leads to higher or lower prices depends on which of these conflicting factors dominates.

Although the idea that technology licensing can deter or limit competition is not a new one (see the literature review that follows), this paper proposes an original model
that distinguishes the different welfare effects of strategic licensing. By adopting a linear demand system, we are able to identify those environments—in the space of entry cost and technological asymmetry between the two incumbents (size of the innovation)—in which strategic licensing is profitable and welfare increasing/decreasing. In doing so, insights into the trade-off of lower prices to deter entry versus higher prices from a more concentrated market are crystallized: we show that the strategy will be effective in deterring entry for intermediate values of the entry cost, where the minimum cost level above which entry is deterred decreases in the size of the innovation. When strategic licensing is privately profitable, it increases consumer welfare if the entry cost (or size of innovation) is sufficiently small for a given innovation size (or entry cost) since, for those parameter values, the benefits from the lower royalty to deter entry outweigh the welfare costs of a more concentrated market structure.

In addition to unilateral licensing, the main mechanism of our model can also be extended to cross-licensing agreements (and patent pools). Theoretical work has demonstrated the optimality of high royalties as a collusive device, in the absence of entry threats (Fershtman and Kamien 1992). However, most cross-licensing agreements entail very low—even zero—royalties. In the microprocessor industry, for example, cross-licensing among the big firms, such as Intel and IBM, with low royalties is the norm (Shapiro 2001, pp. 129–30). Interestingly enough, the market structure has been relatively stable in this industry, with Intel being able to maintain its dominant position in the market. Thus our model can rationalize low royalties when firms face the threat of entry. Although it is hard to conclusively establish entry deterrence, the above example provides evidence for a correlation between low royalties and low entry rates (at least entry that would threaten the market shares of the big firms).

Within this context, we investigate the incentives of the incumbent firms to invest in research and development (R&D) through a patent race. We show that R&D incentives are the strongest precisely when firms can use the licensing contract to deter entry. Given that R&D investments are already excessive from a social welfare perspective due to the patent race, entry deterrence through licensing exacerbates this inefficiency (excessive R&D effect). The contribution of the R&D stage to the results that we derive is as follows. When we hold the R&D expenditures fixed, strategic licensing, as mentioned above, can increase or decrease consumer welfare, but it always improves social welfare. When we endogenize R&D spending, however, strategic licensing can also lead to lower social welfare. The interaction of the excessive R&D effect with the other two effects (market structure and price distortion effects) shows that the social welfare predictions very much resemble those for consumer welfare.

There are papers in the literature that examine how licensing can be used to affect competition. All these papers have the common feature of an incumbent holding a patent on a cost-reducing technology who uses licensing to avoid entry by a ‘strong’ competitor. In Gallini (1984), this competitor is the only potential entrant, and it can become strong by investing in costly R&D to develop a new innovation. The paper shows that the incumbent can offer a fixed fee licence (there is no royalty in her model) to the potential entrant in order to discourage it from entering with a better technology. Indeed, in Gallini’s model the entrant’s incentive to innovate increases as the technological gap with the patent holder increases, so the patent holder is willing to give up its monopoly power in order to remain the technological leader. In Rockett (1990), there are two periods—before and after the patent expires—and the patent holder uses licensing during the first period to affect competition during the second period. More precisely, it will grant a

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licence to a weak competitor during the first period in order to make it enter first in the second period (its entry cost is reduced thanks to the transfer of know-how) so the strong competitor stays out.6

The closest paper to our work is Maurer and Scotchmer (2002). In that paper, as in Gallini (1984), a potential entrant can become strong by investing in costly R&D and become an ‘independent inventor’. However, the patent holder is able to keep that independent inventor out by licensing to many weak competitors. The key factor is that the patent holder can increase the number of licensees and lower the royalty that they pay, in order to lower the market price, which in turn makes entry by the strong competitor unprofitable. Therefore the existence of the threat of entry by a strong competitor is welfare-improving, since it lowers the price and avoids the duplication of R&D spending by the deterred entrant. The authors conclude that independent invention defence is always welfare-improving.

In contrast to these papers, in ours there is no potential ‘strong’ competitor: the incumbent patent holder is the technological leader and uses licensing to deter entry by a weak competitor.7 In other words, it is possible to enter without being a licensee or a strong firm, while this possibility is ruled out by the aforementioned papers. Therefore while these papers study the strategic use of licensing to select the type of competitor(s)—weak rather than strong—we show that it can select the number of (weak) competitors accommodated in the market. This highlights a new effect of strategic licensing, namely the market structure effect. Moreover, in contrast to Rockett (1990), there are some licensing contracts that do not deter entry. In particular, a high royalty makes the price high enough for entry to be profitable. The patent holder must thus lower the royalty enough in order to deter entry—in Gallini (1984) there is no royalty, and in Rockett (1990) the royalty rate is exogenous. This leads to the price distortion effect of strategic licensing. Although a comparable mechanism is found in Maurer and Scotchmer (2002), the models are different and they address different issues and policy questions. They study the welfare effects of the entry threat, while we focus on the effect of strategic licensing, given the threat of entry.

An extensive theoretical literature has compared different licensing modes of cost-reducing innovations. Although the early literature concluded that for an outside innovator in a Cournot oligopoly royalty licensing is dominated by fixed fees or auctions (Kamien and Tauman 1986; Kamien et al. 1992), royalties can be superior once the integer constraint on the number of licences is taken into account (Sen 2005).8 Royalty licensing can also be optimal when licensees are competing in price in a differentiated oligopoly (Muto 1993; Caballero-Sanz et al. 2002; Faulí-Oller and Sandonís 2002), when there is uncertainty or asymmetric information (Gallini and Wright 1990; Macho-Stadler and Pérez-Castrillo 1991; Beggs 1992), or when the innovator is one of the incumbent firms in the industry (Shapiro 1985; Wang 1998; Wang and Yang 1999; Kamien and Tauman 2000). Royalties enable the innovator to raise the licensees’ marginal costs, which in turn makes them less aggressive in the market. In particular, in a Cournot duopoly it is optimal for an incumbent innovator to license the other competing firm by using a pure royalty policy with maximum royalty and no fees, even when it can use combinations of fees and royalties (Sen and Tauman 2007). In this paper we show that the threat of entry in a duopoly modifies the role of royalties: to block entry, an incumbent innovator sets lower royalties (together with positive fees) for its incumbent rival. Although antitrust authorities mostly frown on high royalties, our analysis suggests that low royalties may well be anticompetitive, and setting a ‘royalty floor’ may be appropriate in certain situations.

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In his seminal paper, Arrow (1962) argues that licensing leads to socially suboptimal outcomes in oligopolies. Later literature confirms the insufficient private incentives of licensing (Katz and Shapiro 1986; Sen and Tauman 2007), although this result can be reversed when there are fixed costs of installation (Creane 2009). This paper qualifies the issue of discrepancy between private incentives and social optimality in licensing. We show that licensing policies that deter entry raise social surplus. However, when R&D investments of firms are endogenized, entry-deterring licensing policies lead to excessive R&D, which can reduce social welfare. To our knowledge, few papers consider the impact of licensing on \textit{ex ante} innovation incentives.

The paper is organized as follows. Section I presents the model. Section II derives optimal licensing policies and entry decisions. Section III analyses the research and development stage, in the form of a patent race between the two incumbent firms. Section IV explores policy implications. A number of extensions, including cross-licensing, and robustness checks, can be found in Section V. We conclude in Section VI. Proofs are in the Appendix.

I. THE MODEL

Consider a market for a homogeneous good $\eta$ that is served by two incumbent firms: 0 and 1. There is a potential entrant in this market, firm 2. This market is a Cournot oligopoly, that is, firms compete in quantities.\textsuperscript{9} Let $p$ be the market price, and let $Q$ be the total industry output. The inverse market demand is

$$
(1) \quad p = a - Q \text{ if } Q < a \quad \text{and} \quad p = 0 \text{ if } Q \geq a, \quad \text{where } a > 0.
$$

Initially, firms 0, 1 and 2 have the same constant unit cost $c > 0$. Firm 0 has a patent on a cost-reducing technological innovation that reduces the cost from $c$ to 0. Firm 0 can license its patent to firm 1. Firm 2 can either stay outside the industry to obtain zero payoff, or enter by incurring the fixed entry cost $\phi > 0$. If firm 2 chooses to enter, then firm 0 can license its patent to firm 2 as well. In order to focus on situations where firm 0 cannot deter entry by licensing exclusively to firm 1 and excluding firm 2, we assume that when both firms 0 and 1 have zero cost (and zero royalty), the duopoly price $p_D = a/3$ exceeds the old cost $c$, i.e. $c < a/3$.\textsuperscript{10}

The set of licensing policies available to firm 0 is the set of all combinations of an upfront fixed fee and a per unit linear royalty. For $i = 1, 2$, a typical policy offered by firm 0 to firm $i$ is $(r_i, f_i)$, where $r_i \geq 0$ is the royalty that firm $i$ pays for each unit of output that it sells, and $f_i \geq 0$ is the upfront fee that firm $i$ pays to firm 0.

Observe that if firm $i$ accepts a licensing policy with royalty $r_i$, then its \textit{effective marginal cost} becomes $0 + r_i = r_i$. If firm $i$ does not have a licence, then it operates under marginal cost $c$. So no firm will accept a policy with $r_i > c$, and we can restrict $r_i \in [0, c]$. Accordingly, one of the following Cournot oligopoly games is played in the market $\eta$ under inverse demand (1) for $r_1, r_2 \in [0, c]$:

(i) If firm 2 does not enter the industry, then the market $\eta$ is a Cournot duopoly with firms 0 and 1. Denote by $C^D(r_1)$ the Cournot duopoly game with firms 0 and 1 where firm 0 has cost zero and firm 1 has cost $r_1$.

(ii) If firm 2 enters the industry, then the market $\eta$ is a Cournot triopoly with firms 0, 1 and 2. Denote by $C^T(r_1, r_2)$ the Cournot triopoly game with firms 0, 1 and 2 where firm 0 has cost zero, firm 1 has cost $r_1$, and firm 2 has cost $r_2$.

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Lemma 1 characterizes Nash equilibrium (NE) for the games $C^D(r_1)$ and $C^T(r_1, r_2)$. The proof is standard and hence omitted.

Lemma 1. Let $c \in (0, a/3)$ and $r_1, r_2 \in [0, c]$. Under the inverse demand (1), both $C^D(r_1)$ and $C^T(r_1, r_2)$ have a unique NE. Let $q_i^D(r_1)$ and $\phi_i^D(r_1)$ be the NE output and profit of firm $i$, and let $p^D(r_1)$ be the NE price in $C^D(r_1)$. Let $q_i^T(r_1, r_2)$, $\phi_i^T(r_1, r_2)$ and $p^T(r_1, r_2)$ be the corresponding expressions for $C^T(r_1, r_2)$. Then $\phi_i^D(r_1) = [q_i^D(r_1)]^2$, $\phi_i^T(r_1, r_2) = [q_i^T(r_1, r_2)]^2$, and the following hold.

(i) For $C^D(r_1)$: $q_0^D = (a + r_1)/3$, $q_1^D = (a - 2r_1)/3$ and $p^D(r_1) = (a + r_1)/3$.

(ii) For $C^T(r_1, r_2)$: $q_i^T = (a + r_1 + r_2)/4$, $q_1^T = (a - 3r_1 + r_2)/4$, $q_2^T = (a + r_1 - 3r_2)/4$ and $p^T(r_1, r_2) = (a + r_1 + r_2)/4$.

The extensive-form game that models the strategic interaction between firms 0, 1 and 2 is completely characterized by the parameters $a$, $c$ and $\phi$, so we denote it $\Gamma(a, c, \phi)$. Throughout this paper, we consider generic values of the parameters, so inequalities involving functions of these parameters are always strict. This game has the following stages.

Stage I: Firm 0 offers a licensing policy $^{11}$ $(r_1, f_1)$ to firm 1. Firm 1 either rejects the policy ($\lambda_1 = 0$) and has marginal cost $c$, or it accepts ($\lambda_1 = 1$), pays the upfront fee $f_1$ to firm 0, and obtains effective cost $r_1$. Therefore, the marginal cost of firm 1 is $\bar{r}_1 = \lambda_1 r_1 + (1 - \lambda_1)c$.

Stage II: Observing the outcome in Stage I, one of the following happens.

(i) Firm 2 does not enter the industry and obtains zero profit. Then the Cournot duopoly game $C^D(\bar{r}_1)$ is played. Firm 0 obtains its profit from $\eta$ plus royalty payments and fees from firm 1, given by

$$\phi_0^D(\bar{r}_1) + \lambda_1 [r_1 q_1^D(r_1) + f_1].$$

Firm 1 obtains $\phi_1^D(\bar{r}_1) - \lambda_1 f_1$ (profit from $\eta$ net of fees).

(ii) Firm 2 enters the industry, in which case firm 0 offers a licensing policy $(r_2, f_2)$ to firm 2. Firm 2 either rejects the policy ($\lambda_2 = 0$) and has marginal cost $c$, or it accepts ($\lambda_2 = 1$), pays $f_2$ to firm 0, and obtains effective cost $r_2$. So the marginal cost of firm 2 is $\bar{r}_2 = \lambda_2 r_2 + (1 - \lambda_2)c$. The Cournot triopoly game $C^T(\bar{r}_1, \bar{r}_2)$ is played. The payoff of firm 0 is the sum of its profit from $\eta$ plus royalty payments and fees from firms 1 and 2, which is given by

$$\phi_0^T(\bar{r}_1, \bar{r}_2) + \lambda_1 r_1 q_1^T(\bar{r}_1, \bar{r}_2) + \lambda_2 r_2 q_2^T(\bar{r}_1, \bar{r}_2) + \lambda_1 f_1 + \lambda_2 f_2.$$

Firm 1 obtains $\phi_1^T(\bar{r}_1, \bar{r}_2) - \lambda_1 f_1$ (profit from $\eta$ net of fees), and firm 2 obtains $\phi_2^T(\bar{r}_1, \bar{r}_2) - \lambda_2 f_2 - \phi$ (profit from $\eta$ net of fees and entry cost).

We seek to determine subgame perfect Nash equilibrium (SPNE) by backward induction.
II. Analysis

Our main goal is to determine whether the patent holder, firm 0, has incentives to use the licensing contract offered to firm 1, and in particular the royalty, in order to deter entry of firm 2. Moreover, we are interested in the effect of entry costs on the licensing contract and on the incentives to innovate.

Stage II of $\Gamma$

Consider Stage II of $\Gamma$, where firm 1 has cost $\tilde{c}_1$ for some $\tilde{c}_1 \in \{0, 1\}$ and $r_1 \in [0, c]$. Firms 0 and 1 now face the threat of firm 2’s entry. If firm 0 offers a licensing policy $(r_0, f_0)$ to firm 1, it pays $\tilde{c}_1$ and must choose $\tilde{c}_1$. The entry cost becomes sunk following entry, so it can be ignored for subsequent analysis. If firm 0 offers a licensing policy $(r_2, f_2)$ to firm 2, and firm 2 rejects the offer, then its marginal cost stays at $c$ and the game $C^T(\tilde{r}_1, c)$ is played, where firm 2 obtains $\phi^T_1(\tilde{r}_1, c)$. If firm 2 accepts, then the game $C^T(\tilde{r}_1, r_2)$ is played, and firm 2 obtains $\phi^T_2(\tilde{r}_1, r_2) - f_2$. So firm 2 will accept only if $f_2 \leq \phi^T_2(\tilde{r}_1, r_2) - \phi^T_2(\tilde{r}_1, c)$. Therefore for any $r_2 \in [0, c]$, it is optimal for firm 0 to set

\[(4) \quad f_2 = \phi^T_2(\tilde{r}_1, r_2) - \phi^T_2(\tilde{r}_1, c) \equiv \Delta_2(\tilde{r}_1, r_2)\]

so that firm 2 obtains net payoff $\phi^T_2(\tilde{r}_1, c)$, making it just indifferent between accepting and rejecting the offer. Taking $\alpha_2 = 1$, $\tilde{c}_2 = r_2$ and $f_2 = \Delta_2(\tilde{r}_1, r_2)$ in (3), the problem of firm 0 is to choose $r_2 \in [0, c]$ to maximize

\[(5) \quad \pi^T_1(r_2) = \phi^T_0(\tilde{r}_1, r_2) + \tilde{c}_1 r_1 q^T_1(\tilde{r}_1, r_2) + r_2 q^T_2(\tilde{r}_1, r_2) + \tilde{c}_1 f_1 + [\phi^T_2(\tilde{r}_1, r_2) - \phi^T_2(\tilde{r}_1, c)].\]

Ignoring the terms that have no $r_2$, the problem of firm 0 following firm 2’s entry reduces to choosing $r_2 \in [0, c]$ to maximize

\[(\text{5.1}) \quad \psi^T_1(r_2) = \phi^T_0(\tilde{r}_1, r_2) + \tilde{c}_1 r_1 q^T_1(\tilde{r}_1, r_2) + r_2 q^T_2(\tilde{r}_1, r_2) + \phi^T_2(\tilde{r}_1, r_2)\]

The next lemma summarizes the equilibrium in the second stage of the extensive-form game.

Lemma 2.

(I) Suppose that firm 1 has accepted the licensing policy $(r_1, f_1)$ from firm 0 (i.e. $\lambda_1 = 1$).
   (i) If firm 2 does not enter the industry, then firm 1 obtains $\phi^T_1(r_1) - f_1$.
   (ii) If firm 2 enters the industry, then firm 0 offers the policy $(r_2, f_2) = (r_1, \Delta_2(r_1, r_1))$ to firm 2, i.e. firm 2 is offered the same royalty as firm 1, which firm 2 accepts. Firm 1 obtains $\phi^T_1(r_1, r_1) - f_1$, and firm 2 obtains $\phi^T_2(r_1, c) - \phi$.

(II) Suppose that firm 1 has rejected a licensing offer from firm 0 (i.e. $\lambda_1 = 0$).
   (i) If firm 2 does not enter the industry, then firm 1 obtains $\phi^T_1(c)$. 

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(ii) If firm 2 enters the industry, then firm 0 offers a pure fixed fee policy \((r_2, f_2) = (0, \Delta_2(c, 0))\) to firm 2, which firm 2 accepts. Firm 1 obtains \(\phi_1^T(c, 0)\), and firm 2 obtains \(\phi_2^T(c, c) - \phi\).

To see the intuition, observe that if firm 1 has accepted the policy, then its unit cost is \(r_1\). Firm 0 gets a licensing revenue from both firm 1 and firm 2, so it wants them to compete neck and neck, to get the same amount from each of them. If firm 1 has rejected the policy, then firm 0 will get a royalty and fixed fee only from firm 2. As firm 0 cannot drive firm 1 out of the market, the market structure is a triopoly and it is optimal for firm 0 to offer the minimum possible royalty \(r_2 = 0\). In any case, when firm 2 enters the industry, it obtains its profit without a licence minus the entry cost.

**Entry decision of firm 2** If firm 2 stays out, then it obtains 0. By Lemma 2, if firm 2 enters the industry, then it obtains (i) \(\phi_2^T(c, c) - \phi\) if firm 1 has rejected firm 0’s licensing offer, and (ii) \(\phi_2^T(r_1, c) - \phi\) if firm 1 has accepted a licensing policy \((r_1, f_1)\). Since \(\phi_2^T(r_1, c)\) is increasing in \(r_1\) (by Lemma 1) and \(r_1 \in [0, c]\), we have

\[
\phi_2^T(0, c) \leq \phi_2^T(r_1, c) \leq \phi_2^T(c, c).
\]

Hence the post-entry profit of firm 2 is bounded above by \(\phi_2^T(c, c)\) and bounded below by \(\phi_2^T(0, c)\).

**Lemma 3.**

(I) If \(\phi < \phi_2^T(0, c)\), then firm 2 stays out of the market.

(II) If \(\phi > \phi_2^T(c, c)\), then firm 2 stays out of the market.

(III) If \(\phi_2^T(0, c) < \phi < \phi_2^T(c, c)\), then there exists a royalty \(r_1^*(\phi) := 4\sqrt{\phi} + 3c - a \in (0, c)\) such that \(\phi_2^T(r_1, c) > \phi \Leftrightarrow r_1^* > \phi_1^*(\phi)\). Consequently:

(i) if firm 1 has rejected a licensing policy, then firm 2 stays out;

(ii) if firm 1 has accepted a licensing policy \((r_1, f_1)\), then firm 2 enters if \(r_1 \in (r_1^*(\phi), c]\), stays out if \(r_1 \in [0, r_1^*(\phi)]\), and is indifferent between entering and staying out if \(r_1 = r_1^*(\phi)\).

Lemma 3 is quite intuitive. If the entry cost of firm 2 falls below its minimum possible post-entry profit, then it will enter. On the other hand, if its entry cost exceeds its maximum possible post-entry profit, then it will stay out. For intermediate values of the entry cost, its decision is determined by the efficiency level of firm 1. According to Lemma 2, if firm 2 enters after firm 1 has accepted the licensing policy \((r_1, f_1)\), then it obtains its profit without a licence, given by \(\phi_2^T(r_1, c)\). This profit increases as \(r_1\) increases, so firm 2 will enter for relatively large values of \(r_1\) and stay out for small values of \(r_1\), with \(r_1^*(\phi)\) standing for the entry-deterring threshold.

**Stage I: equilibrium entry structure**

Having characterized the entry decision for firm 2, now we are in a position to state the main result.

**Proposition 1.** For generic values of \(a, c\) and \(\phi\), \(\Gamma(a, c, \phi)\) has a unique SPNE where firm 1 accepts the licensing policy that it is offered by firm 0; if firm 2 enters, then it also accepts
the licensing policy that firm 0 offers to it. The SPNE has the following properties, where \( \hat{c} \in (0, a/3) \).\(^{12}\)

(I) **Entry cannot be deterred (C).** For low values of the entry cost \([\hat{\phi} < \phi^T_1(0, c)]\), firm 0 offers firm 1 a licence with the maximum royalty \( r_1 = c \) and the fixed fee \( f_1 = \phi^T_1(c, c) - \phi^T_1(c, 0) > 0 \). Firm 2 enters the industry, and firm 0 offers firm 2 a licence with the maximum royalty \( r_2 = c \) and no fixed fee.

(II) **Blocked entry (B).** For high values of the entry cost \([\hat{\phi} > \phi^T_2(c, c)]\), firm 0 offers firm 1 a licence with the maximum royalty \( r_1 = c \) and no fixed fee. Firm 2 stays out of the market.

(III) For intermediate values of the entry cost \([\phi^T_2(0, c) < \hat{\phi} < \phi^T_2(c, c)]\), whether entry is deterred or accommodated depends on \( \hat{c} \). Specifically:

(a) **Entry is deterred (D).** If \( c \in (0, \hat{c}) \), then entry is deterred. Firm 0 offers firm 1 a licence with the royalty \( r_1 = r_1^*(\hat{\phi}) \in (0, c) \) and fixed fee \( f_1 = \phi^D_1(r_1^*) - \phi^T_1(c, 0) > 0 \). Firm 2 stays out of the market.

(b) **If** \( c \in (\hat{c}, a/3) \), then there is a decreasing function \( \hat{\phi}(c) \in (\phi^T_2(0, c), \phi^T_2(c, c)) \) such that whether entry is deterred or accommodated depends on \( \hat{\phi}(c) \) as follows.\(^{13}\)

(i) **Entry is accommodated (A).** If \( \phi^T_2(0, c) < \hat{\phi} < \phi^T_2(c, c) \), then entry is accommodated. Firm 0 offers firm 1 a licence with the maximum royalty \( r_1 = c \) and fixed fee \( f_1 = \phi^T_1(c, c) - \phi^T_1(c, 0) \). Firm 2 enters the industry, and firm 0 offers firm 2 a licence with the maximum royalty \( r_2 = c \) and no fixed fee.

(ii) **Entry is deterred (D).** If \( \hat{\phi}(c) < \hat{\phi} < \phi^T_2(c, c) \), then entry is deterred and the outcome is the same as (III)(a).

Figure 1 depicts our main result. To see the intuition for Proposition 1, first recall that following entry, firm 2 can always ensure a profit of at least \( \phi^T_2(0, c) \), but it can obtain no more than \( \phi^T_2(c, c) \). If firm 2’s entry cost \( \phi \) is below its worst possible post-entry profit, then entry cannot be deterred (Proposition 1(I)). On the other hand, if its entry cost exceeds its best possible post-entry profit, then it will not enter in any case and therefore entry deterrence is redundant (Proposition 1(II)).

For intermediate values of the entry cost \([\phi^T_2(0, c) < \hat{\phi} < \phi^T_2(c, c)]\), firm 0 can use the royalty \( r_1 \) that it offers to firm 1 to either deter or accommodate entry. In the absence of any threat of entry, it is optimal for firm 0 to set \( r_1 = c \) so that its sole rival firm 1 effectively operates under the existing cost. To deter entry from firm 2, firm 0 has to provide an efficiency edge to its incumbent rival firm 1. This is achieved by lowering \( r_1 \) from its maximum level \( c \) to \( r_1^*(\hat{\phi}) < c \) (Lemma 3). Thus in deciding whether to deter or accommodate entry, firm 0 faces a trade-off. It can deter the entrant only at the cost of creating a more efficient incumbent rival.

To understand how this trade-off is resolved, it is important to observe that firm 0’s power in this contractual setting depends on the significance of its patented technology vis-à-vis the existing one. When the initial production cost is sufficiently small \((c < \hat{c})\), both firms 1 and 2 are already quite efficient even without the new technology. For this case the patented technology is not very significant, resulting in a weak position for firm 0 in the Cournot market. This gives it a strong incentive to restrict competition, which explains the result that for \( c < \hat{c} \), entry is always deterred (Proposition 1(III)(a)).

Once the initial cost of production is relatively large \((c > \hat{c})\), the entry cost \( \phi \) comes into play in determining whether it is optimal to deter or accommodate entry. Note that
$r_1^*(\phi)$ is increasing in $\phi$, implying that when firm 2 has a smaller cost of entry, firm 0 must make its incumbent rival even more efficient in order to deter entry. For small values of $\phi$ ($\phi < \hat{\phi}$), the ‘entry-deterring royalty’ $r_1^*$ is also small, resulting in a very efficient firm 1. For this case the gain from restricting competition is outweighed by the loss of creating a strong incumbent rival. As a result, it is optimal for firm 0 to accommodate entry (Proposition 1(III)(b)(i)). For larger values of $\phi$ ($\phi > \hat{\phi}$), these relative effects work in the opposite direction, rendering it optimal for firm 0 to deter entry (Proposition 1(III)(b)(ii)). Finally, observe that as the patented technology becomes more significant (i.e. $c$ increases), it is expected that firm 0 will be able to deter entry even for relatively small values of the entry cost $\phi$. This explains why the threshold $\hat{\phi}(c)$ is decreasing in $c$.

To sum up, for intermediate values of the entry cost, firm 0 prefers to get a lower royalty from firm 1 in order to deter firm 2’s entry, rather than a higher royalty that would induce entry. The gain from a low royalty in terms of competition (leading to a duopoly instead of a triopoly) offsets the loss in terms of cost advantage. Note that this equilibrium outcome gives one explanation for the low royalty rates that are observed in the real world. Our model predicts (see Figure 1) that this is ‘more likely’ to take place in industries where the entry costs are intermediate. An empirical implication of this result is to check whether there is a direct relationship between the magnitudes of the royalty rates specified in the licensing contracts and the barriers to entry in the industry.  

The impact of this entry deterrence strategy on welfare is ambiguous. At first glance, a lower royalty raises welfare through a lower market price. However, taking its impact on entry into consideration can reverse this result. In the next subsection, we perform a welfare analysis.

What keeps the entrant out of the market is the incumbent patent holder’s ability to affect the entrant’s outside option by varying the royalty that it offers to the rival incumbent firm. Indeed, the entrant’s outside option $\phi_2^T(r_1, c)$—which determines the entrant’s profit if it enters the market—is increasing in $r_1$, the inefficiency of one of the incumbent firms. A low royalty can drive $\phi_2^T(r_1, c)$ below the entry cost $\phi$ and prevent the entrant from entering the market. This result is quite general and does not hinge on

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the special type of competition that we have assumed in this paper. Even in more general models, the profit of a firm decreases as a rival becomes more efficient. Nevertheless, the simple structure of the Cournot model allows us to compare payoffs across the different subgames in order to determine the set of conditions where the entry-deterrence strategy emerges in equilibrium. In a more general model this payoff comparison would be extremely hard and not clean.

Welfare analysis

In this subsection we focus on region D of Proposition 1, where entry is deterred (for values of the entry cost such that max\{ϕ2^T(0, c), ̂ϕ(c)\} < ̂ϕ < ϕ^T(c, c)). Our objective is to study the welfare impact of firm 0’s entry-deterrence strategy through a lower royalty. We examine how consumer and social welfare would change if firm 0 were unable to use its licensing agreement with firm 1 in order to deter entry. We first examine the change in consumer surplus, and then we look at the impact on social surplus. The impact on the price, and hence on consumer surplus, is not straightforward: while such a policy would increase competition through entry, it would also increase the price through a higher royalty. When firm 0 is willing and able to deter entry, it offers firm 1 a royalty 1 = r1^*(̂ϕ). The resulting market structure is a duopoly, and the corresponding price is pD(r1^*) = (a + r1^*)/3. If entry can never be deterred, then the market structure will always be a triopoly. Firm 0 then offers firm 1 (as well as firm 2) the maximum royalty r1 = r2 = c. The resulting price is equal to pT(c, c) = (a + 2c)/4. The following proposition compares these two prices, and Figure 2 depicts the consumer welfare comparison.

Proposition 2 Consumer welfare implications of entry deterrence. Let max\{ϕ2^T(0, c), ̂ϕ(c)\} < ̂ϕ < ϕ^T(c, c). There is a constant c=a/6 such that we have the following.

(I) If c ∈ (0, c), then entry deterrence decreases consumer welfare, i.e. pT(c, c) < pD(r1^*(̂ϕ)).

(II) If c ∈ [c, a/3), then there exists a function ̂ϕ^*(c) with max\{ϕ2^T(0, c), ̂ϕ(c)\} < ̂ϕ^*(c) < ϕ^T(c, c) such that:

(i) for relatively low values of the entry cost (̂ϕ < ̂ϕ^*(c)), entry deterrence increases consumer welfare, i.e. pT(c, c) > pD(r1^*(̂ϕ));

(ii) for relatively high values of the entry cost ( ̂ϕ > ̂ϕ^*(c)), entry deterrence decreases consumer welfare, i.e. pT(c, c) < pD(r1^*(̂ϕ)).

Entry deterrence has two effects: (i) a price distortion effect, that is, the royalty is lower (and hence the price is closer to marginal cost) than it would have been if entry were not deterred; (ii) a market structure effect, that is, market structure is a duopoly instead of a triopoly. When the entry cost ̂ϕ and/or the size of the innovation are high (region α in Figure 2), entry is relatively difficult, and for entry deterrence to work, the royalty need not be very low. In this case the market structure effect is stronger than the price distortion effect, and entry deterrence hurts consumers. The reverse is true when entry cost and/or the size of innovation are low (region β in Figure 2).

The following proposition compares social surplus (the sum of consumer surplus and firms’ payoffs) between the cases where licensing policies can and cannot be used to deter entry.
Proposition 3 Social surplus implications of entry deterrence. The ability of the patent holder to use licensing policies to deter entry increases social welfare, compared to the case where entry cannot be deterred.

Next, we show that this result can be reversed when we endogenize the incentives for innovation.

III. RESEARCH AND DEVELOPMENT STAGE

We now consider the research and development (R&D) stage that takes place prior to patent licensing and product market competition. In this stage the incumbent firms of the industry, firms 0 and 1, compete in a patent race game, where they simultaneously choose their R&D investments. The purpose of this section is to demonstrate the impact of the third effect: the excessive R&D effect. We derive two results. First, we show that the ability of the patent holder (the winner of the race) to use the licensing contract to deter entry exacerbates the inefficiency due to the excessive R&D effect. Second, we show that when we account for the excessive R&D investments the social welfare result of Section II can get reversed and resembles the consumer welfare comparison: entry deterrence decreases expected net social welfare, relative to when entry cannot be deterred, if and only if the entry cost is relatively high.

The two incumbents engage in an R&D race in continuous time (Loury 1979). At the beginning of the race, the two firms choose, simultaneously and independently, their R&D investments $x_i, i = 0,1$ (with some abuse of notation, since prior to the discovery we do not know which firm is 0 and which firm is 1). We assume that prior to a discovery $(D)$, firms 0 and 1 can produce with the basic technology at marginal cost $c$. Once a firm makes a discovery (firm 0), its marginal cost is zero, while the loser of the race (firm 1) can still produce at $c > 0$. The potential entrant, firm 2, appears when the patent race is over, and it can also produce with the basic technology once it incurs the fixed cost of

\[
\phi^T(c,c)
\]

\[
\alpha: \text{Entry deterrence decreases consumer welfare}
\]

\[
\beta: \text{Entry deterrence increases consumer welfare}
\]
entry. Once the race is over, the game is the one that we analysed in the previous sections. The payoff of the winner is $p_0$, and the payoff of the loser is $p_1$, with $p_0 > p_1$.

The instantaneous probability of success is $x \, dt$ (constant hazard rate). The probability of discovery up to time $t$ is

$$\Pr(D \leq t) = 1 - e^{-xt}.$$  

The probability of discovery at time $t$ is

$$\Pr(D = t) = xe^{-xt}.$$  

For simplicity, we set the interest rate $r$ equal to zero. This does not affect our results qualitatively. The probability of firm $i$ winning at time $t$ is

$$\Pr(W = t) = x_i e^{-[x_i + x_{-i}]t}.$$  

The expected profits of firm $i$ are

$$p_i(x_i, x_{-i}) = -x_i + \int_0^\infty \pi_0 x_i e^{-[x_i + x_{-i}]t} dt + \int_0^\infty \pi_1 x_{-i} e^{-[x_i + x_{-i}]t} dt$$

$$= -x_i + \frac{\pi_0 x_i + \pi_1 x_{-i}}{x_i + x_{-i}}.$$  

The unique Nash equilibrium in R&D investments is

$$x_i^* = x_{-i}^* = \frac{\Delta \pi}{4},$$

where $\Delta \pi \equiv \pi_0 - \pi_1$. It is a well-known result that private incentives exceed social incentives in R&D race models. Our result shows that this inefficiency becomes even more pronounced when the winner of the race can use licensing to deter entry; that is, entry deterrence increases $\Delta \pi$. This can be seen as follows. The loser’s payoff, $p_1$, is always equal to its outside option (whether entry can be deterred or not), which is $\phi_i^T(c, 0)$ (see Lemma 1). But the winner’s payoff is higher if it can use its licensing contract to deter entry. The possibility of licensing increases the incentives to innovate. We show that the possibility of licensing with entry deterrence increases the incentives even more. In sum, $\Delta \pi$ is higher when entry can be deterred than when it cannot.

It is straightforward to extend the above analysis to the other regions of Proposition 1 (using the payoffs from these regions). Although the details are omitted, we have shown that R&D investments follow an inverse U-shape pattern with respect to the cost of entry. The strongest incentives are in region D, where entry is deterred. This result is related to Aghion et al. (2005), who show evidence of an inverted-U relationship between product market competition and innovative activity, and find this to be steeper in neck-and-neck industries.22

Finally, we show that these excessive investments can lower the expected net social surplus. We use equations (A11) and (A12) from the Appendix, and equation (7), to compute the expected net social surplus when entry can and cannot be deterred. It can be
shown that entry deterrence lowers social surplus if and only if the entry cost $\phi$ is in the region
\[
\left[ \left( \frac{48 - \sqrt{138}}{152} \right)^2, \left( \frac{48 + \sqrt{138}}{152} \right)^2 \right] \approx [0.05688(a - 2c)^2, 0.1545(a - 2c)^2].
\]

The upper bound of region D (Figure 1), $\phi^T_2(c, c) \equiv (a - 2c)^2/16 = 0.0625(a - 2c)^2$, is below the upper bound of the above region. Thus the relevant threshold is the lower bound of the above region, which lies strictly inside region D, much like $\phi^S(c)$ does in Figure 2. Therefore once we incorporate the incentives for innovation, the social welfare implications are very much in line with those for consumer surplus. When the entry cost is high, entry deterrence decreases expected net social welfare, but for low entry costs, entry deterrence increases expected net social welfare.

IV. Policy Implications

We explore two policies that can affect licensing strategies. The first one is the ‘most favoured nation’ or ‘most favoured licensee’ (MFL) clause, which allows a licensee to benefit from the terms of a subsequent licence agreement with another party that are more favourable than those of the licensee’s original agreement. The second policy is the imposition of a minimum royalty, or ‘royalty floor’, in licensing contracts. For our analysis, we focus on regions A and D of Proposition 1; the entry cost is such that $\phi^S_2(0, c) < \phi < \phi^T_2(c, c)$, so firm 0 faces a trade-off between deterring entry through a low royalty $r_1 < r^*_1(\phi)$, and accommodating entry through a high royalty.

**Most favoured licensee clause**

The application of the MFL clause may affect the amount of royalties payable by the licensee, as well as the fixed fee. Suppose that firm 0 is forced to license its technology at equal terms to firms 1 and 2, that is, $r_1 = r_2$ and $f_1 = f_2$. If firm 2 enters, then the optimal contract that firm 0 offers to firm 2 is $r_2 = r_1$, and $f_2 = \phi^T_2(r_1, r_1) - \phi^T_2(r_1, c)$. Therefore the MFL clause is satisfied in terms of royalties. However, whether firm 0 chooses to accommodate or deter entry, it will have to offer firm 1 the same fixed fee as it would (or will) offer to firm 2: $f_1 = \phi^T_2(r_1, r_1) - \phi^T_2(r_1, c)$. This fixed fee is lower than it would be with no MFL. Therefore the MFL lowers the expected payoff to firm 0, with both entry deterrence and entry accommodation. That payoff is still an increasing function of $r_1$ under both strategies, so the MFL does not modify the optimal royalty that firm 0 offers to firm 1 ($r_1 = c$ with entry accommodation, and $r_1 = r^*_1$ with entry deterrence). Nevertheless, the MFL decreases the fixed fee that firm 0 receives from firm 1 under both strategies: it is now 0 (instead of $\phi^T_1(c, c) - \phi^T_1(c, 0)$) with entry accommodation, and $\phi^T_1(r^*_1, r^*_1) - \phi^T_2(r^*_1, c)$ (instead of $\phi^T_1(r^*_1) - \phi^T_1(c, 0)$) with entry deterrence. But the fixed fee with entry deterrence decreases more than the fixed fee with entry accommodation.

As a result, the MFL reduces firm 0’s incentives to deter entry: firm 0 prefers to deter entry if $\phi > \phi(c)$, where $\phi(c) < \phi(c) < \phi^T_2(c, c)$.

In Section II we showed that the entry deterrent licensing contract lowers consumer welfare—compared to a non-entry deterrent contract—if the entry cost is high.
If firm 0 is forced to include a MFL clause into its contract with firm 1, then the entry deterrence region (region D in Figure 1) shrinks, because its lower bound moves up. Note that the new lower bound for this region \( \phi(c) \) is above \( \phi^*(c) \). The impact on consumers is the following. If the entry cost is high \( \phi > \phi^*(c) \), then the MFL has no impact on consumers, as it does not prevent entry deterrence. If the entry cost is intermediate \( \phi^*(c) \leq \phi \leq \hat{\phi}(c) \), then the MFL increases consumer surplus, as it avoids entry deterrence that would make consumers worse off. Finally, if the entry cost is low \( \hat{\phi}(c) < \phi < \phi^*(c) \), then the MFL harms consumers, as it avoids entry deterrence that would make consumers better off. Therefore introducing an MFL clause benefits consumers when entry deterrent royalties are anticompetitive, i.e. in markets where the entry cost is relatively high (region \( \alpha \) in Figure 2). Such MFL clauses are often imposed for licensing in patent pools and standard setting organizations. Our analysis suggests that they could also have a useful role in more traditional licensing contracts.\(^{27}\)

However, it is important to note that the impact of an MFL on social welfare is not positive. Indeed, if the entry cost is high \( \phi > \phi^*(c) \), then the MFL does not prevent entry deterrence, so social surplus is unchanged. But if the entry cost is low \( \hat{\phi}(c) < \phi < \phi^*(c) \), then the MFL prevents entry deterrence while it would increase social welfare. Therefore the MFL is not always a sufficient instrument to solve the social inefficiencies created by entry deterrent royalties.

Minimum royalty

Another possible policy is to impose a minimum royalty, or ‘royalty floor’, when the entry cost is relatively high \( \phi > \phi^*(c) \), region \( \alpha \) in Figure 2). Such a policy directly removes the ability of the incumbent to deter entry precisely when entry deterrence is detrimental to consumers, or to expected net social welfare. In particular, if firm 0 is forced to offer firm 1 a royalty higher than \( r_1(\phi) \), then firm 2 enters. Such a royalty floor must therefore depend positively on the entry cost \( \hat{\phi} \), as well as on the size of the innovation (measured by \( c \)).

Most of the policy recommendations with respect to the level of royalties in licensing agreements advocate for royalty caps (ceilings), because high royalties are viewed as anticompetitive.\(^ {28}\) Our analysis identifies situations where a royalty floor might be warranted.

V. EXTENSIONS AND ROBUSTNESS CHECKS

In order to illustrate the mechanisms of strategic entry deterrence through licensing in the simplest and most intuitive way, in the preceding model we have made some strong assumptions. In this section we relax some of these assumptions. Importantly, while the analytics may change slightly, the main result of the model—that shows how and when a patent holder chooses to lower the royalty offered to a licensee in order to deter further entry—continues to hold. All proofs can be found in the online appendix.

Incumbent patent holder facing two entrants

In the main model we have assumed that firm 0 faces two potential licensees: firm 1 (an incumbent) and firm 2 (a potential entrant). As opposed to firm 2, firm 1 has already incurred the entry cost, which creates an asymmetry. However, another
possible situation would involve a monopoly incumbent patent holder facing two potential entrants. In that case there is no longer asymmetry between firms 1 and 2, as neither of them has incurred the entry cost. At the beginning of the game, firm 0 makes an offer \((r_i, f_i)\) to each entrant \(i \in \{1, 2\}\), which can then (i) accept the offer and enter with a licence, (ii) reject the offer and enter without a licence with marginal cost \(c > 0\), or (iii) not enter. This situation introduces the possibility for firm 0 to deter both entrants and keep a monopoly position, if the entry cost is high enough \((\phi > \phi_1^D(c))\) so that even being the only entrant in the market is not profitable. Otherwise, our main results continue to hold qualitatively. In particular, for intermediate values of the entry cost, firm 0 must accommodate at least one entrant but has the opportunity to deter the other by making its rival more efficient through a lower royalty \(r_i\). The difference compared to our main model is the fixed fee that firm 0 can extract from its sole licensee (and competitor) in this entry deterrence strategy. In the main model, firm 1’s reservation payoff from rejecting firm 0’s offer is \(\phi_1^T(c, 0)\), while here it is the duopoly profit with no licence \(\phi_1^D(c)\), since both entrants make their entry and licensing decisions simultaneously. Since \(\phi_1^T(c, 0) < \phi_1^D(c)\), firm 0 extracts a lower fixed fee from its licensee in this setting. As a result, the range of values of the entry cost such that entry deterrence is a profitable strategy is smaller than in our main model.30

Two incumbent patent holders and cross licensing as an entry deterrent

In our main model we focus on a unilateral licensing agreement where an incumbent patent holder can deter further entry by licensing its patent to an incumbent competitor for a low royalty. Interestingly enough, anecdotal evidence suggests that this strategy is also observed in cross-licensing agreements. As we mentioned in the Introduction, most cross-licensing agreements entail very low—even zero—royalties (Shapiro 2001). For the same reasons as in our main model, this observation may be explained by an entry deterrence strategy from patent holders. We can show that our main mechanism is still in place by extending our model to a cross-licensing setting where each incumbent firm has a patent and the cost reduction can be realized only if both patents are used (perfect complements). In the first stage, both incumbent firms (0 and 1) agree on a royalty plus fixed fee policy that each must pay to access the ‘pooled’ technology. In the second stage, the potential entrant (firm 2) makes its entry decision, and in the third stage following entry it is offered a licensing policy by the two incumbents to access the ‘pooled’ technology. In the absence of any entry threat, the optimal royalties that are set between the two incumbents in the first stage are high (Fershtman and Kamien 1992), because high royalties facilitate collusion. As in our model, the threat of entry can change this strategy. The difference here is that the optimal policy offered to the entrant is a pure royalty contract (maximum royalty, no fixed fee), since it is offered jointly by the two incumbents, firms 0 and 1. Regarding the choice of setting royalties for themselves in the initial stage, the two incumbents face a trade-off between setting high royalties that increase their ‘pooled’ payoffs and lower royalties that deter entry from firm 2. Under the same conditions as in one-sided licensing, the two incumbents have an incentive to enter into a cross-licensing agreement with low royalties to deter entry for intermediate values of the entry cost. Hence entry deterrence considerations can rationalize the observation of low royalties in cross-licensing contracts.
Different timing of licensing contract offer and entry decision

In our main model, the incumbent patent holder (firm 0) makes a licensing offer to the entrant (firm 2) after its entry decision, once it has incurred the entry cost. However in some instances it may be possible for the patent holder to make the offer before entry occurs, in particular in industries with a small number of potential entrants that are already known by the patent holder. In such a setting, firm 0 makes a licence offer to firm 1 in stage 1, firm 1 accepts or rejects it, and then firm 0 makes another licence offer to firm 2, who chooses between entering with no licence, entering with a licence or not entering. This setting differs from our main model because by the time firm 0 makes a licensing offer to firm 2, firm 2 has not entered yet. Therefore firm 0 may be able to directly influence firm 2’s entry decision through its offer. In particular, if firm 2’s outside option from rejecting firm 0’s offer is to stay out (as opposed to entering without a licence), firm 0 is able to deter entry by making an offer that will be rejected. This is equivalent to the situation where firm 2 does not enter in our main model. But in this setting, when the entry cost is not too high, it may actually be profitable for firm 0 to induce firm 2’s entry when the fixed fee that firm 0 can extract from firm 2 when inducing entry is sufficiently high. As a result, when the entry cost is below that lower bound but above \( \hat{\phi}(c) \), firm 0 is unable to commit to entry deterrence through a ‘low’ royalty \( r < C_3 \). This may be a profitable strategy as it enables firm 0 to exploit the threat of licensing to firm 2 in order to extract more from firm 1. In particular, when the entry cost is low so that entry cannot be deterred, it is optimal for firm 0 to make firm 1 the most efficient possible and therefore offer a pure fixed fee contract with no royalty. As a result, firm 0 can extract more licensing revenues from firm 1, but this gain is offset by the lost licensing revenues from firm 2. Therefore an exclusive licensing contract with firm 1 is not a profitable strategy for firm 0.

Exclusive licensing

It is important to mention the possibility for patent holders to sign exclusive licensing contracts with their licensees. In our model, when firm 2 enters following a licensing agreement between the two incumbent firms, firm 0 offers a licence agreement to firm 2. However, when signing a contract with firm 1, firm 0 may commit to not offering any licensing contract to other firms. In that case, when firm 2 enters following a contract between firms 0 and 1, firm 0 has two competitors but only one licensee (firm 1), and firm 2’s marginal cost is \( c \). This may be a profitable strategy as it enables firm 0 to exploit the threat of licensing to firm 2 in order to extract more from firm 1. In particular, when the entry cost is low so that entry cannot be deterred, it is optimal for firm 0 to make firm 1 the most efficient possible and therefore offer a pure fixed fee contract with no royalty. As a result, firm 0 can extract more licensing revenues from firm 1, but this gain is offset by the lost licensing revenues from firm 2. Therefore an exclusive licensing contract with firm 1 is not a profitable strategy for firm 0.

VI. CONCLUSION

We develop a model with two incumbent Cournot competitors and one potential entrant. One of the incumbent firms holds a patent on a cost-reducing technology, which can be licensed via a royalty plus fixed-fee contract. Under certain conditions, the patent holder finds it optimal to use the licensing contract strategically to deter further entry. To achieve this, the royalty is set at low levels so that the rival incumbent, who obtains the licence, is made more efficient relative to the potential entrant, who finds entry unprofitable. Given its ability to restrain competition, this type of a licensing agreement can be anticompetitive. Deterrence of entry restricts competition, and a high royalty rate
creates inefficiency. When seen in isolation, each of these two factors is perceived to be anticompetitive. Our results show that looking at these two factors in isolation may often be misleading. As a lower rate of royalty can be used by incumbent firms to achieve entry deterrence, two qualitative conclusions emerge from our analysis: (i) entry deterrence may not necessarily result in higher prices, and (ii) a lower royalty may not necessarily result in lower prices.

Our analysis unveils three sources of inefficiency due to the following three effects: (i) market structure effect, (ii) price distortion effect and (iii) excessive R&D effect. Entry deterrence mitigates the second effect (because entry deterrence is achieved via a low royalty), but exacerbates the first and third effects. Within the region where patent licensing is used to deter entry, when the entry cost and/or the size of the innovation are (relatively) high, entry deterrence hurts consumer welfare and expected net social surplus. This is because the royalty need not be very low to deter entry, and as a result the price distortion effect is relatively weak. For low entry costs and/or innovation size, on the other hand, the price distortion effect strengthens, and entry deterrence improves both consumer and expected net social welfare. Our main insights extend to cross-licensing agreements.

Although there are papers in the literature that have investigated the impact of strategic licensing on competition, our model uniquely combines the following elements: (i) existence of entry threat, (ii) entrants can enter without the licence (at a higher marginal cost) and (iii) the licensing contract entails a royalty plus a fixed fee. By adopting a linear demand structure, we are able to offer a comprehensive picture—in terms of entry costs and technological asymmetry between the patent holder and the rest of the firms (size of innovation)—about the private and social benefits of strategic licensing.

Our analysis fits markets where the ease of entry is intermediate and there are ongoing ‘important’ technological innovations. In such markets, licensing via low royalties should be scrutinized by antitrust authorities. A policy prescription that could improve market efficiency is a royalty floor or the imposition of a ‘most favoured licensee’ clause in licensing contracts. Although most of the concerns of antitrust agencies regarding the level of royalties in licensing of intellectual property have been focused on the anticompetitive implications of high royalties, our analysis identifies instances where low royalties might be harmful for welfare.

**APPENDIX**

*Proof of Lemma 2*

(I)(i) & (II)(i): If firm 1 has accepted the policy \((r_1,f_1)\) and firm 2 does not enter the industry, then the duopoly game \(C^D(r_1)\) is played between firms 0 and 1 in the market \(\eta\). Firm 1 obtains \(\phi^D_1(r_1) - f_1\) (its NE profit at \(C^D(r_1)\) net of fees), and firm 2 obtains 0, which proves (I)(i). If firm 1 has rejected a licensing offer and firm 2 does not enter the industry, then the duopoly game \(C^D(c)\) is played between firms 0 and 1 in the market \(\eta\). Firm 1 obtains \(\phi^D_1(c)\), and firm 2 obtains 0, which proves (II)(i).

(I)(ii) & (II)(ii): If firm 2 enters the industry, then by (5), the problem of firm 0 is to choose \(r_2 \in [0,c]\) to maximize

\[
\psi(r_2) = \phi^T_0(\bar{r}_1,r_2) + \lambda_1 r_1 q^T_1(\bar{r}_1,r_2) + r_2 q^T_2(\bar{r}_1,r_2) + \phi^T_2(\bar{r}_1,r_2)
\]

(A1)
(I)(ii): Suppose that firm 1 has accepted the policy \((r_1,f_1)\). Then \(\lambda_1 = 1\) and \(\tilde{r}_1 = r_1\). Using these in (1), by Lemma 1(ii) we have
\[
\psi(r_2) = \frac{(a + r_1 + r_2)^2}{16} + \frac{r_1(a - 3r_1 + r_2)}{4} + \frac{r_2(a + r_1 - 3r_2)}{4} + \frac{(a + r_1 - 3r_2)^2}{16}. 
\]

As \(\psi'(r_2) = (r_1 - r_2)/4 \geq 0\) if and only if \(r_2 \leq r_1\), the maximum of \(\psi(r_2)\) is attained at \(r_2 = r_1\), so \(f_2 = \Delta_3(r_1,r_1)\) (by (4)), making firm 2 just indifferent between accepting and rejecting. Therefore firm 2 obtains post-entry payoff \(\phi_2^T(r_1, c)\), and hence its net payoff is \(\phi_2^T(r_1, c) - \phi\). As the triopoly \(C_3^D(r_1, r_1)\) is played in market \(\eta\), firm 1 obtains \(\phi_1^T(r_1, r_1) - f_1\).

(II)(ii): Suppose that firm 1 has rejected the licensing offer. Then \(\lambda_1 = 0\) and \(\tilde{r}_1 = c\). Using these in (A1), by Lemma 1(ii) we have
\[
\psi(r_2) = \frac{(a + c + r_2)^2}{16} + \frac{r_2(a + c - 3r_2)}{4} + \frac{(a + c - 3r_2)^2}{16}. 
\]

As \(\psi(0) = 0\) and \(\psi'(r_2) = -r_2/4 < 0\) for \(r_2 > 0\), the maximum of \(\psi(r_2)\) is attained at \(r_2 = 0\). This is a pure fixed fee policy with fee \(f_2 = \Delta_3(c,0)\) (by (4)). As firm 2 is made just indifferent between accepting and rejecting, it obtains post-entry payoff \(\phi_2^T(c, c)\), yielding net payoff \(\phi_2^T(c, c) - \phi\). As the triopoly \(C_3^D(c, 0)\) is played in market \(\eta\), firm 1 obtains \(\phi_1^T(c, 0)\). \(\square\)

**Proof of Lemma 3**

(I) & (II): It follows from (6) that if firm 2 enters the industry, then its post-entry payoff is at least \(\phi_2^T(0, c)\) and at most \(\phi_2^T(c, c)\), which proves (I) and (II).

(III): Let \(\phi_2^T(0, c) < \phi < \phi_2^T(c, c)\). Since \(\phi_2^T(r_1, c)\) is increasing for \(r_1 \in [0, c]\) (by Lemma 1) it follows that there is an \(r_2^*(\phi) \in (0, c)\) such that \(\phi_2^T(r_1, c) \geq \phi\) if and only if \(r_1 \geq r_2^*(\phi)\). By Lemma 1(ii), \(\phi_2^T(r_1, c) = (a + r_1 - 3c)^2/16\). Equating this with \(\phi\), we obtain \(r_2^*(\phi) = 4\sqrt{\phi} + 3c - a\).

To prove (i), observe that if firm 2 enters the industry after firm 1 has rejected a licensing offer, then the post-entry payoff \(\phi_2^T(c, c)\) of firm 2 is more than \(\phi\), which proves that firm 2 enters the industry if firm 1 rejects a licensing offer.

To prove (ii), note that if firm 2 enters the industry following the acceptance of the policy \((r_1,f_1)\) by firm 1, then the post-entry payoff of firm 2 is \(\phi_2^T(r_1, c)\). Then (ii) follows by noting that \(\phi_2^T(r_1, c) \geq \psi(\phi)\) if and only if \(r_1 \leq r_2^*(\phi)\). \(\square\)

It will be useful to define for any price \(p \in [0,a]\), the function

\[
(A2) \quad F(p) := pQ(p) = p(a - p). 
\]

Note that \(F(p)\) presents the monopoly profit at price \(p\) under the reduced cost \(0\), so its unique maximum is attained at the monopoly price \(p_M = a/2 > c\). Thus \(F(p)\) is increasing for \(p < p_M\) and decreasing for \(p > p_M\).

**Lemma A1.** Suppose that \(\phi_2^T(0, c) < \phi < \phi_2^T(c, c)\). Denote \(r_2^*(\phi) := 4\sqrt{\phi} + 3c - a\) and

\[
(A3) \quad h^r(\phi) := F\left(p^D(r_2^*(\phi))\right) - F(p^T(c, c)) + \phi_2^T(c, c).
\]

This function has the following properties.

(i) \(h^r(\phi)\) is increasing in \(\phi\).

(ii) There exists \(\tilde{c} \equiv (3 - \sqrt{2})a/6 \in (0, a/3)\) such that:

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(a) if \( c \in (0, \bar{c}] \), then \( h'(\phi) > 0 \) for all \( \phi \in (\phi^T_1(0, c), \phi^T_T(c, c)) \);
(b) if \( c \in (\bar{c}, a/3) \), then there exists \( \hat{\phi}(c) \in (\phi^T_2(0, c), \phi^T_T(c, c)) \), given by

\[
\hat{\phi}(c) = \frac{9(2 - \sqrt{2})^2(a - 2c)^2}{256},
\]

such that \( h'(\hat{\phi}(c)) \geq 0 \) if and only if \( \phi \geq \hat{\phi}(c) \).

**Proof.**

(i) Since \( p^D(r_1^T(\phi)) \) is increasing in \( \phi \) and less than \( p_M \), and \( F(p) \) is increasing for \( p < p_M \), it follows that \( \int_{\phi}^{p^D(r_1^T(\phi))} \) is increasing in \( \phi \), and so is \( h'(\phi) \).

(ii) Recall from Lemma 1(ii) that \( p_T(c, c) = (a + 2c)/4 < p_M \). If \( \phi = \phi^T_2(c, c) = (a - 2c)^2/16 \), then \( p^D(r_1^T(\phi^T_2(c, c))) = (a + c)/3 \) and \( p^D(r_1^T) - p^T(c, c) = (a/2 - c)/6 > 0 \). Since both \( p^D(r_1^T) \) and \( p^T(c, c) \) are less than \( p_M \), for this case we have \( F(p^D(r_1^T)) > F(p^T(c, c)) \). Then by (A3), \( h'(\phi^T_2(c, c)) > F(p^D(r_1^T(\phi^T_2(c, c)))) - F(p^T(c, c)) \).

Since \( F(p) = p(a - p), p_T(c, c) = (a + 2c)/4 \) and \( \phi^T_2(c, c) = (a - 2c)^2/16 \), by (A3) we have

\[
(A4) \quad h'(\phi) = F\left( \frac{p^D(r_1^T(\phi))}{16} \right) - \frac{(a + 2c)(3a - 2c) - (a - 2c)^2}{16}.
\]

Now suppose that \( \phi = \phi^T_2(0, c) \). As \( \phi^T_2(0, c) = (a - 3c)^2/16 \) (by Lemma 1(ii)), we have \( r_1^T(\phi^T_2(0, c)) = 0 \), \( p^D(r_1^T) = a/3 \) and \( F(p^D(r_1^T)) = 2a^2/9 \). Using this in (A4), for this case we have

\[
h'(\phi^T_2(0, c)) = \frac{\omega(c)}{72}, \quad \text{where } \omega(c) := 36c^2 - 36ac + 7a^2.
\]

As \( \omega(c) \) is a u-shaped quadratic function of \( c \), \( \omega(0) = 7a^2 > 0 \) and \( \omega(a/3) = -a^2 < 0 \), it follows that there exists \( \hat{c} \in (0, a/3) \) such that \( \omega(c) \equiv 0 \) if and only if \( c \equiv \hat{c} \). Solving \( \omega(c) = 0 \), it can be shown that \( \hat{c} = \left( 3 - \sqrt{2} \right)a/6 \).

Therefore \( h'(\phi^T_2(0, \hat{c})) = 0 \), and \( h'(\phi^T_2(0, c)) < 0 \) if \( c \in (\hat{c}, a/3) \), and \( h'(\phi^T_2(0, c)) > 0 \) if \( c \in (0, \hat{c}) \). Since \( h'(\phi^T_2(c, c)) > 0 \), the results (a) and (b) follow by the monotonicity of \( h'(\phi) \). The expression of \( \hat{\phi}(c) \) is derived by standard computations. \( \square \)

**Proof of Proposition 1**

If firm 2 enters the industry following the acceptance of the policy \( (r_1, f_1) \) by firm 1, then firm 0 offers the policy \( (r_1, \Delta_2(r_1, r_1)) \) to firm 2 (Lemma 2(I)(ii)). Taking \( \lambda_1 = 1, \lambda_1 = r_1 \) and \( r_2 = r_1 \) in (5), the payoff of firm 0 is

\[
(A5) \quad \phi(r_1) = \phi_T^0(r_1, r_1) + r_1q_T^0(r_1, r_1) + r_1q_T^0(r_1, r_1) + f_1 + \phi_T^T(r_1, r_1) - \phi_T^T(r_1, c).
\]

(1) Let \( \phi < \phi^T_1(0, c) \). For this case, regardless of the decision of firm 1, firm 2 enters the industry (Lemma 3(1)). If firm 1 accepts the policy \( (r_1, f_1) \), then it obtains \( \phi_T^1(r_1, r_1) - f_1 \) (Lemma 2(I)(ii)), and if it rejects, then it obtains \( \phi^T_1(c, 0) \) (Lemma 2(II)(ii)). Therefore for any \( r_1 \), it is optimal for firm 0 to set \( f_1 = \phi_T^1(r_1, r_1) - \phi_T^1(c, 0) \) that makes firm 1 just indifferent between accepting and rejecting. Noting that \( \phi_0^T(r_1, r_1) = p_T(r_1, r_1)q_0^T(r_1, r_1) \) and \( \phi_T^1(r_1, r_1) = (p_T(r_1, r_1) - c + r_1) q_1^T(r_1, r_1) \) for \( i = 1, 2 \), using the optimal \( f_1 \) and the function \( F \) from (A2) in (A5), firm 0’s problem in stage I is

\[
(A6) \quad \text{choose } r_1 \in [0, c] \quad \text{to maximize } \bar{\pi}(r_1) := F(p^T(r_1, r_1)) - \phi_T^T(r_1, c) - \phi_T^T(c, 0).
\]
Since \( p^T(r_1, r_1) = (a + 2r_1)/4 \) and \( \phi_2^T(r_1, c) = (a + r_1 - 3c)^2/16 \) (Lemma 1(ii)), by (A6) we have

\[
\tilde{\pi}(r_1) = \frac{(a + 2r_1)(3a - 2r_1)}{16} - \frac{(a + r_1 - 3c)^2}{16} - \phi_1^T(c, 0).
\]

As \( \tilde{\pi}(r_1) = (a + 3c - 5r_1)/8 \geq (a + 3c - 5c)/8 = (a - 2c)/8 > 0 \) (since \( c < a/3 < a/2 \)), we conclude that \( \tilde{\pi}(r_1) \) is increasing for \( r_1 \in [0, c] \). So it is optimal for firm 0 to offer royalty \( r_1 = c \) to firm 1. Taking \( r_1 = c \), the fee that firm 0 charges to firm 1 is \( f_1 = \phi_1^T(c, c) = \phi_1^T(c, 0) > 0 \).

Following the acceptance of this policy by firm 1, firm 2 enters the industry. Taking \( r_1 = c \) in Lemma 2(I)(ii), firm 0 offers the policy \( (r_2, f_2) = (c, \Delta_2(c, c)) \) to firm 2. Since \( \Delta_2(r_1, r_1) = \phi_2^T(r_1, r_1) - \phi_2^T(r_1, c) \) (by (4)), we have \( \Delta_2(c, c) = 0 \).

(I): Let \( \phi > \phi_2^T(c, c) \). Then regardless of the decision of firm 1, firm 2 stays out of the market (Lemma 3(II)). If firm 1 accepts the policy \( (r_1, f_1) \), then it obtains \( \phi_2^T(c) \) (Lemma 2(I)(ii)), and if it rejects, it then obtains \( \phi_2^D(c) \) (Lemma 2(II)(i)). Therefore for firm 0, it is optimal to set fee \( f_1 = \phi_2^D(r_1) - \phi_2^D(c) = (p^D(r_1) - r_1)q_D^0(r_1) - \phi_2^D(c) \) from firm 1. The payoff of firm 0 is the sum of (i) \( \phi_0^T(r_1) = p^D(r_1)q_D^0(r_1) \) (its profit in the market \( \eta \)), (ii) \( r_1q_D^0(r_1) \) (royalty payments from firm 1), and (iii) the fee \( f_1 \). Using (i)–(iii) and the function \( F \) from (A2), firm 0’s problem in stage 1 is

\[
\text{(A7)} \quad \text{choose } r_1 \in [0, c] \text{ to maximize } F(p^D(r_1)) - \phi_1^T(c, 0).
\]

Since \( F(p) \) is increasing for \( p < p_M \), and \( p^D(r_1) \) is less than \( p_M \) and increasing, it follows that \( F(p^D(r_1)) \) is increasing in \( r_1 \). Then by (A7), it is optimal for firm 0 to offer royalty \( r_1 = c \) to firm 1. Taking \( r_1 = c \), the fee is \( f_1 = \phi_1^D(c) = \phi_1^T(c, 0) = 0 \). Following the acceptance of this policy by firm 1, firm 2 stays out of the market.

(III): Let \( \phi_2^T(0, c) < \phi < \phi_2^T(c, c) \). Then by Lemma 3(III), if firm 1 rejects a policy, then firm 2 enters the industry, and if firm 1 accepts a policy \( (r_1, f_1) \), then there is a threshold \( r_1^*(\phi) = 3c - a + 4\sqrt{\phi} \in (0, c) \) that determines the entry decision of firm 2.

Case 1: \( r_1 \in [0, r_1^*(\phi)) \). If firm 1 accepts the policy \( (r_1, f_1) \), then firm 2 stays out (Lemma 3(III)), so firm 1 obtains \( \phi_2^T(c, 0) \) (Lemma 2(II)(ii)). If firm 1 rejects, then firm 2 enters and firm 1 obtains \( \phi_1^T(c, 0) \) (Lemma 2(II)(i)). So it is optimal for firm 0 to set the fee \( f_1 = \phi_2^D(r_1) - \phi_1^T(c, 0) = (p^D(r_1) - r_1)q_D^0(r_1) - \phi_1^T(c, 0) \). The payoff of firm 0 is the sum of (i) \( \phi_0^T(r_1) = p^D(r_1)q_D^0(r_1) \) (its payoff in the market \( \eta \)), (ii) \( r_1q_D^0(r_1) \) (royalty payments from firm 1), and (iii) the fee \( f_1 \). Using (i)–(iii) and the function \( F \) from (A2), firm 0’s problem for this case is

\[
\text{(A8)} \quad \text{choose } r_1 \in [0, r_1^*(\phi)) \text{ to maximize } \tilde{\pi}(r_1) := F(p^D(r_1)) - \phi_1^T(c, 0)
\]

Since \( F(p^D(r_1)) \) is increasing in \( r_1 \), it follows from (A8) that

\[
\text{(A9)} \quad \tilde{\pi}(r_1) < \tilde{\pi}(r_1^*(\phi)) = F(p^D(r_1^*(\phi))) - \phi_1^T(c, 0) \quad \text{for all } r_1 \in [0, r_1^*(\phi))
\]

Case 2: \( r_1 \in (r_1^*(\phi), c] \). For this case, firm 2 enters regardless of the decision of firm 1 (Lemma 3(III)). From the proof of (I), firm 0’s problem is to maximize \( \tilde{\pi}(r_1) \) given in (A6). We know from the proof of (I) that \( \tilde{\pi}(r_1) \) is increasing, so its maximum for this case is attained at \( r_1 = c \) with \( f_1 = \phi_1^T(c, c) = \phi_1^T(c, 0) \). Taking \( r_1 = c \) in (A6), the payoff of firm 0 is

\[
\text{(A10)} \quad \tilde{\pi}(c) = F(p^T(c, c)) - \phi_2^T(c, c) - \phi_1^T(c, 0).
\]
Case 3: \( r_1 = r_1^*(\phi) \). If firm 1 accepts a policy that has royalty \( r_1 = r_1^*(\phi) \), then firm 2 is indifferent between entering the industry and staying out (Lemma 3(III)). Firm 2 entering the industry cannot be sustained as SPNE, because in that case by taking \( r_1 = r_1^*(\phi) \) in Case 2, firm 0 would obtain \( \pi(r_1^*(\phi)) < \pi(c) \) (since \( \pi(r_1) \) is increasing and \( r_1^*(\phi) < c \)), so firm 0 can improve its payoff by deviating to \( r_1 = c \). Therefore if firm 1 accepts a policy with \( r_1 = r_1^*(\phi) \) in an SPNE, then firm 2 must stay out so that firm 0 obtains \( \pi(r_1^*(\phi)) \) given in (A9).

Using the conclusion of Cases 1–3, there are two candidates for SPNE:

(i) \( r_1 = r_1^*(\phi), f_1 = \phi_1^0(r_1^*(\phi)) = \phi_1^0(c, 0), \) firm 2 stays out, market \( \eta \) is a duopoly with price \( p^D(r_1^*(\phi)) = c + 4\sqrt{\phi}/3 \), and firm 0 obtains \( \pi(r_1^*(\phi)) \);

(ii) \( r_1 = c, f_1 = \phi_1^T(c, e) = \phi_2^T(c, 0), r_2 = c, f_2 = 0, \) firm 2 enters the industry, market \( \eta \) is a triopoly with price \( p^T(c, e) \), and firm 0 obtains \( \pi(c) \).

To determine SPNE, we compare \( \pi(r_1^*(\phi)) \) and \( \pi(c) \) from (A9) and (A10). Note that \( \pi(r_1^*(\phi)) - \pi(c) = b^*(\phi) \), given in (A3) of Lemma A1. It follows by Lemma A1(ii) that there exists \( \hat{c} \in (0, a/3) \) such that:

(i) If \( c \in (0, \hat{c}] \), then \( \pi(r_1^*(\phi)) > \pi(c) \) for all \( \phi \in (\phi_1^0(0, c), \phi_1^T(c, e)) \), which proves (III)(a).

(ii) if \( c \in (\hat{c}, a/3) \), then there exists \( \hat{\phi}(c) \in (\phi_1^T(0, c), \phi_2^T(c, e)) \) such that \( \pi(r_1^*(\phi))(\phi) \pi(c) \) if and only if \( \phi > \hat{\phi}(c) \). Hence for \( \phi \in (\phi_2^T(0, c), \hat{\phi}(c)) \), the result is same as in (I), and for \( \phi \in (\hat{\phi}(c), \phi_1^T(c, e)) \), the result is the same as in (III)(b).

This completes the proof of Proposition 1. □

Proof of Proposition 2

We focus on region D of Proposition 1, where max\{\( \phi_2^T(0, c), \hat{\phi}(c) \}\} < \phi < \phi_1^T(c, e). When firm 0 can deter entry, the market price is \( p^D(r_1^*(\phi)) = (a + r_1^*(\phi))/3 \), where \( r_1^*(\phi) = 4\sqrt{\phi} + 3c - a \). When firm 0 is unable to deter entry, the market price is \( p^T(c, e) = (a + 2e)/4 \). Entry deterrence therefore increases the price if and only if \( p^D(r_1^*(\phi)) > p^T(c, e) \) if and only if \( 4r_1^*(\phi) > 6c - a \). So if \( c \leq e \equiv a/6 \), then entry deterrence always increases the price. If \( c > e \), then entry deterrence leads to a higher price if and only if \( \phi > \phi^*(c) := 9(a - 2c)/256 \). This is a decreasing function of \( c \), with \( \phi^*(c) \geq \phi(c) \) for all \( c \leq a/3 \), and \( \phi^*(c) \geq \phi_2^T(0, c) \) if and only if \( c \geq a/6 \).

Proof of Proposition 3

The social surplus, i.e. the sum of consumer surplus and firm payoffs when the patent holder can use the licensing contract to deter entry, is

\[
SS = \frac{88}{9} \phi + \frac{44}{3} \sqrt{\phi} - \frac{20}{3} a \sqrt{\phi} + \frac{11}{2} c^2 - 5ac + \frac{3}{2} a^2,
\]

while when the licensing contract cannot be used to deter entry, the social surplus is

\[
\widetilde{SS} = \frac{15}{32} a^2 - \frac{5}{8} a c + \frac{7}{8} c^2 - \phi.
\]

It follows directly that \( SS > \widetilde{SS} \). □

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NOTES

1. Rostoker (1984) finds that royalty alone is used 39% of the time, fixed fee alone 13%, and both instruments together 46%. Taylor and Silverston (1973), and Macho-Stadler et al. (1996) report similar percentages.

2. This example is drawn from Rockett (1990).

3. Empirical evidence on licensing shows that royalty rates appear to be ‘low’ (Rostoker 1984; Farrell and Gallini 1988; Rockett 1990). Our analysis suggests a strategic explanation for these types of contract with low royalties.

4. For an analysis of this type of arrangement from the perspective of the antitrust authorities, see Antitrust Enforcement and Intellectual Property Rights: Promoting Innovation and Competition, issued by the US Department of Justice and the Federal Trade Commission (2007, ch. 3).

5. The argument that licensing to a competitor may be a way to slow down the R&D race and thereby to remain the technological leader is also found in Gallini and Winter (1985). However, there is no entry threat in their model. Duchène and Serfes (2012) show that high fixed fees in patent settlement agreements can deter entry by sending a credible signal to outsiders that the patent is not weak.

6. Eswaran (1994) generalizes this result to show that an incumbent in a market threatened by entry can exploit its first-mover advantage by licensing its technology not to a potential entrant but to firms that otherwise would have remained outside the industry. Yi (1998) overturns the result of Rockett (1990) by allowing for two-part tariffs, and shows that the patent holder’s optimal licensing policy is to license the ‘strong’ competitor.

7. Even when we endogenize R&D efforts in Section III, there is still only one technological leader—the patent holder—after the patent race ends. In our model licensing occurs ex post, while in Gallini (1984) licensing is ex ante, i.e. before the rival engages in R&D.

8. The formal analysis of patent licensing was initiated by Arrow (1962). For the early literature, see, for example, Kamien and Tauman 1984; Katz and Shapiro 1985, 1986. See Kamien (1992) for a review of the early literature, and Bhattacharya et al. (2014) for a recent review.

9. We consider homogeneous Cournot competition, but as we explain at the end of Section II, the insights that we derive are general enough and do not hinge on that special type of competition. However, the Cournot model allows us to compare profits across the different subgames and to derive clean characterizations.

10. The innovation is drastic (Arrow 1962) if the monopoly price under zero cost \( p_M = a/2 \) does not exceed the old cost \( c \); otherwise, it is non-drastic. If firm 0 has a drastic innovation, it becomes a monopolist and it has no incentive to license the patent. By assuming \( c < a/3 \), we restrict our analysis to the subset of non-drastic innovations that are not large enough to sustain a duopoly structure. This ensures that if firm 2 chooses to enter the industry, then regardless of the licensing configuration, all three firms are active in the market \( q_T \). It should be mentioned that our qualitative conclusions remain unaltered over the set of all non-drastic innovations \( c < a/2 \).

11. By offering the policy \((c,0)\) (i.e. royalty \( r_1 = c \) and zero fee) to firm 1, firm 0 can ensure that firm 1’s cost stays at \( c \) so that the resulting subgames following this offer are the same as the case when there is no licensing to firm 1. As firm 0 obtains positive royalty revenue under \((c,0)\), this specific policy is superior to no licensing or any policy that results in firm 1 rejecting the licensing offer. For this reason there is no loss of generality in considering only policies that are accepted by firm 1.

12. More specifically, \( \hat{c} = \frac{1}{4} a \left\{ \frac{1}{2} (3 - \sqrt{2}) \right\} \).

13. More specifically, \( \hat{d}(c) = 9(2 - \sqrt{2})^2(a - 2c)^2/256 \).

14. When entry is deterred, the patent holder makes the rival incumbent quite efficient. As a result, its output increases, while the patent holder’s output decreases, given strategic substitutability. What matters for entry deterrence is the aggregate output produced by incumbents. Our game exhibits strategic substitutability, and actions are tough. According to the taxonomy in Tudenberg and Tirolo (1984), the strategic (indirect) effect of licensing on the licensor’s payoff is positive, provided that aggregate output increases. This is indeed the case as \( q_b^0(r_1) + q_1^0(r_1) > q_b^1(c,c) + q_1^0(c,c) \); in other words, the patent holder commits to a large (aggregate) output to deter entry. However, our analysis goes beyond that. First, in our framework, we do not know under what (if any) conditions on the primitives (entry cost, technology asymmetry) this strategy is profitable. This is because in addition to the strategic (indirect) effect, the direct effect is also important. Second, the welfare implications cannot be derived from the taxonomy.

15. Antitrust authorities in most developed countries, including the USA and the European Union, use the consumer surplus as a measure for evaluating the welfare implications of a policy.
16. Note that in Rockett (1990), if strategic licensing is illegal, then the market structure is a duopoly with a low-cost firm. The resulting price is unambiguously higher.

17. More specifically, \( \phi(c) = \frac{9(a - 2c)^2}{256} \).

18. More precisely, for a given innovation size a higher entry cost, and for a given entry cost a higher innovation size (provided that the entry cost is not too low), makes it more likely to end up in region \( z \) of Figure 2.

19. We focus our attention on the region where entry can be deterred, that is, region D of Figure 1.

20. Note that this patent race framework is different from Maurer and Scotchmer (2002). In our model, there are already two incumbents in the market, and the potential entrant does not participate in the race. In Maurer and Scotchmer (2002), there is no incumbent \textit{ex ante}, and a large number of firms participate. Therefore while their model is applicable to innovation for a new product, ours better fits markets where an established product already exists and the innovation is an improvement that requires specific know-how that only incumbents have.

21. In his seminal paper, Dixit (1980) argues that apart from restricting competition, entry deterrence entails further inefficiencies as an incumbent firm may have to incur wasteful expenditure to build an excess capacity. The excessive R&D effect that we obtain is similar in spirit to this conclusion.

22. See also Aghion et al. (2009), where the effect of entry on (incumbent) innovation and productivity is considered to be a function of distance from the technological frontier. They show that the threat of entry spurs innovation incentives in sectors close to the technology frontier, where successful innovation allows incumbents to survive the threat, but discourages innovation in laggard sectors, where the threat reduces incumbents’ expected rents from innovating.

23. The lower bound \( (48 - \sqrt{138})(a - 2c)/152 \) is higher than \( \phi(c) \), and it intersects \( \phi(c) \) at \( c = 0.042a \).

24. With no MFL, the fixed fee offered to firm 1 would be \( \phi^2(r_1, r_1) - \phi^2(r_1, 0) \) with entry accommodation, and \( \phi^2(r_1) - \phi^2(r_1, 0) \) with entry deterrence.

25. Firm 0’s payoff is \( \phi^2(r_1, r_1) + 2r_1q_2^T(r_1, r_1) + 2\phi^2(r_1, r_1) - 2\phi^2(r_1, c) \) with entry accommodation, and \( \phi^2(r_1) + r_1q_2^T(r_1) + \phi^2(r_1, r_1) - \phi^2(r_1, c) \) with entry deterrence.

26. Firm 0’s payoff from entry accommodation is \( \phi^2(c, c) + 2cq_2^T(c, c) \), and its payoff from entry deterrence is \( \phi^2(r_1^*) + r_1q_2^T(r_1^*) + \phi^2(r_1^*, r_1^*) - \phi^2(r_1, c) \). Entry deterrence yields a higher payoff if and only if

\[
\phi \in \left[ \frac{3(11 - \sqrt{15})}{106} (a - 2c)^2, \frac{3(11 + \sqrt{15})}{106} (a - 2c)^2 \right].
\]

The upper bound is higher than \( \phi^2(c, c) \), so the relevant threshold is the lower bound, which we note is \( \tilde{\phi}(c) \).

27. Most favoured licensee (MFL) clauses are not imposed by the antitrust authorities, who follow a rule of reason in most cases of licensing of intellectual property. In our model, a commitment of the patent holder to adopt an MFL clause is not profitable, as having the flexibility to set different terms across different licensees is more profitable. We believe that this exercise is still valuable because it can inform antitrust authorities about the welfare consequences of an MFL clause. In addition, there is always the probability of a law suit if a licensor offers discriminatory licensing contracts (discrimination can be viewed as an illegal practice under the Robinson–Patman Act). Therefore under such a threat, firms would want to know the payoff gain (and more importantly the qualitative effects) from not adopting an MFL policy, in order to compare it with the expected loss from a law suit.


29. Unless firm 0 adopts this entry deterrence strategy, it is optimal for firm 0 to offer the pure royalty policy (c,0) to each entrant for all values of the entry cost (i.e. even if the entry cost is low and entry cannot be deterred, or if the entry cost is high and only one firm enters).

30. Firm 0 prefers to deter one of the entrants rather than accommodate both if the entry cost is such that \( \max\{\phi^2(0, c), \phi(c)\} < \phi < \phi^2(c, c) \), where \( \phi(c) = (6 - \sqrt{11})^2(a - 2c)^2/256 > \tilde{\phi}(c) \).

31. There is no change compared to the main model when firm 2 enters after firm 1 has rejected firm 0’s offer.

32. The superscript \( r_1^* \) is dropped from the function \( \psi \) for notational ease.

33. Since \( \phi^2(r_1) \geq \phi^2(c, c) > \phi^2(c, 0) \), this fee is non-negative.

34. Calculations are straightforward and are omitted.

REFERENCES


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