Cross-border Technology Licensing and Trade Policy*

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Abstract

We construct a theoretical model in which an outside technology licenser licenses its superior technology to either a home firm or a foreign firm, both of which are engaged in Cournot competition in the home market. We specifically explore the relationship between cross-border technology licensing and home tariffs when the two firms are asymmetric. Licensing benefits consumers but harms both home and foreign firms regardless of which firm becomes the licensee. The tariff rate affects the choice of the licensee and home welfare. In contrast with the existing literature on international technology licensing, the welfare-maximizing home government may choose such a tariff rate that induces the licenser to license the technology to the foreign firm. The optimal tariff rate may become negative in the presence of licensing. Trade liberalization may lead the licenser to switch the licensee.

JEL Classification: F12, F13, L13, L24

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1 Introduction

The markets for technology have been growing and technology licensing is recently very active (e.g., Athreye and Cantwell, 2007; Arora and Gambardella, 2010). In fact, various types of technology licensing are observed. Thus, there are extensive economic issues regard-
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...ing technology licensing.  For instance, the licenser is either a competitor or a non-competitor of the licensee(s). License payments are by means of either a fixed fee alone, or a royalty alone, or a combination of a fixed fee plus a royalty. License payments are determined by either negotiation or auction. Licensing is either exclusive or non-exclusive. The patented innovation is either a process innovation or a product innovation. The patented innovation is either drastic or non-drastic. The effects of technology licensing depend on the structure of market in which licensees participate. Scope of licensing and enforcement of intellectual property rights (IPR) also matter.

Cross-border technology licensing is well documented in the global economy (e.g., Saggi, 2002; Athreye and Cantwell, 2007; Arora and Gambardella, 2010). With international licensing, various location and ownership patterns for licensers and licensees have been witnessed. Trade polices as well as industrial policies influence the location and price of cross-border licensing.

In this paper, we deal with international technology licensing in the presence of trade polices. Specifically, we analyze the relationship between tariffs imposed by the host country and cross-border technology licensing. Since there exists considerable literature on technology licensing, our model basically follows the seminal paper by Kamien and Tauman (1986). An innovator that conducts a non-drastic cost-reducing innovation is not a rival of licensees in the product market. Two potential licensees have different constant marginal costs (MCs) to produce a homogeneous product and engage in Cournot competition in the market. The innovator licenses its technology to one of the potential licensees exclusively by the means of fixed fees alone.

Our open-economy features are as follows. The licenser is located abroad. One of the potential licensees is a home firm, while the other is a foreign firm. These potential licensees compete in the home product market. The home government may set a specific import tariff.

1) See Kamien (1992) for a survey on licensing literature.
2) The differences between our study and Kamien and Tauman (1986) are as follows. In their “main” model, i) there are n identical potential licensees, ii) the cost-reducing innovation could be drastic, iii) license payments are by means of either a fixed fee only or a royalty only, and iv) the economy is closed. The main purpose of Kamien and Tauman (1986) is to show that an outside licenser prefers fixed-fee licensing to royalty licensing.
3) For example, the innovator may be a university or an independent research lab. In 2012, the numbers of licenses granted by Japanese and U.S. universities are 2,298 and 5,130, respectively (http://www.scj.go.jp/ja/member/iinkai/gakushikin/pdf23/gakushikin-siryo4-2.pdf). Alternatively, the patent holder and the potential licensees may have different uses for the patented technology (e.g., Hernandez-Murillo and Llobet, 2006).
4) Wang and Yang (2004) introduce asymmetric production costs into the model of Kamien and Tauman (1986). They show that royalty licensing can be superior to fixed-fee licensing for the patent-holder.
5) Exclusive licensing is common in practice. In 2006, the number of license contracts whose licensers are U.S. universities is 4,150. Among them, 2,051 contracts are exclusive (https://www.nict.go.jp/global/le9n2000000bmhf-att/re0811.pdf).
6) Yang and Maskus (2009) mention “a lump-sum license fee without per-unit royalties captures the empirical reality that a large portion of technology contracts in developing countries have this feature”. For example, in the analyses of international licensing, Mukherjee (2002), Kabiraj and Marjit (2003), Ghosh and Saha (2008), Yang and Maskus (2009), and Gosh and Ishikawa (2018) deal only with fixed-fee licensing.
7) An suitable example is that Microsoft licenses its connected car technology to Toyota. BMW uses Microsoft’s connected vehicle platform but does not hold a license contract with Microsoft (https://
to manipulate not only imports but also the licensing decision. We specifically explore how home tariffs affect the licensing strategy of the foreign patent holder and home welfare in the presence of asymmetric MCs. We show that cross-border licensing benefits consumers but harms potential licensees and, as a result, home welfare may deteriorate. In particular, under certain circumstances, the home government strategically sets a tariff so that the licenser grants a license not to the home firm but to the foreign firm. Also as trade is liberalized, the licenser may switch the licensee from the home firm to the foreign firm.

Our prediction may help understanding some real cases of cross-border technology licensing. For instance, a French fashion brand AIGLE had licensed brand business in Japan to a Japanese apparel maker Yamato International since 1993. In 2017, the licensee was changed to another French brand Lacoste. Accordingly, a large portion of production shifted from Japan to France and Hong Kong. Though the company did not announce the detail reason behind the change, the Japan–EU Economic Partnership Agreement (EPA) may have affected the decision. The EPA reached agreement in 2017 and Japan abolished tariffs on apparel products in 2018, which was average 9 percent and maximum 13.4 percent in 2017 according to UNCTAD TRAINS.

In our analysis, the optimal tariff rate may be negative. If there is no licensing opportunity in our framework, the optimal tariff is positive unless the demand function is very convex (e.g., Brander and Spencer, 1984; Furusawa et al., 2003). The tariff harms consumers but shifts rent from the foreign firm to the home country. As a result, home welfare improves. In the presence of licensing, however, the choice of the licensee depends on a tariff. This generates an additional effect on home welfare. The licensee choice influences consumer surplus more strongly than home profits. Therefore, consumer welfare becomes a more important determinant of the optimal policy. As a result, the optimal tariff can be negative, that is, an import subsidy can be optimal.

Cross-border technology transfer with “tariffs” in the context of international oligopoly has been analyzed by Kabiraj and Marjit (2003), Mukherjee and Pennings (2006), Ishikawa (2007), and Horiuchi and Ishikawa (2009) among others. 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 home rival only if the initial cost difference between the foreign and the home 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 home or foreign entrants by a foreign monopolist and the timing of the imposition of the (optimal...)

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8) There are studies that investigate the welfare effects of cross-border technology transfer with other policies. Mukherjee (2002) considers production subsidies. He indicates the possibility of “production-subsidy-induced” technology transfer through licensing. Ghosh and Saha (2008) introduce technology licensing into the third-country-market model and show that the optimal policy for the licensee’s government could be an export tax. Introducing costly licensing in a North–South oligopoly framework, Yang and Maskus (2009) examine the role of IPR in the context of trade and licensing. They convincingly argue that strengthening IPR protection can benefit South by reducing the costs of technology transfer. Ghosh and Ishikawa (2018) also show that licensing from North to South caused by South’s strengthening IPR protection improves South welfare.
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Ishikawa (2007) and Horiuchi and Ishikawa (2009) explore the strategic relationship between tariffs and North–South technology transfer in a North–South oligopoly model. It should be pointed out, however, that the above four studies are primarily concerned with how the home government can induce technology transfers from a “foreign rival firm” to a home firm through home tariffs. Furthermore, licensing is welfare-improving for the home country in those studies.

Chang et al. (2016) is somewhat similar to our analysis in the sense that they also introduce firm heterogeneity and show international licensing by a foreign outside patent holder may worsen home welfare. However, their focus is different from ours. Chang et al. (2016) basically compare between fixed-fee and royalty licensing in a Cournot duopoly model with asymmetric absorptive capacity as well as asymmetric production costs. Their focus is more on asymmetric absorptive capacity (rather than asymmetric production costs) of the licensees. Furthermore, since both potential licensees are home firms, no trade policy is investigated. To our knowledge, the current study is the first that investigates the relationship between trade policies and cross-border licensing by an outside patent holder.

The rest of the paper is organized as follows. In Section 2, we present an international Cournot duopoly model with licensing. We analyze to which firm a foreign outside patent holder licenses its technology in the presence of tariffs on the foreign product. In Section 3, we explore the welfare effects of cross-border licensing with tariffs. In Section 4, we investigate the optimal tariffs. Section 5 concludes.

2 Basic Model

We consider a model with three countries called Home, Foreign and Third. There is a single firm in each country. The home and the foreign firms produce a homogenous good and engage in Cournot competition in the home market. Third firm owns a superior technology to produce the good but does not engage in producing the good. Instead it grants an exclusive license to either the home firm or the foreign firm.9)

The output levels of the home firm and the foreign firm are $x$ and $X$, respectively. The demand function in the home market is linear10)

$$p = A - a(x + X),$$

where $p$ is the goods price and $A$ and $a$ are positive parameters. Without licensing, the MCs of the home firm and the foreign firm are, respectively, $c$ and $C$. If a license is granted to a firm, its MC becomes zero. The home government may impose a specific tariff $t$ on imports of the good. We allow $t$ to be negative (i.e., $t < 0$).

9) Since we observe many exclusive licenses in the real world (see footnote 5), we simply focus on exclusive licensing in our analysis. It should be pointed out that an exclusive licensing results in the larger license fee than a non-exclusive licensing under certain conditions. In such a case, the licensor will choose an exclusive licensing contract. See Appendix A for the conditions.

10) Even if a general demand function is used in our analysis, the essence of our main results would not change.
2.1 Preliminary: Equilibrium without Licensing

We first consider equilibrium without licensing. We summarize useful properties of a Cournot duopoly with constant MCs. The first order conditions

\[ A - a(x + X) - c - ax = 0, \]
\[ A - a(x + X) - (C + t) - aX = 0 \]
determine the outputs \( x(c, C+t) \) and \( X(c, C+t) \):

\[ x(c, C+t) = \frac{A - 2c + (C + t)}{3a}, \quad X(c, C+t) = \frac{A - 2(C + t) + c}{3a}. \]

Here, noting \( t < 0 \) is allowed, we assume \( \min\{A - 2c + (C + t), A - 2(C + t) + c\} > 0 \), or, \( -(A - 2c + C) < t < (A - 2C + c)/2 \) to ensure positive outputs.

The total output and the price are

\[ x(c, C+t) + X(c, C+t) = \frac{2A - (c + C + t)}{3a} \quad \text{and} \quad p(c, C+t) = \frac{A + c + C + t}{3}. \tag{1} \]

Consumer surplus is given by

\[ CS(c, C+t) = \frac{a(X + x)^2}{2} = \frac{1}{2a} \left( \frac{2A - (c + C + t)}{3} \right)^2. \tag{2} \]

(1) and (2) imply that the price and consumer surplus are functions of the sum of the two firm’s effective MCs (i.e., \( c + C + t \)).

The profits of the home firm and the foreign firm become

\[ \pi(c, C+t) = a(x(c, C+t))^2 = \frac{1}{a} \left( \frac{A - 2c + C + t}{3} \right)^2, \tag{3} \]

\[ \Pi(c, C+t) = a(X(c, C+t))^2 = \frac{1}{a} \left( \frac{A - 2(C + t) + c}{3} \right)^2. \tag{4} \]

Thus, as the output increases, the profits increase.

The home tariff revenue is

\[ TR(c, C+t) = tX(c, C+t) = t \left( \frac{A - 2(C + t) + c}{3a} \right). \tag{5} \]

The tariff revenue is increasing in the MCs of the home firm and decreasing in the MCs of the foreign firm.

**Equilibrium without licensing** Consider a benchmark case without licensing. The equilibrium outputs and profits of the home firm and the foreign firm are respectively given by

\[ x_{NL} = x(c, C+t), \quad X_{NL} = X(c, C+t), \]
\[ \pi_{NL} = \pi(c, C+t), \quad \Pi_{NL} = \Pi(c, C+t). \]
The equilibrium price, consumer surplus and tariff revenue are

\[ p_{NL} = p(c, C + t), \quad CS_{NL} = CS(c, C + t), \text{ and } TR_{NL} = tX(c, C + t). \]

Home welfare, which is the sum of the home profits, consumer surplus and tariff revenue, is given by

\[
W_{NL} = CS_{NL} + \pi_{NL} + TR_{NL}
\]

\[
= \frac{1}{2a} \left( \frac{2A - (c + C + t)}{3} \right)^2 + \frac{1}{a} \left( \frac{A - 2c + C + t}{3} \right)^2 + t \left( \frac{A - 2(C + t) + c}{3a} \right)
\]

\[
= \frac{(2A^2 - 4Ac + C^2 - 2Cc + 3c^2) + (2A - 2C)t - 3t^2}{6a}. \quad (6)
\]

Thus, the optimal tariff is positive:

\[
t_{NL}^{opt} = \frac{A - C}{3} > 0. \quad (7)
\]

### 2.2 Equilibrium with Licensing

To investigate technology licensing, we build a three-stage game with a given tariff. We investigate the optimal tariff in Section 4. In Stage 1, the licensor decides to which firm it licenses its technology and makes a take-it-or-leave-it offer with a fixed license fee. The licensor makes a commitment to grant its license to at most one firm. In Stage 2, the offered firm decides whether to accept the offer. If it accepts the offer, its MCs become 0. If the offer is rejected, the licensor makes a take-it-or-leave-it offer to the other firm. If it accepts the offer, its MCs become 0. If it rejects the offer, the MCs of both firms do not change. In the final Stage 3, the firms produce outputs and compete in the home market.

We assume the following sufficient condition for duopoly in equilibrium.

**Assumption 1 (Duopoly)**

(i) Market size \( A \) and marginal costs \( c \) and \( C \) satisfy

\[ A > \max \{2c, 2C\}. \quad (8) \]

(ii) Tariff-cum-subsidy \( t \) satisfies

\[ -(A - 2c) < t < \frac{A - 2C}{2}. \quad (9) \]

Condition (i) implies that both firms produce positive outputs under free trade regardless of whether the license is granted to the home firm or the foreign firm. Condition (ii) requires tariff-cum-subsidy not to be too large so that both firms produce positive outputs regardless of the choice of the licensor.

### 2.2.1 Stage 3: Market competition

Since technology is licensed to only one firm, there are three possible cases: (i) no licensing: neither firm accepts the offer; (ii) home licensing: technology is licensed to the home firm; and (iii) foreign licensing: technology is licensed to the foreign firm.
Under home licensing, the MCs of the home firm reduce to 0 and that of the foreign firm remains at the initial level $C$. The outputs and the profits of each firm are

$$\begin{align*}
  x_{HL} &= x(0, C + t), \\
  X_{HL} &= X(0, C + t), \\
  \pi_{HL} &= \pi(0, C + t) - R_{HL}, \\
  \Pi_{HL} &= \Pi(0, C + t),
\end{align*}$$

where $R_{HL}$ is the fixed license fee paid by the home firm. Similarly, the outputs and the profits of each firm under foreign licensing are given by

$$\begin{align*}
  x_{FL} &= x(c, t), \\
  X_{FL} &= X(c, t), \\
  \pi_{FL} &= \pi(c, t), \\
  \Pi_{FL} &= \Pi(c, t) - R_{FL}.
\end{align*}$$

### 2.2.2 Stage 2: Acceptance decision

In Stage 2, the firm to which the licensor makes a license offer determines whether to accept it.

**Initial offer to the home firm** Consider a subgame in which the licensor initially makes an offer to the home firm. If the home firm accepts the offer, its profits are given by $\pi_{HL} = \pi(0, C + t) - R_{HL}$. If it declines the offer, then the licensor offers a license contract to the foreign firm. If the foreign firm also rejects the offer, the licensor does not earn any license fee. Thus, the licensor offers the foreign firm a license contract with a fixed fee $\Pi_{HL} = \Pi(c, t) - R_{FL}$ which the foreign firm is willing to accept. If this happens, the home profits become $\Pi_{HL} = \Pi(c, t)$ which is an outside option for the home firm. Therefore, when making the initial offer to the home firm, the licensor sets the license fee so that the profits of the home firm equal the outside option (i.e., $\pi_{HL} = \pi_{FL}$):

$$\pi(c, t) = \frac{1}{a} \left( \frac{A - 2c + t}{3} \right)^2,$$

which is an outside option for the home firm. Therefore, when making the initial offer to the home firm, the licensor sets the license fee so that the profits of the home firm equal the outside option (i.e., $\pi_{HL} = \pi_{FL}$):

$$\begin{align*}
  R_{HL} &= \pi(0, C + t) - \pi(c, t) \\
  &= \frac{1}{9a} (C + 2c)(2A + C - 2c + 2t) > 0
\end{align*}$$

and the home firm will accept it despite the fact that the home profits are lower than those under no licensing.

The license fee increases in the tariff ($\partial R_{HL} / \partial t > 0$). When the tariff is raised, the home profits increase ($\partial \pi(c, C + t) / \partial t > 0$). Therefore, the licensor can increase the license fee for the home firm to extract this additional profit. A tariff increases the home profits under home licensing more than under foreign licensing.

**Initial offer to the foreign firm** Consider the other subgame where the licensor makes an initial offer to the foreign firm. If the foreign firm accepts the offer, then the foreign profits are $\Pi_{FL} = \Pi(c, t) - R_{FL}$. If it declines the offer, the licensor makes a license offer to the home firm so that the home firm is willing to accept it. Then, the foreign profits become $\Pi_{HL} = \Pi(0, C + t)$. Expecting this outcome, the foreign firm’s outside option is $\Pi_{HL}$. Therefore, the licensor sets the license fee so that the profits of the foreign firm equal its outside option (i.e., $\Pi_{FL} = \Pi_{HL}$):

$$\begin{align*}
  &R_{FL} = \pi(c, t) - \pi(0, C + t) \\
  &\quad = \frac{1}{9a} (C + 2c)(2A + C - 2c + 2t) > 0
\end{align*}$$
The license fee is decreasing in the tariff \( \frac{\partial R_{FL}}{\partial t} < 0 \). An increase in the tariff decreases the foreign profits. Thus, the licenser has to decrease the license fee for the foreign firm.

### 2.2.3 Stage 1: Licensing decision

In the stage 1, the licenser decides to which firm it makes an initial offer. The licenser makes an initial offer to the home firm if and only if \( R_{HL} \geq R_{FL} \). In view of (11) and (12), we have

\[
\Delta R = R_{HL} - R_{FL} = \left( c - C \right) \left( 2A - 5(c + C) \right) + 2t \left( \frac{5c + 4c}{9a} \right)
\]

Therefore, the following holds:

\[
\Delta R \geq 0 \iff \left( c - C \right) \left( 2A - 5(c + C) \right) + 2t \left( 5c + 4c \right) \geq 0.
\]

The inequality in (14) depends on the MCs of the two firms as well as the tariff rate. To see an economic intuition, first, consider free trade \( t = 0 \). There exist two cases where the licenser is indifferent between the two firms, \( R_{HL} = R_{FL} \). The first obvious case is when the two firms have the same MCs, \( c = C \). To see the second case, suppose the MC of the foreign firm increases. Note that with \( t = 0 \), we have

\[
R_{HL} = \pi(0,C) - \pi(c,0), \quad R_{FL} = \Pi(c,0) - \Pi(0,C).
\]

An increase in \( C \) increases \( R_{HL} \) by increasing the home profits under home licensing, \( \pi(0,C) \), and increases \( R_{FL} \) by decreasing the foreign profits under home licensing, \( \Pi(0,C) \). Which effect dominates depends on the MC of the foreign firm. From (13), we have

\[
\frac{\partial \Delta R}{\partial C} = \frac{\partial \pi(0,C)}{\partial C} + \frac{\partial \Pi(0,C)}{\partial C} = \frac{2}{9} \left( \frac{A - 5C}{a} \right),
\]

\[
\frac{\partial^2 \Delta R}{\partial C^2} > 0.
\]

\( \Delta R \) is a U-shaped curve with respect to the foreign MCs. When the foreign firm has sufficiently low MCs and/or holds a sizable market share (i.e., \( C < A/5 \)), the profit loss of the foreign firm dominates the profit gain of the home firm. On the other hand, when the foreign firm has sufficiently high MC and/or holds only a small market share (i.e., \( C > A/5 \)), the profit gain of the home firm dominates the profit loss of the foreign firm. The U-shaped curve of \( \Delta R \) implies that for given \( c \), there is a level of \( C (\neq c) \) with which the licenser becomes indifferent between home and foreign licensing (i.e., \( \Delta R = 0 \)). A simple calculation using (15) can show that \( \Delta R = 0 \) holds if \( c + C = 2A/5 \).

Figure 1 illustrates how the MCs of the two firms determine the sign of \( \Delta R \) when \( t = 0 \). The two solid lines are \( c = C \) and \( c + C = 2A/5 \), respectively. Whereas \( \Delta R > 0 \) holds in the shaded areas, \( \Delta R < 0 \) holds in the blank areas.

A positive tariff unambiguously increases \( \Delta R \) and encourages home licensing by increas-
ing $R_{HL}$ and decreasing $R_{FL}$ from (11) and (12). That is, when $t > 0$, $\Delta R$ is more likely to be positive and the shaded areas in Figure 1 become larger. If $t < 0$, on the other hand, the blank areas become larger. An economic intuition behind this result is as follows. The effective MC of the foreign firm is $C + t$ without licensing and is $t$ with foreign licensing. When $t$ is large, foreign licensing does not increase the foreign profits much. But home licensing increases the home profits a lot. Thus, the licensor is more likely to choose the home firm as the licensee.

Noting $\Delta R = 0$ holds at $t = (C - c)(2A - 5C - 5c) / (2(5C + 4c)) \equiv t^*$ from (14), we obtain the following proposition.11)

**Proposition 1** (i) The home firm becomes the licensee if $t > t^*$, while the foreign firm becomes the licensee if $t < t^*$. (ii) Under free trade $t = 0$, the home firm becomes the licensee if $c > C$, while the foreign firm becomes the licensee if $c < C$.

Proposition 1 implies that the home government may manipulate the tariff to affect the licensing decision. In particular, the licensee may switch as a result of trade liberalization. To see this, suppose the initial tariff, $t_0$, is greater than $t^* (> 0)$ and trade liberalization decreases the tariff. Then home licensing occurs with $t = t_0$. Once $t$ becomes less than $t^*$, however, the licensee switches from the home firm to the foreign firm. Note that with $0 < t_0 < t^*$, the licensee remains the foreign firm even if trade is liberalized. Similarly, with $t^* < 0 < t_0$, the licensee remains the home firm.12)

Thus, the following proposition is established.

11) We can verify that if $c$ and $C$ are sufficiently close, inequality (9) holds at $t = t^*$.
12) We can analogously examine the case with $t_0 < 0$. In this case, trade liberalization means an increase in $t$. 
Proposition 2 Suppose $t_0 > 0$. As trade is liberalized, the licensee switches from the home firm to the foreign firm if $0 < t^* < t_0$, but remains the foreign firm if $0 < t_0 < t^*$ and the home firm if $t^* < 0 < t_0$.

3 Effects of Licensing on Home Welfare

We examine the effect of licensing on consumer surplus, firm profits and welfare by comparing between equilibria with and without licensing for a given tariff level. The next section will investigate endogenous determination of the tariff.

3.1 Effects on Firms

The profits of each firm are the same between home licensing and foreign licensing. The home firm earns profits $\pi(c, t)$ under home licensing as well as under foreign licensing. The foreign firm earns profit $\Pi(0, C + t)$ under foreign licensing as well as under home licensing. Compared to the case without licensing, both firms lose regardless of which firm becomes the licensee. Therefore, the following lemma holds.

Proposition 3 With a given tariff rate, licensing is necessarily harmful to both home and foreign firms regardless of which firm becomes the licensee. The home profits decrease from $\pi(c, C + t)$ to $\pi(c, t)$, while the foreign profits decrease from $\Pi(c, C + t)$ to $\Pi(0, C + t)$.

Proposition 3 may appear counter-intuitive, because the opportunity of obtaining better technology harms both firms. To understand this result, note that licensing leads to both positive and negative effects to potential licensees. Licensing increases the gross profits (i.e., the profits before license payments) of the licensee by improving its technology. Licensing also decreases profits of the non-licensee, which in turn reduces the outside option of the licensee. The licensor has a monopoly power of extracting all rents from them.

From (3), the change in the home profits due to licensing is given by

$$\Delta \pi = \pi(c, t) - \pi(c, C + t)$$

$$= -\frac{C(2A - 4c + 2t + C)}{9a} < 0.$$ 

3.2 Effects on Consumers

The changes in the home consumer surplus under home licensing and foreign licensing are respectively obtained from (2) as follows:

$$\Delta CS_{HL} = CS_{HL} - CS_{NL}$$

$$= \frac{1}{2a} \left( \frac{2A - (C + t)}{3} \right)^2 - \frac{1}{2a} \left( \frac{2A - (c + C + t)}{3} \right)^2$$

$$= \frac{c(4A - 2(C + t) - c)}{18a} > 0,$$
\[ \Delta CS_{FL} = CS_{FL} - CS_{NL} \]
\[ = \frac{1}{2a} \left( \frac{2A - (c + t)}{3} \right)^2 - \frac{1}{2a} \left( \frac{2A - (c + C + t)}{3} \right)^2 \]
\[ = \frac{C(4A - 2(c + t) - C)}{18a} > 0, \]

where \( CS_{NL} \), \( CS_{HL} \) and \( CS_{FL} \) are, respectively, the home consumer surplus under no licensing, home licensing and foreign licensing. We also have
\[ \Delta CS_{FL} - \Delta CS_{HL} = \frac{1}{18} (C - c) \frac{4A - C - c - 2t}{a} \]
\[ \iff C \gtrless c. \]

Thus, the following proposition is immediate.

**Proposition 4** With a given tariff rate, licensing necessarily decreases the price and increases consumer surplus regardless of which firm becomes the licensee. Consumers gain more when the licensee originally has the higher MCs than the non-licensee.

### 3.3 Effects on Tariff Revenue

The change in the tariff revenue differs between home licensing and foreign licensing. We obtain the changes from (5) as follows:
\[ \Delta TR_{HL} = TR_{HL} - TR_{NL} = -\frac{ct}{3a}, \]
\[ \Delta TR_{FL} = TR_{FL} - TR_{NL} = \frac{2ct}{3a}, \]

where \( TR_{NL} \), \( TR_{HL} \) and \( TR_{FL} \) are the home tariff revenue under no licensing, home licensing and foreign licensing, respectively.

Thus, the following proposition is established.

**Proposition 5** With a given tariff rate, compared with no licensing, the home tariff revenue decreases under home licensing and increases under foreign licensing if \( t > 0 \), and vice versa if \( t < 0 \).

### 3.4 Effects on Aggregate Welfare

We now investigate home welfare. Home welfare with home licensing and with foreign licensing are, respectively,
\[ W_{HL} = \pi_{HL} + CS_{HL} + TR_{HL} = \pi(c, t) + CS_{HL} + TR_{HL} \]
\[ = \frac{1}{18a} \left\{-9t^2 + t(6A - 10C - 8c) - 4AC - 8Ac + 6A^2 + C^2 + 8c^2 \right\}, \quad (16) \]
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\[
W_{FL} = \pi_{FL} + CS_{FL} + TR_{FL} = \pi(c, t) + CS_{FL} + TR_{FL} \\
= \frac{1}{6a}(-3t^2 + 4At - 4Ac + 2A^2 + 3c^2).
\]  

(17)

It should be noted that \( \pi_{HL} = \pi_{FL} = \pi(c, t) \) and that \( W_{FL} = W_{NL}|_{c=0} \).

**Home Licensing** Under home licensing, the net welfare change from no licensing is given by

\[
W_{HL} - W_{NL} = \Delta CS_{HL} + \Delta \pi + \Delta TR_{HL} \\
= \frac{4A(C - c) + 2C(C - 3c) + c^2 + 4t(C + 2c)}{18a} \\
= \frac{(c - C)(2A - 5(c + C)) + t(10C + 8c)}{9a} \\
+ \frac{(c - C)(3c + 4C) + cC - 8t(C + c)}{6a}.
\]

The welfare consequence of licensing is generally ambiguous. \( W_{HL} = W_{NL} \) holds at \( t = -\{4A(C - c) + 2C(C - 3c) + c^2\} / \{4(C + 2c)\} (\equiv \tilde{t}) \). In the view of the second line, \( W_{HL} < W_{NL} \) holds if both \( C \geq 3c \) and \( t \geq 0 \) hold, for example. On the other hand, in the view of the third line and (13), \( W_{HL} > W_{NL} \) if home licensing occurs with \( t \leq cC / \{8(c + C)\} \), for example.

We obtain the following lemma.\(^{13}\)

**Lemma 1** With a given tariff rate, home welfare is higher under home licensing than under no licensing if and only if \( t < \tilde{t} \).

**Foreign Licensing** Under foreign licensing, the net welfare change is

\[
W_{FL} - W_{NL} = \Delta CS_{FL} + \Delta \pi + \Delta TR_{FL} \\
= \frac{C(2c - C + 2t)}{6a},
\]

which implies \( W_{FL} = W_{NL} \) at \( t = (C - 2c) / 2 (\equiv \hat{t}) \).

The following lemma is established.\(^{14}\)

**Lemma 2** With a given tariff rate, home welfare is higher under foreign licensing than under no licensing if and only if \( t > \hat{t} \).

**Home Licensing versus Foreign Licensing** Finally, we compare home welfare between under home licensing and under foreign licensing:

\(^{13}\) \(-A(c - 2c + C) < \tilde{t} < (A + c - 2C) / 2\) may not hold, that is, (9) may not holds at \( t = \tilde{t} \).

\(^{14}\) \(-A(c - 2c + C) < \hat{t} < (A + c - 2C) / 2\) may not hold, that is, (9) may not holds at \( t = \hat{t} \).
\[ W_{FL} - W_{HL} = \Delta CS_{FL} - \Delta CS_{HL} + \Delta TR_{FL} - \Delta TR_{HL} = \frac{(C - c)(4A - c - C) + 2t(5C + 4c)}{18a}. \]  

(18)

\( W_{HL} = W_{FL} \) holds at \( t = (c - C)(4A - c - C)/\{2(5C + 4c)\} \equiv t^*. \)

Thus, the following lemma is immediate.

**Lemma 3** With a given tariff rate, home welfare is higher under home licensing than under foreign licensing if and only if \( t < t^* \).

The next question is whether home (foreign) licensing actually arises if home welfare is higher (lower) under home licensing than under foreign licensing. Noting (9), we obtain the following proposition.16)

**Proposition 6** (i) Home welfare is higher under home licensing than under foreign licensing, and home licensing arises if \( t^* < t < t^* \) holds. (ii) Home welfare is higher under foreign licensing than under home licensing, and foreign licensing arises if \( t^* < t < t^* \) holds.

Regarding this proposition, we investigate two special cases. First, we consider the free-trade case. With \( t = 0 \) in (18), we have

\[ W_{FL}|_{t=0} - W_{HL}|_{t=0} = \frac{1}{18a}(C - c)(4A - c - C). \]

Thus, under free trade, \( W_{HL} \geq W_{FL} \) holds if and only if \( c \geq C \). The economic intuition is as follows. Home welfare consists of the home profits, consumer surplus and tariff revenue. The home profits are identical between home licensing and foreign licensing and are given by (10). There is no tariff revenue under free trade. Thus, the difference in welfare simply equals the difference in consumer surplus. The lower the sum of the MCs is, the higher the consumer surplus. With \( t = 0 \), the sum of MCs is \( C \) under home licensing and is \( c \) under foreign licensing. Thus, licensing to the less efficient firm results in higher home welfare than licensing to the other firm.

**Lemma 4** Under free trade, home welfare is higher under home licensing than under foreign licensing if and only if \( c > C \).

Second, we pay attention to the threshold tariff rate \( t^* \), at which the licenser switches the licensee. As was shown in Proposition 1, the technology is licensed to the foreign firm if \( t < t^* \) and to the home firm otherwise. From (18), we compare home welfare between home licensing and foreign licensing at \( t^* \):

\[ W_{FL}|_{t=t^*} - W_{HL}|_{t=t^*} = \frac{1}{3a}(C - c)(A - C - c). \]

15) \( -(A - 2c + C) < t^* \) \((A + c - 2C)/2 \) may not hold, that is, (9) may not hold at \( t = t^* \).

16) We can confirm \( t^* \) \((A - 2C)/2 \) holds if \( c > C \) and \( -(A - 2c) < t^* \) holds if \( c < C \).
Thus, when the home government sets \( t = t^* \), \( W_{HL} \geq W_{FL} \) holds if and only if \( c \geq C \). That is, licensing to the firm with the higher MC results in higher home welfare than licensing to the other.

To understand this result, we first suppose \( c = C \). Then we have \( t^* = 0 \), with which both home profits and consumer surplus are identical between home licensing and foreign licensing. Thus, \( W_{FL} \big|_{c=C} = W_{HL} \big|_{c=C} \). Next, suppose \( c < C \). Then \( c + t^* < C + t^* \) (i.e., the sum of effective MCs is less under foreign licensing than under home licensing), meaning consumer surplus is greater under foreign licensing than under home licensing. If \( t^* > 0 \) also holds, the tariff revenue is greater under foreign licensing than under home licensing, because the imports are larger. If \( t^* < 0 \) holds (i.e., imports are subsidized), on the other hand, the government subsidy expenditure is greater under foreign licensing than under home licensing. In this case, however, the consumer gains dominate the government losses. Thus, whether \( t^* > 0 \) or \( t^* < 0 \), \( W_{FL} \big|_{c=C} > W_{HL} \big|_{c=C} \) holds with \( c < C \). Analogously, \( W_{HL} \big|_{c=C} > W_{FL} \big|_{c=C} \) with \( c > C \).

**Lemma 5** With \( t = t^* \), home welfare is higher under home licensing than under foreign licensing if and only if \( c > C \).

### 4 The Optimal Tariffs

In this section, we consider an extended game where in Stage 0, prior to the licenser’s choice of the licensee, the home government sets the tariff rate which maximizes home welfare.

#### 4.1 The Quasi-Optimal Tariffs

We first investigate the optimal tariffs under a given licensing regime, which we call “the quasi-optimal tariffs”. From (16) and (17), we can readily verify that the quasi-optimal tariff under foreign licensing \( t_{FL}^{opt} \) and that under home licensing \( t_{HL}^{opt} \) become

\[
t_{FL}^{opt} = \frac{A}{3} > 0 \text{ and } t_{FL}^{opt} > t_{HL}^{opt} > t_{HL}^{opt} = \frac{1}{9}(3A - 5C - 4c).
\]

Under foreign licensing, a small tariff raises home welfare by extracting the rent from the foreign firm. A small tariff decreases consumer surplus but increases home profits and tariff revenue. The latter effect dominates the former with a small tariff. This rent extraction effect is the same with the one under no licensing, because, under foreign licensing, the home firm does not pay the license fee and \( C = 0 \) holds, that is, \( W_{FL} = W_{NL} \big|_{C=0} \) holds. Thus, the optimal tariff \( t_{FL}^{opt} \) can be obtained simply by setting \( C = 0 \) in (7). Since the foreign firm captures a greater market share under foreign licensing than under no licensing, the tariff can extract greater rent from the foreign firm under foreign licensing than under no licensing. Therefore, \( t_{FL}^{opt} > t_{NL}^{opt} \) holds. On the other hand, the quasi-optimal tariff under home licensing is smaller than that under no licensing, because the licenser partly captures the rent shifted from the foreign firm to the home firm by increasing the license fee, which can be seen from (11) as \( \frac{dR_{HL}}{dt} = \frac{2(C + c)}{9a} > 0 \). We call this effect “the leakage effect”. If the leakage effect is sufficiently large, an optimal policy can be even an import subsidy (i.e., \( (3A - 5C - 4c)/9 < 0 \)).
Under the quasi-optimal tariffs, home welfare under foreign licensing and under home licensing are, respectively, given by
\[ W_{FL\mid l_{FL}^{opt}} = \frac{-12Ac + 7A^2 + 9c^2}{18a}, \]
\[ W_{HL\mid l_{HL}^{opt}} = \frac{-66AC - 96Ac + 40Cc + 63A^2 + 34C^2 + 88c^2}{162a}. \]

Thus,
\[ W_{FL\mid l_{FL}^{opt}} - W_{HL\mid l_{HL}^{opt}} = \frac{1}{162a}(66AC - 12Ac - 40Cc - 34C^2 - 7c^2). \]

We compare the welfare levels under the two regimes. First, we consider the case with \( C = c \). A straightforward calculation gives a rise to
\[ (W_{FL\mid l_{FL}^{opt}} - W_{HL\mid l_{HL}^{opt}})_{C=c} = \frac{1}{6a}c(2A - 3c) > 0. \]

Home welfare is larger under foreign licensing than under home licensing because of the leakage effect.

Next we compare the welfare levels when \( C \neq c \). Since
\[ \frac{d}{dC}(W_{FL\mid l_{FL}^{opt}} - W_{HL\mid l_{HL}^{opt}}) = \frac{1}{81a}(33A - 34C - 20c) > 0 \]
\[ \frac{d}{dc}(W_{FL\mid l_{FL}^{opt}} - W_{HL\mid l_{HL}^{opt}}) = -\frac{1}{81a}(6A + 20C + 7c) < 0, \]
the welfare difference \( (W_{FL\mid l_{FL}^{opt}} - W_{HL\mid l_{HL}^{opt}}) \) increases as \( (C - c) \) increases. This is because the leakage effect becomes larger if the home firm has a lower marginal cost and a larger market share than the foreign firm. In addition, since
\[ \frac{d}{dA}(W_{FL\mid l_{FL}^{opt}} - W_{HL\mid l_{HL}^{opt}}) = \frac{1}{27a}(11C - 2c), \]
\[ W_{FL\mid l_{FL}^{opt}} > W_{HL\mid l_{HL}^{opt}} \] is likely to hold for sufficiently large \( A \) if \( C > 2c/11 \).

**Lemma 6** (i) \( W_{FL\mid l_{FL}^{opt}} > W_{HL\mid l_{HL}^{opt}} \) if \( C \geq c \). (ii) \( W_{FL\mid l_{FL}^{opt}} > W_{HL\mid l_{HL}^{opt}} \) if \( C > 2c/11 \) and \( A \) is sufficiently large.

**Quasi-optimal Tariffs and Licensee-switching Tariff** The optimal tariff is obtained when the licenser endogenously chooses the licensee. We compare the quasi-optimal tariffs with the licensee-switching tariff \( t^* \):
\[ t_{FL}^{opt} - t^* = \frac{4AC + 15C^2 + c(14A - 15c)}{6(5C + 4c)} > 0, \]
\[ t_{HL}^{opt} - t^* = \frac{(12C + 42c)(A - \tilde{A})}{18(5C + 4c)}, \] where \( \tilde{A} \equiv \frac{5C^2 + 80Cc + 77c^2}{12C + 42c} \).
The above analysis is summarized in the following lemma.

**Lemma 7**  (i) \( t_{HL}^{\text{opt}} < t_{NL}^{\text{opt}} < t_{FL}^{\text{opt}} \); (ii) \( t^* < t_{NL}^{\text{opt}} < t_{FL}^{\text{opt}} \); (iii) \( t_{HL}^{\text{opt}} > 0 \) if \( A > (5C + 4c) / 3 \) and \( t_{HL}^{\text{opt}} < 0 \) if \( A < (5C + 4c) / 3 \); and (iv) \( t_{HL}^{\text{opt}} < t^* \) holds if \( A < \tilde{A} \) and \( t_{HL}^{\text{opt}} > t^* \) holds if \( A > \tilde{A} \).

Foreign licensing is chosen if and only if \( t < t^* \). Thus, the quasi-optimal tariff under foreign licensing is not realized. Similarly, if \( A < \tilde{A} \), the quasi-optimal tariff under home licensing is not realized, either.

### 4.2 Derivation of the Optimal Tariffs

In the rest of this section, we derive the optimal tariff rates. We consider two cases classified according to the feasibility of the quasi-optimal tariff \( t_{HL}^{\text{opt}} \) under home licensing: Case 1 with \( A \leq \tilde{A} \) and Case 2 with \( A > \tilde{A} \). Whereas \( t_{HL}^{\text{opt}} \) cannot be the optimal tariff (except the boundary case with \( A = \tilde{A} \)) in Case 1, \( t_{HL}^{\text{opt}} \) can be an optimal tariff in Case 2.

#### 4.2.1 Case 1: \( A \leq \tilde{A} \)

Lemma 7 implies

\[ t_{HL}^{\text{opt}} \leq t^* < t_{FL}^{\text{opt}}. \]

From Proposition 1, foreign licensing occurs if \( t < t^* \) and home licensing occurs if \( t > t^* \). Therefore, the quasi optimal tariffs of both licensing regimes are not realized. \( W_{FL} \) is increasing in \( t \) for \( t < t^* \), while \( W_{HL} \) is decreasing in \( t \) for \( t > t^* \). Therefore, both \( W_{FL} \) and \( W_{HL} \) are maximized at \( t = t^* \). Lemma 5 tells which licensing regime yields a higher level of welfare at \( t = t^* \).

Thus, the following proposition holds.

**Proposition 7**  Suppose \( A \leq \tilde{A} \). Let \( \varepsilon > 0 \) be the minimum unit of change in the tariff. (i) If \( C > c \), the optimal tariff is \( t^* - \varepsilon \) and foreign licensing arises. (ii) If \( C < c \), the optimal tariff is \( t^* + \varepsilon \) and home licensing arises.

---

*Figure 2: Example 1*
Examples 1 and 2 in Appendix B, respectively, provide numerical examples for cases (i) and (ii) in Proposition 7 and are drawn in Figures 2 and 3. In the figures, the red, the blue and the black curves represent the welfare levels under home licensing, foreign licensing and no licensing, respectively. The feasible welfare levels are illustrated by the solid red or blue curves. Note that even with the optimal tariff, the existence of technology licensing may not improve home welfare. In Example 1, home welfare under the optimal tariff, \( t^* - \varepsilon \), is lower than that under no licensing with \( t = t^*_{NL} \).

4.2.2 Case 2: \( A > \tilde{A} \)

Lemma 7 implies

\[ t^* < t^*_{HL} < t^*_{FL} . \]

The quasi optimal tariff under home licensing \( t^*_{HL} \) is feasible, while that under foreign licensing \( t^*_{FL} \) is not. \( W_{FL} \) is increasing in \( t \) for \( t < t^* \) and is maximized at \( t^* \). Therefore, to obtain the optimal tariff, we need to compare \( W_{FL} \big|_{t = t^*} \) and \( W_{HL} \big|_{t = t^*_{HL}} \). We decompose the welfare difference between the two regimes as follows:

\[ W_{FL} \big|_{t = t^*} - W_{HL} \big|_{t = t^*_{HL}} = \left( W_{FL} \big|_{t = t^*} - W_{HL} \big|_{t = t^*} \right) - \left( W_{HL} \big|_{t = t^*_{HL}} - W_{HL} \big|_{t = t^*} \right) . \quad (21) \]

The first difference term in (21)

\[ W_{FL} \big|_{t = t^*} - W_{HL} \big|_{t = t^*} = \frac{1}{3a} (C - c) (A - C - c) \quad (22) \]

expresses the welfare difference between the two regimes at the same tariff \( t^* \). As stated in Lemma 5, this term is positive if and only if \( C > c \). The license should be given to the firm with higher marginal costs. The second difference term in (21)

\[ W_{HL} \big|_{t = t^*_{HL}} - W_{HL} \big|_{t = t^*} = \frac{\left( t_{HL}^* - t^* \right)}{18a} \left( 6A - 10C - 8c - 9 \left( t_{HL}^* + t^* \right) \right) \geq 0 . \quad (23) \]
expresses the welfare gain from the optimal tariff under home sourcing. This term is non-negative by definition.

We consider two sub-cases: Case 2-1 with $C \leq c$ and Case 2-2 with $C > c$.

**Case 2-1:** $C \leq c$ The first difference term (22) becomes negative. Therefore, $W_{FL}|_{t^*} < W_{HL}|_{t^*}$ and $t_{HL}^{opt}$ is the optimal tariff with home licensing. That is,

**Proposition 8** Suppose $A > \tilde{A}$ and $C \leq c$. The optimal tariff is $t_{HL}^{opt}$ and home licensing arises.

Example 3 in Appendix B provides a numerical example of this case and is illustrated in Figure 4. In Example 3, the welfare level under the optimal tariff is slightly lower than that under no licensing with $t = t_{NL}^{opt}$.

**Case 2-2:** $C > c$ The first difference term (22) becomes positive. Therefore, it is generally ambiguous which of $W_{FL}|_{t^*}$ and $W_{HL}|_{t^*}$ is greater. However, it is determined for some cases. If $C - c$ is sufficiently small, then $W_{FL}|_{t^*} - W_{HL}|_{t^*}$ is close to zero from (22). Thus, $W_{FL}|_{t^*} < W_{HL}|_{t^*}$ holds and the optimal tariff becomes $t_{HL}^{opt}$. If $A$ is sufficiently close to $\tilde{A}$, then $W_{HL}|_{t^*} - W_{HL}|_{t^*}$ is close to zero from (23). Thus, $W_{FL}|_{t^*} > W_{HL}|_{t^*}$ holds and the optimal tariff is $t^* - \varepsilon$.

Thus, we obtain the following proposition.

**Proposition 9** Suppose $A > \tilde{A}$ and $C > c$. Let $\varepsilon > 0$ be the minimum unit of change in tariff. (i) The optimal tariff is $t_{HL}^{opt}$ and foreign licensing arises if $C$ is sufficiently close to $c$. (ii) The optimal tariff is $t^* - \varepsilon$ and home licensing arises if $A$ is sufficiently close to $\tilde{A}$.
Examples 4 and 5 provide numerical examples. The optimal tariff rate is $t^{\text{opt}}_{HL}$ in Example 4 and is $t^* - \varepsilon$ in Example 5. Figures 5 and 6 illustrate Examples 4 and 5, respectively. In both examples, the welfare level under the optimal tariff is lower than that under no licensing with $t = t^{\text{opt}}_{NL}$.

### 4.2.3 Summary of the Optimal Tariffs

Table 1 summarizes the optimal tariffs and the resulting licensing regimes. If the home firm has larger MCs than the foreign firm, the optimal tariff induces home licensing. If the foreign firm has larger MCs than the home firm, the optimal tariff is more subtle. If the market size is small in the sense that the licenser would not choose the home firm as the licensee with $t = t^{\text{opt}}_{HL}$, foreign licensing arises under the optimal tariff. If the market size is not so small, the
optimal tariff induces either home licensing or foreign licensing, depending on parameter values.

### Table 1: Summary of the optimal tariffs and licensing remimes

|          | $A \leq \bar{A}$ | $\bar{A} < A$ |
|----------|------------------|----------------|
| $C \leq c$ | $t^* + \varepsilon$, Home | $t_{HL}^{opt}$, Home |
| $C > c$   | $t^* - \varepsilon$, Foreign | $(t_{HL}^{opt}, \text{Home})$ or $(t^* - \varepsilon$, Foreign) |

Four remarks are in order. First, $t^*$ and/or $t_{HL}^{opt}$ can be negative. That is, the optimal policy can be an import subsidy instead of an import tax. Second, even with the optimal tariff, technology licensing can worsen home welfare. Third, the license can be granted to the foreign firm. With free trade, foreign licensing occurs if and only if $t^* > 0$. With the optimal tariff, on the other hand, foreign licensing occurs only if $C > c$. Finally, we can confirm that the licensee may switch from the home firm to the foreign firm as trade is liberalized under licensing (i.e., as $t$ decreases).

### 5 Concluding Remarks

We have built a simple international duopoly model in which an outside technology licenser exclusively licenses a non–drastic, cost–reducing technology to either a home firm or a foreign firm by means of a fixed fee. The two firms are heterogeneous and are engaged in Cournot competition in the home market. We have specifically explored the relationship between cross–border technology licensing and home tariffs.

Our interesting results are as follows. First, the presence of licensing opportunity is necessarily harmful to both home and foreign firms regardless of which firm becomes the licenee. Second, the home government may have an incentive to set a tariff so that the licener grants a license not to the home firm but to the foreign firm. Third, the presence of licensing may lead the home government to switch the optimal trade policy from an import tax to an import subsidy. Last, trade liberalization may induce the licener to switch the licensee. In this case, the switch is from the home firm to the foreign firm.

Using a simple model, we have shed new light on cross–border licensing and its relationship with tariffs. However, our results depend on some specific assumptions including fixed fee payments, exclusive licensing, and non–drastic technology licensing. The robustness of our results should be investigated under different scenarios. This is left for the future research.

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Appendix A

In this appendix, we show that an exclusive license may generate more license fees than a non-exclusive license. For this, we derive the conditions under which the license fee is greater under an exclusive license than under a non-exclusive license. Table 2 is the payoff matrix when the licenser simultaneously makes a take–it–or–leave–it offer to both firms.

In the Nash equilibrium, both firms accept the offer. The license fees to each firm in the

| Home firm, Foreign firm | Accept | Refuse |
|-------------------------|--------|--------|
| Accept                  | $\frac{1}{a} \left( \frac{A+t}{3} \right)^2$, $\frac{1}{a} \left( \frac{A-2t}{3} \right)^2$ | $\frac{1}{a} \left( \frac{A+(C+t)}{3} \right)^2$, $\frac{1}{a} \left( \frac{A-2(C+t)}{3} \right)^2$ |
| Refuse                  | $\frac{1}{a} \left( \frac{A-2c+t}{3} \right)^2$, $\frac{1}{a} \left( \frac{A+c-2t}{3} \right)^2$ | $\frac{1}{a} \left( \frac{A-2c+(C+t)}{3} \right)^2$, $\frac{1}{a} \left( \frac{A+c-2(C+t)}{3} \right)^2$ |
Nash equilibrium are

\[
R_H = \frac{1}{a} \left( \frac{A + t}{3} \right)^2 - \frac{1}{a} \left( \frac{A - 2c + t}{3} \right)^2 = \frac{4c(A - c + t)}{9a},
\]

\[
R_F = \frac{1}{a} \left( \frac{A - 2t}{3} \right)^2 - \frac{1}{a} \left( \frac{A - 2(C + t)}{3} \right)^2 = \frac{4C(A - C - 2t)}{9a},
\]

\[
R_{HF} = R_H + R_F = \frac{4 \left( AC + Ac - 2Ct + ct - C^2 - c^2 \right)}{9a}.
\]

Comparing the license fees between an exclusive license and a non-exclusive license:

\[
R_{HF} - R_{HL} = \frac{C(2A - 5C - 10t)}{9a},
\]

\[
R_{HF} - R_{FL} = \frac{c(2A - 5c + 8t)}{9a},
\]

we can claim that \( R_{HL} > R_{HF} \) if and only if \( 2A - 5C - 10t < 0 \) and that \( R_{FL} > R_{HF} \) if and only if \( 2A - 5c + 8t < 0 \).

An economic intuition why the license fee can be greater under an exclusive license than under a non-exclusive license is as follows. The licenser can obtain license fees from both firms when granting the license to both firms. This tends to increase the license fees. However, when both firms obtain the license, the competition becomes fiercer and the profits become less. This tends to decrease the license fees. With the above conditions, the latter effect dominates the former.

**Appendix B**

This appendix provides the details of the numerical examples discussed in the main text.

| Parameters       | a   | C   | c   | A   | \( \tilde{A} \) | Tariff Domain         |
|------------------|-----|-----|-----|-----|-----------------|-----------------------|
| Case 1: \( A \leq \tilde{A} \) | Example 1 | 1   | 1   | 2/3 | 2.2  | 2.31        | \((-0.87, 0.1)\)     |
|                  | Example 2 | 1   | 1   | 3   | 6.5  | 6.80        | \((-0.5, 2.25)\)      |
| Case 2: \( A > \tilde{A} \) and \( C \leq c \) | Example 3 | 1   | 1   | 2   | 10   | 3.32        | \((-6, 4)\)           |
| Case 2: \( A > \tilde{A} \) and \( C > c \) | Example 4 | 1   | 1.1 | 1   | 20   | 3.10        | \((-18, 8.9)\)         |
|                  | Example 5 | 1   | 1   | 2/3 | 2.32 | 2.31        | \((-0.99, 0.16)\)      |

Note: Tariff domain is \((-A + 2c, (A - 2C)/2)\).
Table 4: Optimal Tariffs and Welfare

|       | $t^*$ | $t_{HL}^{opt}$ | $t_{NL}^{opt}$ | $t_{FL}^{opt}$ | $W_{FL} |_{t^*}$ | $W_{HL} |_{t^*}$ | $W_{FL} |_{t^*}$ | $W_{NL} |_{t^*}$ | $W_{FL} |_{t^*}$ |
|-------|-------|----------------|----------------|----------------|--------------|--------------|--------------|--------------|--------------|
| Example 1 | -0.09 | -0.12          | 0.4            | -              | 0.79         | 0.73         | 0.88         | -            |
| Example 2 | 0.41  | 0.28           | 1.83           | -              | 6.40         | 8.07         | 6.43         | -            |
| Example 3 | -0.19 | 1.89           | 3              | -              | 21.34        | 25.84        | 26           | -            |
| Example 4 | 0.16  | 5.61           | 6.3            | 6.67           | 121.52       | 135.81       | 140.18       | 142.72       |
| Example 5 | -0.080 | -0.078        | 0.44           | -              | 0.92         | 0.85         | 1.03         | -            |