Review of Industrial Organization
https://doi.org/10.1007/s11151-020-09755-1

Bargaining in Patent Licensing with Inefficient Outcomes

Yair Tauman[1,2] · **Yoram Weiss**[3] · **Chang Zhao**[4]

Abstract

A monopoly (M) faces an outside innovator who owns a technology that eliminates the entry cost and hence allows a profitable entry. M is willing to pay for that technology, so as to exclude entry and to keep enjoying its monopoly profits. Before bargaining with M about the technology, the innovator may benefit from selling some licenses to entrants, even though this sale shrinks the total "bargaining cake", and is inefficient for the bargainers. Introducing entry prior to bargaining typically increases the optimal number of additional licenses that the innovator sells in case the bargaining fails. This increases the (credible) threat vis-à-vis M and strengthens the bargaining position of the innovator. It is shown that entry may occur if the ex-ante bargaining power of the innovator is relatively weak.

Keywords Patent licensing · Bargaining · Preemption · Monopoly

1 Introduction

The potential of a monopoly incumbent to fight against the introduction of a technology in an attempt to prevent the loss of its market profit is an important subject in the theory of industrial organization. In the classical work of Gilbert and Newbery (1982) (GN hereafter), it is shown that a monopoly has an incentive to maintain its

✉ Chang Zhao
zhaochangtd@hotmail.com

Yair Tauman
amty21@gmail.com

Yoram Weiss
weiss@post.tau.ac.il

1 School of Economics, Stony Brook University, Nicolls Rd 100, Stony Brook, NY, USA

2 The Interdisciplinary Center, Herzliya, Israel

3 School of Economics, Tel-Aviv University, Chaim Levanon St 30, Tel Aviv, Israel

4 Institute for Social and Economic Research, Nanjing Audit University, Yushan West Rd 99, Nanjing, Jiangsu, China

Published online: 16 April 2020

monopoly power by patenting new technologies to preempt potential competition, which leads to patents that are neither used nor licensed to others (shelving). GN show that this happens if the cost of preemptive patenting is less than the profits that are gained by preventing entry.

In this paper, we study a model where a monopoly incumbent faces an outside innovator who owns (e.g., through a patent) a new technology, which allows profitable entry and hence can hurt the incumbent's profit if licensed to new entrants. We show that—even if the incumbent's willingness to pay for preventing entry is higher than the innovator's payoff from selling licenses to entrants—entry may occur, which is contrary to GN.

Such an outcome is *inefficient* for both the innovator and the incumbent, since entry reduces the total industry profit. But even though selling a few licenses before bargaining with the incumbent reduces the "bargaining cake", it increases the bargaining position of the innovator. The credible damage of the new technology vis-à-vis the incumbent is typically higher when the innovator sells more licenses before bargaining; hence pre-bargaining entry increases the incumbent's willingness to pay to avoid additional sale of licenses.

1.1 Model and Main Results

In a monopolistic market, an outside innovator holds a patent on a new technology that allows profitable entry. The new technology may or may not reduce the pre-innovation marginal cost. In both cases, the incumbent is willing to pay for the intellectual property (IP) of this technology to limit entry. The innovator bargains with the incumbent over the IP of the new technology; and if they reach an agreement, they sign a contract that transfers the entire patent right to the incumbent firm. Prior to the bargaining stage, the innovator can sell some licenses to entrants for an upfront fee.[1]

The number of licenses that are sold prior to the bargaining stage—the first-batch, which are denoted r—determines the "bargaining cake" and the disagreement payoffs. We show that the innovator is best off selling one or more first-batch licenses, if the following conditions hold: (i) The total industry profit is decreasing in the number of licensees; (ii) in case of disagreement, the optimal number of additional licenses that the innovator sells (the second-batch) is non-decreasing in r; and (iii) the innovator has relatively ex-ante weak bargaining power.

Part (i) is intuitive and assures that competition in the market reduces the total market profit. Part (ii) asserts that the number of competitors that the incumbent faces if no agreement is reached is increasing in the number of licenses that were sold prior to bargaining. This holds if each entrant's industry profit decreases only mildly with the total number of licensees. In such cases, given that a larger number of producers are already in the market, if bargaining fails, the innovator is better off selling a larger number of additional licenses to capture a larger share of the total

[1] In Sect. 5 we allow the innovator to sell licenses also for a per-unit royalty.

market profit. This is the case, for instance, in a Cournot competition with linear demand.

For industries that satisfy (i) and (ii), a first-batch licensee on the one hand reduces the "bargaining cake"; but on the other hand this licensee increases the threat vis-à-vis the incumbent. If, in addition, the innovator has relatively weak bargaining power (condition (iii)), the loss of a small share of a shrinking "cake" is more-than-compensated by the change in the disagreement point to the advantage of the innovator (and thus a larger share), and entry occurs.

Anecdotal evidence suggests that strategic incentives do lead innovators in some markets to license their technology before selling the IP to the monopoly incumbent. For instance, in the k-cup industry, Green Mountain Coffee Roasters (GMCR) was a monopoly until 2000 and Keurig had the patent for producing k-cups. In 2001, Keurig sold four licenses before GMCR fully acquired Keurig and prevented additional sale of licenses: GMCR started increasing its percentage ownership of Keurig in 2003, and the full acquisition was completed in 2006.[2]

1.2 Related Literature

Licensing that may result in inefficient outcomes (in terms of the total industry profit) if licensing contracts are restricted or subject to information and other frictions has already been studied in the literature. Schmitz (2002, 2007), and Jiang et al. (2007) study the case in which an innovator holds the patent on a new product innovation and there is private information on the side of the potential licensees. They show that asymmetric information can lead to non-exclusive licensing, even though under complete information the innovator would have sold one exclusive license.

Katz and Shapiro (1985) study a model with an inside innovator who holds the patent on a cost-reducing innovation and show that if licensing contracts are restricted to upfront fee only (and do not contain any royalty component), the firm that can make the best use of the innovation may be restrained from using it. Having the license to use the new technology, an efficient competitor reduces the innovator's industry profit and hence reduces the incentive of the incumbent innovator to sell a license to a potentially more efficient rival. This phenomenon is absent from our model since the innovator in our model is assumed to be an outside lab and not a producer.

In general, restricting the form of licensing contracts can lead to the sale of non-exclusive licenses (Li and Wang 2010), and hence results with inefficient outcomes (again, in terms of the total industry profit). The source of inefficiency in our model is different: It is the possibility of the innovator's selling licenses to new entrants—prior to the bargaining with the monopoly. On the one hand this sale reduces the total "bargaining cake"; but on the other hand this sale serves as a credible commitment device to increase the innovator's bargaining position. This explanation for

[2] Interestingly, GMCR then acquired (2009–2010) the other four licensees to maintain monopoly power.

inefficiency is novel in the patent licensing literature, and we provide sufficient conditions for this to occur.

Similar inefficiency results as in our case have been described in the context of incomplete contracts: the hold-up problem (Williamson 1979; Klein et al. 1978; Spiegel 1996). In a procurement relationship between two parties, one party can make a relation-specific investment that can benefit both of them. Yet, this party may refrain from making such investment because the investment may give the other party additional bargaining power. This can happen when the parties cannot sign an ex-ante complete and binding contract, and it results in underinvestment that leads to an inefficient outcome. Diverting from this literature, we show that—even in a complete-contract environment—in the context of patent licensing the bargaining outcome may still be ex-ante inefficient.

Optimal licensing strategies have been extensively studied in the literature; but much of this literature assumes that incumbent firms are the only potential licensees. This paper is among a few exceptions that allow entrant licensees. In Hoppe et al. (2006) and Tauman and Zhao (2018) entry is allowed; but the innovator sells all licenses simultaneously, and not sequentially, as in our model. Moreover, those two papers assume non-cooperative environments without the possibility that the innovator can bargain with incumbent firms.

The idea that firms may have incentives to sell licenses in order to attain a more favourable outcome appears in the literature in other contexts. For instance, under the context of patent race, Gallini (1984) shows that an incumbent firm may license its production technology, so as to reduce the incentive of a potential entrant to develop its own technology.

The paper is organized as follows: The model is presented in Sect. 2. An example of Cournot competition with linear demand is shown in Sect. 3. The main results appear in Sect. 4. The concluding discussion is in Sect. 5. Most proofs are relegated to the "Appendix".

2 The Model

2.1 The Industry

We consider a monopoly (M) that produces a single good at a marginal cost c, $c \geq 0$. There are many potential entrants that are unable to enter the market under the existing technology, which requires a high entry cost. An outside innovator (Inn) develops an alternative technology that eliminates the entry cost and has the marginal cost $c + \epsilon$; ϵ can be either positive or negative. If $\epsilon \geq 0$, the new technology is useless for M. Nevertheless, M may be willing to pay for the IP of the new technology, so as to limit entry.

Denote by $\pi_0(k)$ and $\pi_e(k)$ the profit of M and each entrant licensee, respectively, in the case where M competes with k entrant licensees while M does *not* have access to the new technology. The profits $\widehat{\pi}_0(k)$ and $\widehat{\pi}_e(k)$ are similarly defined, but for the case where M uses the new technology. The following assumptions are made on the firms' profit functions.

Assumption 1

(i) $\pi_e(1) > 0$.
(ii) $\pi_0(k)$, $\widehat{\pi}_0(k)$, $\pi_e(k)$, $\widehat{\pi}_e(k)$, $\pi_0(k) + k\pi_e(k)$, and $\widehat{\pi}_0(k) + k\widehat{\pi}_e(k)$ are all decreasing in k.

Assumption 1(i) asserts that the new technology is useful for entrants: The marginal cost, $c + \epsilon$, under the new technology is not too high. Part (ii) asserts that, additional competition in the market reduces the total industry profit, the profit of M, and the profit of each entrant licensee. Furthermore, this is true regardless of whether M uses the new technology or not. This implies that M's willingness to pay to forestall entry exceeds Inn's gain from selling licenses to entrants.

2.2 Licensing Procedure

Inn and M are the strategic players in the following three-stage game G.

- *Stage 1* Inn offers to sell r, $r \geq 0$, (first-batch) licenses to new entrants and charge each of them a take-it-or-leave-it upfront fee for the license.[3]
    - A licensing contract with an entrant is a triple (f_1, r, δ), where f_1 is an upfront license fee; r is the number of licenses that Inn sells before bargaining with M over the IP, and δ is a commitment to sell no more than δ licenses in total ($\delta = \infty$ means no restriction on the number of future licenses).

        $*$ If $r = 0$, no contract is signed and the game proceeds to Stage 2.
        $*$ If $r = \delta$, no additional licenses can be sold and M's willingness to pay for the IP is zero. The game ends with a payoff $r\pi_e(r)$ to Inn and $\pi_0(r)$ to M.
        $*$ If $r < \delta$, the game proceeds to Stage 2.
    - When Inn offers a license to an entrant, the entrant anticipates the later outcomes that will occur in Stages 2 and 3 after it purchases the license.
- *Stage 2* Inn bargains with M over the IP of the new technology. The detailed (non-strategic) bargaining process will be discussed later.
    - If an agreement is reached, M purchases the IP.
    - If no agreement is reached, Inn remains the owner of the IP.
- *Stage 3* If an agreement is reached and M becomes the owner of the IP, M selects a number m of additional licenses to sell (the second-batch). If no agreement is reached, Inn selects a number n of additional licenses to sell.

[3] The assumption that Inn can sell licenses to entrants via a take-it-or-leave-it offer can be relaxed. Suppose, instead, Inn bargains with entrants. Denote by $\widehat{\beta}$ the relative bargaining power of Inn when bargaining with potential entrants. Our current model is a special case with $\widehat{\beta} = 1$. Since Inn's payoff is continuous in $\widehat{\beta}$, if entry occurs for $\widehat{\beta} = 1$, entry will occur for sufficiently large $\widehat{\beta}$; and our main result is robust to small perturbation of $\widehat{\beta}$.

- A contract with each one of the second-batch licensees is a pair (f_2, j) where f_2 is an upfront license fee and j is a commitment of the IP owner to sell at most j licenses in the second-batch.
- Both m and n are bounded by the previous commitment of Inn, namely $m, n \leq \delta - r$.

We analyze the subgame perfect equilibrium of G. Let us first analyze Stage 3. Given (r, δ) in Stage 1, suppose an agreement with M is reached (resp. no agreement is reached) in Stage 2. Denote by $m(\delta, r)$ (resp. $n(\delta, r)$) the subsequent optimal number of licenses M (resp. Inn) sells in Stage 3. Formally, let $\mathbb{N}$ be the set of non-negative integers; we then have

$$m(\delta, r) = \underset{\substack{0 \leq m \leq \delta - r \\ m \in \mathbb{N}}}{\operatorname{argmax}} \left(m\widehat{\pi}_e(m + r) + \widehat{\pi}_0(m + r) \right), \tag{1}$$

and

$$n(\delta, r) = \underset{\substack{0 \leq n \leq \delta - r \\ n \in \mathbb{N}}}{\operatorname{argmax}} \left(n\pi_e(r + n) \right). \tag{2}$$

In the case where Inn sets no restriction on the number of future licenses, $\delta = \infty$, we omit δ from our notations, and write $n(r)$ and $m(r)$ instead of $n(\delta, r)$ and $m(\delta, r)$, respectively.

Assumption 2 For any $r \geq 0$, $k\pi_e(r + k)$ and $k\widehat{\pi}_e(k + r) + \widehat{\pi}_0(k + r)$ are both single-peaked in k.

Assumption 2 assures that, irrespective of the number r of first-batch licenses, the number of second-batch licenses $n(\delta, r)$ or $m(\delta, r)$ are uniquely determined as real numbers. Since we restrict our analysis to integers, the maximum is attained at most for two integers. In case of a tie, we take $n(\delta, r)$ (or $m(\delta, r)$) to be the lowest of the two.

Remark 1 M can only sell licenses if she reaches an agreement with Inn and purchases the IP. It is only Inn's technology that eliminates the entry cost and allows for profitable entry.

Remark 2 In some cases $n(\delta, r)$ or $m(\delta, r)$ may be larger than 1.[4] When there are other producers in the market, a larger number of second-batch licensees can typically capture a larger share of the market profit (even though it increases competition).

In the Bargaining Stage 2, we adopt the *generalized Nash bargaining solution*. The **Pareto-frontier** of this bargaining problem consists of all divisions (between Inn and M) of the subsequent highest industry profit: $v(\delta, r)$ (the "bargaining cake").

[4] $m(\delta, r)$ may be larger than 1 only when $r \geq 1$, while $n(\delta, r)$ may be larger than 1 even if $r = 0$.

This is the profit of M when having the IP of the new technology, together with the profits of the additional $m(\delta, r)$ entrant licensees. Formally,

$$v(\delta, r) = m(\delta, r)\hat{\pi}_e\big(r + m(\delta, r)\big) + \hat{\pi}_0\big(r + m(\delta, r)\big). \tag{3}$$

The **disagreement payoffs** – $\big(d_{inn}(\delta, r), d_M(\delta, r)\big)$ – are the payoffs that Inn and M obtains if the bargaining fails. In this case M has no access to the new technology and Inn sells additional $n(\delta, r)$ licenses. Formally,

$$d_{inn}(\delta, r) = n(\delta, r)\pi_e\big(r + n(\delta, r)\big) \tag{4}$$

and

$$d_M(\delta, r) = \pi_0\big(r + n(\delta, r)\big). \tag{5}$$

Inn and M bargain over their shares in the surplus $s(\delta, r) = v(\delta, r) - \big(d_{inn}(\delta, r) + d_M(\delta, r)\big)$. If the surplus is negative, no agreement is reached, and Inn remains the owner of the IP. If the surplus is non-negative, an agreement is reached, and the surplus is shared according to an exogenously given bargaining power: $(\beta, 1-\beta)$ for Inn and M, respectively.

Formally, in the **generalized Nash bargaining solution**, the "bargaining cake" $v(\delta, r)$ is shared as follows:

$$b_{inn}(\delta, r) = \beta s(\delta, r) + d_{inn}(\delta, r) \tag{6}$$

and

$$b_M(\delta, r) = (1-\beta)s(\delta, r) + d_M(\delta, r). \tag{7}$$

The Nash bargaining solution is a special case, where $\beta = \frac{1}{2}$. If $\beta = 1$, Inn makes a take-it-or-leave-it offer to M; and if $\beta = 0$, it is M that makes such an offer to Inn.

Finally, in Stage 1, Inn chooses the number r of first-batch licensees and a contract (f_1, r, δ). The license fee that Inn charges to each of the first r licensees takes into account the expected bargaining outcome.

Inn's total payoff $\pi_{inn}(\delta, r)$ consists of the license fees that it collects from the first r licensees plus $b_{inn}(\delta, r)$ from selling the IP to M.

3 Example: Cournot Competition

In this section, we illustrate our main result with a simple example: Suppose that firms are engaged in a Cournot competition. Let $p(Q) = \max(1-Q, 0)$ be the inverse demand function. Suppose, in addition, that $c = \epsilon = 0$. That is, M produces with a marginal cost 0, and Inn's new technology is useless for M. In this case, M is willing to pay for the IP only to exclude entry. We show that even though M's willingness to pay is higher than Inn's payoff from selling licenses to entrants, entry occurs when the bargaining power of Inn is relatively small.

The profit function of M and each entrant licensee is $\pi_0(k) = \hat{\pi}_0(k) = \pi_e(k) = \hat{\pi}_e(k) = \left(\frac{1}{k+2}\right)^2$. In the absence of entry ($k = 0$), M obtains $\frac{1}{4}$.

We first consider the case where Inn bargains with M before selling any licenses to entrants ($r = 0$).

- The "bargaining cake" is the monopoly profit, $v(0) = \frac{1}{4}$.
- It is easy to verify that the (credible) threat of Inn (in case of no agreement) is to sell two additional licenses, in which case Inn earns $d_{inn}(0) = \frac{1}{8}$ and M obtains $d_M(0) = \frac{1}{16}$.
- Inn and M bargain over the surplus $s(0) = v(0) - d_{inn}(0) - d_M(0) = \frac{1}{16}$.
- Given the bargaining power $(\beta, 1-\beta)$ of Inn and M, respectively, Inn obtains $b_{inn}(0) = \frac{1}{8} + \beta\frac{1}{16}$, and M obtains $b_M(0) = \frac{1}{16} + (1-\beta)\frac{1}{16}$.

Since no licenses are sold prior to bargaining, Inn's payoff is obtained only from the sale of its IP to M: $\pi_{inn}(0) = \frac{1}{8} + \beta\frac{1}{16}$.

Let us now consider the case where Inn first sells one license and then bargains with M over the IP ($r = 1$). Suppose Inn offers to the first entrant licensee the contract ($f_1 = \frac{1}{16}, r = 1, \delta = \infty$): The licensing fee is $\frac{1}{16}$; Inn commits to sell no more first-batch licenses; and there is no commitment as to the number of licenses that Inn or M can sell after their bargaining. We will verify later that an entrant who is offered this contract is willing to accept it. Given a single entrant licensee in the market, the bargaining between Inn and M is described as follows:

- If Inn and M reach an agreement, M obtains the IP, and it is easy to verify that M is best off selling one additional license ($m(1) = 1$). Therefore, the "bargaining cake" is $v(1) = \hat{\pi}_0(2) + \hat{\pi}_e(2) = \frac{1}{8}$.
- Since the first licensee paid his license fee upfront, it is easy to verify that in case the bargaining fails, Inn is best off selling three additional licenses. Inn obtains from these three licensees $d_{inn}(1) = 3\pi_e(4) = \frac{1}{12}$, and M competes with (in total) four entrants and earns $d_M(1) = \pi_0(4) = \frac{1}{36}$.
- Inn and M bargain over the surplus $s(1) = v(1) - d_{inn}(1) - d_M(1) = \frac{1}{72}$.
- Given the bargaining power of Inn and M, the allocation of the "bargaining cake" is: $b_{inn}(1) = \frac{1}{12} + \beta\frac{1}{72}$ to Inn and $b_M(1) = \frac{1}{36} + (1-\beta)\frac{1}{72}$ to M.

The total payoff $\pi_{inn}(0)$ of Inn consists of the license fees that it collects from the first-batch licensee and the payoff that it obtains from M. Hence, $\pi_{inn}(0) = f_1 + b_{inn}(1) = \frac{7}{48} + \beta\frac{1}{72}$. It is left to verify that the first entrant is willing to pay $\frac{1}{16}$ for the license. Indeed, in equilibrium an agreement is reached between Inn and M. As argued above, after obtaining the IP, M will sell one additional license, and the profit of each entrant licensee will be $\hat{\pi}_e(2) = \frac{1}{16}$. A licensee is willing to pay all his profit since his opportunity cost is zero.

The payoffs that are related to the above two scenarios are summarized in Table 1.

Table 1 The payoff structure

r	$f_1(r)$	$m(r)$	$v(r)$	$n(r)$	$d_{inn}(r)$	$d_M(r)$	$s(r)$	$b_{inn}(r)$	$\pi_{inn}(r)$
0	\	0	$\frac{1}{4}$	2	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{8}+\beta\frac{1}{16}$	$\frac{1}{8}+\beta\frac{1}{16}$
1	$\frac{1}{16}$	1	$\frac{1}{8}$	3	$\frac{1}{12}$	$\frac{1}{36}$	$\frac{1}{72}$	$\frac{1}{12}+\beta\frac{1}{72}$	$\frac{7}{48}+\beta\frac{1}{72}$

If $\beta < \frac{3}{7}$, $\pi_{inn}(1) > \pi_{inn}(0)$ and Inn is better off selling one license before bargaining with M.

To summarize: If Inn approaches M immediately ($r = 0$) and no agreement is reached, Inn is best off selling 2 licenses ($n(0) = 2$). Suppose instead that Inn sells—before bargaining with M—one license ($r = 1$) for an upfront fee. If no agreement is reached, given an industry with two producing firms (the incumbent and a licensee), Inn is best off selling 3 additional licenses ($n(1) = 3$). In the first scenario, if no agreement is reached, M competes with 2 entrants and earns $\frac{1}{16}$, while in the second scenario M faces 4 competitors and earns $\frac{1}{36}$. Even though in the latter case the "bargaining cake" is smaller, M has a greater incentive to compromise. In the case where β is small, the second effect dominates the effect of the shrinking of the "cake" and entry occurs.[5]

4 Main Results

We divide our analysis into two parts. In the case where $\epsilon \geq 0$, while the new technology eliminates the entry cost and allows for a profitable entry, it is useless for M. Examples include the development of the mobile MRI scanner, which, technologically, is the same as a fixed MRI, but eliminates much of the installation cost. In the case $\epsilon < 0$, the technology itself is useful for M, and M's willingness to pay for the IP reflects both benefits: reducing marginal cost, and limiting entry.

4.1 The Case $\epsilon \geq 0$

In the case where $\epsilon \geq 0$, M is willing to pay for the IP only to limit entry. If M is the only producer in the market and it purchases the IP, the new technology will be "shelved"—To maintain M's monopoly power, M will eliminate entry and do not use the technology. The technology will be used only if Inn sells some licenses before bargaining with M. We therefore focus on the first-stage entry.

Since the marginal cost of M remains c regardless of whether it obtains the IP or not, we have $\pi_0(k) = \hat{\pi}_0(k)$ and $\pi_e(k) = \hat{\pi}_e(k)$. By (3)–(5), Inn and M bargain over the surplus:

[5] It can be verified that $r \geq 2$ is never optimal in this Cournot example.

$$\begin{aligned} s(\delta, r) &= v(\delta, r) - (d_{inn}(\delta, r) + d_M(\delta, r)) \\ &= m(\delta, r)\pi_e\big(r + m(\delta, r)\big) + \pi_0\big(r + m(\delta, r)\big) - \Big(n(\delta, r)\pi_e\big(r + n(\delta, r)\big) + \pi_0\big(r + n(\delta, r)\big)\Big) \\ &\geq 0. \end{aligned} \tag{8}$$

The last inequality holds by the definition of $m(\delta, r)$ [see (1)]. Therefore, in the case where $\epsilon \geq 0$, no matter how many licenses Inn sells prior to bargaining with M, an agreement between Inn and M is reached.

The next proposition states that, when selling the first-batch of licenses, it is optimal for Inn to have no restriction on the total number of licenses that the IP holder can sell after the bargaining stage.

Proposition 1 *Suppose that Assumptions 1 and 2 hold and* $\epsilon \geq 0$. *Then (i) for any* $r \geq 0$, $m(r) \leq n(r)$; *and (ii) if Inn sells r licenses to entrants in Stage 1, it is optimal for Inn to set* $\delta \geq r + n(r)$.

Proof See "Appendix 1". □

Recall that $m(r)$ (resp. $n(r)$) is the unconstrained optimal number of licenses M (resp. Inn) sells if an agreement is reached (resp. no agreement is reached). Part (i) of Proposition 1 asserts that, if the bargaining fails and if there is no restriction on the total number of licenses, Inn is better off selling at least as many licenses as M would sell if an agreement is reached. The reason is straightforward: Although a larger number of licensees increases M's revenue from license fees, it also reduces M's own operating profit (because of stronger competition). The latter effect does not apply to an outside innovator, since Inn does not compete in the market.

Part (ii) asserts that, it is optimal for Inn to set $\delta \geq r + n(r)$. In particular, $\delta = \infty$ is optimal. A restrictive δ reduces Inn's disagreement payoff and hurts its bargaining position.

Proposition 2 *Suppose that Assumptions 1 and 2 hold and* $\epsilon \geq 0$. *If* $m(1) < n(0) \leq n(1)$, *then there exists* $\beta_0 \in (0, 1)$ *such that entry occurs for all* $\beta \in [0, \beta_0]$.

Proof See "Appendix 1". □

Proposition 2 constitutes the main result of this section. It provides conditions that guarantee no shelving of the innovation. The condition $n(r) \leq n(r + 1)$ states that—if there are already r entrants in the market and the bargaining between Inn and M fails—the optimal number of additional licenses Inn sells is non-decreasing in r (recall that the license fees of the first r licensees are paid upfront and before Inn bargains with M). Actually, for Proposition 2, we need this condition to hold for just $r = 0$.

The condition $n(r) \leq n(r+1)$ holds if the industry profit of each licensee is decreasing but not too sharply with the total number of licensees (e.g., Cournot competition with linear demand). In such cases, if a larger number of producers are already in the market, Inn is better off selling a larger number of additional licenses to capture a bigger proportion of the total industry profit, and it further implies a greater threat vis-à-vis M in case the bargaining fails.

Since $n(0) \leq n(1)$, on the one hand the choice $r = 1$ reduces the total "bargaining cake"; but on the other hand it increases the credible threat vis-à-vis M, and hence improves Inn's bargaining position. The second condition $m(1) < n(0)$ implies that, even if one entrant is already in the market when M purchases the IP, the number of subsequent licenses that M sells is relatively low. In this case, the shrinking of the "bargaining cake" due to $r = 1$ is nondramatic. If, in addition, Inn has a relatively weak bargaining power, the loss of a small share of a mildly shrinking "cake" is compensated by the change of the disagreement point in favor of Inn. Hence entry occurs.

4.2 The Case $\epsilon < 0$

We next consider the case $\epsilon < 0$. In this case, the new technology is useful for M and $\widehat{\pi}_0(k)$ (resp. $\widehat{\pi}_e(k)$) might be different from $\pi_0(k)$ (resp. $\pi_e(k)$). We make two additional assumptions.

Assumption 3 For any $k \geq 0$, the payoff function $\pi_e(k)$ and $\widehat{\pi}_e(k)$ are both continuous in ϵ.

Since $\pi_e(k) = \widehat{\pi}_e(k)$ for $\epsilon = 0$, Assumption 3 guarantees that, when ϵ is small, the difference between $\pi_e(k)$ and $\widehat{\pi}_e(k)$ is small.

Assumption 4 For any $r \geq 0$ and $\delta \geq r$,

$$\max_{\substack{0 \leq m \leq \delta - r \\ m \in \mathbb{N}}} \big(m\widehat{\pi}_e(m+r) + \widehat{\pi}_0(m+r)\big) \geq \max_{\substack{0 \leq m \leq \delta - r \\ m \in \mathbb{N}}} \big(m\pi_e(m+r) + \pi_0(m+r)\big).$$

Assumption 4 assures that, regardless of the number r of the first-batch entrant licensees and the commitment on the total number of licenses δ, after purchasing the IP, M is always better off using the new technology.

This assumption is clearly satisfied if $r = 0$ (in which case $\delta = \infty$). After purchasing the IP, M will sell no license ($m(0) = 0$), and Assumption 4 simply states that M makes a larger profit with the use of a more efficient technology. If, instead, $r \geq 1$, Assumption 4 rules out the possibility that M sells additional licenses and does not use the new technology itself (if M can credibly commit to this restraint). Even though it reduces M's marginal cost, the use of the new technology increases the competition that is faced by the new entrant licensees, and thereby reduces their profit, which in turn affects M's revenue.

Under Assumption 4, in the bargaining between Inn and M, by (3)–(5), the surplus can be re-written as

$$\begin{aligned} s(\delta,r) &= v(\delta,r) - (d_{inn}(\delta,r) + d_M(\delta,r)) \\ &= m(\delta,r)\hat{\pi}_e\big(r+m(\delta,r)\big) + \hat{\pi}_0\big(r+m(\delta,r)\big) - \Big(n(\delta,r)\pi_e\big(r+n(\delta,r)\big) + \pi_0\big(r+n(\delta,r)\big)\Big) \\ &\geq \max_{\substack{0\leq m\leq \delta-r \\ m\in\mathbb{N}}} \big(m\pi_e(r+m) + \pi_0(r+m)\big) - \Big(n(\delta,r)\pi_e\big(r+n(\delta,r)\big) + \pi_0\big(r+n(\delta,r)\big)\Big) \\ &\geq 0. \end{aligned} \tag{9}$$

Therefore, regardless of (δ, r), an agreement between Inn and M is always reached in equilibrium. The next proposition provides a sufficient condition for entry to occur even if $\epsilon < 0$.

Proposition 3 *Suppose Assumptions 1–4 hold and* $\epsilon < 0$. *If* $m(1) < n(0) \leq n(1)$, *then there exists* $\epsilon_0 < 0$ *and* $\beta_0 \in (0,1)$ *such that entry occurs for all* $\epsilon \in [\epsilon_0, 0)$ *and* $\beta \in [0, \beta_0]$.

Proof See "Appendix 1". □

The condition $m(1) < n(0) \leq n(1)$ is identical to the one in Proposition 2. In addition, to guarantee entry we require that the magnitude of the innovation—$|\epsilon|$—should be relatively small. If instead the innovation is sizable, the damage to the "bargaining cake" due to $r = 1$ is too severe, and the improved bargaining position of Inn does not provide a sufficient offset.

5 Conclusion and Extensions

This paper analyzes the interaction between a monopoly incumbent and an outside innovator that owns a new technology, which may or may not have industrial value to the monopoly but does allow a profitable entry. We focus on cases where the monopoly's willingness to pay for the IP exceeds the innovator's gain from selling licenses to entrants. Yet, we show that as a means to improve its threat-point vis-à-vis the incumbent, the innovator may benefit from selling a few licenses before selling the IP to the incumbent, even though this outcome is inefficient in the sense that it shrinks the total industry profit. We next discuss several extensions of our model, mainly to show the robustness of our main result.

5.1 Licensing by Royalty

Consider the case where Inn can choose to sell licenses either through an upfront fee or through a per-unit royalty—whichever is more profitable for Inn. We argue that also in this case, Inn may benefit from selling some licenses before it bargains with M. We illustrate this using the same framework as was presented in Sect. 3: Firms are engaged in a Cournot competition under the linear demand $p = 1 - Q$, and $c = \epsilon = 0$. In particular, the new technology only allows for entry but it does not reduce the marginal cost of the current technology.

Suppose first that Inn bargains with M before selling any licenses (r=0). The "bargaining cake" is the monopoly profit: $\frac{1}{4}$. The disagreement payoffs are determined by Inn's optimal licensing policy if no agreement is reached. In this case, if Inn sells licenses by charging an upfront fee, Inn is best off selling two licenses, and its subsequent payoff is $\frac{1}{8}$. If Inn sells licenses with the use of a per-unit royalty, it is best off[6] selling licenses to all, say n, potential entrants, and it then obtains $\frac{n}{n+2} \cdot \frac{1}{8}$. Inn is therefore best off charging an upfront fee.

Following the exact analysis as in Sect. 3, Inn's maximum payoff in the case where $r = 0$ is $\pi^{FR}_{inn}(0) = \frac{1}{8} + \beta\frac{1}{16} = \pi^{F}_{inn}(0)$. Here π^{FR}_{inn} stands for Inn's payoff when Inn can choose to charge either an upfront fee or a royalty, while π^{F}_{inn} corresponds to the case where the licensing is restricted to an upfront fee.

Consider next the case where Inn sells one license (either by an upfront fee or by a per-unit royalty) before bargaining with M. Clearly, Inn's total payoff—$\pi^{FR}_{inn}(1)$—is at least $\pi^{F}_{inn}(1) = \frac{7}{48} + \beta\frac{1}{72}$ (see Table 1 in Sect. 3). For small β, we have $\pi^{FR}_{inn}(0) = \pi^{F}_{inn}(0) < \pi^{F}_{inn}(1) \leq \pi^{FR}_{inn}(1)$, and entry occurs.

5.2 Adding a Time Component

In some industries—such as the high-tech industry—innovations are relevant for only a limited time before a new innovation makes the previous one obsolete. Bargaining with a monopoly may take relatively long time, especially if the innovation is useful just to new entrants and the monopoly is willing to pay for the IP only to limit entry. In this section, we add time variable to our model, and study the effect of bargaining time on entry.

To analyze this case, suppose the innovation is relevant for 1 unit of time. Competition between M and entrant licensees takes place along the whole period. The density of the demand and the profits of all firms are assumed to be constant over time, and players do not discount future payoffs. That is, the profit of, say, M along t, $0 < t < 1$, units of time, when there are in total k entrant licensees in the market and M produces with the old technology, is $t\pi_0(k)$.

6 Suppose that Inn sells k licenses to entrants with a per-unit royalty charge of y. Then there are $k + 1$ firms in the market: M, which produces at the marginal cost 0; and k firms that produce at the marginal cost y. Inn's payoff from the license fees that it collects from the k entrant licensees is $\frac{k}{k+2} \cdot y(1 - 2y)$; and that payoff is maximized at $y = \frac{1}{4}$, and $k = n$ (here n is the number of potential entrants).

Since there is a large number of potential entrants whose opportunity cost is zero, we assume for simplicity that selling licenses to entrants is instantaneous and takes no time. The bargaining stage, however, takes z, $0 \leq z < 1$, units of time. Here z captures an exogenously given deadline for the bargaining process which may be determined by social norm or industry convention.

Inn's payoff in this case consists of: (i) the license fees that Inn obtains from the first r licensees that compete with M for z units of time; and (ii) Inn's payoff from selling the IP, which is useful for the remaining $1 - z$ units of time, through bargaining with M. When z increases, a larger weight is assigned to part (i), and it can be verified that under Assumptions 1–4, if in equilibrium entry occurs for $z = \hat{z}$, then entry occurs for $z > \hat{z}$.

The longer is the bargaining time, the greater is the incentive of Inn to introduce entry. Indeed, the upfront fee that is paid by the first r licensees includes their industry profit during the bargaining phase. It is therefore not surprising that Inn's benefit from selling licenses prior to bargaining is higher when the bargaining stage lasts longer.

5.3 Allowing the Incumbent to Buy Back Previous Licenses

In our example with regard to the k-cup industry, the patent holder Keurig sold four licenses before it was acquired by the incumbent Green Mountain in 2006. Interestingly, in 2009–2010, Green Mountain further acquired all four licensees, so as to maintain its monopoly power. Our model ignores the possibility of M to buy back previous licenses. Let us now assume, instead, that M can reduce the number of entrant licensees simply by paying them back the license fee that they paid.

First notice that M has no incentive to buy back any license unless M obtains the IP. As long as Inn is the owner of the IP, Inn can sell an additional license per every licensee acquired by M.

In contrast, after purchasing the IP, in a market where the total industry profit is decreasing in the number of licensees, M is better off buying back all existing licenses, so as to earn the monopoly profit. Nevertheless, even though the ability of M to buy back licenses excludes post-bargaining entry, the buy-back option encourages pre-bargaining entry. Indeed, pre-bargaining entry still increases the severity of the threat on M, while the size of the "bargaining cake" is not reduced.

If the new technology is expected to be relevant for a relatively short time—and the bargaining takes a non-negligible amount of time—entry occurs prior to the bargaining stage, and buying back occurs later. It might be a coincidence, but it is interesting to note that in the k-cup example, the four licenses were sold in 2001, and they were acquired by Green Mountain only in 2010.

5.4 Bargaining More Than Once

Finally, our model assumes that Inn can meet M only once. This makes sense if M is a powerful firm while Inn is a small lab, and M can credibly commit not to meet Inn again if the bargaining fails.

Let us relax this assumption and allow Inn to bargain with M for a second time. We argue that entry may still occur if bargaining can last for a non-negligible period of time. Inn in this case could approach M immediately before selling any license, with the threat that if bargaining fails, Inn will sell a few licenses before coming back to the bargaining table. If M is convinced, the two could have shared the monopoly profit with a larger share for Inn.

However, if the bargaining lasts for z units of time, the continuation game following the first failure is no longer the same as the original game since some time has already been wasted. Knowing that the second bargaining takes additional time and further reduces the remaining value of the IP, M could claim a larger share already in the first meeting. As a result, it may still be beneficial for Inn to bargain with M only after selling a few licenses, in which case they bargain only once.

Appendix

Proof of Proposition 1

We first prove Part (i). Let $\widetilde{n}(r) := \text{argmax}_{n\geq 0} n\pi_e(r+n)$ and $\widetilde{m}(r) := \text{argmax}_{m\geq 0}\big(m\pi_e(m+r) + \pi_0(m+r)\big)$. Note that unlike $n(r)$ and $m(r)$, here $\widetilde{n}$ and $\widetilde{m}$ need not be integers. By Assumption 2, $\frac{\partial n\pi_e(r+n)}{\partial n}|_{n=\widetilde{n}(r)} = 0$ and $\frac{\partial m\pi_e(m+r)}{\partial m}|_{m=m(r)} + \frac{\partial \pi_0(m+r)}{\partial m}|_{m=\widetilde{m}(r)} = 0$. Since $\pi_0(m+r)$ is decreasing in m (Assumption 1(ii)), $\frac{\pi_0(m+r)}{\partial m} < 0$. This implies that $\frac{\partial m\pi_e(m+r)}{\partial m}|_{m=\widetilde{m}(r)} > 0$. Since $k\pi_e(r+k)$ is single-peaked in k (Assumption 2), $\widetilde{m}(r) < \widetilde{n}(r)$. When restricting to integers, we have $m(r) \leq n(r)$.

We next prove Part (ii). Suppose Inn sells r licenses in the first stage. By definition, $\delta \geq r$.

Step 1 It is not optimal for Inn to set $\delta = r$.

If $\delta = r$, Inn does not approach M, and Inn obtains at most $A := \max_k k\pi_e(k)$. We argue that by setting $\delta \geq r + n(r)$ and bargaining with M, Inn obtains at least A. If Inn sells no license in Stage 1 and approaches M directly, the disagreement payoff of Inn is A. Since $m(0) < n(0)$ (Assumption 1(iv)), the surplus in the bargaining problem is positive, and Inn's payoff from the bargaining stage is strictly higher than Inn's disagreement payoff A, as claimed.

Step 2 It is not optimal to set $\delta \in (r, r+m(r)]$.

It is sufficient to show that if $\delta \in (r, r+m(r)]$, then Inn obtains no more than A. Denote $l = \delta - r$. By Assumption 2, $n(\delta, r) = \min\big(l, n(r)\big)$ and $m(\delta, r) = \min\big(l, m(r)\big)$. In the case where $l \leq m(r)$, $m(\delta, r) = n(\delta, r) = l$, implying

$s(\delta, r) = 0$. Inn's total payoff from bargaining with M is $(l + r)\pi_e(l + r) \leq A$, as claimed.

Step 3 It is not optimal to set $\delta \in \big(r + m(r), r + n(r)\big)$.

Denote $l = \delta - r$. In this case, we have $m(r) < l < n(r)$, and hence $n(\delta, r) = l$ and $m(\delta, r) = m(r)$. The total payoff of Inn is

$$\begin{aligned}\pi_{inn}(r, l) = &\overbrace{\beta[(m(r) + r)\hat{\pi}_e(m(r) + r) + \hat{\pi}_0(m(r) + r)] + (1 - \beta)r\hat{\pi}_e(m(r) + r)}^{\text{part 1}} \\ &+ \underbrace{(1 - \beta)l\pi_e(l + r) - \beta\pi_0(l + r)}_{\text{part 3}}.\end{aligned} \tag{10}$$

Inn's total payoff when $l \geq n(r)$ is

$$\begin{aligned}\pi_{inn}(\delta, r) = &\overbrace{\beta[(m(r) + r)\hat{\pi}_e(m(r) + r) + \hat{\pi}_0(m(r) + r)] + (1 - \beta)r\hat{\pi}_e(m(r) + r)}^{\text{part 1}} \\ &+ \underbrace{(1 - \beta)n(r)\pi_e(n(r) + r) - \beta\pi_0(n(r) + r)}_{\text{part 2}}.\end{aligned} \tag{11}$$

Note that part 1 of (10) is the same as part 1 of (11). We claim that part 3 of (10) is smaller than part 2 of (11). The reason is that $k\pi_e(k + r)$ is maximized at $k = n(r)$, and $\pi_0(k + r)$ is decreasing in k. Therefore $m(r) < l < n(r)$ is not an optimal choice for Inn. Intuitively, moving from $l \geq n(r)$ to $m(r) < l < n(r)$, the license fee paid by the first r entrants as well as the subsequent "bargaining cake" remain the same. But the disagreement point changes to the disadvantage of Inn—since the optimal number of additional licenses Inn sells if no agreement is reached is now restricted by l.

Proof of Proposition 2

Let $\beta = 0$. Inn's total payoff is

$$\pi_{inn}(r)|_{\beta=0} = r\pi_e\big(r + m(r)\big) + n(r)\pi_e\big(r + n(r)\big).$$

We next compare $\pi_{inn}(1)$ and $\pi_{inn}(0)$.

$$\begin{aligned}\pi_{inn}(1)|_{\beta=0} - \pi_{inn}(0)|_{\beta=0} &= \overbrace{\pi_e\big(1 + m(1)\big)}^{\geq \pi_e(n(0))} + n(1)\pi_e\big(1 + n(1)\big) - n(0)\pi_e\big(n(0)\big) \\ &\geq \pi_e\big(n(0)\big) + n(1)\pi_e\big(1 + n(1)\big) - n(0)\pi_e\big(n(0)\big) \\ &= n(1)\pi_e\big(1 + n(1)\big) - \big(n(0) - 1\big)\pi_e\big(n(0)\big) \\ &> 0.\end{aligned} \tag{12}$$

Since $m(1)$ and $n(0)$ are both integers, and since $m(1) < n(0)$, we have $m(1) \leq n(0) - 1$. This observation and the decreasing of $\pi_e(k)$ in k, imply the first inequality in (12). The second inequality holds since $n\pi_e(1+n)$ is single-peaked (Assumption 2), since by (2) it is maximized at $n = n(1)$, and since $n(1) \geq n(0) > n(0) - 1$.

Inequality (12) implies that if $\beta = 0$, selling a license prior to the bargaining stage is better for the innovator than approaching M immediately. Entry occurs in this case. The continuity of π_{inn} with respect to β implies that entry occurs for sufficiently small β.

Proof of Proposition 3

Let $\beta = 0$. Inn's total payoff is

$$\pi_{inn}(r)|_{\beta=0} = r\hat{\pi}_e\big(r + m(r)\big) + n(r)\pi_e\big(r + n(r)\big).$$

We next compare $\pi_{inn}(1)$ and $\pi_{inn}(0)$.

$$\pi_{inn}(1)|_{\beta=0} - \pi_{inn}(0)|_{\beta=0} = \hat{\pi}_e\big(1 + m(1)\big) + n(1)\pi_e\big(1 + n(1)\big) - n(0)\pi_e\big(n(0)\big). \tag{13}$$

By Assumption 3 and since $\pi_e(k) = \hat{\pi}_e(k)$ for $\epsilon = 0$, the RHS of (12) is close to $A := \pi_e\big(1 + m(1)\big) + n(1)\pi_e\big(1 + n(1)\big) - n(0)\pi_e\big(n(0)\big)$. By the proof of Proposition 2, $A > 0$ if $m(1) < n(0) \leq n(1)$. Therefore, for sufficiently small ϵ, the RHS of (12) is positive. The continuity of π_{inn} with respect to β further implies that entry occurs for sufficiently small ϵ and β.

References

Gallini, N. T. (1984). Deterrence by market sharing: A strategic incentive for licensing. *The American Economic Review*, *74*(5), 931–941.

Gilbert, R. J., & Newbery, D. M. (1982). Preemptive patenting and the persistence of monopoly. *The American Economic Review*, *72*, 514–526.

Hoppe, H. C., Jehiel, P., & Moldovanu, B. (2006). License auctions and market structure. *Journal of Economics & Management Strategy*, *15*(2), 371–396.

Jiang, M. S., Aulakh, P. S., & Pan, Y. (2007). The nature and determinants of exclusivity rights in international technology licensing. *Management International Review*, *47*(6), 869–893.

Katz, M. L., & Shapiro, C. (1985). On the licensing of innovations. *The RAND Journal of Economics*, *16*, 504–520.

Klein, B., Crawford, R. G., & Alchian, A. A. (1978). Vertical integration, appropriable rents, and the competitive contracting process. *The Journal of Law & Economics*, *21*(2), 297–326.

Li, C., & Wang, J. (2010). Licensing a vertical product innovation. *Economic Record*, *86*(275), 517–527.

Schmitz, P. W. (2002). On monopolistic licensing strategies under asymmetric information. *Journal of Economic Theory*, *106*(1), 177–189.

Schmitz, P. W. (2007). Exclusive versus non-exclusive licensing strategies and moral hazard. *Economics Letters*, *97*(3), 208–214.

Spiegel, Y. (1996). The role of debt in procurement contracts. *Journal of Economics & Management Strategy*, *5*(3), 379–407.

Tauman, Y., & Zhao, C. (2018). Patent licensing, entry and the incentive to innovate. *International Journal of Industrial Organization*, *56*, 229–276.

Williamson, O. E. (1979). Transaction-cost economics: The governance of contractual relations. *The Journal of Law & Economics*, *22*(2), 233–261.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.