LICENSING A STANDARD: FIXED FEE VERSUS ROYALTY.

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Abstract

This paper considers the allocation of essential patents by a profit maximizing monopoly. Using a model incorporating product differentiation and network externalities we show that fixed fee licences are optimal either when there is little competition downstream or when it is desirable to restrict entry. By opposition, royalty based licenses allows for more downstream firms (thanks to higher prices) and lead to a revenue which is less sensitive to more product homogeneity. They are optimal when downstream entry is desirable, which occurs either because there are positive network externalities, or for some intermediate values of product differentiation.

1 Introduction

The question of how to license the intellectual property rights that are embodied in an industry standard has become a hot topic in standard setting organizations. Part of the debate opposes those who advocate the adoption of royalty based licenses and those who prefer royalty-free licenses including eventually a fixed fee. Beyond arguments that are often ideological, economic theory can contribute to this debate by providing rigorous analyses and clear-cut results. In the economic literature early works have actually concluded that fixed fee licensing is a better way to maximize the profit of the licensor (Kamien and Tauman (1986), (1992)). Yet the paradox is that recent surveys find that most standards setting organizations rather rely on royalty-based licenses (Lemley (2002), Chiao, Lerner & Tirole (2005))[1]. In this paper we dissipate the paradox

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[1] Lemley (2002) surveys 29 standard setting organizations. He finds that RAND licenses are requested or required for patents in 16 of them, while royalty free licenses are used in only 3 cases. Chiao, Lerner and Tirole (2002) survey 59 standard setting organizations. Thirty six of them use RAND licenses while only six of them use royalty free licenses.

as we bring forward the advantages of both regimes and then show that under some conditions royalty based licenses can indeed outperform fixed fee licences.

Our approach is based on Kamien and Tauman (1986)-(1992). In these papers, the authors show that fixed fee is superior to a royalty regime, for both the patent holder and the consumers. They obtain this result by considering an oligopoly and homogeneous products with competition in quantity (Cournot) or prices (Bertrand). Muto (1993) and Caballero and al. (2002) show that royalty can become a superior policy for the patent holder as we introduce product differentiation. Both papers consider the licensing of a cost-reducing innovation to 2 firms competing in prices. We generalize their insights as we consider and a downstream oligopoly with competition in quantities. We also allow for compatibility gains resulting from indirect network externalities. The idea being that the value of a standard potentially depends on the number of different products it supports. These play an important role as a determinant of the benefits of limited entry.

We show that although consumers are always better off under a fixed fee regime, the licensor's profit maximizing choice depends on how competitive the downstream market is, on how close substitutes the products are and on the potentiality of compatibility gains. We also consider total surplus and show that the patent holder's favoured regime does not systematically maximize welfare.

There are two advantages of a fixed fee regime. First, it allows the patent holder to extract all downstream rents. Second, it permits to tune the number of licensees by fixing their entry cost. The royalty regime also has two advantages. First, while it does not always control for entry, it softens competition via higher costs. Second, it leads to a revenue that is less sensitive to the degree of product differentiation.

Without compatibility gains a licensee's profit decreases as more licenses are sold. As a result, the fixed fee is superior in two extreme cases: when downstream products are either nearly homogeneous or else very differentiated. In both cases the fixed fee is superior because it allows the licensor to extract close to monopoly profits from each licensee. In particular a single license is sold for the case of homogeneous products. In the intermediate cases, competition between the licensees prevails and the royalties are profit maximizing partly because they reduce price competition and partly because the revenue they generate is less sensitive to more homogeneity between downstream products.

As we introduce compatibility gains in our setting, we capture the specificity of markets exhibiting network externalities. In such markets, a firm's profits potentially increases as more licenses are sold. Then, there is no reason to limit entry. Thus, the fixed fee regime loses appeal. It only becomes superior to the royalty regime either when there are few downstream producers, or else when products are sufficiently differentiated. Besides, the greater the number of licensees, the more differentiated downstream products need to be for the fixed fee regime to be superior. We finally show that the same logic applies for the more realistic case where downstream profits increase with the number of licenses sold until a certain threshold beyond which they decrease. The only difference being that the fixed fee regime, due to its ability to limit entry, does better for a wider range of parameters.

We finally enrich our basic setting by introducing a fixed cost of developing a product upon the standard. As innovation upon a standard requires additional R&D investments, we do this to check the robustness of our results. The main implication of introducing fixed costs is that the licensor can control entry even with a royalty-based license, for too much competition does not permit to recover the fixed costs. We show that our general findings still hold, although adding a fixed cost tends to promote the use of a fixed fee when there are no compatibility gains and to promote the use of a royalty under strong compatibility gains.

In the next section we present the model. We then solve for three different setting exposed in two different sections: substitute products in section 3, and strong compatibility gains (or complementary outputs) and mitigated compatibility gains in section 4. Section 5 considers total welfare and section 6 is dedicated to the introduction of a fixed cost of production. We conclude in section 7.

2 The model

Consider an innovator who owns a patented technology which has no substitute and therefore constitutes an essential facility to enter a new market. This market is composed of n ($n \geq 1$) symmetric firms capable of using this technology to develop new products. We consider that there is imperfect competition on the product market and assume that firms compete à la Cournot. Let the demand function for product i, produced by firm i when k ($1 \leq k \leq n$) firms sell compatible products be given by:

$$p_i(q_i, Q_{-i}) = a(k) - q_i - \alpha Q_{-i},$$

where $i = 1, ..., k$ and $Q_{-i} = \sum_{j \neq i} q_j$. The total cost function is linear and such that $TC(q) = cq$. Assume that for any k we have $a(k) > c$, meaning that production of each product is worthwhile.

The parameter α measures either product substitutability when $0 < \alpha < 1$ or product complementarity when $-1 < \alpha < 0$. Indeed it has the same sign as the cross-elasticity between the firms' products. We will mostly focus on substitutes, yet we mention complements as we consider network externalities.

Parameter α is one key difference between this model and the setting developed by Kamien & Tauman (1986). Indeed they have focused on a market where products are homogeneous. Hence their results hold only for the particular case of our model where $\alpha = 1$.

Because downstream products are standardized, and thus compatible, the model incorporates the two following features:

First, it allows for potential compatibility gains which, if sufficiently significant, can increase a consumer's benefit of buying an item compatible with many others and thus his willingness to pay. Basically we consider that the value, to a consumer, of a specific item can increase as more compatible items are on the market. (An example of such items are children's toys. A household may be willing to pay more as a toy offers more mix and match possibilities.) This feature is accounted for via the parameter $a(k)$. It measures the highest willingness to pay of consumers when k compatible products are available on the market. While we initially consider $\frac{da}{dk} = 0$, which allows us to isolate the consequences of introducing product differentiation, we also analyze in details situations where $\frac{da}{dk} > 0$ a.e.. This second case captures positive network externalities.

Second we consider that complying with the standard is a requirement to enter the market. In particular, firms make no revenue if they do not buy the licence.

The patent policies are non discriminatory and described as follows:

-Under the fixed fee, the patent holder decides one fixed fee and each and every firm can buy or not the patent.

-Under royalty payment, the patent holder sets a fixed per unit royalty that each adopting firm must pay.

Auction is an alternative possibility to license a technology. However, given that we set the outside opportunity to zero (due to the necessity to comply with the standard) the outcome of an auction is equivalent to the fixed fee regime. Indeed, the main difference between an auction and a fixed fee regime lies in the fact that the numbers of licenses to be sold is fixed under an auction. Thus if the patent holder decides to auction N licences, each firm knows that N licensees will be marketing their product downstream whether it buys a licence or not. Under a fixed fee regime, there will be N licensees provided the N^{th} firm buys a licence given that $(N-1)$ firms did so. If the N^{th} firm does not buy a licence, there will only be $(N-1)$ licensees downstream. If it were possible to survive without a licence, a firm's willingness to pay for it would be the difference between how much it gets with it and how much it gets without it. What it gets without it depends on whether an auction or fixed fee is being used. In the setting we consider, a firm's willingness to pay for a licence is simply how much it gets with it. This benefit is the same under the auction and fixed fee regime.

The timing is the following: First the patent holder announces the patent policy (royalty versus fixed fee). Second, the firms decide to buy the licence or not (outside option is 0). Then firms, knowing how many competitors they face, compete a la Cournot.

An equilibrium in this game is defined as follows. The parameters (l^*, k^*)

form a Nash equilibrium under fixed fee and (r^*, k^*) form a Nash equilibrium under the royalty policy if the following 3 statements hold:

- Statement 1: Given a fixed fee $l = l^*$ or a royalty $r = r^*$, and given that $(k^* - 1)$ firms have adopted the new technology, it is in the best interest of firm k^* to adopt the technology.
- Statement 2: Given a fixed fee $l = l^*$ or a royalty $r = r^*$, and given that k^* firms have adopted the new technology, it is in the best interest of any other firm not to adopt the technology,
- Statement 3: The values of l^* or r^* maximize the patent holder's profit given that it will lead k^* firms to adopt the technology.

Output, price and profits under the fixed fee regime.
A fixed fee is a fixed cost paid up-front. Thus it does not affect the Cournot outcome. Each firm solves

$$\max_{q_i} \left[a(k) - q_i - \alpha Q_{-i}\right] q_i - c q_i.$$

Using the fact that they are symmetric, the equilibrium quantity is

$$q^F = \frac{a(k) - c}{2 + \alpha(k-1)}.$$

The resulting price at equilibrium verifies:

$$p^F - c = q^F.$$

And the equilibrium profit function is

$$\pi^F(k) = \left(\frac{a(k) - c}{2 + \alpha(k-1)}\right)^2. \tag{1}$$

Output, price and profits under the royalty regime.
Under the royalty regime each firm solves

$$\max_{q_i} \left[a(k) - q_i - \alpha Q_{-i}\right] q_i - (c + r)\, q_i,$$

where r refers to the royalty rate, and given that k firms adopted the technology. The unique symmetric equilibrium is such that

$$q^R = \begin{cases} \left(\dfrac{a(k) - c - r}{2 + \alpha(k-1)}\right) & \text{if } a(k) > c + r, \\ 0 \text{ otherwise.} & \end{cases}$$

The resulting symmetric price, provided there is production is such that

$$p^R - (c + r) = q^R.$$

And the equilibrium profit function is given by:

$$\pi^R(k) = \begin{cases} \left(\dfrac{a(k) - c - r}{2 + \alpha(k-1)}\right)^2 & \text{if } a(k) > c + r, \\ 0 \text{ otherwise.} \end{cases} \tag{2}$$

3 Focusing on product differentiation

We compare as a first step the fixed fee- and royalty-based licensing regimes in the most simple setting, with no network externality. Recall that Kamien and Tauman (1986) and Kamien and Tauman (1992) considered homogeneous products and deduced in such a setting that a fixed fee regime was revenue maximizing. Although we reach the same conclusion as $\alpha \to 1$, we show that this result no longer holds for all possible values of α.

Assume we have $a(k) = a > c$. This would reflect a situation where firms do not gain from the presence of compatible products. Under this assumption, profits decrease as the number of licensees increase:

$$\frac{d\pi^t}{dk} < 0 \text{ for } t = F, R.$$

We study successively the fixed fee and royalty regimes before comparing them as a third step.

Fixed fee regime

Under the fixed fee regime the licensor fixes the fee l, which in turn determines the number of licensees at equilibrium. For a given fee l^* and a number of licenses k^* to form an equilibrium, we must have

$$\pi^F(k^*) - l^* \geq 0 \tag{3}$$

and

$$\pi^F(k^* + 1) - l^* < 0. \tag{4}$$

The first condition guarantees full extraction of the surplus by the patent holder: $l^* = \pi^F(k^*)$. The second condition makes sure that no more firms than k^* firms will want to purchase a licence given that k^* firms hold one.

Since profits are decreasing, for any given $l \leq \pi^F(n)$, there exists a unique $\widehat{k}$ such that $l = \pi^F(\widehat{k})$. Moreover, at this price, entry would take place until $k = \widehat{k}$. Indeed, since $\pi^F(k)$ is decreasing, it would be true that $\pi^F(\widehat{k} + 1) - \pi^F(\widehat{k}) < 0$. Thus the revenue maximizing number of licences, k^*, solves

$$\max_k k\pi^F(k).$$

Lemma 1: *The revenue maximizing number of licences is given by*

$$k^* = \min\left\{\frac{2-\alpha}{\alpha}, n\right\}.$$

When the standard leads to the development of products that are close substitutes ($\alpha \to 1$) the innovator will set a high licence fee to have a single, monopolistic, user of the technology. As products issued from the standard are more differentiated, he will allow more firms to enter the industry.

Lemma 1 summarizes the licensor's strategy under the fixed fee regime. He will use the fixed fee to set the number of licensees that maximizes the general industry profits. If the products are perfectly homogeneous, the optimal number of licences is one. It is however profitable for the licensor to let the number of competitors increase when the products are more differentiated.

Royalty regime

Under the royalty, the patent holder's licensing policy determines the licensees' marginal cost. The licensor maximizes the following expression:

$$\max_{r,k} r.k(r).q^R(r,k)$$

such that

$$q^R(r,k) = \begin{cases} \dfrac{a-c-r}{2+\alpha(k-1)} & \text{if } a-c-r > 0 \\ 0 \text{ otherwise.} \end{cases}$$

If $r > (a-c)$ none of the firms will purchase the licence. If $r \leq (a-c)$ then all n firms will want to purchase the licence. Thus, the patent holder's profit is given by

$$\Pi^R(r) = \begin{cases} r.n.\dfrac{a-c-r}{2+\alpha(n-1)} & \text{if } r \leq a-c \\ 0 \text{ otherwise.} \end{cases}$$

Lemma 2: *The optimal royalty is given by $r^* = \frac{1}{2}(a-c)$. At this price all firms develop a product ($k^* = n$).*

The royalty regime does not allow the licensor to control the number of competitors: all the n firms will actually enter the market. The decision of the licensor then results from a complex trade-off between the direct revenue per unit of output which is sold, and the negative effect of the royalty on the number of outputs sold by each licensor. This situation is equivalent to double marginalization with imperfect competition downstream.

Comparing the 2 regimes.

Proposition 1 and Figure 1 sum up the results of the comparison, as regards respectively the choice of the licensor and the prices charged to consumers.

Proposition 1: *Whether or not entry is restricted consumers are better-off under the fixed fee regime ($p^R > p^F$). The patent holder's preference are shown in the graph below:*

See Figure 1.

Proof: See Appendix.

Consider Figure 1. When the standard either supports sufficiently differentiated products (α low) or appeals to very few users (n low), a fixed fee license granted to all is superior to a royalty-based license. Indeed it allows to extract all of the close to monopoly profits from each licensee.
Aside from these two situations, the fixed fee regime is no longer systematically profit maximizing. For any given k sold licenses, the revenue from either regime decreases as product become more homogeneous ($\alpha \to 1$). Yet, because the revenue from the royalty is proportional to quantity only it does not suffer as much from an increase in α as the fixed fee revenue which depends on both, price and quantity. Under a fixed fee the licensor can balance losses from an increased α via direct control over downstream competition. Notice in particular that as $\alpha \to 1$, we find that the fixed fee is superior because the licensor limits entry to only one firm. This corresponds to the findings in Kamien and Tauman (1986). This ability to limit entry is not always sufficient for the fixed fee to dominate. As it appears, the royalty prevails for some range of product differentiation.

Proposition 1 also states that, for any number n of firms with a degree α of product differentiation, prices will be lower under the fixed fee regime. This result would be straightforward for equal numbers of licensees, because the royalty increases the firms' marginal cost while the fixed fee is neutral as regards individual pricing decisions. Yet proposition 1 extends this intuition to the seemingly more ambiguous case where the fixed fee limits the number of competitors below n while all firms would compete under the royalty regime. Prices remain higher with the royalty in all cases. This implies for example that when products are nearly homogeneous and firms are numerous, the licensor will fix so high royalties that the competitive price will be higher than the monopoly price. We have here an interesting application of the Cournot (1836) double marginalization theorem to an industry where the downstream monopoly is replaced by differentiated competitors.

4 Introducing compatibility gains.

After having cleared the basic setting, we can now introduce compatibility gains that could result from network externalities. We study successively two settings. One, somehow extreme situation, where these externalities have a dominant impact on profits and one where the impact is mitigated by competition. The first situation allows us to consider the specific case of complementary outputs.

4.1 Dominant compatibility gains.

When outputs are complements ($\alpha \in (-1, 0)$ and $n = 2$), or when the consumers' willingness to pay increases significantly with k, we can reach a situation where

$$\frac{d\pi^t}{dk} > 0 \text{ for } t = F, R.$$

As in the basic case, we study successively the fixed fee and royalty regimes before comparing them as a third step.

Fixed fee regime

Lemma 3: *In equilibrium we have* $l^* = \pi(n)$ *and* $k^* = n$.

Proof: As argued in the above section, conditions (3) and (4) must hold in equilibrium. Suppose $l = \pi(k)$ with $k < n$, since $\pi(k+1) - \pi(k) > 0$, it would be beneficial for any other firm to buy a licence. Thus, entry cannot be restricted. Any licence fee $l = \pi(k) \leq \pi(n)$ will lead to the sales of n licences. Setting $l^* = \pi(n)$ is therefore the only consistent fee. It is moreover revenue maximizing since

$$n \in \arg\max_k k\pi(k).$$

Here the licensor will issue a license to all the firms because it can thereby maximize the value created by complementarity or network effects. The fixed fee furthermore allows it to appropriate the whole profit of the licensors. Note however that this equilibrium requires that all firms expect that n licenses will be issued, because $(n-1)$ products would not yield enough profit for a licensee to recover the fixed license fee.

Royalty regime

Lemma 4: *In equilibrium we have* $r^* = \dfrac{a(n) - c}{2}$ *and* $k^* = n$.

Proof: As long as $r \leq a(k) - c$, at least k firms will develop a product and pay the licence. Assume that the patent holder fixes the royalty at $r = a(k) - c$ for some $k \leq n$. Since $a(k)$ is increasing, we have $r + c < a(k+1)$, which means that any firm who did not develop a downstream product (if any) would be better-off doing so. Thus, for any $r \leq a(n) - c$ having all firms purchasing a licence is an equilibrium. Thus,

$$\Pi^R = r.n.\frac{a(n) - c - r}{2 + \alpha(n-1)}$$

As in the basic setting the licensor is not able to control the number of licensees. Yet it is not a problem because it is profitable for it to sell n licenses. By contrast with the fixed fee, the royalty does however not allow the licensor to extract the full profit of the licensees.

Comparing the regimes

We have

$$\Pi^F = n\left(\frac{a(n) - c}{2 + \alpha(n-1)}\right)^2,$$

and

$$\Pi^R = \frac{1}{4}n\frac{(a(n) - c)^2}{2 + \alpha(n-1)}.$$

Proposition 2: *Consumers are better-off under the fixed fee regime ($p^R > p^F$). The patent holder will favour the fixed fee regime if and only if $\alpha \leq \frac{2}{n-1}$. When 2 complementary outputs are produced, the fixed fee systematically dominates and prices are lower under this policy.*

Proof: See Appendix.

Figure 2 below illustrates proposition 2 for the case of substitutes.

See Figure 2

Figure 2 shows that a fixed fee is preferable either when products issued from the standard are sufficiently differentiated or complements or when the standard appeals to a reduced number of users. In all other cases, the royalty prevails. Indeed limiting entry is not desirable when there are network externalities. The problem is rather to limit price competition between the licensees when they are numerous or when the products are significantly substitutable. (Low prices would only divert the value created by the network effects to the consumers.) Because the royalty is an effective way to raise prices it is then a better policy.

4.2 Mitigated compatibility gains.

Let us now focus at a situation where $a(k)$ is such that profits are concave[2]. This reflects a situation where profits initially increase as more compatible products

[2] One possibity is to have $a(k)$ increasing and concave.

appear on the market but eventually decrease as competition becomes more substantial. In order to be able to solve, we need to introduce additional assumptions. We will assume that n represents

(i) the number of users that would exhaust all compatibility benefits: $\left.\frac{da}{dk}\right|_{k=n} = 0$,

(ii) while $n^* \leq \frac{n}{2}$ is the number of users maximizing the per profit revenue[3] $\left.\frac{d\pi^F}{dk}\right|_{k=n^*} = 0$.

Fixed fee regime

Lemma 5: *There exists a unique $k^* \in]n^*, n]$ and $l^* = \pi^F(k^*)$ forming an equilibrium. It is defined such that $k^* = n$ for all $\alpha \leq \frac{2}{n+1}$, while entry is restricted to some k^* for all $\alpha > \frac{2}{n+1}$, with $k^* > n^*$.*

Proof: See appendix.

As the network effect are mitigated, restricting entry is once again potentially desirable. Interestingly, the number of licenses that maximizes the licensor's payoff is always superior to the number of licensees that maximizes a firm's willingness to pay.

Royalty regime

Lemma 6 presents our results under the royalty regime.

Lemma 6: The only equilibrium is to set $r^* = \frac{a(n) - c}{2}$ and sell $k^* = n$ licenses.

Proof: Because the function $a(k)$ is increasing any $r \leq a(n) - c$ will sell n licenses. Indeed assume that the patent holder sets a royalty at some level $r = a(k) - c$. Then it is true that $a(k+1) - c > r$, and therefore the $(k+1)^{th}$ firm should also develop the product and pay the royalty. Thus the patent holder solves the same problem as the one presented in the proof of lemma 4.

Under the royalty regime the licensor is not able to limit the number of licensees. It can just set a higher royalty in order to extract the consumers' willingness to pay which is due to the network effect.

Comparing the regimes

[3] The assumption according to which $n^* \leq \frac{n}{2}$ is more restrictive than actually needed.

Let us now compare the two regimes in order to deduce the licensor's optimal licensing policy and its impact on the prices charged to consumers. Proposition 3 sums up our results.

Proposition 3: *Whether entry is restricted or not we always have $p^R > p^F$. Thus, once again, consumers are better-off under the fixed fee regime. The patent holder preferences are such that there exists a unique $\overline{n}$, such that $\Pi^F > \Pi^R$ for all $n \leq \overline{n}$. For each and every $n > \overline{n}$, there exists a unique decreasing function $\alpha(n)$, such that*

$$\Pi^R = \Pi^F \Leftrightarrow \alpha = \alpha(n),$$

and

$$\Pi^R \geq \Pi^F \Leftrightarrow \alpha \geq \alpha(n).$$

Graphically we have:

See Figure 3

Proof: See Appendix.

The patent holder issues more licences than what is required to maximize downstream profits when using a fixed fee. In a general context it can easily be shown that for any $n^* < n$ such that $\frac{d\pi^F}{dk} = 0$ at $k = n^*$, we always have $k^* > n^*$. Indeed, the optimal number of licences (k^*) solves

$$(n - k^*) \frac{d\Pi^F}{dk} = (n - k^*) \left(l^* + k^* \left. \frac{d\pi^F}{dk} \right|_{k=k^*} \right) = 0.$$

Evaluated at n^*, the above expression is positive.

As opposed to the case of significant externalities, entry is now restricted under the fixed fee regime to counteract losses from the production of closer substitutes. Once again though, for a sufficiently large number of downstream users, the royalty regime dominates as products become closer substitutes, because it is a way to combine a high number of licensees and a mild price competition.

5 A note on welfare

In order to analyze welfare we need to identify total surplus. Following Vives (1999), we know that total surplus in an economy with differentiated item, with linear cost and linear demand can be written as

$$TS^T = U\left(q_1^T, ..., q_k^T\right) - \sum_{i=1,...k} cq_i^T$$

where T stands for the regime under consideration ($T = F, R$) and $U(.)$ is a quadratic utility function from a representative consumer:

$$U(q_1, ...q_k) = a(k) \sum_{i=1,...,k} q_i - \frac{1}{2}\left[\sum_{i=1,...k} q_i^2 + 2\alpha \sum_{\substack{j=1,...,k \\ j\neq i}} q_i q_j\right].$$

Given our results the total surplus for the fixed fee regime can be expressed as:

$$TS^F = \frac{1}{2}\left[\pi^F(k^*)\right]\left[3k^* + 2\alpha(k^*-1)^2\right]$$

and the total surplus for the royalty regime is given by:

$$TS^R = \frac{1}{2}\left[\pi^R(n)\right]\left[7n + 2\alpha(n-1)(2n-1)\right],$$

where $\pi^F(k^*)$ is given by (1) and $\pi^R(n)$ is given by (2) considering $r = \frac{1}{2}(a(n) - c)$.

Lemma 7: When $k^* = n$, the fixed fee regime leads to a higher total surplus. (The proof is straightforward and thus omitted.)

The intuition behind the above result is straightforward. The fixed fee regime with no entry restriction leads to the same number of products downstream as the royalty regime (one can verify that both total surplus increase with variety) but with lower prices. Thus total surplus is therefore higher under this regime. Given this lemma we know that under strong compatibility gains, selecting the royalty regime goes against the maximization of total surplus.

The question is whether $TS^R > TS^F$ when entry is restricted under the fixed fee regime. For the case of product differentiation only, $a(k) = a$, we know that for all $\alpha \geq \dfrac{2}{n+1}$ we have $k^* = \dfrac{2-\alpha}{\alpha}$. Substituting this value into TS^F we can compare the two surplus for different values of n. The following lemma summarizes our findings.

Lemma 8: Under product differentiation only, the exist a range of parameters α and n for which the royalty regime is selected and leads to a higher total surplus. The figure below represents this range.

(Proof: notice that the precise value of $(a - c)$ is irrelevant to compare the total surpluses. We used Excel and Mathematica to plot the total surpluses for different values of n.)

See figure 4

The dotted lines refer to figure 1. Finally for the case of mitigated compatibility gains, it depends on the function $a(.)$. Indeed, while

$$\left(\frac{a(k^*) - c}{2 + \alpha(k^*-1)}\right)^2 > \left(\frac{a(n) - c}{2 + \alpha(n-1)}\right)^2$$

we do not necessarily have

$$3k^* + 2\alpha(k^*-1)^2 > \frac{7n + 2\alpha(n-1)(2n-1)}{4}$$

for all $k^* > n^*$.

6 Introducing a fixed cost

In this section we test our results by introducing a fixed cost of developing an innovation upon the licensed standard. Indeed, it is reasonable to assume that the development of a new product can require some fixed investment. Let us assume that $TC(q) = cq + f$ for each firm. We consider only 2 extreme cases: one where there are no network externalities and one where these are dominant. In the first case restricting entry is desirable for close enough substitutes, in the second case entry must be encouraged.

Effect of the presence of fixed cost on a fixed fee regime

Let us assume that $\pi^F(1) > f$. Thus, a monopoly's earning is greater than the fixed cost. For a given fee l^* and a number of licenses k^* to form an equilibrium, we must have

$$\pi^F(k^*) - f - l^* \geq 0$$

and

$$\pi^F(k^* + 1) - f - l^* < 0.$$

Thus the patent holder will now solve

$$\max_k k\left[\pi(k) - f\right].$$

Lemma 9: *The presence of fixed cost reduces the revenue from the fixed fee regime and leads to more restricted entry to the downstream market.*
Proof. The above result stems from the fact that $k\left[\pi(k) - f\right] < k\pi\left(k\right)$ for any given k and that $\arg\max_k \left[\pi(k) - f\right] < \arg\max_k k\pi(k)$. ■

Effect of the presence of fixed cost on a royalty regime

The existence of a fixed cost yields a condition of entry that did not exist under the royalty regime in our precedent setting. Let us assume that $\pi^R(1, r = 0) > f$. Thus, a monopoly's earning is greater than the fixed cost provided there is no royalty to pay. For a given royalty r^* and a number of licenses k^* to form an equilibrium, we must have

$$\pi^R(k^*, r^*) - f \geq 0$$

and

$$\pi^R(k^* + 1, r^*) - f < 0.$$

In the absence of fixed cost, and since $a(.)$ is non-decreasing, all firms will buy the licence as long as $r < a(n) - c$. As seen, there is no possibility to restrict entry with a royalty in the absence of fixed costs. This is no longer systematically the case when there is a fixed cost. It will only remain true under dominant compatibility gains. In any other situations, for any given r, and any given α, there may exist $k(r, \alpha) < n$ such that

$$\pi^R(r, \alpha, k(r, \alpha)) > f,$$

while

$$\pi^R(r, \alpha, k(r, \alpha) + 1) < f.$$

An important consequence of this is that the licensor is now able to control the number of competitors with the royalty regime.

Comparing revenues in the absence of compatibility gains.

We can now compare the two regimes with fixed costs. In order to capture the impact of fixed costs we consider a situation where $(a - c) = 1$, and $f = 0.1$. Figure 4 represents how the area over which the royalty regime dominates has been affected as we introduced fixed fee. The grey area corresponds to the area where the royalty was superior in our initial setting, that is with $f = 0$. As $f = 0.1$, the royalty regime is profit maximizing within the lighter grey area.

See Figure 5

Under the fixed fee regime the licensor ends up paying for the entire fixed cost since

$$l^* = \pi(k^*) - f.$$

Under the royalty regime entry is not as costly to the licensor since the prevailing higher prices facilitate the recovery of fixed cost. This particular advantage of the royalty explains why this regime takes over the fixed fee regime for low values of α. As product differentiation increases, entry should be promoted and the royalty is then a better tool.

The royalty regime's superiority for greater values of α lied in the fact that the revenue it generated was not as sensitive to an increase in α as the revenue issued from a fixed fee. This advantage disappears when entry is restricted. In such cases, the revenue simply equals the fixed cost which does not depend on α. Thus for close substitutes the fixed fee regime which allows a direct control on the number of firms entering the market and a full appropriation of their profits takes over the royalty regime.

Comparing revenues under dominant compatibility gains.

In that situation, it is never desirable (nor possible) to limit entry. Since $\pi^F(k)$ is increasing in k, any licence fee affordable to k downstream innovators, is profitable to $(k+1)$, $(k+2)$ ... up to n innovators. Similarly for the royalty regime. Assume that r is set such that $\pi^R(k, r) - f \geq 0$ so that at least k innovators would buy a licence we necessarily have $\pi^R(k+1, r) - f \geq 0$, since profits are increasing with the number of licensees. The fact that entry is not restricted has a drawback: for sufficiently high values of α, and sufficiently high values of f, the patent holder may get no rents for firms may not be able to recover their fixed cost when products are close substitutes. To recover fixed cost, either products need to be sufficiently differentiated and/or a substantial number of users need to buy the license for compatibility gains to increase profits.

Proposition 4: *In the case of significant compatibility gains,* $k^* = n$

$$r^* = \begin{cases} \frac{1}{2}\left(a(n) - c\right) \text{ for } \alpha < \underline{\alpha}, \\ r_\alpha \text{ such that } \pi^R(r_\alpha, \alpha, n) = f \text{ for } \alpha \in \left[\underline{\alpha}, \overline{\alpha}\right], \\ 0 \text{ for } \alpha > \overline{\alpha}, \end{cases}$$

where $\underline{\alpha}$ *is defined such that*

$$\pi^R(n, r, \underline{\alpha}) = f \text{ at } r = \frac{1}{2}\left(a(n) - c\right)$$

and $\overline{\alpha}$ *is defined such that* $r_{\overline{\alpha}} = 0$.

The optimal license fee is such that

$$l^* = \begin{cases} \pi^F(n) - f \text{ for } \alpha < \overline{\alpha}, \\ 0 \text{ otherwise.} \end{cases}$$

(The intuition below explains how we proceeded to establish those results.)

Basically, the royalty is the same as the optimal royalty defined in absence of fixed cost as long as downstream profits are high enough to cover the fixed cost. Then, as α increases, the royalty decreases so as to always accommodate n entrants. Eventually, the patent holder may not be in a position to charge anything as even with a zero royalty firms would not enter. The optimal license fee is equal to profits as long as they are positive. Since $\pi^R(n, r = 0) = \pi^F(n)$, the value of α above which entry is not occurring is the same ($\alpha = \overline{\alpha}$). We use a model wherein $c = f = 1$, to evaluate graphically the impact of a fixed cost. For such parameters we have

$$\underline{\alpha} = \frac{1}{2} - \frac{2}{n-1},$$

and

$$\overline{\alpha} = 1 - \frac{2}{n-1}.$$

The patent holder's revenue is then given by

$$\Pi^R = \begin{cases} \frac{n}{4}\frac{(n-1)^2}{2+\alpha(n-1)} \text{ for } \alpha \leq \underline{\alpha}, \\ n\left[(n-1)(1-\alpha) - 2\right] \text{ for } \alpha \in \left[\underline{\alpha}, \overline{\alpha}\right], \\ 0 \text{ for } \alpha \geq \overline{\alpha}, \end{cases}$$

and

$$\Pi^F = \begin{cases} n\left[\left(\frac{(n-1)}{2+\alpha(n-1)}\right)^2 - 1\right] \text{ for } \alpha \leq \overline{\alpha}, \\ 0 \text{ for } \alpha \geq \overline{\alpha}. \end{cases}$$

Graphically we have:

See Figure 6.

Figure 5 shows how the region over which fixed fee is favoured has been affected by the addition of fixed cost. The arrows indicate that product differentiation needs to be more stringent for the fixed fee regime to be selected. This is due to the fact that entry must always be promoted under strong externalities. As explained above, entry is more costly under the fixed fee regime which explains why it loses to the royalty regime.

7 Conclusion

The results established in this paper may be summarized by stating that the superiority of the fixed fee regime is not as general as it seemed. Its main advantages lie in the ability for the licensor to extract all of the generated surplus and to directly control entry. It therefore prevails in the 3 following cases:

(i) when there are few competitors downstream

(ii) when products are sufficiently differentiated so that each firm has significant market power

(iii) when it is desirable to restrict entry, which is particularly true when there are no compatibility gains.

A royalty based regime controls for more downstream competition through higher prices and leads to a revenue which is less sensitive to more product homogeneity. It takes over the fixed fee regime whenever entry restriction is not an immediate concern.

There are many other reasons why the royalty regime can prevail. Consider for instance that the licensor is not able to assess perfectly downstream revenues as he may not know each licensees' production cost. He may then have to set low fixed fees to guarantee that the higher cost users will buy a licence (recall that discrimination is generally illegal). A royalty offers the advantage of leading to a revenue correlated to each licensee's outcome. Thus a revenue that is greater for lower cost downstream producers. In such settings, if restriction of entry is not always desirable, the requirement to set low fixed fees for these to be accepted by higher cost producer may discourage licensor to used such a policy.

Appendix

Proof of proposition1.

In equilibrium, we have

$$\Pi^F = k^* \left[\frac{(a-c)}{(2+\alpha(k^*-1))} \right]^2,$$

where $k^* = \min \left\{ \frac{2-\alpha}{\alpha}, n \right\}$, and

$$\Pi^R = \frac{1}{4} n \frac{(a-c)^2}{(2+\alpha(n-1))}.$$

When $\alpha \leq \frac{2}{n+1}$, we have $k^* = n$ and for all such cases

$$\Pi^F > \Pi^R \Leftrightarrow \alpha < \frac{2}{n-1},$$

which is systematically true.

When $\alpha > \frac{2}{n+1}$, we have $k^* = \frac{2-\alpha}{\alpha}$ and for all such cases

$$\Pi^F > \Pi^R \Leftrightarrow n < \frac{2-\alpha}{\alpha(1-\alpha)}.$$

The per regime, symmetric, prices may be written as

$$p^F = \frac{a-c}{D(k^*)} + c,$$

and

$$p^R = \frac{1}{2}(a+c) + \frac{1}{2} \frac{(a-c)}{D(n)},$$

with

$$D(x) = 2 + \alpha(x-1) > 2.$$

Thus, after simplifications, we get

$$p^R > p^F \Leftrightarrow D(n)\left(D\left(k^*\right) - 2\right) + D\left(k^*\right) > 0,$$

which is always true.

Proof of proposition 2.

The comparison of revenues is trivial and therefore omitted.

To compare the prices, simplifications lead to

$$p^R - p^F = r^* \frac{1 + \alpha(n-1)}{2 + \alpha(n-1)} > 0.$$

(Proving the dominance of the fixed fee regime for complementary outputs is obvious as we set $n = 2$.)

Proof of Lemma 5.

The range of license fee that we are interested in is $\left[\min\left\{\pi^F(1), \pi^F(n)\right\}, \pi^F(n^*)\right]$. Any licence fee above this range would lead to no sale, and below that range would lead to selling n at a price too low to maximize revenue. For any $l \in \left[\min\left\{\pi^F(1), \pi^F(n)\right\}, \pi^F(n^*)\right]$ there may be one or two values for k such that $\pi^F(k) = l$.

Suppose that $\pi^F(1) < \pi^F(n)$. In that case we must have $l^* \geq \pi^F(n)$ since any $l \in \left[\pi^F(1), \pi^F(n)\right]$ would sell more licenses than desired. For each $l \in \left[\pi^F(n), \pi^F(\frac{n}{2})\right]$ there are 2 values of k such that $l = \pi^F(k)$. However, only the highest one can form an equilibrium with free entry since $\pi^F(k)$ must be decreasing at the equilibrium level of k. Thus, to guarantee that no other firm will want to purchase the license we must have $\left.\frac{d\pi}{dk}\right|_{k=k^*} \leq 0$. In that case, the patent holder solves

$$\max_k k\pi^F(k)$$

$$\text{such that } k = \max\left\{x : \pi^F(x) = \pi^F(k)\right\}.$$

The solution, $k = k^*$ solves

$$(n - k^*)\left(l^* + k^* \left.\frac{d\pi}{dk}\right|_{k=k^*}\right) = 0. \tag{5}$$

We have

$$\left.\frac{d}{dk}k\pi^F(k)\right|_{k=n} = q^F(n)\left[(a(n) - c)\left(\frac{2 - \alpha(n+1)}{2 + \alpha(n-1)}\right) + 2n \left.\frac{da(k)}{dk}\right|_{k=n}\right].$$

Since $\left.\frac{da(k)}{dk}\right|_{k=n} = 0$ by assumption, we have $k^* = n$ for any $\alpha \leq \frac{2}{n+1}$. When $\alpha > \frac{2}{n-1}$, we have $\left.\frac{d}{dk}k\pi^F(k)\right|_{k=n} < 0$ and thus entry is limited. For (5) to hold, the optimal number of licensees must be such that $\left.\frac{d\pi}{dk}\right|_{k=k^*} < 0$, which implies that $k^* > \frac{n}{2}$. This, together with the concavity of $\pi(.)$ guarantees that the second order condition holds:

$$k^* \left.\frac{d^2\pi^F}{dk^2}\right|_{k=k^*} + 2 \left.\frac{d\pi^F}{dk}\right|_{k=k^*} < 0.$$

Thus the solution to (5) such that $\left.\frac{d\pi^F}{dk}\right|_{k=k^*} < 0$ is indeed an equilibrium.

If $\pi^F(1) > \pi^F(n)$, any $l \in \left[\pi^F(n), \pi^F(1)\right]$ potentially forms an equilibrium since for any such l, there exists a unique k such that $l = \pi^F(k)$, and profits would be decreasing at any such k. Thus both, first order and second order conditions would hold.

Proof of proposition 3.

Prices. We have

$$p^F - c = \frac{a(k^*) - c}{2 + \alpha(k^* - 1)}$$

with $k^* \leq n$, while

$$p^R - c = \frac{a(n) - c}{2 + \alpha(n-1)} \frac{3 + \alpha(n-1)}{2}.$$

Since $a(k)$ is increasing in k, we have $a(k^*) \leq a(n)$, which leads to (after simplifications)

$$p^F - c \leq \left(p^R - c\right) \frac{2\left(2 + \alpha(n-1)\right)}{\left(2 + \alpha(k^* - 1)\right)\left(3 + \alpha(n-1)\right)} < p^R - c.$$

Profit maximizing regime. We can rewrite the revenues from both regime as:

$$\Pi^R = \frac{n}{4}\left(2 + \alpha(n-1)\right)\pi^F(n),$$

and

$$\Pi^F = \max_{k \leq n} k\pi^F(k).$$

From such expressions one can deduce that for any $\alpha \leq \frac{2}{n-1}$ the fixed fee will achieve a higher (or equal) revenue since for such α

$$\frac{n}{4}\left(2 + \alpha(n-1)\right)\pi^F(n) < n\pi^F(n) \leq \max_{k \leq n} k\pi^F(k).$$

Consider any $\alpha > \frac{2}{n-1}$. For any such α, there exists a unique $\alpha(n)$ such that, for a given n,

$$\Pi^R = \Pi^F \Leftrightarrow \alpha = \alpha(n),$$

and

$$\Pi^R \geq \Pi^F \Leftrightarrow \alpha \geq \alpha(n).$$

Moreover, $\frac{d\alpha(n)}{dn} < 0$.

1-Existence of $\alpha(n)$.

At $\alpha = \dfrac{2}{n-1}$,

$$\Pi^R = n\pi^F(n) < \max_{k \le n} k\pi^F(k) = \Pi^F$$

since entry is restricted. Then, as $\alpha \to 1$, both revenues decrease. At $\alpha = 1$

$$\Pi^R = \frac{n}{4}(n+1)\pi^F(n) > \max_{k \le n} k\pi^F(k) = \Pi^F,$$

for n sufficiently large, this inequality holds. Note that $\overline{n}$, is necessarily unique since once can check that Π^R increases (strictly) with n, while Π^F is immune to a change in n when entry is restricted, as it is when $\alpha = 1$.

Thus for $n > \overline{n}$, there exists at least one $\alpha(n)$ such that

$$\Pi^R = \Pi^F \Leftrightarrow \alpha = \alpha(n),$$

and

$$\Pi^R \ge \Pi^F \Leftrightarrow \alpha \ge \alpha(n).$$

2-Uniqueness

The variable $\alpha(n)$ is unique since we have

$$\left| \frac{d\Pi^F}{d\alpha} \right| > \left| \frac{d\Pi^R}{d\alpha} \right|,$$

whenever $\Pi^F = \Pi^R$. In words, whenever they cross, the profit from the fixed fee regime is steeper. Thus, since the profit functions are decreasing in α, they may only cross once.

After simplifications (using the chain rule) we have

$$\left| \frac{d\Pi^F}{d\alpha} \right| = 2\frac{(k^* - 1)}{2 + \alpha\,(k^* - 1)} k^* \pi^F(k^*),$$

and

$$\left| \frac{d\Pi^R}{d\alpha} \right| = \frac{(n-1)}{4} n\pi^F(n).$$

We must evaluate both slopes at $\alpha(n)$ defined such that

$$\frac{n}{4}\left(2 + \alpha\,(n-1)\right)\pi^F(n) = k^* \pi^F(k^*).$$

Using this prior equality we can simplify the derivatives and find that, at $\alpha = \alpha(n)$

$$\left| \frac{d\Pi^F}{d\alpha} \right| > \left| \frac{d\Pi^R}{d\alpha} \right| \Leftrightarrow k^* \ge \frac{2(n+1) + \alpha(n-1)}{4 + \alpha(n-1)},$$

which holds since $\dfrac{2(n+1) + \alpha(n-1)}{4 + \alpha(n-1)} < \dfrac{n}{2}$ for any $\alpha > \dfrac{2}{n-1}$, while $k^* > \dfrac{n}{2}$.

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Figures

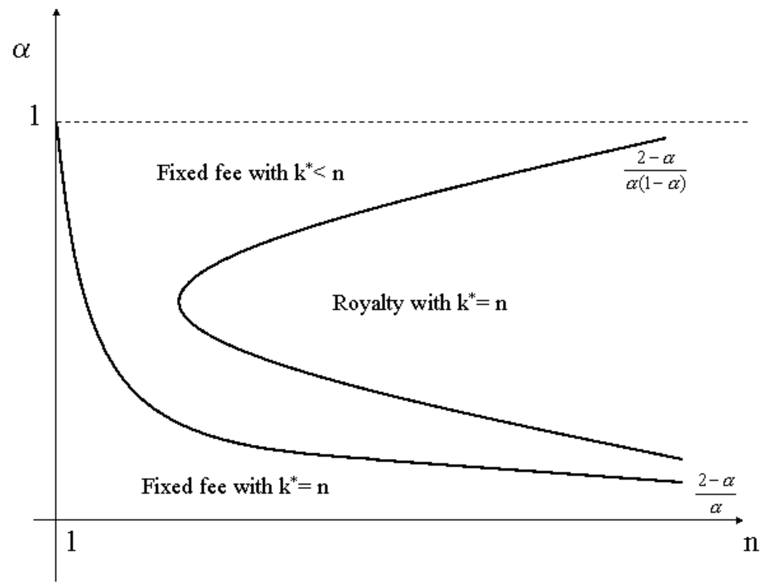

Figure 1: Figure 1: Optimal policy under product differentiation.

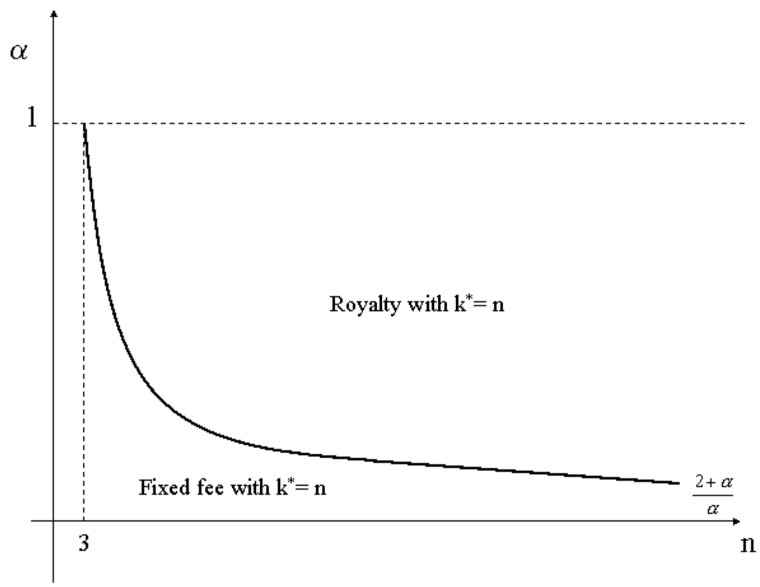

Figure 2: Optimal policy under dominant compatibility gains.

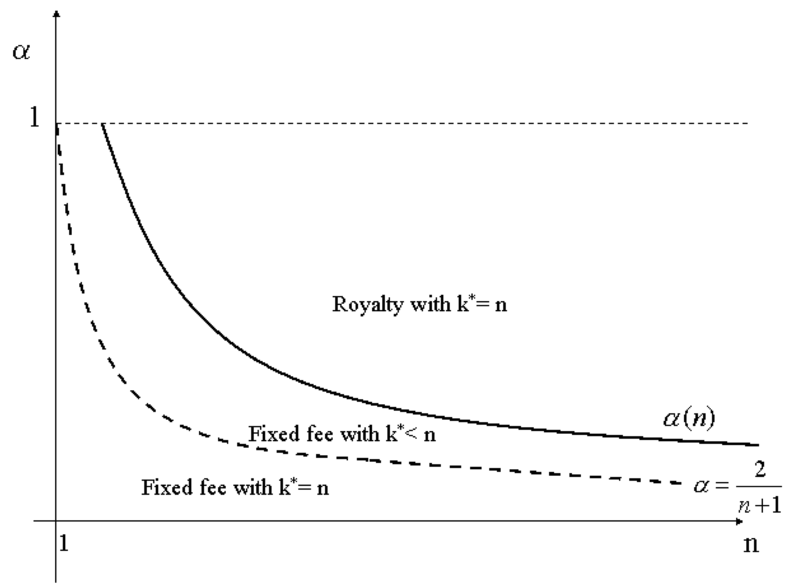

Figure 3: Optimal policy under mitigated compatibility gains.

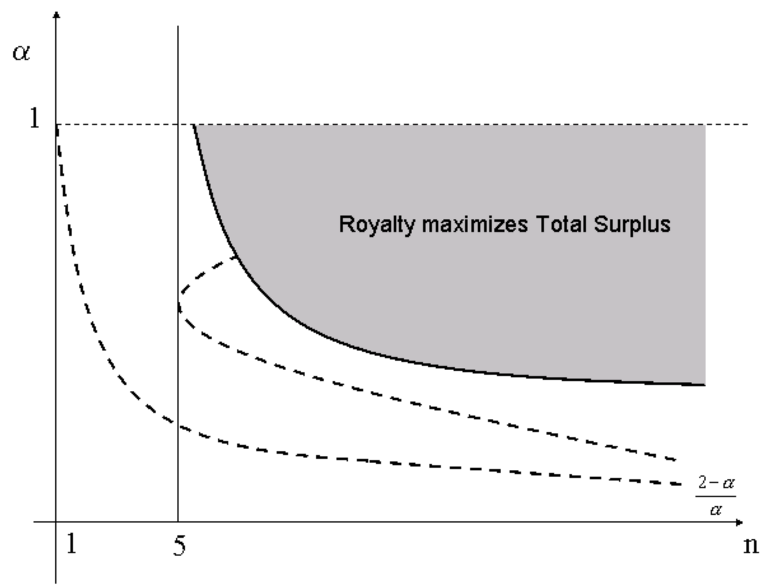

Figure 4: Total Surplus and Royalty regime

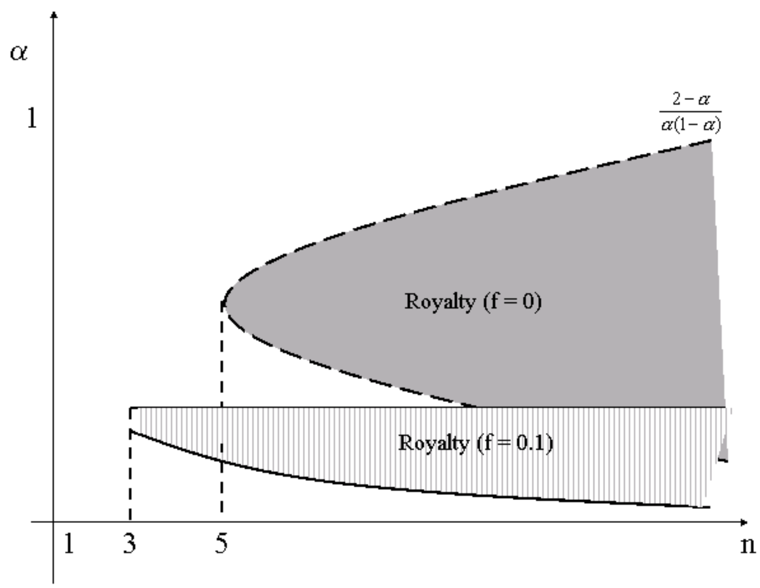

Figure 5: Impact of a fixed fee under product differentiation.

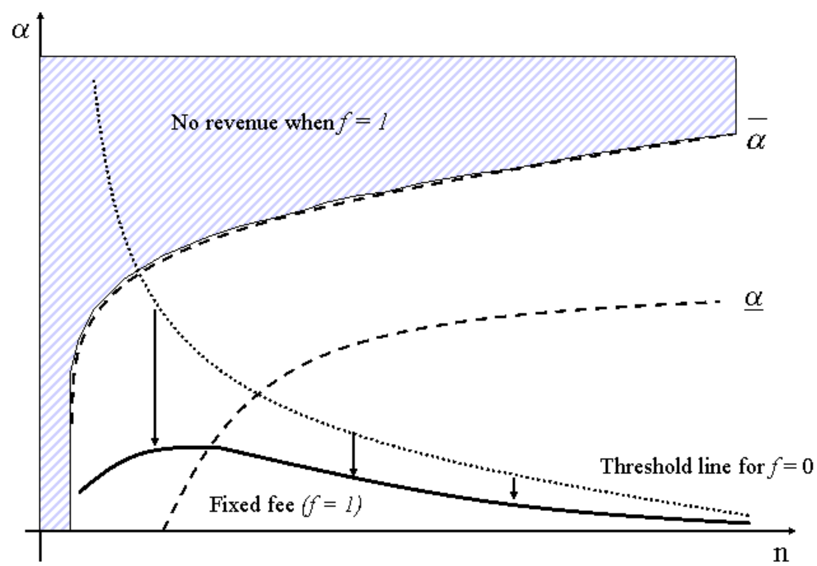

Figure 6: Impact of a fixed fee under strong compatibility gains.