

Trade and Industrial Policy Subtleties with International Licensing*

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Abstract

We see various hybrid forms of organization and competition in which domestic and foreign firms may cooperate in some phases of production such as technology development and then compete in product markets. Here we assume that for a foreign firm to produce a good to export into the domestic market of its rival, it has to acquire technology either through R&D or through licensing from the domestic firm. The domestic firm has an incentive to offer a licensing contract that deters the foreign firm from doing its own R&D, but this in turn creates an interdependency not considered in the traditional literature. We show that both domestic and foreign optimal policies with licensing can be the exact opposite of optimal policies without licensing. Interestingly, imposing an export tax on the "foreign" firm, the foreign government can shift the licensing revenue from the "domestic" firm.

Key words: international oligopoly, trade and industrial policy, R&D, licensing, rent-shifting

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1 Introduction

The basic principles of trade and industrial policies in the presence of oligopolistic market structures are well understood, as are the consequences of many variations on the basic assumptions.¹ However, most research exploring “optimal” trade and industrial policies has focused on situations in which domestic and foreign firms are strictly independent and their profits enter only the income stream of the country in which they are located. This is obviously unsatisfactory, because the world has become more complicated, and we see various hybrid forms of organization and competition in which firms may cooperate in some phases of production such as technology development and then compete in product markets.

A typical example is cross-border technology transfer between rivals. Technology transfer can be made through licensing or provisions of intermediate products² and/or capital goods.³ In particular, it has been observed widely that firms in developed countries help developing countries to launch new industries through production technology transfer.⁴ For example, Mitsubishi Motors Co. transferred production technology to Proton (a Malaysian automaker) and Hyundai Motor Co. at the time of their establishment.⁵ Similarly, POSCO (a Korean steelmaker) obtained technology from Japanese steelmakers when it was established in 1973, while Samsung Electronics Co., Ltd. entered a number of licensing contracts with Japanese and European firms in the 1980’s.

One may wonder what motivates technology holders to transfer technology to (potential) rivals. One of the motives is that even if a technology holder does not transfer its technology to (potential) rivals, they may obtain production technologies from other technology holders or engage in research and development (R&D) to develop their own production technologies. Obviously, technology holders can receive some payments in the case of their technology transfer to (potential) rivals but no payments in the case of other technology holders’ technology transfer or rival’s R&D. The presence of technology transfer potentially gives rise to strategic interdependence between firms. In such an

¹Brander (1995) provides an excellent survey.

²The essence of technology is often embodied in sophisticated intermediate products.

³Partial corporate control of a foreign rival through partial ownership such as a joint venture or other hybrid forms of organization are another channel of technology. See, for example, Ishikawa, Sugita and Zhao (2009, 2011).

⁴Technology transfer is not necessarily confined to that between developed and developing countries. For instance, Toyota’s patents on gasoline-electric hybrid engine system control and emission purification were licensed for use in Ford’s own hybrid system.

⁵Nissan Motor Co., Ltd. also provided technological assistance to Samsung Motors.

environment, trade and industrial policies cannot simply focus on the market shares of domestic versus foreign firms, for example. Against this background, the aim of this paper is to explore, in an international duopoly framework, how the availability of both R&D and technology transfer affects optimal trade and industrial policies.

The relationship between the degree of competition among technology holders and their incentive for technology transfer is an interesting research topic. Since Fosfuri and Arora (2003), Ishikawa (2007), and Horiuchi and Ishikawa (2009) deal with this issue, however, this paper focuses on the R&D case, which has not been explored.⁶ We specifically consider a situation in which a domestic firm and a foreign rival engage in Cournot competition in the domestic market. The foreign firm, to produce the good it wants to sell in the domestic market, has to acquire technology either through R&D or through licensing from the domestic firm.⁷ The domestic firm has an incentive to offer a licensing contract that deters the foreign firm from doing its own R&D, because such a strategy reduces the loss to the domestic firm caused by the entry of the foreign firm into the domestic market. This creates an interdependency between firms not considered much in the traditional literature.

Without licensing (i.e. without firms' interdependency), the domestic government typically sets a tariff to improve domestic welfare,⁸ while the foreign government provides the foreign firm with an export (a production) subsidy to enhance foreign welfare.⁹ Whereas tariffs shift the rent from the foreign firm to the domestic government, export subsidies shift the rent from the domestic firm to the foreign firm. With licensing, however, the profits of the domestic and the foreign firm are interdependent, which affects rent-shifting opportunities. In particular, when the domestic firm sets license fees, it tries to extract as much rent from the foreign firm as possible. In this situation, the foreign government has an incentive to reduce license fees.¹⁰ Thus, this incentive is

⁶Whereas Fosfuri and Arora (2003) focus more on the industrial or market structure under the possibility of licensing in a closed economy, Ishikawa (2007) and Horiuchi and Ishikawa (2009) focus more on the relationship between tariffs and technology transfer from North to South.

⁷The essence of our analysis and results would not change even if the channel of technology transfer is imports by the foreign firm of an intermediate product from the domestic firm.

⁸See Brander and Spencer (1984a,b) and Furusawa, Higashida, and Ishikawa (2003), for example.

⁹Rent-shifting through export (or production) subsidies was originally pointed out in the "third-market" model developed by Brander and Spencer (1985) and has been explored by many studies. The optimal policy becomes export taxes under Bertrand competition. Also the number of firms affects the optimal policy even with Cournot competition. For details, see Brander (1995).

¹⁰There are other ways in which the government could try to intervene, such as direct regulations, but we confine ourselves to taxes and subsidies in our analysis.

taken into account when the optimal export subsidy is tailored by the foreign government. Interestingly, the foreign government, by imposing an export tax on the “foreign” firm, could shift the license revenue from the “domestic” firm to the foreign government. Yet, the intervention by the foreign government, through which the domestic firm loses all licensing revenue, may still benefit the domestic firm. Moreover, it is shown that the domestic government may provide an import subsidy. Therefore, both domestic and foreign optimal policies with licensing can be the exact opposite of optimal policies without licensing.

Cross-border technology transfer to rivals in the context of international oligopoly has been analyzed by Kabiraj and Marjit (2003), Mukherjee and Pennings (2006), Ghosh and Saha (2008), and Horiuchi and Ishikawa (2009) among others.¹¹ The focus of the present paper is different from that in the papers just cited. Kabiraj and Marjit (2003) and Mukherjee and Pennings (2006) point out the possibility of “tariff-induced” technology transfer through licensing. Specifically, using a duopoly model, Kabiraj and Marjit (2003) show that the foreign firm has an incentive to license its superior technology to the domestic rival only if the initial cost difference between the foreign and the domestic firm is small, implying that the introduction of a tariff, by reducing the cost difference, may induce licensing. Mukherjee and Pennings (2006), on the other hand, consider the relationship between the licensing to potential domestic or foreign entrants by a foreign monopolist and the timing of the imposition of the (optimal) tariff. Horiuchi and Ishikawa (2009) explore the strategic relationship between tariffs and North–South technology transfer in an oligopoly model when technology is embodied in a key component that only North firms can produce. The above three studies are primarily concerned with how government can induce technology transfers through tariffs in the presence of strategic use of licensing.¹² Ghosh and Saha (2008) introduce technology licensing into

¹¹On the other hand, a number of studies focus on various hybrid forms of organization and competition, but “without” technology transfer. Spencer and Jones (1991,1992), Ishikawa and Lee (1997), and Chen, Ishikawa, and Yu (2004), for example, deal with trade in intermediate inputs between rivals. Ishikawa, Mukunoki, and Morita (2010,2012) are concerned with service provisions between rival firms after production. We should mention that our focus is different from studies such as Spencer and Raubitschek (1996) and Ishikawa and Spencer (1999), because, in their models, domestic firms import intermediate products not from foreign rivals but from foreign suppliers.

¹²Strategic use of licensing has also been widely examined in the literature on industrial organization (IO). The IO literature primarily focuses on the strategic use of licensing as a deterrent to entry (see, for example, Gallini, 1984; Rockett, 1990; and Yi, 1999). However, the studies in the field of IO essentially deal with a closed economy and therefore do not make it possible to consider cross-border rent-shifting through trade and industrial policies.

the third-market model and show that the optimal policy could be an export tax. Although this result is similar to ours, the mechanism through which the result is derived is different. What is crucial in their model is that technology licensing decreases the licensee's marginal cost. That is, the marginal-cost reduction caused by licensing switches the optimal trade policy in the licensee's country from an export subsidy to an export tax.

The mechanism of rent-shifting through a foreign export tax under licensing is somewhat similar to that of Brander and Spencer (1981), that developed a model with two firms, a foreign and a domestic firm. The domestic market is monopolized by the foreign firm and the domestic firm is a potential entrant. The foreign monopolist deters the domestic firm from entering the market. In this situation, the domestic government can set a tariff without raising the consumer price, because the foreign monopolist keeps the consumer price constant to deter entry. That is, the domestic government can shift the monopoly rent from the foreign firm to itself without generating any burden on the domestic country. By contrast, in our model, the domestic firm deters the foreign firm not from entering the goods market but from doing its own R&D. This behavior results in opportunities for rent-shifting by the governments.

A specific feature of our model is that we introduce not only licensing but also R&D into the framework of international oligopoly. In our analysis, we also investigate R&D subsidies instead of export subsidies in the foreign country. We show that the foreign government does not need to pay any subsidy in equilibrium. Spencer and Brander (1983) and Bagwell and Staiger (1994) introduce R&D into the third-market model to examine the role of R&D subsidies instead of export subsidies. However, their focus is on the relationship between export subsidies and R&D subsidies. They do not deal with licensing and hence the interdependency between firms does not arise.

Another aspect in which our study differs from existing ones is that we derive the optimal license fees in the presence of the opportunity of entrant's R&D. Specifically, the case we consider is one with differentiated goods and two-part tariffs.¹³ We show that depending on the parameter values, three cases could arise: licensing by means of a fixed fee alone, licensing by means of a royalty alone, and licensing by means of a fixed fee plus a royalty. The existing literature on licensing usually focuses on one of the three cases. While Mukherjee and Pennings (2006) assume licensing with both a fixed fee and

¹³Wang (2002) compares licensing by means of a fixed-fee with that by means of a royalty in a differentiated Cournot duopoly model. Although he obtains the optimal license fee, Wang (2002) considers neither R&D by the inefficient firm nor licensing with a fixed fee plus a royalty.

a royalty, Kabiraj and Marjit (2003) and Ghosh and Saha (2008) deal with licensing with a fixed fee alone. Meanwhile, Horiuchi and Ishikawa (2009) consider trade in an intermediate product. This means that their case corresponds to licensing with a royalty alone.

The rest of the paper is organized as follows. In Section 2, we present an international Cournot duopoly model. Specifically, we consider a situation in which foreign production becomes possible either through R&D or through licensing. We explore the optimal tariff set by the domestic government in the presence of R&D and licensing in Section 3 and the optimal export tax imposed by the foreign government in Section 4. We then consider simultaneous interventions by both governments in Section 5. Section 6 concludes.

2 Basic Model

2.1 Model Setting

There are two firms, a domestic firm (firm d) and a foreign firm (firm f). Firm d produces good Y in the domestic country and serves the domestic market. Firm f enters the domestic market by producing good X , which may be a close substitute of good Y . To produce good X , however, firm f needs to acquire the technology to produce good X . We specifically consider two possibilities. In the first case, firm f engages in R&D itself to develop good X . In this case, firm f incurs the fixed costs (FCs) associated with R&D, F . In our analysis, we assume for simplicity that there is no uncertainty regarding R&D, that is, firm f can always develop good X by engaging in R&D.¹⁴ In the second case, firm f obtains a license from firm d for the technology to produce good X . In this case, firm f pays license fees to firm d .

Demand is characterized by a representative consumer that consumes goods X and Y as well as a numéraire good. The numéraire good is competitively produced and freely traded between countries.

We assume the following utility function:

$$U = \alpha x + \beta y - \frac{x^2 + y^2}{2} - \phi xy + m,$$

where x , y and m are, respectively, the consumption of goods X and Y and the numéraire good, α and β are parameters, and $0 \leq \phi \leq 1$ is a parameter indicating the degree of substitutability between goods X and Y .

¹⁴Even if uncertainty is introduced, the essence of our analysis and results would not change.

Then the inverse demand for the imperfectly substitutable goods X and Y is, respectively, given by

$$p_x = \alpha - x - \phi y, \quad (1a)$$

$$p_y = \beta - y - \phi x, \quad (1b)$$

where p_x and p_y are the consumer prices of goods X and Y . The consumer surplus (CS) is given by

$$CS = \alpha x + \beta y - \frac{x^2 + y^2}{2} - \phi xy - (p_x x + p_y y) = \frac{x^2 + y^2}{2} + \phi xy$$

We first consider the case in which firm f engages in R&D. The profits of firms f and d can be written respectively as

$$\begin{aligned} \pi_R^f &= (p_x - c_x)x - F, \\ \pi_R^d &= (p_y - c_y)y, \end{aligned}$$

where c_i ($i = x, y$) is the constant marginal cost (MC) to produce good i . Then the first order conditions (FOCs) for profit maximization are:

$$\begin{aligned} \frac{d\pi_R^f}{dx} &= -x + p_x - c_x = 0, \\ \frac{d\pi_R^d}{dy} &= -y + p_y - c_y = 0. \end{aligned}$$

In the equilibrium with R&D, we have

$$x_R^* = \frac{2A - \phi B}{4 - \phi^2}, y_R^* = \frac{2B - \phi A}{4 - \phi^2},$$

where $A \equiv \alpha - c_x$ and $B \equiv \beta - c_y$. As the size of the market, $\alpha(\beta)$, increases and/or the MC, c_x (c_y), decreases, A (B) becomes larger. We call A (B) “the effective market size” for good X (Y). In the following analysis, we focus on the case where both firms serve the market in equilibrium (even with taxes and subsidies). With free trade, this implies $2B - \phi A > 0$ and $2A - \phi B > 0$.

Using the FOCs, the profits of firms f and d are given by

$$\pi_R^{f*} = (x_R^*)^2 - F, \pi_R^{d*} = (y_R^*)^2. \quad (2)$$

Thus, the equilibrium profits increase if and only if the equilibrium output rises.

2.2 Licensing When the Entrant Can Engage in R&D

We next examine firm d 's technology licensing to firm f and compare this licensing equilibrium with the R&D equilibrium. We specifically consider the following three-stage game. In the first stage, firm d decides whether or not to provide a take-it-or-leave-it licensing offer to firm f .¹⁵ In the second stage, if firm d decided to offer a licensing contract, firm f chooses either to accept the offer or to engage in R&D itself. On the other hand, if firm d does not offer a licensing contract, firm f conducts R&D. In the third stage, the firms engage in Cournot competition in the domestic market.

We focus on the case where in the absence of licensing, firm f is willing to develop good X through R&D. Since firm f necessarily enters the market, firm d prefers licensing to R&D. This is because licensing generates revenue for firm d and reduces the loss it suffers as a result of firm f 's entry. Thus, firm d designs a licensing contract so that firm f is willing to accept it. We should mention that firm d cannot extract all the rent from firm f because of firm f 's outside option, i.e., R&D.

In the presence of licensing, the profits of the two firms are given by

$$\begin{aligned}\pi_L^f &= (p_x - c_x)x - (R + rx) = (p_x - c_x - r)x - R \\ \pi_L^d &= (p_y - c_y)y + (R + rx),\end{aligned}$$

where R and r are, respectively, a fixed fee and a per-unit royalty. We assume $R \geq 0$ and $r \geq 0$. Moreover, we assume for simplicity that firm f 's MC under licensing and that under R&D are the same. Without this assumption, the analysis becomes messy, because there are too many possible cases. Since the outside option for firm f is R&D, firm d faces the following maximization problem:

$$\max_{r,R} \pi_L^d; \text{ s.t. } \pi_L^f \geq \pi_R^{f*}, r \geq 0, R \geq 0, \quad (3)$$

where π_R^{f*} is firm f 's profits with R&D, which is the outside option for firm f . In the equilibrium, firm f is indifferent between R&D and licensing.

Given r , the equilibrium outputs are

$$\hat{x}_L(r) = \frac{2(A - r) - \phi B}{4 - \phi^2}, \hat{y}_L(r) = \frac{2B - \phi(A - r)}{4 - \phi^2}. \quad (4)$$

Thus, noting the constraints, we obtain

$$\hat{\pi}_L^d(r) = (\hat{y}_L(r))^2 + \hat{R}(r) + r\hat{x}_L(r), \quad (5)$$

¹⁵Our results remain qualitatively unchanged as long as the domestic firm has some bargaining power. For the case where the foreign firm has full bargaining power, see the concluding section.

where

$$\widehat{R}(r) = (\widehat{x}_L(r))^2 - \pi_R^{f*} = \left(\frac{2(A-r) - \phi B}{4 - \phi^2}\right)^2 - \left(\frac{2A - \phi B}{4 - \phi^2}\right)^2 + F.$$

We are now ready to derive the optimal license fees when the entrant can engage in R&D. We can show that depending on the parameter values, there are three types of licensing contract: licensing by means of a fixed-fee, licensing by means of a royalty, and licensing by means of a fixed fee plus a royalty. Concretely, the following proposition holds.¹⁶

Proposition 1 *Suppose that if the domestic firm does not offer a licensing contract to the foreign firm, the foreign firm acquires production technology through R&D and enters the domestic market. Then the domestic firm has an incentive to offer the following contract to the foreign firm to deter the foreign firm from engaging in R&D. When $\phi(4B + B\phi^2 - 4A\phi) \leq 0$, firm d sets $r = 0$ and $R = F$. When $\phi(4B + B\phi^2 - 4A\phi) > 0$, firm d sets $r = \bar{r}$ and $R = 0$ if $r^* \geq \bar{r}$ and sets $r = r^*$ and $R = R^*$ if $r^* < \bar{r}$, where*

$$\begin{aligned} r^* &\equiv \frac{-\phi(4B + B\phi^2 - 4A\phi)}{2(3\phi^2 - 4)}, \\ \bar{r} &\equiv A - \frac{1}{2}B\phi - \Omega, \\ R^* &\equiv \left(\frac{2(A - r^*) - \phi B}{4 - \phi^2}\right)^2 - \pi_R^{f*}, \\ \Omega &\equiv \sqrt{\pi_R^{f*}(4 - \phi^2)}/2 > 0. \end{aligned}$$

The above three cases are illustrated in Figure 1. The three curves, $l_1l'_1$, $l_2l'_2$, and $l_3l'_3$, respectively, show (5) with $\phi(4B + B\phi^2 - 4A\phi) \leq 0$, (5) with $\phi(4B + B\phi^2 - 4A\phi) > 0$ and $r^* \geq \bar{r}$, and (5) with $\phi(4B + B\phi^2 - 4A\phi) > 0$ and $r^* < \bar{r}$. Points L_1 , L_2 , and L_3 , respectively, give the highest profits of firm d .¹⁷ However, the domain of royalty is given by $0 \leq r \leq \bar{r}$. $r \geq 0$ holds by assumption and firm f does not accept a licensing offer when $r > \bar{r}$. Thus, point L'_1 at which $r = 0$ holds gives the highest profits with $\phi(4B + B\phi^2 - 4A\phi) \leq 0$, implying licensing by means of a fixed fee alone. Similarly, point L'_2 at which $r = \bar{r}$ holds gives the highest profits with $\phi(4B + B\phi^2 - 4A\phi) > 0$ and $r^* \geq \bar{r}$, implying licensing by means of a royalty alone. Since point L_3 is an interior solution, license fees consist of both fixed fee and royalty.

¹⁶For the proof, see Appendix A.

¹⁷All curves go through point L'_1 . The intercept is given by $\pi_R^{d*} + F$, where π_R^{d*} is firm d 's profits with R&D.

To grasp the intuition behind the above proposition, it should be noted that an increase in r affects each term of (5) in the following manner. The first term (i.e., firm d 's profits from producing good Y) increases, the second term (i.e., the license revenue from the fixed fee) decreases, and the third term (i.e., the license revenue from royalties) may or may not increase. When the effective market size for good Y , B , is small relative to that for good X , A , the increase in firm d 's profits from producing good Y is relatively small, but the decrease in the license revenue from the fixed fee is relatively large. If $\phi(4B + B\phi^2 - 4A\phi) \leq 0$, the decrease in the license revenue from the fixed fee dominates the other two effects,¹⁸ implying that firm d charges for its license only in the form of a fixed fee. If $\phi(4B + B\phi^2 - 4A\phi) > 0$, on the other hand, firm d sets $r > 0$. The maximum royalty firm d can charge (i.e., \bar{r}) is determined by firm f 's outside option (i.e., π_R^{f*}).

We next compare welfare between the R&D case and the licensing case. Domestic welfare with licensing consists of firm d 's profits and CS:

$$W_L^d(r, R) = \left\{ \left(\frac{2B - \phi(A - r)}{4 - \phi^2} \right)^2 + r \left(\frac{2(A - r) - \phi B}{4 - \phi^2} \right) + R \right\} + \left\{ \frac{\left(\frac{2(A - r) - \phi B}{4 - \phi^2} \right)^2 + \left(\frac{2B - \phi(A - r)}{4 - \phi^2} \right)^2}{2} + \phi \left(\frac{2(A - r) - \phi B}{4 - \phi^2} \right) \left(\frac{2B - \phi(A - r)}{4 - \phi^2} \right) \right\}. \quad (6)$$

With licensing, firm d 's profits are larger, but CS could be smaller. If $r = 0$, the prices of the goods are not affected by licensing. Thus, domestic welfare is higher by the license fee in the licensing case than in the R&D case. However, if $r > 0$, licensing increases the prices of both goods. Although firm d benefits from licensing, consumers lose from licensing.

When $R = 0$, $W_L^d(r, R)$ is maximized at $r = A/3$. This implies that $W_R^{d*} = W_L^d(0, 0) = W_L^d(2A/3, 0) < W_L^d(r, 0)$ for $\forall r \in (0, 2A/3)$, where W_R^{d*} is domestic welfare with R&D (which is constant).¹⁹ Moreover, it is obvious that $W_L^d(r, 0) < W_L^d(r, R)$ for $R > 0$. Thus, as long as $0 \leq r < 2A/3$ holds, domestic welfare is higher under licensing regardless of the type of licensing contract.

With respect to foreign welfare, this consists of firm f 's profits alone. Since firm d designs the license fee such that firm f is indifferent between licensing and R&D, foreign welfare is the same between the two cases.

Thus, we obtain the following proposition.

¹⁸If B is quite small relative to A , an increase in r increases the license revenue from royalties.

¹⁹This is correct only if the output of firm f is positive with $r = 2A/3$.

Proposition 2 *If $0 \leq r < 2A/3$, then domestic welfare is higher under licensing than under R&D. Foreign welfare is the same between the licensing case and the R&D case.*

3 Domestic Optimal Tariffs

In the following analysis, we explore rent-shifting opportunities by governments. We start by investigating measures the domestic government may take to shift the rent from firm f to itself. Specifically, we investigate the case where the domestic government sets a specific tariff, T . We assume that the domestic government commits itself to adopting a tariff before the firms move (i.e., in stage 0) and that the foreign government is passive. As we will see below, the optimal tariff rates are different between the R&D case and the licensing case. Thus, the government announces two tariff rates: a tariff rate under R&D and a tariff rate under licensing.

In a standard international oligopoly model where domestic and foreign firms simply engage in Cournot competition in the domestic market without any relationship between firms, the domestic government can shift the rent from firm f to itself through a tariff. In our analysis, we have to take both R&D and licensing into account.

First, we consider the R&D case. In the R&D case, domestic welfare consists of firm d 's profits, CS, and tariff revenue:

$$\begin{aligned} \widetilde{W}_R^d(T) &= \left(\frac{2B - \phi(A - T)}{4 - \phi^2} \right)^2 \\ &+ \left\{ \frac{\left(\frac{2(A - T) - \phi B}{4 - \phi^2} \right)^2 + \left(\frac{2B - \phi(A - T)}{4 - \phi^2} \right)^2}{2} + \phi \left(\frac{2(A - T) - \phi B}{4 - \phi^2} \right) \left(\frac{2B - \phi(A - T)}{4 - \phi^2} \right) \right\} \\ &+ T \left(\frac{2(A - T) - \phi B}{4 - \phi^2} \right) \\ &= -\frac{1}{2(\phi^2 - 4)} (A^2 - 2\phi AB + 3B^2 + 2AT - 3T^2). \end{aligned}$$

We can easily verify the following lemma.

Lemma 1 *In the case of R&D, the optimal tariff is given by $T_R^* = A/3$.*

We have

$$W_{RT}^{d*} \equiv \widetilde{W}_R^d\left(\frac{A}{3}\right) = \frac{4A^2 - 6\phi AB + 9B^2}{6(4 - \phi^2)}.$$

Since R&D itself has nothing to do with firm d , the result obtained in the standard international oligopoly model is still valid. We assume that the domestic government

sets $T = T_R^*$ with R&D when it employs a tariff. The profits of firm f with $T = T_R^*$ are given by

$$\pi_{RT}^{f*} \equiv \left(\frac{2(A - T_R^*) - \phi B}{4 - \phi^2} \right)^2 - F.$$

Next, we consider the licensing case. In this case, domestic welfare, which consists of firm d 's profits, CS, and tariff revenue, is given by

$$\begin{aligned} \widetilde{W}_L^d(r, T) &= \left\{ \left(\frac{2B - \phi(A - T - r)}{4 - \phi^2} \right)^2 + r \frac{2(A - T - r) - \phi B}{4 - \phi^2} + R \right\} \\ &+ \left\{ \frac{\left(\frac{2(A - T - r) - \phi B}{4 - \phi^2} \right)^2 + \left(\frac{2B - \phi(A - T - r)}{4 - \phi^2} \right)^2}{2} \right. \\ &\quad \left. + \phi \left(\frac{2(A - T - r) - \phi B}{4 - \phi^2} \right) \left(\frac{2B - \phi(A - T - r)}{4 - \phi^2} \right) \right\} \\ &+ T \frac{2(A - T - r) - \phi B}{4 - \phi^2}, \end{aligned}$$

where $R = \widetilde{R}(r, T) = \left(\frac{2(A - r - T) - \phi B}{4 - \phi^2} \right)^2 - \pi_{RT}^{f*}$.

There are three cases to analyze, depending on the type of licensing contract. The first case we consider is the licensing with a fixed fee alone (i.e., with $\phi(4B + B\phi^2 - 4A\phi) \leq 0$). Domestic welfare in this case is given by

$$\begin{aligned} \widetilde{W}_L^d(0, T) &= \left\{ \left(\frac{2B - \phi(A - T)}{4 - \phi^2} \right)^2 + \widetilde{R}(0, T) \right\} \\ &+ \left\{ \frac{\left(\frac{2(A - T) - \phi B}{4 - \phi^2} \right)^2 + \left(\frac{2B - \phi(A - T)}{4 - \phi^2} \right)^2}{2} + \phi \left(\frac{2(A - T) - \phi B}{4 - \phi^2} \right) \left(\frac{2B - \phi(A - T)}{4 - \phi^2} \right) \right\} \\ &+ T \frac{2(A - T) - \phi B}{4 - \phi^2}. \end{aligned}$$

The optimal tariff is given by

$$T_{L1}^* = -\frac{4B\phi - A\phi^2 - 4A}{(3\phi^2 - 4)} = \frac{2(2A - \phi B) - \phi(2B - A\phi)}{(3\phi^2 - 4)}. \quad (7)$$

We can verify that $T_{L1}^* < 0$ with $\phi(4B + B\phi^2 - 4A\phi) \leq 0$. Thus, a negative tariff (i.e., an import subsidy) is optimal. The intuition is as follows. Without tariff, firm d wants to set a negative royalty and a positive fixed fee. However, due to the constraints, $r \geq 0$ and $R \geq 0$, firm d is forced to design a license contract with $r = 0$ and $R = F$. The effect of an import subsidy is basically the same as that of a negative royalty. An import subsidy decreases firm f 's effective MC. Although the government has to finance the subsidy, the whole subsidy is eventually shifted from f to firm d through the fixed fee charged to firm f . Moreover, an import subsidy increases CS. We should note that $\widetilde{W}_L^d(0, T) \geq W_R^d(T)$ necessarily holds for a given T , because $\widetilde{W}_L^d(0, T) - W_R^d(T) = \widetilde{R}(0, T) \geq 0$. This implies

that $\widetilde{W}_L^d(0, T_{L1}^*) \geq W_{RT}^{d*}$. Thus, the domestic government has an incentive to induce licensing.

The second case is licensing with a royalty alone (i.e., with $\phi(4B + B\phi^2 - 4A\phi) > 0$ and $r^* \geq \bar{r}$). Domestic welfare with a royalty alone is given by

$$\begin{aligned} \widetilde{W}_L^d(r, T) = & \left\{ \left(\frac{2B - \phi(A - T - r)}{4 - \phi^2} \right)^2 + r \frac{2(A - T - r) - \phi B}{4 - \phi^2} \right\} \\ & + \left\{ \frac{\left(\frac{2(A - T - r) - \phi B}{4 - \phi^2} \right)^2 + \left(\frac{2B - \phi(A - T - r)}{4 - \phi^2} \right)^2}{2} \right. \\ & \left. + \phi \left(\frac{2(A - T - r) - \phi B}{4 - \phi^2} \right) \left(\frac{2B - \phi(A - T - r)}{4 - \phi^2} \right) \right\} \\ & + T \frac{2(A - T - r) - \phi B}{4 - \phi^2}, \end{aligned}$$

Equation (6) suggests that a royalty and a tariff are perfect substitutes from a welfare point of view. Given Lemma 1, therefore, the optimal tariff, T_{L2}^* , should satisfy $T_{L2}^* + r = A/3$. This is depicted in Figure 2, where ww' shows domestic welfare.²⁰ However, when $T + r > \bar{r}$, licensing does not arise. If $\bar{r} < A/3$ (say, $\bar{r} = m$ in Figure 2), then the domestic welfare level under licensing is given by point M . Therefore, the domestic government sets $T_{L2}^* = A/3$ and induces R&D instead of licensing. If $\bar{r} = A/3$, the domestic government does not impose any tariff (i.e., $T_{L2}^* = 0$) and $r^* = \bar{r}$ holds. If $\bar{r} > A/3$ (say, $\bar{r} = n$ in Figure 2), then the government cannot induce licensing with $T + \bar{r} = A/3$, because, observing T , firm d sets r so that $T + r = \bar{r}$ holds. In this case, optimal tariff (which results in the welfare level given by point N) is $T_{L2}^* \leq \bar{r}$ and is not unique. In fact, the domestic government does not need to impose any tariff in this case.

The last case is licensing with both a fixed fee and a royalty.

$$\begin{aligned} \widetilde{W}_L^d(r^*, T) = & \left\{ \left(\frac{2B - \phi(A - T - r^*)}{4 - \phi^2} \right)^2 + r^*(T) \frac{2(A - T - r^*) - \phi B}{4 - \phi^2} + R^*(T) \right\} \\ & + \left\{ \frac{\left(\frac{2(A - T - r^*) - \phi B}{4 - \phi^2} \right)^2 + \left(\frac{2B - \phi(A - T - r^*)}{4 - \phi^2} \right)^2}{2} \right. \\ & \left. + \phi \left(\frac{2(A - T - r^*) - \phi B}{4 - \phi^2} \right) \left(\frac{2B - \phi(A - T - r^*)}{4 - \phi^2} \right) \right\} \\ & + T \frac{2(A - T - r^*) - \phi B}{4 - \phi^2}, \end{aligned}$$

where

$$r^*(T) \equiv \frac{-\phi(4B + B\phi^2 - 4(A - T)\phi)}{2(3\phi^2 - 4)}, R^*(T) \equiv \left(\frac{2(A - r - T) - \phi B}{4 - \phi^2} \right)^2 - \pi_R^{f*}.$$

²⁰Since a royalty and a tariff are perfect substitutes from a welfare point of view, ww' under licensing coincides with ww' under R&D. That is, as long as the sum of a royalty and a tariff rate under licensing equals a tariff rate under R&D, the welfare levels are the same.

It is easy to verify that the optimal tariff is given by

$$T_{L3}^* = \frac{-(2A - B\phi)}{2} < 0. \quad (8)$$

The loss of consumers due to higher consumer prices exceeds the gain of the domestic firm. Thus, the domestic government has an incentive to provide an import subsidy to mitigate the loss of consumers. Moreover, setting $T = \hat{T} \equiv (8A - 12B\phi + 6A\phi^2 - 3B\phi^3) / (24 - 6\phi^2)$, the effective MC of firm f becomes $A/3$ and hence $\widetilde{W}_L^d(r^*(\hat{T}), \hat{T})$ is larger than W_{RT}^{d*} by $R^*(\hat{T})$. Therefore, $\widetilde{W}_L^d(r^*(T_{L3}^*), T_{L3}^*) \geq W_{RT}^{d*}$ holds, implying that the domestic government has an incentive to induce licensing.

Therefore, we obtain the following proposition.

Proposition 3 *Suppose that the foreign government is passive. When licensing is either by means of a fixed fee alone or by means of both a fixed fee and a royalty, the optimal tariff is negative and licensing arises. In contrast, when licensing is by means of a royalty alone, licensing may not arise with the optimal tariff. If $\bar{r} \geq A/3$, the domestic government does not have to impose any tariff and licensing arises. If $\bar{r} < A/3$, on the other hand, the optimal tariff rate is $A/3$ and R&D arises.*

4 Foreign Optimal Export Taxes

In this section, we investigate measures the foreign government may take to shift the rent from firm d to itself, because in the presence of licensing, firm d sets a license fee to extract as much rent from firm f as possible. We assume that the domestic government is passive and that the foreign government commits itself to adopting a rent-shifting policy before the firms move (i.e., in stage 0).

We begin with export taxes. We can verify that the R&D case is basically the same as the standard international Cournot duopoly model, in which the foreign government can shift the rent from firm d to firm f through an export subsidy.²¹ Foreign welfare consists of firm f 's profits and tax revenue, i.e.,

$$\begin{aligned} \widetilde{W}_R^f(\tau) &= \left(\frac{2(A - \tau) - \phi B}{4 - \phi^2}\right)^2 + \left(\frac{2(A - \tau) - \phi B}{4 - \phi^2}\right)\tau \\ &= \frac{1}{(\phi^2 - 4)^2} (4A^2 - 4AB\phi - 2A\tau\phi^2 + B^2\phi^2 + B\tau\phi^3 + 2\tau^2\phi^2 - 4\tau^2). \end{aligned} \quad (9)$$

²¹Since all foreign output is exported, production subsidies are equivalent to export subsidies.

Then the tax rate which maximizes (9) is negative and is given by

$$\tau_R^* = -\frac{\phi^2(2A - B\phi)}{4(2 - \phi^2)} < 0. \quad (10)$$

We should note that foreign welfare with the optimal export tax is less than firm f 's profits, $\pi_{R\tau}^{f*}$, because the optimal tax rate is negative. As was shown by Brander and Spencer (1985), the foreign government has an incentive to provide firm f with an export subsidy, because the increase in firm f 's profits, which we denote by $\Delta\pi_\tau^f (\equiv \pi_{R\tau}^{f*} - \pi_R^{f*})$, exceeds the amount of the subsidy. In the following analysis, we assume that the foreign government sets $\tau = \tau_R^*$ with R&D when it employs an export tax. We also assume $\Gamma \equiv F - \Delta\pi_\tau^f > 0$.²²

Next, we examine the licensing case. In this case, it is possible for the foreign government to shift the rent back from firm d through export taxes. The economic intuition is as follows. Firm d can charge license fees, because firm f 's profits under licensing without any fees are greater than those under R&D. That is, licensing arises because of the scope for arbitrage for firm d . The foreign government can impose an export tax to indirectly shift the rent by reducing the scope for arbitrage.

In fact, we can show that the optimal tax is positive in the licensing case. Since firm d designs the license fee such that firm f is indifferent between licensing and R&D, foreign welfare equals the sum of firm f 's profits under R&D and tax revenues. To make our argument clearer, we focus, for a moment, on the case in which $r = \bar{r}$ and $R = 0$. If a specific export tax, τ , is introduced before firm d makes a licensing offer, we have $r + \tau = \bar{r}$. This is because firm f will engage in R&D itself if the effective MC (which equals $c_x + r + \tau$) exceeds $c_x + \bar{r}$. Therefore, an increase in τ decreases the license fee. That is, an export tax reduces the scope for arbitrage. In particular, if the foreign government sets $\tau = \bar{r}$, firm f obtains the technology without making any payment to firm d . However, we should note that the profits of firm d are still larger under licensing than under R&D even with $\tau = \bar{r}$, because firm f 's effective MC under licensing, $c_x + \bar{r}$, is higher than that under R&D, $c_x + \tau_R^* (< c_x)$. Thus, the profits of firm d are still larger under licensing than under R&D even with full rent-shifting. We should note that the foreign government does not have an incentive to increase τ beyond \bar{r} , because of the constraint $r \geq 0$. If $\tau > \bar{r}$, then firm f engages in R&D.

Formally, in the presence of an export tax, (3) becomes as follows regardless of the

²²If this assumption does not hold, there is no room for firm d to charge a license fee in the licensing case.

type of license fees:²³

$$\pi_{L\tau}^{d*} \equiv \max_{r,R} \pi^d; \text{ s.t. } \pi_L^f - \tau x_L \geq \pi_{R\tau}^{f*}, r \geq 0, R \geq 0.$$

By affecting the constraint, an export tax makes indirect rent-shifting possible. Noting that foreign welfare simply consists of $\pi_{R\tau}^{f*}$ (which is given and constant) and tax revenues in the licensing case, the maximization problem for the foreign government is given by²⁴

$$\max_{\tau} \tau x_L; \text{ s.t. } \pi_{L\tau}^{d*} \geq \pi_{R\tau}^{d*}, r \geq 0, R \geq 0,$$

where $\pi_{R\tau}^{d*}$ is firm d 's profits under the optimal export tax in the R&D case. Obviously, the optimal export tax in the licensing case is positive. Thus, foreign welfare with the optimal export tax in the licensing case is higher than that in the R&D case. That is, the foreign government has an incentive to induce licensing.

Therefore, the following proposition is established.

Proposition 4 *Suppose that the domestic government is passive. The foreign government can indirectly shift the rent associated with licensing from the domestic firm to the foreign country by imposing a specific export tax on the foreign firm under licensing. Even if the payment from the foreign firm to the domestic firm is fully shifted by a specific export tax on the foreign firm under licensing, the domestic firm still gains from licensing. The optimal export tax is positive and licensing arises.*

Next we explore two other measures the foreign government can adopt to shift the rent from firm d to itself. As we will see, each policy affects the profit maximization problem of firm d differently.

The first measure is to introduce a lump-sum R&D subsidy, S , to firm f before firm d moves. How such a subsidy could shift the rent can clearly be seen when we consider the licensing contract with fees $r = 0$ and $R = \Gamma$. When the lump-sum R&D subsidy, S , is announced, firm d has to set $R = \Gamma - S$ to deter firm f from engaging in R&D. This implies that the foreign government does not pay the subsidy in equilibrium as long as $S \leq \Gamma$. The license fee becomes lower as the subsidy rises. To maximize the rent that is shifted, therefore, the foreign government sets $S = \Gamma$.

Formally, with an R&D subsidy, (3) is modified as follows regardless of the type of license fees:

$$\pi_{Ls}^{d*} \equiv \max_{r,R} \pi^d; \text{ s.t. } \pi^f \geq \pi_{R\tau}^{f*} + S, r \geq 0, R \geq 0.$$

²³Here we do not assume $r = \bar{r}$ and $R = 0$ anymore.

²⁴The constraint $\pi_{L\tau}^{d*} \geq \pi_R^{d*}$ is not binding in equilibrium. $r < 0$ is necessary to obtain $\pi_{L\tau}^{d*} = \pi_R^{d*}$.

By affecting the constraint, the foreign government can use the R&D subsidy as a device to shift the rent from firm d . Whereas the LHS of the constraint is modified by the export tax, the RHS is modified by the R&D subsidy. To maximize the rent that is shifted, the foreign government sets $S = \Gamma$ so that $\pi_{Ls}^{d*} = \pi_{Rr}^{d*}$ holds. With $S = \Gamma$, firm f obtains the license without any payment and hence foreign welfare is higher. In contrast with the export-tax case, the profits of firm d are identical between the R&D case and the licensing case with full rent-shifting. This is because the subsidy is lump-sum.

Thus, we establish the following proposition.

Proposition 5 *Suppose that the domestic government is passive. The foreign government can shift the rent associated with licensing from the domestic firm to the foreign country indirectly by committing itself to a lump-sum R&D subsidy. By setting $S = \Gamma$, the foreign government can induce technology transfer without any payment. With $S = \Gamma$, the domestic firm and country are indifferent between licensing and R&D, while foreign welfare is higher with licensing.*

The second measure is a tax on the license fees.²⁵ It is rather obvious that such a tax shifts the rent from firm d to the foreign government. Formally, in the presence of a specific tax on the license fee, t , (3) is modified as follows regardless of the type of license fees:

$$\pi_{Lt}^{d*} \equiv \max_{r,R} \pi^d - tx_L; \text{ s.t. } \pi^f \geq \pi_R^{f*}, r \geq 0, R \geq 0$$

where the objective function is modified by the tax. Then, the foreign government faces the following maximization problem:

$$\max_t tx_L; \text{ s.t. } \pi_{Lt}^{d*} \geq \pi_R^{d*}, r \geq 0, R \geq 0.$$

It should be noted that in our model, the imposition of a tax on the license fees does not cause tax shifting. This is because the tax shifting leads firm f to engage in R&D itself. Thus, the following proposition holds.

Proposition 6 *Suppose that the domestic government is passive. By imposing a tax on the license fees, the foreign government can shift the rent associated with licensing from the domestic firm to the foreign country without generating any burden on the foreign firm.*

²⁵For example, India imposes such a tax.

5 Simultaneous Moves by the Governments

In this section, we consider the case in which before the firms move, both the domestic and the foreign government move simultaneously to maximize their welfare. We assume that the domestic government imposes a specific tariff, T , while the foreign government imposes a specific export tax, τ . Domestic welfare consists of firm d 's profits, the consumer surplus, and tax revenue. Foreign welfare consists of firm f 's profits and tax revenue.

To find a Nash equilibrium, we examine the reaction of each government. First, we consider the R&D case. Since the optimal tariff rate is given by $A/3$, the domestic reaction curve is given by

$$T(\tau) = \frac{A - \tau}{3}. \quad (11)$$

Given (10), the foreign reaction curve is given by

$$\tau(T) = -\frac{\phi^2\{2(A - T) - B\phi\}}{4(2 - \phi^2)}.$$

In Figure 3, DD' and FF' are respectively the domestic and the foreign reaction curve. The Nash equilibrium with R&D is given by point R :

$$(\tau_R^N, T_R^N) = \left(-\frac{\phi^2(4A - 3B\phi)}{2(12 - 5\phi^2)}, \frac{8A - 2A\phi^2 - B\phi^3}{2(12 - 5\phi^2)} \right),$$

implying that the domestic government imposes a tariff and the foreign government provides an export subsidy. We can verify $\tau_R^N + T_R^N > 0$, that is, when both governments intervene simultaneously, the effective MC of firm f becomes higher.

It should be noted that the output of firm f is zero along JJ' (which intersects FF' on the vertical axis, i.e., at F''), while the output of firm d is zero along KK' . Thus, the relevant area is one between JJ' and KK' .

Keeping the R&D case in mind, we now consider the licensing case. As in Section 3, we have three cases, depending on the type of the licensing contract. The first case is licensing by means of a fixed fee alone. In this case, given (7), the domestic reaction curve is given by

$$T(\tau) = -\frac{4B\phi - (A - \tau)\phi^2 - 4(A - \tau)}{(3\phi^2 - 4)}. \quad (12)$$

We next consider the foreign reaction curve. By setting τ , the foreign government tries to extract as much rent from firm f as possible to minimize the rent shifted from

firm f to the domestic country. Given $\bar{\tau}$, the maximum τ , the foreign government can set, is

$$\tau = \bar{\tau} - (T + r) = \frac{2A - B\phi}{2} - \Omega_\tau - (T + r).$$

We should note $\Omega_\tau \equiv \sqrt{\pi_{R\tau}^{f*}(4 - \phi^2)}/2$, where $\pi_{R\tau}^{f*}$ is the foreign profits with R&D and the optimal export tax. Since the foreign government sets τ before license fees are determined, however, the foreign reaction curve is given by

$$\tau(T) = -T + \bar{\tau} = -T + \frac{2A - B\phi}{2} - \Omega_\tau. \quad (13)$$

In Figure 4, ff' shows (13). The following should be noted. First, the profits of firm f are the same between the R&D case and the licensing case. This implies that given T , foreign welfare is higher in the case with the higher tax revenue. Second, R&D arises if $\tau + T > \bar{\tau}$, which holds in the area above ff' . Third, the foreign reaction curve is independent of the licensing types.

Therefore, we obtain the following lemma.

Lemma 2 *The foreign reaction curve consists of segment $f'f''$ and segment $f''F''$.*

In Figure 4, $d_1d'_1$ is the domestic reaction curve under licensing given by (12). Since R&D arises in the area above ff' , $d_1d'_1$ terminates on ff' and the domestic reaction curve jumps to point D''' at point d'_1 . Thus, the domestic reaction curve consists of segment $d_1d'_1$ and segment $D'''D''$.

The Nash equilibrium is given by point d''_1 , where the domestic and the foreign government impose a tariff and an export tax, respectively. However, we should note that when Ω_τ is sufficiently large, the equilibrium point could be located below the horizontal axis (i.e., in the fourth quadrant), implying that an import subsidy is provided. Even if $T_{L1}^N < 0$, we have $T_{L1}^N + \tau_{L1}^N > 0$ from (13).²⁶

The next case is licensing by means of a royalty alone. The domestic government induces licensing with $\bar{\tau} - \tau \geq (A - \tau)/3$ and R&D with $\bar{\tau} - \tau < (A - \tau)/3$. Appendix B shows that there are two cases to consider. The cases are shown in two panels of Figure 5. The domestic reaction correspondence consists of the area on and below $d_2d'_2$ and segment d'_2D'' in both panels. In Panel (a), we have multiple Nash equilibria given by segment $f''d'_2$, where licensing arises. We have $T_{L2}^N + \tau_{L2}^N > 0$. In Panel (b), the Nash equilibrium is given by point R , where R&D arises.

²⁶ T_{Li}^N and τ_{Li}^N are, respectively, the Nash tariff rate and the Nash export tax rate in the i 'th licensing case.

The last case is licensing by means of both a fixed fee and a royalty. This case is similar to the first case. From (8), the domestic reaction curve under licensing is given by

$$T(\tau) = -\frac{2(A - \tau) - B\phi}{2}.$$

In Figure 6, the domestic reaction curve consists of segment d_3d_3'' and segment $D'''D''$. Thus, the Nash equilibrium is given by point d_3'' . If $\Omega_\tau = 0$, then the foreign reaction curve under licensing coincides with JJ' . Note that JJ' and d_3d_3' intersect on the horizontal axis. Since $\Omega_\tau > 0$, point d_3'' is always located below the horizontal axis (i.e., in the fourth quadrant). In the Nash equilibrium, therefore, the domestic and the foreign government, respectively, employ an import subsidy and an export tax. As in the first case, we have $T_{L3}^N + \tau_{L3}^N > 0$.

Therefore, we obtain the following proposition.

Proposition 7 *Suppose that the domestic government imposes a tariff and the foreign government imposes an export tax. Even if one of the taxes is negative in a Nash equilibrium, the sum of the taxes is positive. Thus, when both governments intervene simultaneously, the effective MC of the foreign firm becomes higher in the Nash equilibrium.*

6 Concluding Remarks

Using an international duopoly model, this study explored possible strategic interactions between a domestic and a foreign country in the presence of R&D and licensing. A domestic firm and a foreign rival compete in the domestic market. The foreign firm, to produce the good it wants to sell in the domestic market, has to acquire technology either through R&D or through licensing from the domestic firm. With both R&D and licensing opportunities, the domestic firm offers a licensing contract to deter the foreign firm from engaging in R&D. This affects the opportunities for governments to generate international rent-shifting. Interestingly, by imposing an export tax on the “foreign” firm, the foreign government can shift the licensing revenue from the “domestic” firm. Both the domestic and the foreign optimal policies with licensing can be the exact opposite of the optimal policies without licensing.

Six final remarks are in order. First, the analysis here examined a few simple policies that cause rent-shifting and is by no means exhaustive. That is, rent-shifting is possible not only under the policies considered here and one can easily think of other rent-shifting policies.

Second, since in practice technologies are often embodied in sophisticated intermediate products that some firms are unable to produce, the model we consider allows firms to purchase such key intermediate inputs from rival firms.

Third, the presence of R&D plays a crucial role in arriving at the results obtained here, although R&D simply plays the role of an outside option for the foreign firm and R&D expenditures are basically regarded as waste. Thus, the foreign government prefers licensing to R&D when rent-shifting from the domestic firm to the foreign country is possible. However, R&D may generate positive externalities such as technology spillovers to other sectors. In the presence of such externalities, the foreign government may prefer R&D to licensing.

Fourth, we considered the case where the domestic firm has full bargaining power when license fees are determined. Our results remain qualitatively unchanged as long as the domestic firm has some bargaining power. If the foreign firm has full bargaining power instead, the optimal fee is a tiny fixed fee, because a royalty increases the foreign firm's effective MC. The domestic government then has an incentive to decrease the optimal tariff in the presence of licensing, because the decrease leads the foreign firm to increase the fixed license fee in order to induce licensing. At the optimal tariff level, the fixed license fee equals the FCs associated with R&D.

Fifth, if the market is not in the domestic country but in a third country, it would be natural to consider an export (or production) subsidy as a domestic policy instead of a tariff. In the R&D case, an export subsidy is optimal for the domestic government. In the case of licensing, an export (or production) tax could be optimal.

Lastly, it is usually expected that a tariff reduction hurts the domestic firm. In our licensing case, however, the government may have an incentive to lower the tariff to "benefit" the domestic firm and raise domestic welfare. Our analysis thus provides a potential rationale for tariff reductions.

Appendix

A. Proof of Proposition 1

Proof. Given r , the equilibrium profits of firm d are given by (5):

$$\begin{aligned}\hat{\pi}_L^d(r) &= \left(\frac{2B - \phi(A - r)}{4 - \phi^2}\right)^2 + \left(\frac{2(A - r) - \phi B}{4 - \phi^2}\right)^2 - \pi_R^{f*} + r \frac{2(A - r) - \phi B}{4 - \phi^2} \\ &= \frac{(3\phi^2 - 4)r^2 + (B\phi^3 - 4A\phi^2 + 4B\phi)r + (A^2\phi^2 - 4AB\phi + 4B^2)}{(\phi + 2)^2(\phi - 2)^2} + F,\end{aligned}$$

which takes its maximum value at $r = -\phi(4B + B\phi^2 - 4A\phi)/2(3\phi^2 - 4) \equiv r^*$. Since $3\phi^2 - 4 < 0$, $r^* < 0$ if $\phi(4B + B\phi^2 - 4A\phi) < 0$ and $r^* > 0$ if $\phi(4B + B\phi^2 - 4A\phi) > 0$. Thus, given that $r \geq 0$, firm d sets $r = 0$ and $R = F$ when $\phi(4B + B\phi^2 - 4A\phi) \leq 0$. When $\phi(4B + B\phi^2 - 4A\phi) > 0$, we have two cases depending on the size of the maximum royalty firm d can charge, \bar{r} , which satisfies

$$\left(\frac{2(A-r) - \phi B}{4 - \phi^2}\right)^2 = \pi_R^{f*}.$$

Thus,

$$\bar{r} = A - \frac{1}{2}B\phi + \frac{1}{2}\sqrt{\pi_R^{f*}(\phi^2 - 4)} > 0.$$

Given that $R \geq 0$, firm d sets $r = \bar{r}$ and $R = 0$ if $r^* \geq \bar{r}$. If $r^* < \bar{r}$, on the other hand, firm d sets $r = r^*$ and

$$R = \left(\frac{2(A-r^*) - \phi B}{4 - \phi^2}\right)^2 - \pi_R^{f*} \equiv R^* > 0.$$

■

B. Nash equilibria under licensing with a royalty alone

We should recall that with licensing by means of a royalty alone, T and τ are perfect substitutes from a welfare perspective. When $\bar{r} - \tau \geq (A - \tau)/3$ (i.e., $\tau \leq A - 3B\phi/4 - 3\Omega/2$), we obtain $T(\tau) + r = \bar{r} - \tau$. Thus, the domestic reaction ‘‘correspondence’’ is on and below $T = \bar{r} - \tau$.

We have two cases depending on where (11) and (13) intersect. The intersection point, d'_2 , is given by

$$\left(A - \frac{3}{4}B\phi - \frac{3}{2}\Omega, \frac{1}{4}B\phi + \frac{1}{2}\Omega\right).$$

Thus, point d'_2 lies either in the first quadrant or in the second quadrant.

Panel (a) of Figure 5 illustrates the case where point d'_2 is located to the right of point R . In this case, the domestic reaction correspondence consists of the area on and below $d_2d'_2$ and segment d'_2D'' . Thus, the Nash equilibria are segment $f''d'_2$. In Panel (b), point d'_2 is located to the left of point R . The domestic reaction correspondence is basically the same as that in Panel (a). In Panel (b), the Nash equilibrium is R , where R&D arises.

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Figure 1: Three types of licensing

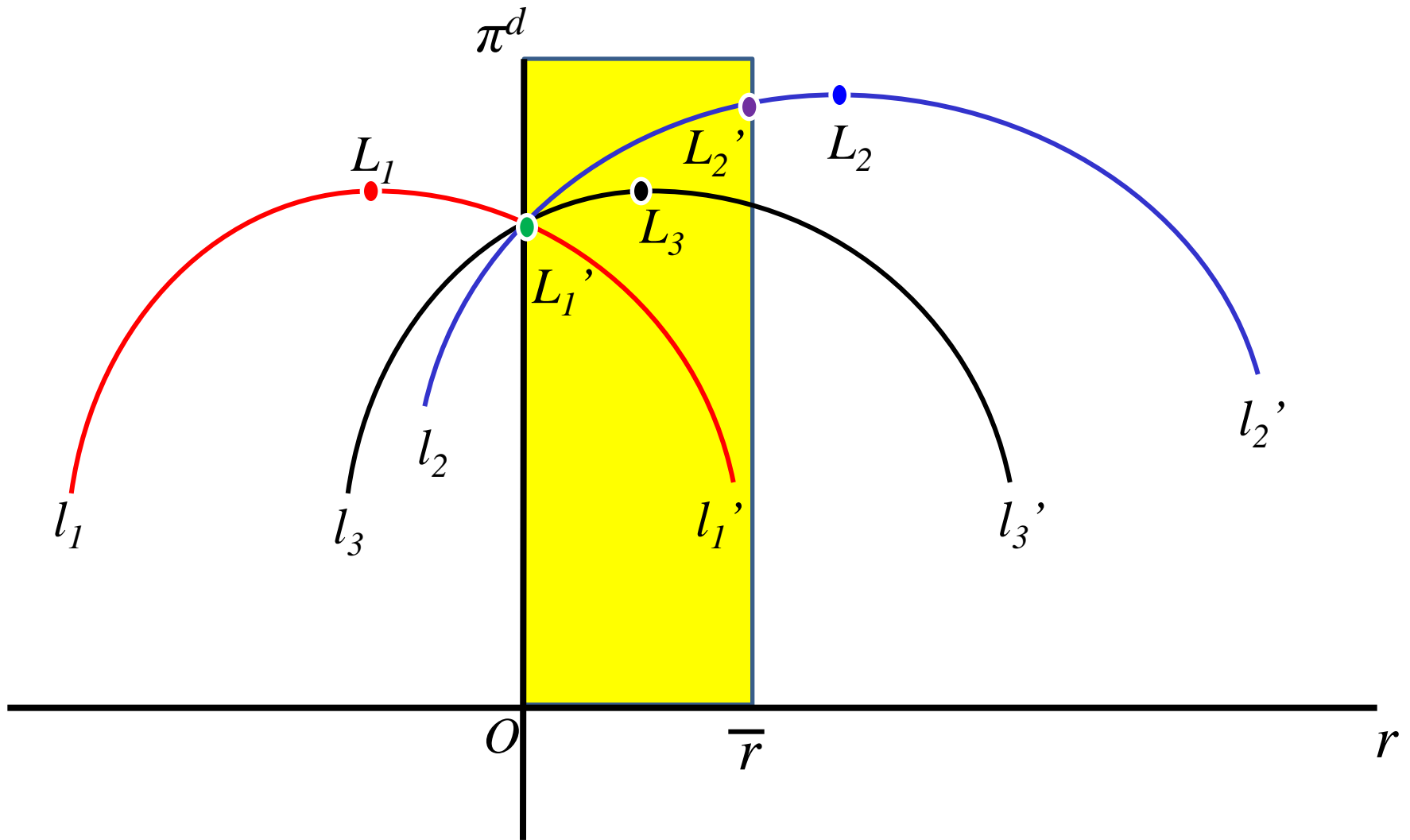


Figure 2: Optimal tariff with licensing with royalty alone

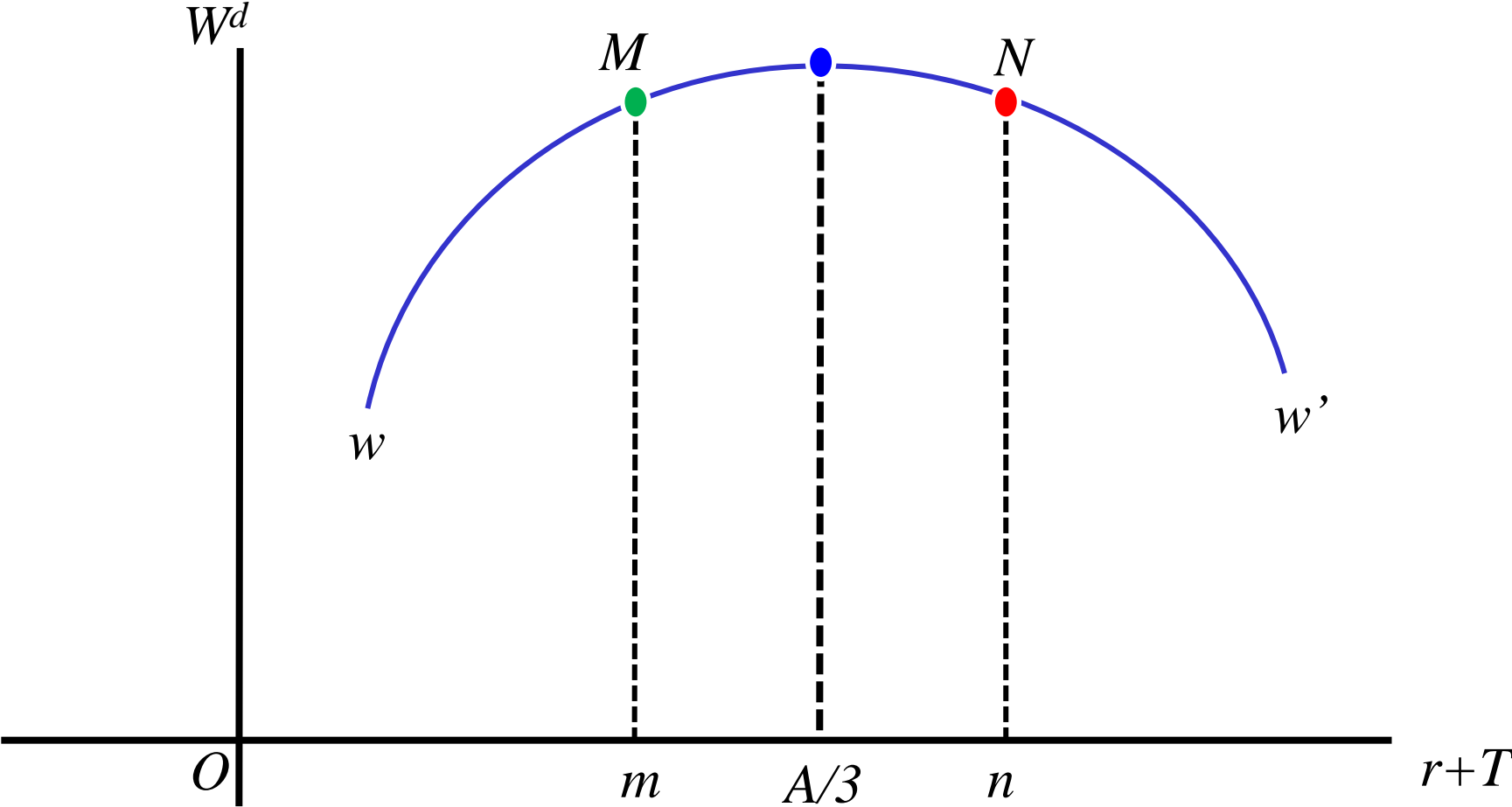


Figure 3: Tariffs and export tax under R&D

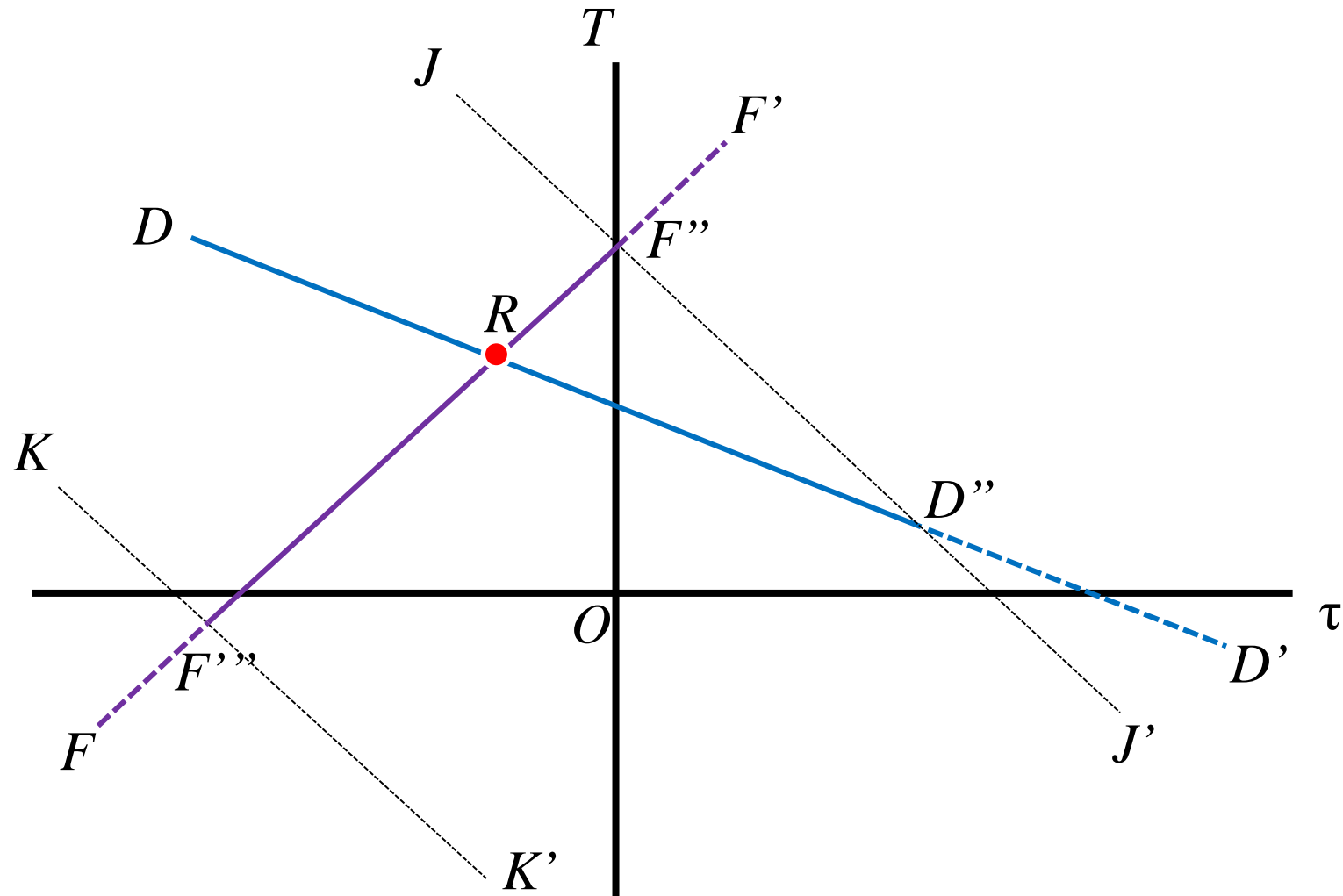


Figure 4: Tariffs and export taxes under licensing with a fixed fee alone

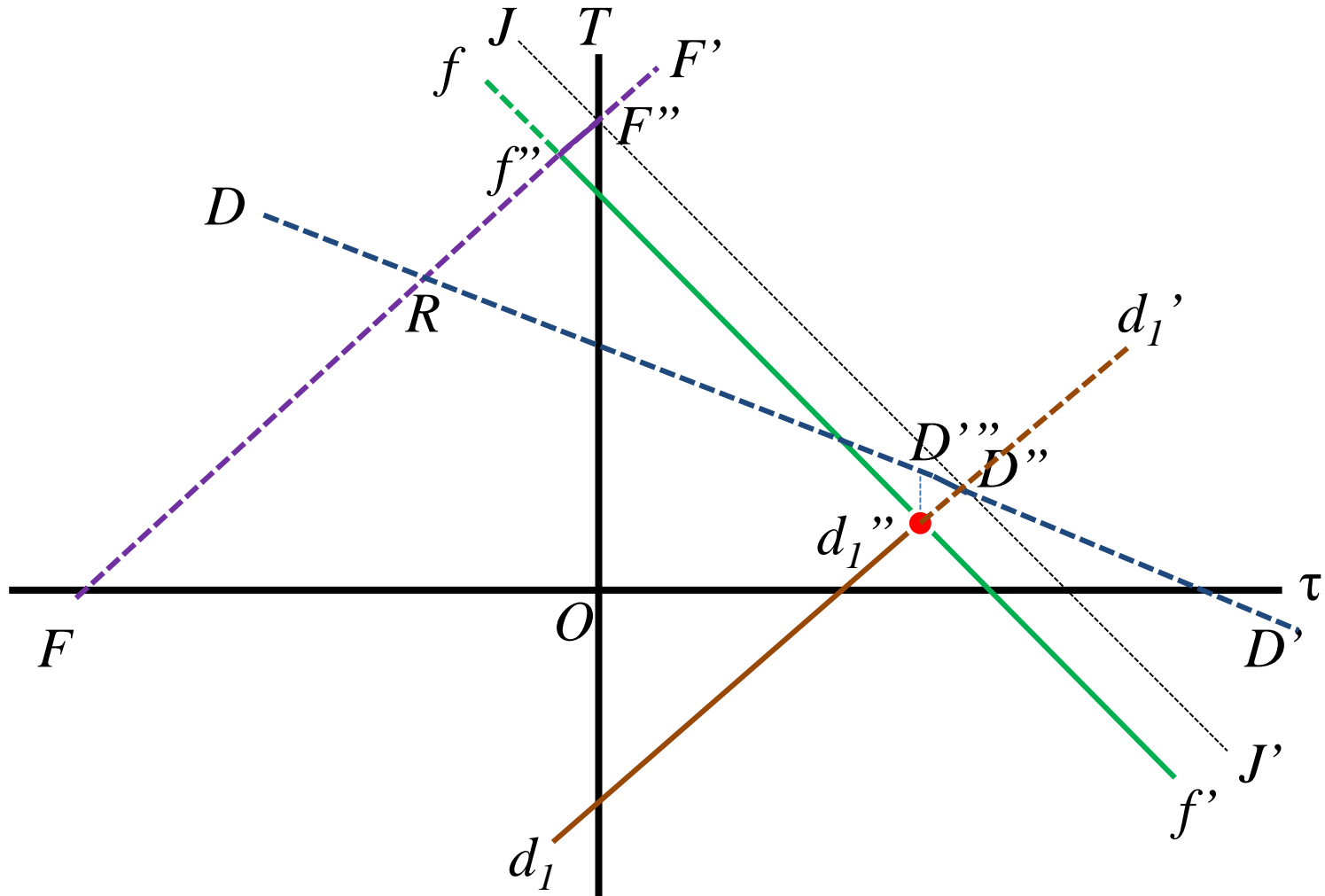


Figure 5: Tariffs and export taxes
under licensing with a royalty alone
Panel (a)

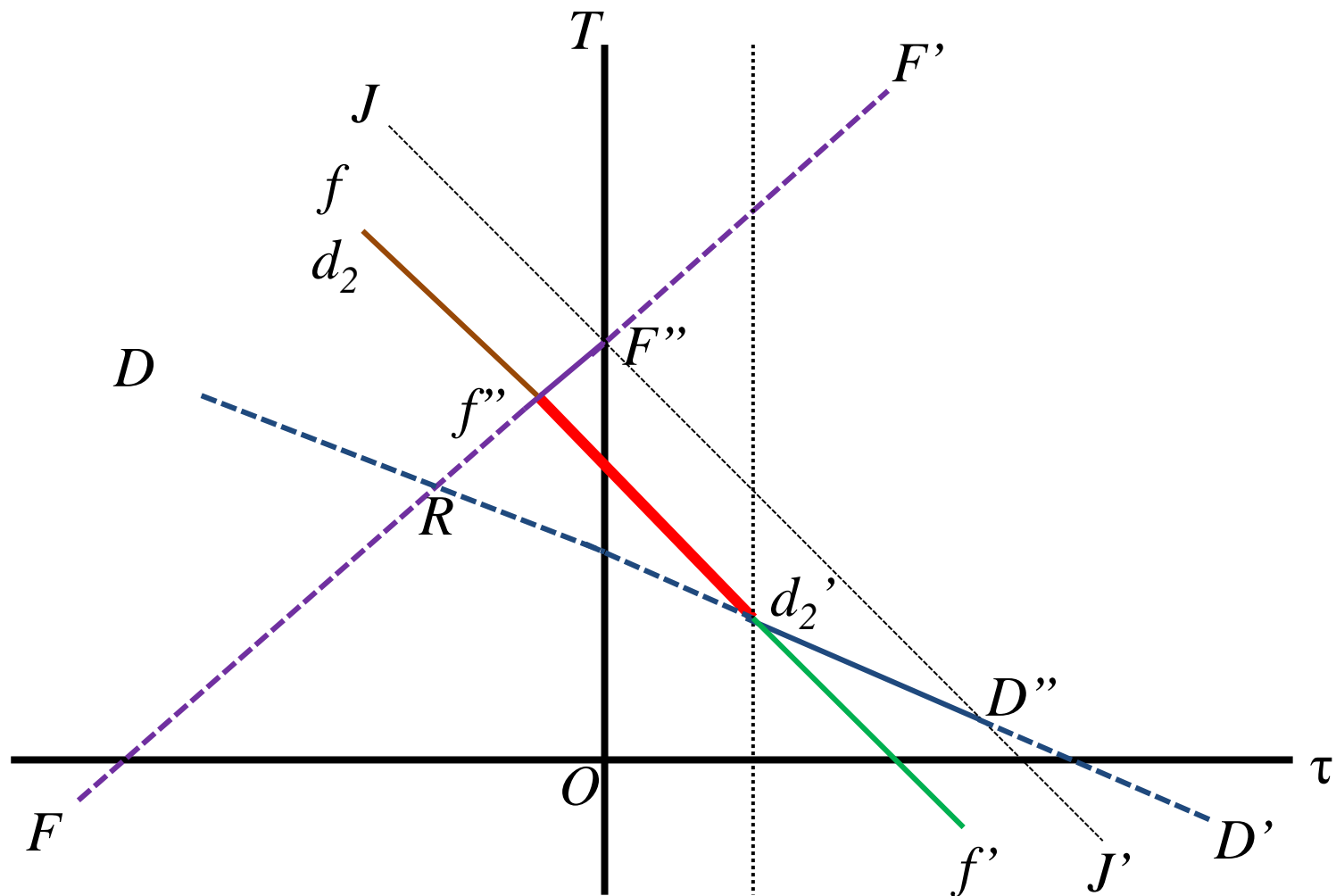


Figure 5: Tariffs and export taxes
under licensing with a royalty alone
Panel (b)

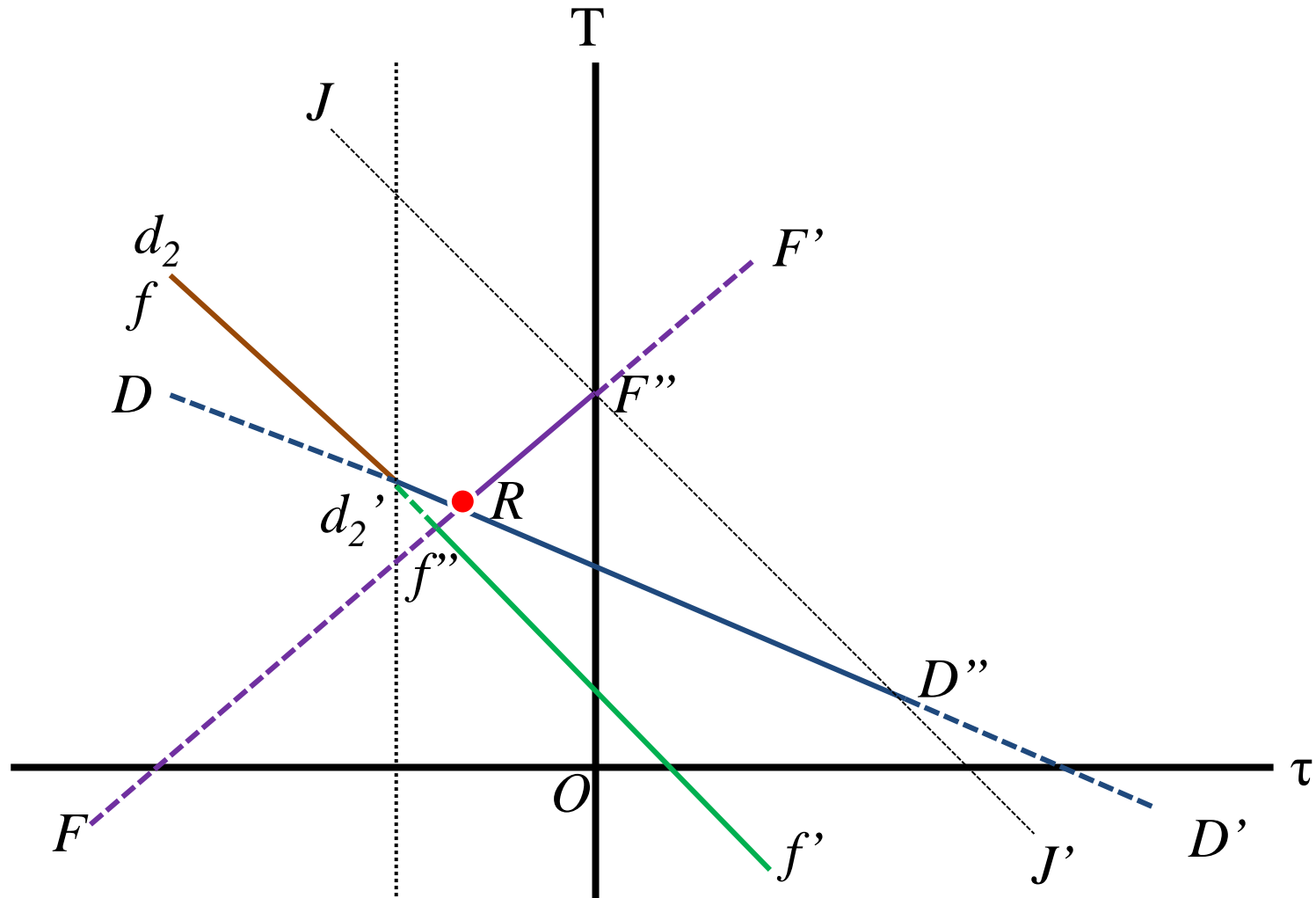


Figure 6: Tariffs and export taxes under licensing with both a fixed fee and a royalty

