

# Optimal Licensing Policy under Vertical Product Differentiation\*

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## Abstract

This paper explores a vertical product differentiation model with licensing arrangement between a multinational firm with superior technology and a domestic firm with obsolete technology. When the technology gap between the firms is small enough, licensing is found to improve the participating firms' profitability and enhance the domestic country's welfare. We also extend the analysis to compare fixed fee and royalty licensing and find that, the firms always prefer fixed fee licensing whereas the social planner always prefers royalty licensing. These results stand in contrast to earlier results using horizontal product differentiation approach.

*JEL classification:* F12, F13, L13.

*Key words:* Licensing, Product Differentiation, Oligopoly, Welfare.

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## 1. Introduction

Licensing between a multinational firm and a domestic competitor is popular in various industries in many countries. By providing its superior knowledge and expertise to the domestic firm through a licensing arrangement, the multinational firm can extract a higher level of rents in the form of the enhanced benefits to the domestic firm as a result of using the multinational firm's advanced technology for production.<sup>1</sup> For instance, in July 2011, One-stop China, a venture between Universal Music, Warner Music and Sony Music set a license fee for Baidu Inc., a Chinese internet-search engine, to allow the latter access to its music contents.<sup>2</sup> In 2010, Chinese automaker Geely purchased Ford's Volvo unit to gain the access to modern automobile technology.<sup>3</sup> According to the World Development Indicators database, between 1998 and 2009, the licensing fee payments by Chinese firms to foreign companies had an annual growth rate of over 34 percent.<sup>4</sup> Grindley and Teece (1997) also document that firms in high-tech industry such as IBM, Texas Instruments, Hewlet-Packard consider the use of licensing as an important part of their business.<sup>5</sup>

Despite the fact that the burgeoning trend of technology licensing, including licensing between competing firms from different countries, has been an important feature of

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<sup>1</sup> In a study on partial equity ownership, Ghosh and Morita (2010) present several examples whereby a multinational firm, after acquiring a certain proportion of shares in its competitor, helps its competitor with the advanced production know-how and expertise.

<sup>2</sup> Available at <http://www.businessweek.com/news/2011-07-19/baidu-to-pay-record-labels-for-beyonce-gaga-music-in-china.html>.

<sup>3</sup> Available at <http://autonews.gasgoo.com/blog/be-brave-to-buy-foreign-brands-090616.shtml>.

<sup>4</sup> Calculated by the authors based on the World Development Indicators database, available at <http://data.worldbank.org/indicator>.

<sup>5</sup> McGrath (209) presents examples of licensing between international competing firms in the Chinese automobile industry.

international trade (Erkal 2005; Ciuriak 2010), to the best of our knowledge, no previous study has examined optimal licensing between firms competing with different product quality. This paper aims to fill this gap in the literature by incorporating the licensing arrangement between the competing firms into the traditional vertical product differentiation model (Mussa & Rosen 1978).

In our set up, a multinational firm possessing superior (low-cost) technology undertakes FDI to compete with a domestic firm with obsolete (high-cost) technology in the domestic market by producing products differentiated by quality levels. Under a licensing arrangement, the multinational firm licences its technology to the domestic firm so that the latter can utilise the former's technology for production to reduce costs. Two alternative methods of technology licensing have been investigated: fixed fee and royalty licensing.

We find that, when the technology gap (or production cost difference) between the firms is small enough, licensing is found to be not just profitable for both firms but also welfare enhancing for the domestic country. In this context, the firms always prefer a fixed fee over royalty licensing. The reason is that royalty licensing, which works like an additional marginal cost for the licensee, induces the domestic firm to choose a higher quality level compared to fixed fee licensing. This reduces the profitability for both firms. However, in equilibrium, we find that the social planner always prefers royalty over fixed fee licensing.

These results contradict those of Erkal (2005) where in his model, which was based on Sign and Vives (1984)'s and Katz and Shapiro (1985)'s horizontal product

differentiation framework, an innovator with cost advantages competes with another firm in a Cournot fashion.<sup>6</sup> The firms do not choose their product quality but quantity, and consumers differentiate their products with a symmetric differentiation parameter. Erkal finds that royalty licensing always raises the profit for the licensor in this context, and fixed fee licensing raises the licensor's profit if the technology gaps between the firms is significantly small, or if the degree of product differentiation is significantly small. Furthermore, he finds that if the innovation size is large, it is socially optimal to allow licensing while if the innovation size is small and the degree of product differentiation is small, it is socially optimal to discourage licensing.

Sinha (2010) examines a multinational's modes of entry into a host country market between export and FDI after it licensed its technology to a host country firm who competes with the multinational in quantity. He shows that, in the case when the multinational chooses FDI, it is optimal for it to choose royalty licensing. When the multinational firm does not change its mode of entry after licensing, licensing does not affect or it can improve the welfare of the host country. Unfortunately optimal licensing policy from the welfare standpoint has not been discussed in Sinha's paper (where he focuses on trade policy's impact on the multinational firm's mode of entry). Therefore, most results in Sinha's paper and ours are qualitatively different.<sup>7</sup>

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<sup>6</sup> The literature on horizontal product differentiation with licensing has been well developed. For instance, Kabiraj and Marjit (1993) investigate the relationship between optimal international technology licensing and trade policy (see also Ghosh & Saha 2008). Arora and Fosfuri (2003) examine a model with many symmetric firms competing with each other and with potential entrants. They show that the incumbents tend to license their technologies to potential entrants more often if their products are less differentiated. Fess, Hoeck and Lorz (2009) explore the competition effect and business stealing effects of international technology licensing.

<sup>7</sup> Mattoo, Olarreaga and Saggi (2004) and Tekin-Koru (2009) explore the impact of trade costs on optimal technology transfers and entry strategy by a multinational firm into a host country where there are several competitors and when acquisition of a host country firm is possible.

Our paper is also related to the growing literature on vertical product differentiation and trade (Das & Donnenfeld 1987, 1989; Boccard & Wauthy 2005; Toshimitsu 2005, among others). The focus thus far under this approach has been on the impacts of trade restrictions on optimal quality and welfare. An exception is Nabin, Nguyen and Sgro (2011) who analyse an international oligopoly model of vertical product differentiation with technology licensing in which a Northern firm licenses its technology to one of two Southern competing firms. The firms produce products that are vertically differentiated in both regions. They find that international technology licensing promotes trade, product variety and is beneficial for all firms, including the outside firm. To maximize social welfare in this context, both countries have an incentive to impose quality standards on the low-quality firm. However, a comparison between fixed fee and royalty licensing was absent in their analysis.

In summary, this paper extends the traditional vertical product differentiation model (Mussa & Rosen 1978) to analyse the impact of licensing between competing firms. We have found significant differences to the earlier results in the literature. The rest of the paper will proceed as follows. The next section presents a duopoly model of vertical product differentiation with licensing arrangement between competitors. Section 3 characterises the equilibrium of the model. Section 4 analyses the welfare impact of fixed fee versus royalty licensing while section 5 concludes.

## 2. The model

Consider an international oligopoly model in which a multinational firm (firm 1) competes with a domestic firm (firm 2) in the domestic market in vertically differentiated products. The multinational firm possesses an advanced technology which allows it to supply products at a lower cost compared to the domestic competitor. Without loss of generality, we assume that the marginal cost is zero and the quality development cost for the multinational firm is zero while that for the domestic firm is given by a convex function,  $C_2(q_2) = kq_2^2$ , where  $q_i (\leq 1)$  ( $i = 1, 2$ ) is the quality level for the product of firm  $i$  and  $k$  denotes the efficiency of production. In the subsequent analysis, we assume that  $k = 1/2$  to find a closed form solution for the model. We then discuss the possibility of generalizing the result for any value of  $k$ .

The market of the domestic country consists of a continuum of nonatomic consumers of mass 1, where each consumer  $j$  is indexed by a taste parameter,  $\theta_j \in [0, 1]$ , and endowed with a reservation utility equal to zero. Assume that  $\theta_j$  is uniformly distributed. Each consumer purchases zero or 1 unit of the product. If the consumer with a taste parameter  $\theta_j$  purchases firm  $i$ 's product, she obtains a net benefit of  $\theta_j q_i - P_i$ , where  $P_i$  is the price charged by firm  $i$ .

Under technology licensing, firm 1 allows firm 2 to use its technology for production of the differentiated product. In return, firm 2 pays firm 1 a licensing fee, which is given by a lump-sum value  $F$  in case of a fixed fee licensing arrangement, and by a

flat royalty payment  $r$  per unit of output for the case of a royalty licensing arrangement.

We analyse a three stage game, described below:

**[Stage 1]** Firm 1 decides on the licensing fee and firms 1 and 2 decide on the arrangement (licensing or royalty).

**[Stage 2]** Firms 1 and 2 set the quality level for their product.

**[Stage 3]** Observing the quality levels set at stage 2, the firms choose the prices for their product and consumers make purchasing decisions.

We end this section by two remarks. First, the assumption that the multinational firm possesses superior technology as compared to the domestic firm is consistent with the literature. Dunning (1981) points out that for multinational firms to enter a domestic market, they must possess either ownership advantages, locational advantages, or internalization advantages (referred to as OLI framework). The multinational's technology lead in our model has been considered as an ownership advantage in earlier study (see Markusen 1995; Saggi 2002; and Agarwal & Ramaswami 1992 for related surveys). Second, our focus is on the case where the multinational commits to entry into the domestic country even with or without licensing (by undertaking FDI). Possible extensions include a comparison of outcomes (profitability for firms and welfare for the domestic country) when the multinational chooses between export, FDI and acquisition. To focus on the optimal licensing policy, we leave this extension for future research.

### 3. Equilibrium characterisation

#### 3.1. No licensing

Denote by  $\theta_1$  the taste parameter of the marginal consumer who is indifferent about buying firm 2's product and buying zero unit of the product, and  $\theta_2$  the taste parameter of the marginal consumer who is indifferent about firm 2's product and firm 1's product.<sup>8</sup> With uniform distribution of the consumer taste parameter, the demand for firm 1's product is given by  $d_1 = (1 - \theta_2)$  and for firm 2 is  $d_2 = (\theta_2 - \theta_1)$  as depicted in Figure 1.

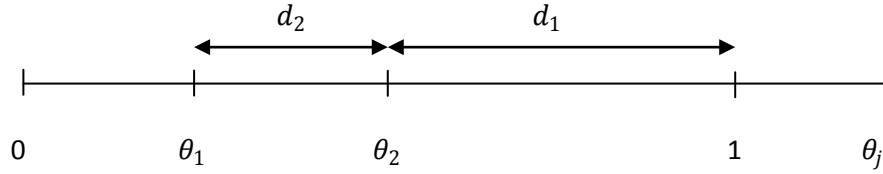


Figure 1: The market segmentation.

The value of  $\theta_1$  and  $\theta_2$  can be found from the incentive constraints,  $\theta_1 q_2 - P_2 = 0$  and  $\theta_2 q_1 - P_1 = \theta_2 q_2 - P_2$ . Thus,  $\theta_1 = \frac{P_2}{q_2}$ ;  $\theta_2 = \frac{P_1 - P_2}{q_1 - q_2}$ . At stage 3, firm 2 chooses  $P_2$  by solving its problem:

$$\max\left[\int_{\theta_1}^{\theta_2} P_2 d\theta - \frac{q_2^2}{2}\right]$$

<sup>8</sup> In the literature, it has been shown that the firm producing the high-quality product makes a higher level of profit compared to the firm producing the low-quality product even when the firms have similar cost structures (for instance, see Aoki & Prusa 1996; Boccard & Wauthy 2005). Thus, in equilibrium, firm 1 possessing superior technology always chooses a higher level of quality compared to firm 2 in our model..



while firm 1 chooses  $P_1$  by solving its problem:

$$\max \int_{\theta_2}^1 P_1 d\theta.$$

Routine calculations yield the solutions  $P_1 = \frac{2q_1(q_1-q_2)}{4q_1-q_2}$ ;  $P_2 = \frac{q_2(q_1-q_2)}{4q_1-q_2}$ . The equilibrium profit for firm 1 is  $\pi_1 = \frac{4q_1(q_1-q_2)}{(4q_1-q_2)^2}$ , which is increasing in  $q_1$ . Thus, firm 1 chooses  $q_1 = 1$  at stage 2. Consequently, firm 2 chooses  $q_2 = 0.058$ . It follows that  $\theta_1 = 0.24$ ;  $\theta_2 = 0.495$ , which yield equilibrium profit for firms 1 and 2 of  $\pi_1 = 0.242$ ;  $\pi_2 = 0.002$ , respectively. The consumer surplus is given by  $CS = \int_{0.495}^1 (\theta - 0.48) d\theta + \int_{0.24}^{0.495} (0.058 - 0.014\theta) d\theta = 0.137$ , and welfare for the domestic country is given by  $W = \pi_2 + CS = 0.139$ .

### 3.2. Fixed fee licensing

Under fixed fee licensing, since the cost structure does not directly affect the optimal prices (even though it affects the optimal quality levels), at stage 3, the equilibrium prices can be found in a similar way as with the case of no licensing. At stage 2, the fixed fee licensing,  $F$ , does not affect the firms' choice of optimal quality levels. Therefore, optimal quality levels for firms 1 and 2 are given by  $q_1 = 1$ ;  $q_2 = 0.571$ , as in Boccard and Wauthy (2005). In equilibrium, we have  $\theta_1 = 0.125$ ;  $\theta_2 = 0.42$ , which yield  $\pi_1 = 0.146 + F$ ;  $\pi_2 = 0.021 - F$ ;  $CS = 0.292$ ;  $W = 0.313 - F$ .

**Lemma 1.** The degree of product differentiation under fixed fee licensing is lower than that under no licensing.

The intuition behind Lemma 1 is straightforward: when the domestic firm utilises the multinational firm's technology for production, it increases its product quality. Since the multinational firm chooses a fixed level of product quality for both no licensing and fixed fee licensing, it follows that products supplied by the firm become more similar under fixed fee licensing.

### 3.3. Royalty licensing

Finally, under royalty licensing, firm 2 incurs a marginal cost of  $r$  per unit of output.

At stage 3, firm 2 chooses  $P_2$  by solving its problem:

$$\max \int_{\theta_1}^{\theta_2} (P_2 - r) d\theta$$

and firm 1 chooses  $P_1$  by solving its problem:

$$\max \left[ \int_{\theta_2}^1 P_1 d\theta + \int_{\theta_1}^{\theta_2} r d\theta \right].$$

Routine calculations yield the solutions  $P_1 = \frac{2q_1(q_1 - q_2) + rq_1}{4q_1 - q_2}$ ;  $P_2 = \frac{q_2(q_1 - q_2) + 2rq_1}{4q_1 - q_2}$ .

Replacing these prices in the profit functions for the firms, we can solve for the optimal quality level at stage 2 for a given value of  $r$ . Then, with backward induction,

we can solve for firm 1's optimization problem at stage 1 to find the optimal licensing fee,  $r$ .

At stage 1, the optimal licensing fee should be set by firm 1 such that firm 2 is slightly better-off compared to no licensing. That is, firm 1 should set  $r$  such that firm 2's profit with royalty licensing is  $\pi_2 = 0.002 + \epsilon$ , where  $\epsilon > 0$ . Thus, the model can be simplified by assuming that any additional profits captured by firm 2 from licensing will be fully (or almost fully) taken by firm 1 (that is,  $\epsilon \approx 0$ ). Thus the equivalent problem for firm 1 is to maximize the total profits (of firms 1 and 2) at stage 2. Thus, it chooses  $q_1$  which solves:

$$\max \left[ \int_{\theta_2}^1 P_1 d\theta + \int_{\theta_1}^{\theta_2} r d\theta + \int_{\theta_1}^{\theta_2} (P_2 - r) d\theta \right] = \max \left[ \int_{\theta_2}^1 P_1 d\theta + \int_{\theta_1}^{\theta_2} P_2 d\theta \right]$$

and with optimal prices, the problem for firm 1 becomes:

$$\max \left[ \frac{2q_1(q_1 - q_2) + rq_1}{4q_1 - q_2} - \frac{(q_2(q_1 - q_2) + 2rq_1)^2}{(4q_1 - q_2)^2 q_2} - \frac{((2q_1 - q_2)(q_1 - q_2) + rq_1)^2}{(4q_1 - q_2)^2 (q_1 - q_2)} \right].$$

The sign of the first order derivative can be found to depend on  $[4q_1^2 - 3q_1q_2 + q_2^2]$ , which is positive for all  $q_1 > q_2$ . Hence, firm 1 chooses  $q_1 = 1$  in equilibrium.

With this result, the first order condition for firm 2 at stage 2 (choosing optimal quality) is given by  $[q_2(1 - q_2)(4 - 7q_2) + r(-2q_2^3 + 9q_2^2 - 18q_2 + 8)] = 0$ . It can

be seen that if  $r = 0$  then the solution is  $q_2 = 0.571$  as was the case of fixed fee licensing. Furthermore,  $[q_2(1 - q_2)(4 - 7q_2)]$  and  $[(-2q_2^3 + 9q_2^2 - 18q_2 + 8)]$  are both negative for all  $q_2 \in [0, 0.571]$  as well as for all  $q_2 \in [0.601, 1]$ , so that the solution is  $q_2 \in (0.571, 1)$ , where the exact value depends on  $r$ . Even though a closed form solution is not possible, the fact that  $q_2 \in (0.571, 1)$  helps us to easily compare profitability of the firms under royalty licensing and fixed fee licensing.

**Lemma 2.** The degree of product differentiation under royalty licensing is lower than that under no licensing but higher than that under fixed fee licensing.

Similar to Lemma 1, Lemma 2 tells us that royalty licensing makes the products of the firms more similar. However, since the domestic firm chooses a higher equilibrium quality level under royalty licensing compared to fixed fee licensing, the degree of product differentiation is lower. This finding suggests that the firms compete more fiercely under royalty licensing than under fixed fee licensing.

**Proposition 1.** When  $k = 1/2$ , the combined equilibrium profit of firms 1 and 2 under no licensing is greater than that under fixed fee licensing. The combined equilibrium profit of firms 1 and 2 under fixed fee licensing is greater than that under royalty licensing.

*Proof.* Under no licensing we have that  $\pi_1 + \pi_2 = 0.244$ . Under fixed fee licensing, we have that  $\pi_1 + \pi_2 = 0.167$  so that total profit is lower under fixed fee licensing compared to no licensing. Furthermore, recall that under royalty licensing, if the licensing fee is zero we have  $q_2 = 0.571$  and total profit under royalty licensing and

fixed fee licensing are the same. However, as shown above, a positive royalty fee induces firm 2 to choose  $q_2 > 0.571$ . It can be verified that  $\frac{\partial \pi_1}{\partial q_2} + \frac{\partial \pi_2}{\partial q_2} < 0$ , so that the higher the value of  $q_2$  the lower the total profit. Thus, the total profit under royalty licensing is always lower than that under fixed fee licensing.

Proposition 1 tells us that when  $k = 1/2$ , under a private licensing arrangement, firm 1 would choose no licensing as the outcome. The technology gap allows firm 1 to achieve a much higher profit if it keeps the technology for its own production.

#### 4. Welfare impact of licensing

In this section, we compare social welfare for the domestic country under no licensing, fixed fee licensing, and royalty licensing. We then identify the optimal licensing policy.

**Proposition 2.** When  $k = 1/2$  and only fixed fee licensing is possible, the domestic government should subsidize firm 1 to induce licensing.

*Proof.* Comparing the fixed fee licensing and no licensing, it follows that social welfare under fixed fee licensing is higher if  $0.313 - F > 0.139 \Leftrightarrow F < 0.174$ .

When  $F = 0.174$  we have  $\pi_2 = 0.146 + .174 = 0.32 > 0.242$ .

Proposition 2 tells us that fixed fee licensing should be encouraged. If the firms cannot conclude on the licensing arrangement, the government should provide a subsidy to firm 1 to enable licensing. The intuition is that with licensing, technology

transfer from firm 1 to firm 2 raises production efficiency and thus it is socially optimal.

**Proposition 3.** The socially optimal licensing policy is royalty licensing.

*Proof.* Consider royalty licensing and assume that  $r = 0$ . It can be verified that  $\frac{\partial W}{\partial q_2} > 0$ . Thus, an increase in royalty fee raises  $W$  and is socially desirable. Recall that the outcome concerning optimal quality and price levels under fixed fee licensing and royalty licensing are the same when  $r = 0$ . Hence, royalty licensing is always socially optimal.

Proposition 3 tells us that royalty licensing yields a better outcome in terms of welfare for the domestic country compared to fixed fee licensing. From the social planner's standpoint, inducing the firms to raise their quality level is always welfare enhancing. Thus, one policy recommendation is that the domestic government should allow only royalty licensing. This strategic policy choice induces the low-quality firm to raise its product quality and improves net benefits for the domestic country.

### **Robustness**

Finally, we generalize the analysis for the any value of  $k$ .

**Proposition 4.** There exist threshold values  $k_1$  and  $k_2$ ,  $0 < k_2 < k_1$ , such that in absence of a government subsidy:

- (i) a private fixed fee licensing arrangement raises the combined equilibrium profit of firms 1 and 2 if and only if  $k < k_1$ ; and
- (ii) a private royalty licensing arrangement raises the combined equilibrium profit of firms 1 and 2 if and only if  $k < k_2$ .

*Proof.* The results can be found by showing that firm 1's profit under no licensing equilibrium is increasing in  $k$  (since  $k$  does not affect the firms' quality level under licensing). Consider the no licensing equilibrium. Since firm 1 chooses  $q_1 = 1$  at stage 2, the first order condition for firm 2 is given by:

$$2kq_2(4 - q_2)^3 + 7q_2 - 4 = 0.$$

It can be established that  $\frac{\partial q_2}{\partial k} < 0$ . That is, the higher the technology level firm 2 possesses (lower  $k$ ) the higher quality level it chooses in equilibrium. Note that when  $k$  increases, firm 2's profitability decreases for two reasons: (i) its production costs become higher and (ii) firm 2's equilibrium quality level becomes lower. Furthermore, with  $\pi_1 = \frac{4(1-q_2)}{(4-q_2)^2}$ , it can be verified that  $\frac{\partial \pi_1}{\partial q_2} < 0$ , so that when firm 2 chooses a lower quality then firm 1's profitability increases. In other words, the no licensing profitability for firm 1 is increasing in  $k$ . By Proposition 1, we obtain the results.

Proposition 4 says that a private licensing arrangement is possible when the technology gap between the two competing firms is low enough. A low cost gap with the multinational firm enables the domestic firm to choose a relatively high level of quality under no licensing, thus reducing the profitability for the multinational firm. In

turn, this makes licensing more attractive for firm 1. In other words, even without a government subsidy, licensing is still possible if the firms possess similar technologies.

## **5. Conclusion**

Licensing between competing firms is popular in many countries. A number of papers have focused on the horizontal product differentiation approach. Using this approach, Erkal (2005) finds that royalty licensing is always profitable for the licensor regardless of its technological lead over the competitor. Furthermore, when the technology gap between the competing firms is small, it is socially optimal to discourage licensing. Sinha (2010) shows that when licensing takes place between a multinational and a domestic firm then if FDI is the multinational's mode of entry into the domestic market, royalty is more profitable as compared to fixed fee licensing.

This paper develops a vertical product differentiation oligopoly model to investigate the impact of licensing between a multinational and a domestic firm on the firms' profitability and domestic welfare. We have identified several results that contradict to the literature. Specifically, it has been found that licensing is profitable for the licensor if and only if the technology gap between the firms is small enough. Furthermore, fixed fee licensing is more profitable as compared to royalty licensing. Finally, licensing is always welfare enhancing, and the social planner should only allow royalty licensing to maximize the domestic country's welfare. These findings suggest that the countries that wish to encourage inflows of international technology should take note of the nature of competition to design their optimal licensing policy.



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