# Patent licensing in a Cournot duopoly from high-cost firm to low-cost firm ⋆

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**Abstract:** We study the optimal patent licensing under Cournot duopoly where the technology transfer takes place from an innovative firm, which is relatively inefficient in terms of production costs to its cost-efficient rival. We determine the output levels at the Nash equilibrium and the corresponding profits of the firms. We found that the optimal licensing arrangement often involves a two part tariff, i.e. fixed fee plus a linear per unit output royalty. Furthermore, we show that the fixed fee decreases as the slope parameter increases, and the royalty does not depend upon the slope parameter of the demand curve.

Keywords: Game Theory, equilibrium, innovation, efficiency enhancement, technology transfer.

## 1. INTRODUCTION

Patent licensing is a fairly common practice that takes place in almost all industries. It is a source of profit for the innovator (also called patentee) who earns rent from the licensee by transferring a new technology. In the literature of patent licensing, two types of patentees are studied closely, namely, the outsider patentee and the insider patentee. When the patentee is an independent R&D organization and not a competitor of the licensee in the product market, it is an outsider patentee; whereas when it competes with the licensee it becomes an insider patentee. So far, the studies of insider and outsider patentee are done separately in different models. The results for optimal licensing policies under a complete information framework are: if the patentee is an outsider, a fixed fee licensing is optimal to the patentee (see Kamien (1992), Kamien and Tauman (2002), and Katz and Shapiro. (1986)); whereas a royalty licensing is optimal to the patentee when the patentee is an insider (see Marjit (1990), Rockett (1990) and Wang (1998)). First, no study has been done to reconcile these two results. Secondly, in general, a new technology is transferred from a firm who is at least as cost efficient as the recipient firm (and in many cases it is the more efficient one). However, no story of technology transfer is modeled when the relative cost efficiencies go other way and a new technology is transferred from a relatively cost inefficient firm to a more efficient firm.

Poddar and Sinha (2005) studied optimal licensing arrangements when a new technology is transferred from a firm which is relatively cost-inefficient in the pre-innovation stage compared to the recipient firm, and provided a framework to bridge the literature on external and internal patentees. The purpose of this work is to do a similar study, by considering a more general inverse demand function. As in Poddar and Sinha (2005), we assume that, in the pre-innovation stage, the patentee is less cost-efficient than the licensee in terms of production of output. When they are equally efficient (or the patentee is more efficient), we are back to the existing literature of patent licensing with internal patentee. Now, as the patentee becomes less efficient, it is as if it becomes "less internal" because it has less profits to defend on its own account. In the limit when it is very inefficient compared to licensee, it becomes, in fact, an external patentee. In our framework with asymmetric costs, as in Poddar and Sinha (2005), we endogenize this particular feature of licensing arrangements. Thus, as the degree of cost asymmetry changes, we go from one extreme to another.

As in Poddar and Sinha (2005), we consider an initial costs asymmetry in the pre-innovation stage, which plays a crucial role in determining the licensing policy of the patentee. Poddar and Sinha proved that fixed fee is optimal for licensing the technology if the initial production cost difference of the two firms are large and royalty is optimal when the initial production cost configurations are very close (see Poddar and Sinha (2005)). We get the same results, and, moreover, we find that the fixed fee decreases with the slope parameter, and the royalty does not depend on the slope parameter of the demand curve. We know from the literature that fixed fee licensing is optimal when the patentee is an outsider and the royalty licensing is optimal when the patentee is an internal firm in a complete information framework. Thus, the previous results are consistent with the optimal licensing policy obtained for internal and external patentees under complete information. Interestingly, when the degree of cost asymmetry is moderate, in the case of non-drastic innovation, a two-part tariff policy is shown to be optimal for the patentee. However, as in Poddar and Sinha (2005), we get that drastic technology is licensed under royalty if the initial cost asymmetry is small and under fixed fee if

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the initial cost asymmetry is large. Moreover, under drastic innovation, a two-part tariff is shown to be always optimal irrespective of the degree of initial cost asymmetry. This result is interesting as we are able to prove the optimality of a two-part tariff licensing even under a complete information framework with homogenous product [1]. However, in this particular context, we provide the rational for a two-part tariff licensing using only the feature of pre-innovation asymmetric costs conditions of the competing firms [2]. Thus, this paper provides an explanation of two-part tariff licensing which is often observed in reality [3].

The paper is structured as follows. In Section 2, we lay down the basic framework and describe competing firms' payoff under no licensing agreement. Main analysis on optimal licensing is done in Sections 3 and 4. Section 3 deals with case of non-drastic innovation and Section 4 with drastic innovation. Finally, Section 5 concludes.

## 2. THE BASIC FRAMEWORK

Consider a Cournot duopoly model with firms producing a homogenous product. The inverse demand function is given by $p = a - bQ$, where $p$ denotes price and $Q$ represents aggregate industry output. The parameters $a > 0$ and $b \geq 1$ are, respectively, the intercept and slope parameters from the demand curve. Initially firms are asymmetric: firm $F_1$, the innovative firm, has marginal cost of production $c_1$ and firm $F_2$ has $c_2$. Without loss of generality, we assume $c_1 > c_2$, so that the innovative firm is the inefficient firm in terms of cost of production. We assume in the pre-innovation stage (i.e. when $c_1 > c_2$), even if firm $F_1$ is inefficient compared to firm $F_2$, yet both firms are active and producing positive quantities, which implies $a - 2c_1 + c_2 > 0$. We also assume that firm $F_1$ is the R&D intensive firm and comes up with a successful cost reducing innovation. After innovation its marginal cost becomes $c_1 - \varepsilon$, where $\varepsilon > 0$ is the amount of cost reduction. The new production cost $c_1 - \varepsilon$ of firm $F_1$ can be greater than or less than $c_2$ depending on the size $\varepsilon$ of innovation. In this paper, we do not explicitly model the R&D part of the innovative firm, since we begin our analysis after the innovation takes place. We will consider both cases of drastic and non-drastic innovation, that depends on the actual size of the cost reduction $\varepsilon$. Following the usual definition of drastic and non-drastic innovation, we say that the innovation is drastic if the rival firm is unable to compete profitably after the innovation if not licensed and stops production; while the innovation is non-drastic if the rival still remains in business, and produces positive output without being licensed. To capture these two situations formally, we need to look at the ensuing competition after innovation when the innovator does not license the innovation to its rival.

### *2.1 No Licensing*

When firm $F_1$ and firm $F_2$ compete in quantities after innovation with production costs $c_1 - \varepsilon$ and $c_2$, respectively, the Nash equilibrium quantities are:

$$q_1 = \frac{a - 2c_1 + c_2 + 2\varepsilon}{3b} \quad \text{and} \quad q_2 = \frac{a + c_1 - 2c_2 - \varepsilon}{3b}.$$

The innovation is drastic when $q_2 = 0$, and the innovating firm $F_1$ remains as a monopoly, i.e. when $\varepsilon \geq a + c_1 - 2c_2$; otherwise, the innovation is non-drastic.

Profits of firms under drastic innovation are:

$$\pi_1^{NL} = \frac{(a - c_1 + \varepsilon)^2}{4b}, \ \pi_2^{NL} = 0. \tag{1}$$

Profits of firms under non-drastic innovation are:

$$\pi_1^{NL} = \frac{(a - 2c_1 + c_2 + \varepsilon)^2}{9b}, \ \pi_2^{NL} = \frac{(a + c_1 - 2c_2 + \varepsilon)^2}{9b}. \tag{2}$$

### *2.2 Licensing*

In the following analysis we are going to consider three licensing policies offered by firm $F_1$, namely (i) (per unit) royalty; (ii) (lump-sum) fixed fee; and (iii) a two part tariff, i.e. a fixed fee plus royalty.

We consider the following three stage licensing game. In the first stage, the patent holding firm $F_1$ decides whether to license out the technology. Licensing reduces the marginal cost of the rival by $\varepsilon$ [4]. In case it offers to license out the technology, it charges a payment from the licensee (a fixed licensing fee or a royalty rate or a combination of both royalty and fixed fee). In the second stage, the firm $F_2$ decides whether to accept or reject the offer made by firm $F_1$. Firm $F_2$ accepts any offer if it receives weakly greater payoff from acceptance than rejection. In the last stage, both firms compete as Cournot duopolists with quantities as the choice variables.

## 3. NON-DRASTIC INNOVATION $(0 < \varepsilon < A + C_1 - 2C_2)$

To discuss a meaningful story of licensing by firm $F_1$, we also need to assume that the size of innovation is such that $c_2 - \varepsilon > 0$ for the rest of the analysis. Let us now consider the general licensing scheme involving both fixed fee and

[1] So far, the theoretical studies which try to explain the prevalence of a two-part tariff licensing contract can be found in models with incomplete (asymmetric) information or uncertainty (see Bousquet et al. (1998), Gallini and Wright (1992), Macho-Stadler et al. (1991)). In the context of differentiated goods, the optimality of two part tariff licensing contract is analysed by Fauli-Oller and Sandonis (2002).

[2] Interestingly, Rockett showed that in a model with complete information if the patentee firm is actually the efficient one (in contrast to our case considered here), then under the possibility of imitation by the licensee, the optimal licensing contract can be of two-part tariff. In our case, as in Poddar and Sinha (2005), we obtain the optimal two-part tariff licensing without any possibility of imitation by the licensee. In Rockett's case with no possibility of imitation, the optimal contract is pure royalty (see Rockett (1990)).

[3] Rostoker in a firms survey finds out royalty plus fixed fee (i.e. a two-part tariff) licensing accounts for 46 percent of the licensing arrangements, royalty alone 39 percent and fixed fee alone 13 percent (see Rostoker (1983)). Similar studies by Taylor and Silberston (1973) find that arrangements with royalties or a mixture of fixed fee and royalty are far more common than a simple fee.

[4] As an example, think of a situation where two firms use two different types of technologies but they use one common device, which can be improved upon using the innovation; or in the case where firms use the same technology, consider they are at the different stages of technological frontier and a common invention can improve both. Under such circumstances, it is always possible for the innovator to reduce the costs of production of both the firms equally, using the new innovation.

a linear royalty per unit of output (i.e. as two part tariff). Note that fixed fee and royalty licensing are special cases of this generalized licensing scheme. Suppose that the firm $F_1$ decides to license the innovation by offering a contract $(f, r)$, where $f$ is fixed fee charged upfront and $r$ is royalty rate per unit of output produced by the licensee. Both $f, r \geq 0$ and $r \leq \varepsilon$.

Suppose that the firm $F_2$ accepts the licensing contract $(f, r)$. The firm $F_2$'s profit would be

$$\frac{(a + c_1 - 2c_2 + \varepsilon - 2r)^2}{9b} - f.$$

In case the firm $F_2$ does not accept the licensing contract, it receives a payoff

$$\frac{(a + c_1 - 2c_2 - \varepsilon)^2}{9b}.$$

Thus, for a given $r$, the firm $F_2$ would accept the licensing contract if the fixed fee is not greater than

$$f = \frac{(a + c_1 - 2c_2 + \varepsilon - 2r)^2}{9b} - \frac{(a + c_1 - 2c_2 - \varepsilon)^2}{9b}.$$

So the firm $F_1$ can at the most charge this $f$ as fixed fee. The firm $F_1$'s payoff under this licensing contract would be its own profit in the product market due to competition plus the fixed fee it charges and the royalty revenue it receives. Thus, the firm $F_1$'s total payoff is

$$\begin{aligned}\pi_1^{f+r} = & \frac{(a - 2c_1 + c_2 + \varepsilon + r)^2}{9b} + \\ & + \frac{(a + c_1 - 2c_2 + \varepsilon - 2r)^2}{9b} - \frac{(a + c_1 - 2c_2 - \varepsilon)^2}{9b} + \\ & + r\frac{a + c_1 - 2c_2 + \varepsilon - 2r}{3b}. \qquad (3)\end{aligned}$$

The unconstrained maximization with respect to $r$ of the above payoff function yields

$$r = \frac{a - 5c_1 + 4c_2 + \varepsilon}{2}. \qquad (4)$$

Nowz, depending on the parameter configuration we have the following three distinct possibilities.

*Case (i)*: $c_1 \leq (a + 4c_2 - \varepsilon)/5$.

Given the restriction that $r < \varepsilon$, the optimal royalty rate is $r^* = \varepsilon$. Furthermore, given the optimal $r^*$, it is also clear from the expression of fixed fee above that $f^* = 0$.

*Case (ii)*: $(a + 4c_2 - \varepsilon)/5 < c_1 < (a + 4c_2 + \varepsilon)/5$.

In this case, the optimal royalty would be

$$r^* = (a - 5c_1 + 4c_2 + \varepsilon)/2.$$

We note that $0 < r^* < \varepsilon$. Therefore, in this case, there would be fixed fee also. Thus, we have two part tariff licensing scheme.

*Case (iii)*: $c_1 \geq (a + 4c_2 + \varepsilon)/5$.

From (4), we get $r \leq 0$ . Applying to the natural restriction $r \geq 0$, we argue that the optimal royalty rate is $r^* = 0$, and the patentee would charge a fixed fee only. The optimal amount of fixed fee is, in this case,

$$f^* = \frac{(a + c_1 - 2c_2 + \varepsilon - 2r)^2}{9b} - \frac{(a + c_1 - 2c_2 - \varepsilon)^2}{9b},$$

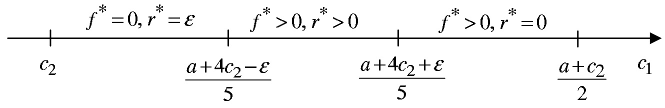


Fig. 1. Characterization of the optimal licensing contract.

which is positive. Figure 1 characterizes the optimal licensing contract. So, we have two-part tariff licensing under non-drastic innovation for the parameter configurations described in case (ii). It is interesting to note that when the initial production cost difference of the two firms are large, then only fixed fee is charged; and when the initial production cost difference is small, then only royalty is charged. However, when the initial production cost difference is in some intermediate level, we find the existence of two part tariff as the optimal licensing contract.

The next theorem summarizes what we have proved above.

*Theorem 1.* Under non-drastic innovation ($0 < \varepsilon < a + c_1 - 2c_2$), the optimal licensing policy is as given below.

(a) If $c_1 \leq (a + 4c_2 - \varepsilon)/5$, then only royalty is charged.

(b) If $(a + 4c_2 - \varepsilon)/5 < c_1 < (a + 4c_2 + \varepsilon)/5$, then two part tariff is charged.

(c) If $c_1 \geq (a + 4c_2 + \varepsilon)/5$, then only fixed fee is charged.

The intuition of the above result is as follows. First, note that there are two effects of licensing the innovation. First effect is the overall efficiency gain in the industry and the second effect is the increase in the competition between two firms. For large enough initial production cost difference the efficiency gain is significant as there is large advantage of shifting production from the patentee to licensee. This gain can be appropriated by the optimal fixed fee. On the other hand, when the initial production cost difference of the two firms are small, there is not much gain associated with the shifting production from patentee to licensee, but, on the contrary, there is much competitive pressure as their production cost levels are close. Then, the patentee maximizes its overall payoff by charging only royalty for licensing which has a competition reducing effect in the market. In the case of intermediate production cost differential, a mixture of fixed fee and royalty balances the two effects in maximizing the overall payoff of the patentee. This is consistent with the earlier results on insider and outsider patentee. When $c_1$ is high, firm $F_1$ is more of an outsider than an insider as a result fixed fee licensing dominates royalty licensing. However, the reverse happens for the lower values of $c_1$.

## 4. DRASTIC INNOVATION ($\varepsilon \geq A + C_1 - 2C_2$)

We have already assumed that in the pre-innovation stage (i.e. when $c_1 > c_2$), both firms are active and producing positive quantities, witch implies $a - 2c_1 + c_2 > 0$. As before, for meaningful analysis, we also assume $c_2 - \varepsilon > 0$. Note that Wang (1998) establishes that no licensing is better than fixed fee or royalty when the pre-innovation costs of the two firms are symmetric. Here, as proved by Poddar and Sinha (2005), we get that, with the cost asymmetry in the pre-innovation stage, even the drastic technology will be licensed either by fixed fee or royalty. Then, we argue that the optimal licensing policy of a drastic technology is always a two-part tariff.

### *4.1 Royalty licensing*

Under royalty licensing, the production costs of firm $F_1$ and firm $F_2$ are $c_1 - \varepsilon$ and $c_1 - \varepsilon + r$, respectively, where $r$ is the per-unit royalty. In this case, the optimal royalty is solved as follows. Note that for a meaningful analysis under royalty licensing, the royalty rate should be such that the output of the firm $F_2$ must be non negative. This restriction implies that $r \leq (a + c_1 - 2c_2 + \varepsilon)/2$. Since $\varepsilon \geq a + c_1 - 2c_2$ under drastic innovation, the royalty rate $r$ must satisfy $r \leq (a+c_1-2c_2+\varepsilon)/2 < \varepsilon$. Thus, we maximize $\pi_1 + rq_2$ with respect to $r$ subject to $r \leq (a+c_1-2c_2+\varepsilon)/2$. The unconstrained maximization yields

$$r^* = \frac{a+\varepsilon}{2} - \frac{c_1 + 4c_2}{10}.$$

Now, $r^* \leq (a + c_1 - 2c_2 + \varepsilon)/2$ follows from the fact that $c_1 > c_2$ and $b \geq 1$. Thus, total income of firm $F_1$ under royalty is given by

$$\pi^R = \pi_1 + r^* q_2 = \frac{(a - c_1 + \varepsilon)^2}{4b} + \frac{(c_1 - c_2)^2}{5b}. \quad (5)$$

Now, we state the following theorem.

*Theorem 2.* Under drastic innovation, royalty licensing is better than no licensing for the patentee.

**Proof.** By comparing (1) and (5), we find that the payoff from royalty is greater than no licensing [5]. □

We note that the optimal royalty under the royalty licensing is strictly less than the amount of cost reduction $\varepsilon$.

### *4.2 Fixed fee licensing*

The optimal fixed fee $f^*$ is given by

$$f^* = \frac{(a + (c_1 - \varepsilon) - 2(c_2 - \varepsilon))^2}{9b} - 0 = \frac{(a + c_1 - 2c_2 + \varepsilon)^2}{9b}.$$

Thus, total payoff of firm $F_1$ under fixed fee is given by

$$\begin{aligned}\pi^F &= \pi_1 + f^* \\ &= \frac{(a - 2c_1 + c_2 + \varepsilon)^2}{9b} + \frac{(a + c_1 - 2c_2 + \varepsilon)^2}{9b}. \quad (6)\end{aligned}$$

### *4.3 Comparison between royalty and fixed fee*

Let $\delta$ the initial difference in the (cost) efficiency levels between firm $F_1$ and firm $F_2$, i.e. is $\delta = c_1 - c_2$. Note that since $c_1 - \varepsilon < c_2$, we have $\delta < \varepsilon$.

*Theorem 3.* For a given size $\varepsilon$ of drastic innovation, in a Cournot duopoly model with asymmetric pre-innovation production costs, fixed fee licensing is superior to royalty licensing when $\delta$ is relatively high. Formally, $\pi^F > \pi^R$ when

$$\delta \left( \frac{2(a - c_1 + \varepsilon)}{b} + \frac{16\delta}{5} \right) - \frac{(a - c_1 + \varepsilon)^2}{4b} > 0,$$

and vice-versa.

**Proof.** Given $c_1 - c_2 = \delta$, from (6) we get

$$\begin{aligned}\pi^F &= \frac{(a - 2c_1 + c_2 + \varepsilon)^2}{9b} + \frac{(a + c_1 - 2c_2 + \varepsilon)^2}{9b} \\ &= \frac{1}{9b}\left(2(a - c_1 + \varepsilon)^2 + 2\delta(a - c_1 + \varepsilon) + 5\delta^2\right),\end{aligned}$$

and from (5) we get

$$\pi^R = \frac{(a - c_1 + \varepsilon)^2}{4b} + \frac{\delta^2}{5b}.$$

Now, by comparing $\pi^F$ and $\pi^R$, the result follows. □

The above result implies as long as initial production cost difference between the patentee firm and the competitor is relatively high, it is better for the patentee to offer fixed fee license instead of royalty [6].

## 5. CONCLUSIONS

In the literature of patent licensing, most of the studies on licensing arrangement (in the case of insider patentee) are done where technology is transferred from a cost-efficient firm to a less (or equal) cost-efficient firm. In this paper, we consider a situation where the technology transfer takes place from a relatively high production cost firm to a low production cost firm. In reality, technology transfer takes place from R&D intensive innovative firm to other firms where the recipient firms can be more cost-efficient than the patentee firm when it comes to the production of output. In other words, here, we distinguish between technological efficiency and cost efficiency, which by and large in the literature of patent licensing are assumed to be the same [7]. Optimal licensing arrangements are studied under this new environment. This analysis also provides a platform to bridge the literature on external and internal patentees. The literature before Poddar and Sinha (2005) showed that fixed fee is better than royalty when the patentee is an outsider, whereas royalty is better than fixed fee when the patentee is an insider under symmetric production initial costs. In Poddar and Sinha's framework with asymmetric production costs, they endogenize this feature of licensing arrangements. As the degree of production cost asymmetry changes, they go from one extreme

[5] In Wang's case, under drastic innovation, the payoff is the same for the innovator under royalty and no licensing (see Wang (1998)).

[6] In Wang's case, under drastic innovation, royalty (or no licensing) is always strictly better than fixed fee licensing to the innovator (see Wang (1998)).

[7] Typically northern countries are the major producers of new technologies and they are high wage economies too. On the other hand, very little innovation takes place in southern countries, which are low wage economies. This paper sheds light on the technology licensing from northern firms to southern firms when they compete in a global market place.

to another. At the same time, they showed that when the production cost asymmetry is moderate, a two-part tariff licensing scheme is optimal for non-drastic innovation. Here, we proved similar results as Poddar and Sinha, by considering a more general inverse demand function. Furthermore, we showed that the fixed fee decreases as the slope parameter increases, and the royalty does not depend upon the slope parameter of the demand curve.

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