Signalling the Value of an Innovation by (not) Litigating Patent Infringers

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Abstract

We examine whether litigating or not litigating other firms who enter a market and infringe an existing patent for a previous innovation can signal the value of the patent. Without entry deterrence patent holder will litigate, if its expected costs exceeds its expected benefits. However, despite avoiding litigation costs, the patent holder might be able to credibly signal a low value of a patent and deter further entry into its market by not litigating a firm which infringes its patent. We will derive in general which conditions must be satisfied for this to happen and present some more specific examples.

Keywords: Innovation; Patent infringement; Entry; Signalling; Patent litigation.
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1 Introduction

Since Schumpeter wrote his theory of economic development in 1911 (see Schumpeter (1961) for an English translation), innovations are considered to be essential for economic growth. While Schumpeter himself did not necessarily acknowledge the importance of patents for innovations (see Guichardaz and Pénin (2019)). Arrow (1962) established the idea, that patents incentivize entrepreneurial firms to invest in R&D and that they in general support innovations in an economy. Therefore, the question, how far the different features of a patent system, including the regulations with regard to the litigation of infringers, are efficient in providing the necessary incentives for R&D, has been a lively field of research during the last thirty years (see e.g. the surveys by Hall and Harhoff (2012) and Hall (2022)). In this context patent litigation is usually seen as an instrument to enforce patents and secure innovation rents for patent holders and lots of scholars have studied the effect of patent litigation and the regulations connected with it on the incentive to innovate, (see e.g. Llobet, 2003; Krasteva, 2014; Krasteva et al., 2020). The relationship between litigation and the incentive to innovate is, however, not the focus here.

We investigate instead, whether patent litigation can transmit information about the value of a patent and this way influence further entry into the market(s) in which the patent creates value. That a patent holder's decision to litigate a potential infringer of a patent can transmit information is not a new idea. Most of the existing literature focusses, however, on information about the validity or strength of the patent. In Meurer (1989) and Choi (1998), for example, the validity of a patent will be revealed in the litigation process. Meurer (1989) assumes that before litigation only the patentee knows the patent's validity. Therefore the licensing contract that the patentee offers a competitor potentially signals the (in-)validity of the patent. Choi (1998) assumes instead symmetric information. In his model the incumbent patentee and two potential entrants, which contemplate to enter the market sequentially, all have the same prior about the probability of the validity of the patent. However, if the incumbent litigates the first entrant, the patent's validity is revealed in the process. The later entrant, thus, decides on entering the market under certainty and only if the patent is invalid. He can show for an intermediate level of patent strength that delaying litigation and the revelation of the patent's validity can be beneficial for the incumbent and deter the entry of the second entrant. Duchêne and Serfes (2012) introduce asymmetric information into the Choi (1998) model. They assume that both, the incumbent and an existing infringer, know the strength of the patent (meaning the probability of the patent's validity), whereas the third firm, a potential entrant, does not. They show for intermediate levels of patent strength that the patentee sues the infringer and settles out of court. The nevertheless observable high settlement payment is then a signal for the patent's sufficient strength, such that the third firm's entry is deterred.

We also analyze a model with asymmetric information, but contrary to Meurer (1989) and Duchêne and Serfes (2012) the strength of the patent is known by all parties, but the value of the patent, meaning the value of the market into which two potential entrants might want to enter is at the start only known to the incumbent.[1] Similar to Choi (1998) the first entrant decides in the first stage, whether to enter and potentially infringe the incumbent's patent or not. If it does, the incumbent can decide whether to litigate the first entrant or not. In the second stage a second entrant can enter the market. In our simple symmetric setting where the expected benefits and expected costs of litigation for the incumbent are known, not litigating the incumbent can be a signal for a low market value and deter the entry of the second potential entrant into the market. We first show for relatively general

[1]Schankerman and Schuett (2021) also consider asymmetric information between a potential patentee and one potential competitor about the value of an innovation because only the potential patentee knows the cost of R&D in order to turn an idea into an innovation. Then the decision to patent an innovation in itself can signal the innovation's value. In our setting the asymmetric information is not about the cost of R&D but about the value of the market where an innovation can finally be applied. We do not consider the incumbent's decision to patent, and therefore the patenting decision can not convey any information about the innovation's/patent's value.

assumptions under which conditions separating signaling equilibria exist. In such equilibria the incumbent litigates the first entrant only if the market value is high and the second entrant enters the market only if the first entrant has been litigated.

Then we analyse a linearized symmetric model following Choné and Linnemer (2020) where (the) linear demand(s) is(are) derived from a representative consumer's quasi-linear utility function and where all firms in the model (the incumbent and the two potential entrants) all have linear cost functions. For this setting we show for which parameters of the model signalling separating equilibria exist. However, we can also show for which parameter constellations only partially separating or pooling equilibria exist. In case a second entrant would enter, given its prior about the value of the market, our separating signalling equilibria are such that not litigating the first infringing entrant deters the entry of the second entrant. This is interesting because this differs from usual models of entry deterrence via signalling (see e.g. Milgrom and Roberts, 1982; Bagwell, 2007; Pires and Catalão-Lopes, 2020). In our setting it is possible that the incumbent can send the relevant message by inaction, meaning without having to bear extra signalling costs. Within our linear framework we analyse two different legal settings, one where the expected damages that an infringer has to pay is a percentage of its realized profits, and one where the expected damages coincide with the lost expected profit of the incumbent due to the market entry of the first entrant/infringer.

In the next section we first present a general model. Then we derive the conditions for different types of equilibria, among others the conditions for the existence of separating signalling equilibria, in the general model. Then we introduce a simplified symmetric linear model. We focus on the case where the second entrant's entry decision depends on the entrant's belief about the value of the market and analyze two different assumptions for the expected damages that a litigated infringer must pay to the patentee. We show which equilibria exist for which parameter constellations in these two different settings. Finally we discuss our results, relate them to some empirical observations with regard to patent litigation and we draw some conclusions.

Text fragments that might be better placed in the conclusions....

However, litigation rates are relatively low (according to Lanjouw and Schankerman (2001) only 1 % of their investigated patents are ever litigated), but is much higher for valuable patents. Bessen and Meurer (2013) come to very similar conclusions, but nevertheless diagnose a litigation explosion because the probability of being sued per dollar of R&D expenditure has increased significantly (by 70%) during the nineties.

Many patent holders spent a lot of resources on litigating other firms for the infringement of their patents, whereas other seem to be more reluctant to do so (**here we need some nice references or well-known cases which confirm this statement!!!**).

2 The General Model

We consider a game between an incumbent I and two potential entrants E_1 and E_2. The incumbent has an innovation which is patented and whose market value can either be high or low. If the incumbent is the only firm in the market, it realizes an expected monopoly profit of π_M^i, with $i \in \{H, L\}$ relating to the high or low value of the innovation. If the incumbent and one of the two potential entrants are active in the market, they produce differentiated products and they each realize the same expected duopoly profit of π_D^i with $i \in \{H, L\}$. If the incumbent and both potential entrants are active in the market, all three firms each realize the same triopoly profit of π_T^i with $i \in \{H, L\}$. Throughout the paper we make the following two assumptions about the expected monopoly, duopoly and triopoly profits and the respective profits, given that the incumbent's innovaton has a high or a low value

$$\pi_M^i > \pi_D^i > \pi_T^i \text{ with } i \in \{H, L\},$$

$$\pi_j^H > \pi_j^L \text{ with } j \in \{M, D, T\}.$$

The incumbent knows whether his innovation has a high or a low value, meaning whether his type i is H or L. The two potential entrants, while being able to imitate the incumbent, do not know whether the market value is high or low. They only know the probability p (or $1-p$) with which a high (or low) market value arises. Their market entry is always observed by the incumbent.

The entrants E_1 and E_2 each have to bear the same entry costs of F, if they enter the market, and decide sequentially about their entry. After E_1 has entered, the incumbent I can decide to litigate E_1 for the infringement of its patent. If I litigates, it has litigation costs of S and expected litigation benefits of L^i with $i \in \{H, L\}$ and $L^H > L^L$. If a court decides that the incumbent's patent is violated or if the two parties privately settle the case after litigation, E_1 must pay licensing fees. Given litigation, the expected licensing fees that E_1 must pay, are identical with I's expected litigation benefits L_i. Note that we do not consider here how licensing fees/litigation benefits or the incumbent's litigation costs can be influenced by the involved parties strategies before going to court, their strategies pursued in courts or when bargaining about licensing fees in private settlements of court cases, and wether the use of particular strategies during these processes might also signal private information.[2] Throughout we assume that $L^i \leq \pi_D^i$ holds and that the respective size of the specific litigation benefit realized after litigation are not observable for the potential second entrant E_2. E_2 can only observe whether the incumbent has litigated E_1 or not and knows I's litigation costs S and the potential sizes of the litigation benefits L^H and L^L in case of a high or a low market value. After the potential entry of E_2, the game ends, and I has no further opportunity to litigate E_2. The extensive form of this sequential game is illustrated in figure 1.

[2]See e.g. Jeitschko and Kim (2012) who analyze the use of preliminary injunctions or Crampes and Langinier (2002) who analyse the incumbent's monitoring efforts to identify potentially infringing entrants.

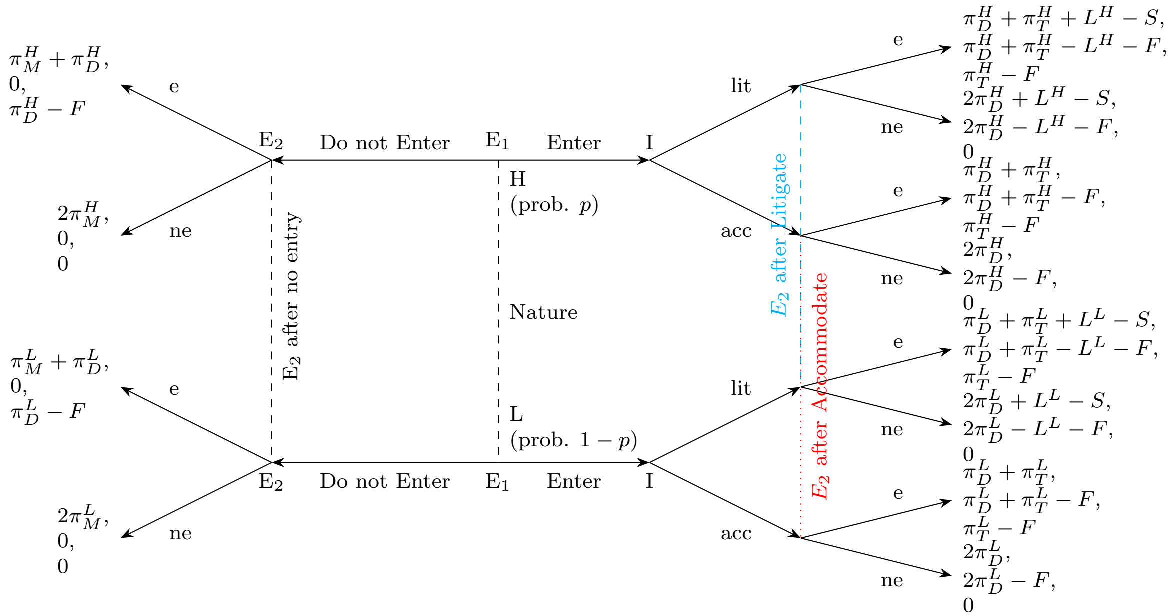

Figure 1: *Game in Extensive Form*

3 Litigation Decisions in the General Model

The sequential game with incomplete information depicted in figure 1 needs to be solved by backward induction. By doing so we can distinguish two situations, one where the second entrant's decision to enter the market is independent of its beliefs about the value of the innovation/market it can potentially enter, and another one, where the second entrant's beliefs about the value of the innovation influences its entry decision.

3.1 The Second Entrant's Market Entry is Independent of its Beliefs about the Innovation's Value

The second entrant's market entry is independent of its beliefs if, it either always or never enters the market, no matter whether the incumbent's innovation is of type H or L. Let us assume for now that the first entrant, E$_1$, has entered the market, then the second entrant

E_2 always enters the market if

$$F < \pi_T^L < \pi_T^H \tag{1}$$

holds. If this condition is satisfied, then, due to our assumptions, this also implies $F < \pi_D^L < \pi_D^H$, meaning the first entrant, E_1 always enters the market if it were sure not to be litigated by the incumbent. Given that E_1 has entered and that condition 1 holds, the incumbent I with $i \in \{H, L\}$, anticipating E_2's entry, litigates if

$$\pi_D^i + \pi_T^i + L^i - S \geq \pi_D^i + \pi_T^i,$$

$$\Leftrightarrow L^i \geq S \text{ holds.} \tag{2}$$

Let us now assume that the first entrant, E_1, has entered the market, but that the second entrant E_2 never enters the market due to

$$F > \pi_T^H > \pi_T^L. \tag{3}$$

Here the incumbent litigates the first entrant E_1 if

$$2\pi_D^i + L^i - S \geq 2\pi_D^i$$

holds which simplifies to the same condition (2) for the incumbent to litigate the first entrant as before. Thus, we can derive the following proposition.

Proposition 1 *If the second entrant's entry decision does not depend on the type of the incumbent's innovation, because it either always enters (condition (1) is satisfied) or never enters (condition (3) is satisfied), then the incumbent of type i with $i \in \{H, L\}$ litigates the first entrant, if its litigation benefits exceed its litigation costs and condition (2) is fulfilled. If the second entrant always enters and condition (1) holds, then the first entrant also always* *enters the market. If the second entrant never enters and condition (3) holds, then it depends on the level of the entry costs, whether the first entrant enters the market or not.*

Proof: See the argument above and Appendix A for further details. □

The fact that the incumbent litigates the first entrant can be informative about the value of the innovation, if $L^H > S > L^L$ holds. However, as long as the value of the innovation does not matter for the third entrant's entry decision, the incumbent's decision to litigate nevertheless only depends on the direct expected benefits and costs of litigation. As we can see in the next section, this changes, if the second entrant's market entry decision depends on the value of the innovation.

3.2 The Second Entrant's Market Entry Depends on its Beliefs about the Innovation's Value

The second entrant's, E_2's, entry decision depends on its belief about the value of the innovation/market, if

$$\pi_T^H > F > \pi_T^L \tag{4}$$

holds. For the remainder of this paper we assume that condition (4) is fulfilled. We first investigate whether litigating the first entrant can convey any information to the second entrant and potentially deter its entry. Thus, we derive conditions for the existence of signalling equilibria. Afterwards we also consider potential pooling equilibria.

3.2.1 Do Signalling Equilibria Exist?

Let us for the start assume that the second entrant has the following belief structure with

$$q = \begin{cases} 1 & \text{if } \mathrm{E}_1 \text{ has entered and I has litigated } \mathrm{E}_1, \\ 0 & \text{if } \mathrm{E}_1 \text{ has entered and I has accommodated } \mathrm{E}_1\text{'s entry}, \\ p & \text{if } \mathrm{E}_1 \text{ has not entered}, \end{cases} \tag{5}$$

being the second entrant's belief that the incumbent's innovation and thus the market into which it could potentially enter has a high value. In a separating signalling equilibrium these expectations must be fulfilled. Therefore, given these beliefs of the second entrant, the incumbent should have an incentive to litigate the first entrant, if its innovation is of type H and to accommodate the entry of the first entrant, if its innovation is of type L. For this to be true

$$\pi_D^H + \pi_T^H + L^H - S > 2\pi_D^H \text{ and } 2\pi_D^L > \pi_D^L + \pi_T^L + L^L - S$$

must hold which is equivalent to

$$L^L - (\pi_D^L - \pi_T^L) < S < L^H - (\pi_D^H - \pi_T^H). \tag{6}$$

Thus we can conclude the following.

Proposition 2 *If the second entrant E_2 has the beliefs described in equation (5), a separating signalling equilibrium exists, if condition (6) holds. In such an equilibrium the incumbent litigates E_1 only, if its innovation has a high value, which then triggers the respective belief of the second entrant and its market entry. If the incumbent's innovation has a low value, the incumbent does not litigate E_1, which then triggers the second entrant's respective belief of a low market value, such that E_2 does not enter the market.*

Proof: See the argument above. □

Note that if the conditions of proposition 2 are fulfilled, then inaction, meaning not litigating the first entrant, can be an entry deterring strategy. This is the case, if the second entrant's prior beliefs p are such that

$$p\pi_T^H + (1-p)\pi_T^L \geq F \Leftrightarrow p \geq \frac{F - \pi_T^L}{\pi_T^H - \pi_T^L} \equiv \underline{p}, \tag{7}$$

the second entrant's expected profit from entering the market would ex ante be positive. Then not observing the incumbent litigating the first entrant, triggers the updated belief of $q = 0$ and induces the second entrant to not enter the market. Usual entry deterring strategies imply to take a costly action (for example distorting one's prices or one's quantity decisions). Here it implies to not take an action and to not litigate a competitor who infringes one's patent.

Note that from the outset we cannot exclude an alternative separating signalling equilibrium where the second entrant holds the alternative beliefs

$$\tilde{q} = \begin{cases} 0 & \text{if } \mathrm{E}_1 \text{ has entered and I has litigated } \mathrm{E}_1, \\ 1 & \text{if } \mathrm{E}_1 \text{ has entered and I has accommodated } \mathrm{E}_1\text{'s entry}, \\ p & \text{if } \mathrm{E}_1 \text{ has not entered}, \end{cases} \tag{8}$$

This could be the basis for an alternative separating signalling equilibrium if the following conditions hold

$$2\pi_D^L + L^L - S > \pi_D^L + \pi_T^L \text{ and } \pi_D^H + \pi_T^H > 2\pi_D^H + L^H - S,$$

which can be summarized to

$$L^H + (\pi_D^H - \pi_T^H) < S < L^L + (\pi_D^L - \pi_T^L). \tag{9}$$

This leads to proposition 3.

Proposition 3 *If the second entrant E_2 has the beliefs described in equation (8), a separating signalling equilibrium exists, if condition (9) holds. In such an equilibrium the incumbent litigates E_1 only, if its innovation has a low value, which then triggers the respective belief of the second entrant such that it does not enter the market. If the incumbent's innovation has a high value, the incumbent does not litigate E_1 which triggers the second entrant's respective belief of a high market value and E_2's market entry.*

Proof: See the argument above. □

Here entry deterrence could also occur under the same condition as described in (7) and the entry deterring strategy would imply to take a costly action as in the classical approaches to entry deterrence. Note, however, that condition (9) can only be fulfilled in very extreme cases where π_T^H is so much larger than π_T^L that it can make up for the fact that in our setting $L^H + \pi_D^H > L^L + \pi_D^L$ always holds. We will see in section 4 that in the linear model, we investigate there, the condition (9) for a separating signalling equilibrium, where the low value incumbent litigates and the high value incumbent does not do so, is never fulfilled. The condition (6), which allows for entry deterrence by inaction, can to the contrary be fulfilled in that model.

3.2.2 Do Pooling Equilibria Exist?

For pooling equilibria to exist the second entrant must have beliefs which either imply that litigation does not convey any information and both types of incumbents want to litigate, given this belief, or they imply that accommodation does not convey any information and, given this belief, both types of incumbents do not want to litigate. Let us start with the first belief which might support a pooling equilibrium

$$\hat{q} = \begin{cases} p & \text{if E}_1 \text{ has entered and I has litigated E}_1, \\ 1 & \text{if E}_1 \text{ has entered and I has accommodated E}_1\text{'s entry}, \\ p & \text{if E}_1 \text{ has not entered.} \end{cases} \tag{10}$$

Given this belief the second entrant always enters if $p > \underline{p}$ or equivalently condition (7) holds, which implies that its market entry is profitable in expectation. Given the second entrant's belief $\hat{q}$ the incumbent always prefers to litigate the first entrant if

$$\pi_D^H + \pi_T^H + L^H - S \geq \pi_D^H + \pi_T^H \text{ and } \pi_D^L + \pi_T^L + L^L - S \geq \pi_D^L + \pi_T^L,$$

hold, which is equivalent to

$$L^H > L^L \geq S. \tag{11}$$

Note that the first entrant does also always enter if $p > \underline{p}$ and condition (11) are satisfied.

Now assume the same belief $\hat{q}$ for the second entrant, but that the second entrant never enters because $p < \underline{p}$ or equivalently that condition (7) no longer holds. Then the incumbent still always litigates, given this belief for the second entrant, if

$$2\pi_D^H + L^H - S \geq 2\pi_D^H \text{ and } 2\pi_D^L + L^L - S \geq 2\pi_D^L$$

hold which also simplifies to condition (11). Additionally anticipating that E_2 never enters and the incumbent always litigates, given that E_2 has the belief $\hat{q}$, E_1 must still want to enter, meaning

$$p(2\pi_D^H - L^H) + (1-p)(2\pi_D^L - L^L) > F \text{ must hold.}$$

Thus we can state the following proposition.

Proposition 4 *A pooling equilibrium exists in which the second entrant has the belief $\hat{q}$ as defined in equation (10) and where the first entrant always enters, the incumbent always litigates*

(i) and the second entrant also always enters if condition (11)and (7) hold.

(ii) and the second entrant never enters, if condition (11) and

$$p(2\pi_D^H - L^H) + (1-p)(2\pi_D^L - L^L) > F > p\pi_T^H + (1-p)\pi_T^L \text{ hold.}$$

Proof: See the argument above. □

Let us now consider the alternative belief

$$\check{q} = \begin{cases} 1 & \text{if } \mathrm{E}_1 \text{ has entered and I has litigated } \mathrm{E}_1, \\ p & \text{if } \mathrm{E}_1 \text{ has entered and I has accommodated } \mathrm{E}_1\text{'s entry}, \\ p & \text{if } \mathrm{E}_1 \text{ has not entered.} \end{cases} \tag{12}$$

Again, let us first assume that the second entrant always enters, after observing that the incumbent accommodates and does not litigate the first entrant. This requires that $p > \underline{p}$ or, equivalently, that condition (7) holds. Then, for the incumbent to always accommodate the entry of the first entrant, it must be the case that

$$\pi_D^H + \pi_T^H \geq \pi_D^H + \pi_T^H + L^H - S \text{ and } \pi_D^L + \pi_T^L \geq \pi_D^L + \pi_T^L + L^L - S,$$

hold which is equivalent to

$$S \geq L^H > L^L. \tag{13}$$

Note that in this case the first entrant, anticipating that the incumbent always accommodates and that the second entrant always enters, also always want to enter.

Now assume that $p \leq \underline{p}$ or, equivalently, that condition (7) is not satisfied. Then the second entrant, holding the belief $\check{q}$ and observing that the incumbent does not litigate the first entrant, never enters. For a pooling equilibrium to exist in which the incumbent independent of its type always accommodates the first entrant's market entry, anticipating no further entry, requires that

$$2\pi_D^H \geq 2\pi_D^H + L^H - S \text{ and } 2\pi_D^L \geq 2\pi_D^L + L^L - S,$$

which is equivalent to condition (13). In order for the first entrant to always enter the market, anticipating that the incumbent accommodates its entry and that the second entrant does not enter, the following must be true

$$p(2\pi_D^H) + (1-p)(2\pi_D^L) > F.$$

Thus, we have identified a second potential pooling equilibrium.

Proposition 5 *A pooling equilibrium exists in which the second entrant has the belief $\check{q}$ as defined in equation (12) and where the first entrant always enters, the incumbent never litigates*

(i) and the second entrant also always enters, if condition (13)and (7) hold.

(ii) and the second entrant never enters, if condition (13) and

$$p(2\pi_D^H) + (1-p)(2\pi_D^L) > F > p\pi_T^H + (1-p)\pi_T^L \textit{ hold.}$$

Proof: See the argument above. □

We have now derived the relevant conditions for the existence of pooling equilibria, and in the previous subsection also for separating signalling equilibria, given relatively general assumptions. However, in order to get a better feeling which equilibria might become relevant in a relatively standard model we will not turn to a fully linearized version of our model.

4 The Linear Model

We consider now a special case of our model which is fully linearized. In this model the demand functions for the differentiated products which are potentially provided by the incumbent and the two entrants are derived from maximizing a quasi-linear utility function for a representative consumer under a budget constraint

$$\max_{q_1,\dots,q_n} V = U(q_1,\dots,q_n) + q_0 \text{ s.t. } \sum_{k=1}^{n} p_k q_k + q_0 \leq m,$$

with $q_1, \dots, q_n$ being the products potentially provided by the incumbent and the two entrants, and q_0 being the numéraire. We assume a quadratic utility function $U(q_1, \dots, q_n)$ which is a symmetric version of the quasi-linear quadratic utility function on which Choné and Linnemer (2020) base their analysis with

$$U(q_1,\dots,q_n) = a\sum_{k=1}^{n} q_k - \sum_{k=1}^{n}\sum_{l>k}^{n} \sigma q_k q_l - \frac{b}{2}\sum_{k=1}^{n} q_k^2 \text{ with } b > \sigma.$$

In our setting we can either have a monopoly market with only the incumbent firm active, or a duopoly market with only the incumbent and one entrant active or a triopoly market where the incumbent and both entrants are active. Solving the maximization problem for these three cases yield the (symmetric) demand function(s) for each active firm k, l with $k \neq l$

$$q_{kM} = \frac{a - p_k}{b} \text{ if the incumbent is the only active firm,}$$

$$q_{kD} = \frac{b(a - p_k) - \sigma(a - p_l)}{b^2 - \sigma^2} \text{ if the incumbent and one entrant are active with } k \neq l,$$

$$q_{kT} = \frac{b(a - p_k) - \sigma(a + p_k - \sum_{l \neq k} p_l)}{(b - \sigma)(b + 2\sigma)} \text{ if the incumbent and both entrants are active with } k \neq l.$$

We also assume that all three firms, the incumbent and the two potential entrants, have the same cost function

$$C(q_k) = cq_k.$$

If the incumbent is the only firm in the market it sets monopoly prices. With one or both entrants active the firms are in a Bertrand competition. The respective monopoly or symmetric Bertrand equilibrium prices are

$$p_M = \frac{a - c}{4b},$$

$$p_D = \frac{a(b - \sigma) + bc}{2b - \sigma}$$

$$p_T = \frac{a(b - \sigma) + (b + \sigma)c}{2b}.$$

The profit of each firm k in the respective market scenario, can be calculated by first substituting the respective demand function and subsequently the respective monopoly or equilibrium price in the profit function

$$\pi_j = (p_i - c)q_{kM} \text{ with } j \in M, D, T.$$

Equivalently, the consumer surplus for each of the three market scenario can be calculated by first substituting the respective demand function and subsequently the respective monopoly

Scenarios	Monopoly	Duopoly	Triopoly
Profits	$\pi_M^H = \frac{v^2}{4b}$	$\pi_D^H = \frac{b(b-\sigma)v^2}{(2b-\sigma)^2(b+\sigma)}$	$\pi_T^H = \frac{(b+\sigma)(b-\sigma)v^2}{4b^2(b+2\sigma)}$
Consumer Surplus	$U_M^H = \frac{v^2}{8b}$	$U_D^H = \frac{b^2v^2}{(2b-\sigma)^2(b+\sigma)}$	$U_T^H = \frac{3(b+\sigma)v^2}{8b^2(b+2\sigma)}$

Table 1: *Profits and Consumer Surplus in the Different Scenarios and with a High Market Value*

or equilibrium prices in the consumer surplus function

$$U_j = U(q_1, \ldots, q_n) - \sum_{k=1}^{n} p_k q_k \text{ with } j \in M, D, T.$$

In table 1 we have summarized the monopoly and equilibrium outcomes of this linear model in terms of profits and consumer surplus, given that the innovation/ the market has a high value. Note that we use the following definition

$$v \equiv a - c,$$

and assume that $v > 0 \Leftrightarrow a > c$ always holds. To keep it simple, we assume that in case of a low market value the variable v in table 1 must be substituted by v' with

$$v' = \lambda v \text{ and } \lambda \in (0, 1).$$

We already assumed that the incumbent's expected litigation benefits (or the first entrant's expected licensing fees) L^i can never exceed the (duopoly) profit that the first entrant can realize in the first stage of the game. Now we also assume that

$$L^i = \alpha \pi_D^i, \tag{14}$$

meaning that the expected litigation benefit (or equivalently the expected licensing fees) are a fixed ratio of the first entrant's profit in the first stage of the game, independent of the value of the innovation/market. Finally we define

$$\sigma \equiv \gamma b \text{ with } \gamma \in (0,1).$$

4.1 Separating Signalling Equilibria in the Linear Model

From proposition 2 we know that a separating signalling equilibrium in which the incumbent signals a low market value by not litigating the first entrant if condition (6) holds. In this simple linearized model this condition can now be expressed by

$$y_1 \equiv \frac{(1-\gamma)\lambda^2[4\alpha(1+2\gamma)-\gamma(4+(3-\gamma)\gamma(1+\gamma))]}{4(2-\gamma)^2(1+\gamma)(1+2\gamma)} < \frac{bS}{v^2} \tag{15}$$
$$< \frac{(1-\gamma)[4\alpha(1+2\gamma)-\gamma(4+(3-\gamma)\gamma(1+\gamma))]}{4(2-\gamma)^2(1+\gamma)(1+2\gamma)} \equiv y_2,$$

which gives a lower and an upper bound for the litigation costs (normalized by v^2/b), as long as the term in the cornered brackets in the numerator of the two expressions on the left- and righthand side of condition (15) is positive. Note that for this to be true $\alpha > \underline{\alpha}$ with

$$\underline{\alpha} \equiv \frac{\gamma[4+(3-\gamma)\gamma(1+\gamma)]}{4(1+2\gamma)}, \quad \lim_{\gamma\to 1}\underline{\alpha} = \frac{2}{3} \text{ and } \frac{\partial\underline{\alpha}}{\partial\gamma} > 0 \text{ for } \gamma \in (0,1),$$

must hold. This means that the level of the litigation benefits (see our assumption (14)) needs to be sufficiently high such that a separating signalling equilibrium in which the high value incumbent litigates and the low value incumbent accommodates the first entrant exists in the linear model. The critical threshold of litigation benefits for the potential existence of this equilibrium is higher if the provided products by the incumbent and the entrant(s) are closer substitutes. Note that the threshold is defined for all levels of substitutability as measured by γ.

Now let us investigate whether the alternative separating signalling equilibrium as described in proposition 3 can also exist in our linear model. For a separating signalling equilibrium in which the low value incumbent litigates and the high value incumbent accommodates the first entrant can only exist, if condition (9) is satisfied which in our linear setting here can be represented by

$$\begin{aligned}\frac{(1-\gamma)[4\alpha(1+2\gamma)+\gamma(4+(3-\gamma)\gamma(1+\gamma))]}{4(2-\gamma)^2(1+\gamma)(1+2\gamma)} &< \frac{bS}{v^2} \\ &< \frac{(1-\gamma)\lambda^2[4\alpha(1+2\gamma)+\gamma(4+(3-\gamma)\gamma(1+\gamma))]}{4(2-\gamma)^2(1+\gamma)(1+2\gamma)}.\end{aligned} \tag{16}$$

This condition can never hold true, because the term on the left-hand side is always larger than the term on the right-hand side, and therefore we can state the following proposition.

Proposition 6 *In the linear model a signalling separating equilibrium in which the low value incumbent accommodates and the high value incumbent litigates the first entrant always exists, if the parameters of the model satisfy condition (15) which is never an empty parameter space. A signalling separating equilibrium in which the high value incumbent accommodates and the low value incumbent litigates the first entrant never exists.*

Proof: See the argument above. □

4.2 Pooling Equilibria in the Linear Model

The pooling equilibrium described in proposition 4 in which both types of incumbents always litigate the second entrant always exists if condition if the litigation benefits for both types are sufficiently high such that (11) is satisfied. In the linear model condition (11) is equivalent to

$$\frac{Sb}{v^2} < \frac{\alpha(1-\gamma)\lambda^2}{(2-\gamma^2)(1+\gamma)} \equiv x_1. \tag{17}$$

Similarly the pooling equilibrium described in proposition 5 in which both incumbents always accommodate the second entrant always exists if condition (13) is satisfied. This condition implies that the litigation benefits are sufficiently low. In the linear model condition (13) is equivalent to

$$\frac{Sb}{v^2} > \frac{\alpha(1-\gamma)}{(2-\gamma^2)(1+\gamma)} \equiv x_2. \tag{18}$$

Note that the parameter sets for which one or the other pooling equilibrium exists are never overlapping and there exists always at most one of these two pooling equilibria.

4.3 Characterization of the Parameter Space for Different Equilibria

We already know that the two pooling equilibria never coexist. However, can pooling equilibria and the separating signalling equilibrium exist for the same parameters? The answer is yes. In figure 2 x-axis represents γ or the level of substitutability of the competing products and the y-axis represents Sb/v^2, the litigation costs normalized by v^2/b. The coloured lines represent the different relevant thresholds for the equilibria described before (y_1, y_2, x_1 and x_2). The figure is drawn for $\lambda = 0.7$ and $\alpha = 1/2$, but, while the specific numbers would of course change, its basic structure does not, if we choose different parameter values for λ and α.

The pooling equilibrium in which both types of incumbents accommodate the first entrant, exist to the north of the blue line and is the only equilibrium that exists for these parameter values. The pooling equilibrium in which both types of incumbents litigate the first entrant, exists to the south of the red line. The only separating signalling equilibrium in the linear model can be found between the orange and the green line. Obviously there is an area between the orange and the green line and to the south of the red line where both equilibria, the pooling equilibrium with both types litigating and the separating signalling

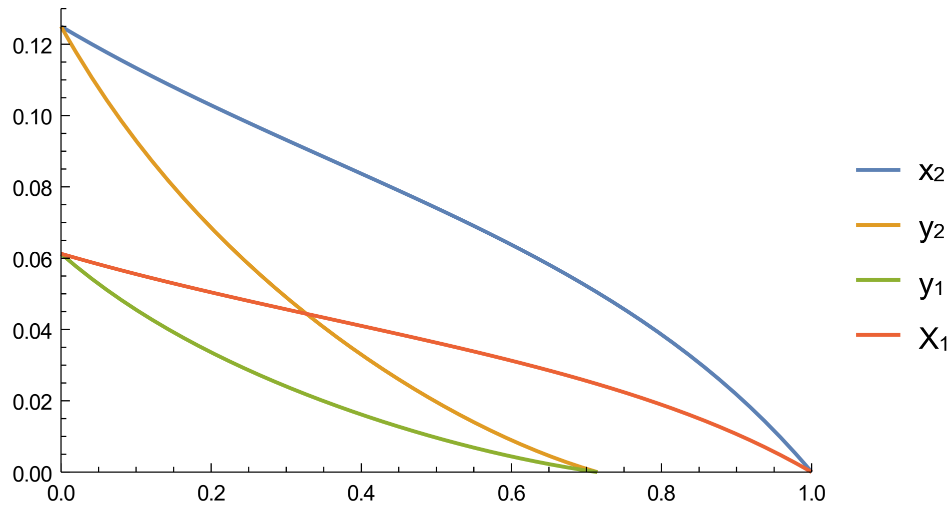

Figure 2: *Different Equilibria*

equilibrium where only the high value incumbent litigates, co-exist.

There is also an area between the blue and the red line and to the east of the orange line where neither of the equilibria, discussed up to now, exist. Here we will have partially pooling equilibria where the high value incumbent litigates the first entrant with a certain probability, whereas the low value incumbent never litigates.

To be continued with a characterization of the partially pooling equilibria

4.4 Discussion of Alternative Litigation Benefits

To be continued with the alternative assumption that the incumbent always gets the damage, the difference between its monopoly and duopoly profit

5 Discussion of Empirical Evidence

6 Conclusions

Appendix

A Proof of Proposition 1

Given condition (1) holds, we can distinguish three situations.

$L^H > L^L \geq S$: Given condition (1), the incumbent anticipates E_2's entry at a later stage and always litigates the first entrant, E_1, after its entry. The incumbent's litigation can therefore not convey any information about the innovation's value. E_1 anticipates that the incumbent will always litigate it after entry, but nevertheless enters the market because it realizes in expectation a positive profit from its market entry, since

$$p(\pi_D^H + \pi_T^H - L^H) + (1-p)(\pi_D^L + \pi_T^L - L^L) > F.$$

$S > L^H > L^L$: Given condition (1), the incumbent anticipates E_2 to always enter in the last stage of the game. The incumbent does nevertheless not litigate the first entrant E_1 after its market entry, because the costs exceeds the benefits of litigation. In stage one E_1 anticipates that the incumbent will not litigate and expects a profit of

$$p(\pi_D^H + \pi_T^H) + (1-p)(\pi_D^L + \pi_T^L) > F,$$

which exceeds the fixed costs of entry. Therefore both firms will enter without the incumbent litigating the first entrant.

$L^H > S > L^L$**:** Given condition (1), the incumbent anticipates that E_2 always enters in the last stage of the game. If E_1 has entered in the first stage of the game, the incumbent only litigates the first entrant, if the market value is high. Litigation here conveys information about the market value to the second entrant, but does not influence E_2's market entry. The first entrant E_1 still always enters the market because its expected profit exceeds the entry costs

$$p(\pi_D^H + \pi_T^H - L^H) + (1-p)(\pi_D^L + \pi_T^L) > F.$$

Let us now consider the same three cases, given that condition (3) holds.

$L^H > L^L \geq S$**:** Given condition (3), the incumbent always litigates the first entrant E_1, and, given E_1 has entered, anticipates E_2 never to enter in the last stage of the game. As before the incumbent's litigation cannot convey any information about the innovation's value. E_1 anticipates that the incumbent will always litigate it after entry, but will nevertheless enter if

$$p(2\pi_D^H - L^H) + (1-p)(2\pi_D^L - L^L) > F,$$

still holds. If this does not hold, which implies $F > p\pi_D^H + (1-p)\pi_D^L$, then neither the first nor the second entrant will enter the market and the incumbent does not litigate.

$S > L^H > L^L$**:** Given condition (3), the incumbent anticipates E_2 not to enter in the last stage of the game, given E_1 has entered in the first stage. The incumbent does not litigate E_1, if it enters the market in stage one, because the costs exceeds the benefits of litigation. In stage one E_1 anticipates that the incumbent will not litigate, and enters if its expected profit exceeds its fixed costs of entry

$$p(2\pi_D^H) + (1-p)(2\pi_D^L) > F.$$

If this is not the case, then neither E_1 nor E_2 will enter and the incumbent does not litigate.

$L^H > S > L^L$: Given condition (3), the second entrant E_2 never enters in the last stage of the game, no matter whether the market value is high or low. If E_1 has entered in the first stage of the game, the incumbent only litigates the first entrant, if the market value is high. Litigation conveys information about the market value to the second entrant without influencig E_2's decision not to enter the market. The first entrant E_1 enters the market if

$$p(2\pi_D^H - L^H) + (1-p)2\pi_D^L > F$$

holds. If it does not, which necessarily implies $F > p\pi_D^H + (1-p)2\pi_D^L$, then neither the first, nor the second entrant enters the market and the incumbent does not litigate.

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