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PREFERENTIAL TARIFF POLICY, PRODUCT QUALITY AND WELFARE

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Abstract

This paper shows that when firms consider quality as a long run choice variable, a preferential free trade arrangement can create a quality gap in favor of its member countries, as long as R&D spillovers are not perfect, and increases welfare of member countries. This result implies that a preferential free trade arrangement such as a free trade area or a customs union can bring an exclusive long run benefit to the member countries.

Keywords: optimal tariff; preferential free trade agreement; product quality; product R&D
JEL Classification: F12; F13; L13

I. *Introduction*

In recent years many trade agreements have been approved by the WTO.[1] These liberalization arrangements have received the attention of numerous economists, in particular, those working in international economics. Both the theoretical and empirical literature have been mainly focused on the effects of these agreements on national welfare.[2] The literature is mainly silent on the effect of such arrangements on product quality which is important from both positive and normative analysis. This paper addresses the issue of the impact of regional agreements on product quality. It is argued that a regional trade agreement may be used as a long-run strategy by a member country to realize gains from trade in high quality products.

The trade literature that analyses the relationship between increasing trade and product quality is mainly concerned with the short-run effect.[3] In this paper product quality is analyzed as a long-run variable.[4] We consider a model in which two exporters compete in an

[1] According to the WTO official website, 117 regional trade agreements have been approved and in effect since 1995. The total numbers would be 168 if we include the numbers from the GATT system starting 1948.

[2] For the complete literature review on regionalism, see Panagariya (1999).

[3] Papers include Corden (1974), Rodriguez (1979), Santoni and Van Cott (1980), Falvey (1979), Aw and Roberts (1986), Das and Donnenfeld (1987, 1989), Krishna (1987), Bond (1988), Donnenfeld (1988), Feenstra (1988), Boorstein and Feenstra (1991) and Ries (1993).

[4] Industrial economists have taken this view for long time. For example, see Gabszewicz and Thisse (1980, 1986), Shaked and Sutton (1982, 1983, 1984), Ronnen (1991), Sutton (1992), Motta (1993) and Aoki and Prussa

import market. It is then established that the member of a free trade agreement (FTA) may produce a higher quality product than the non-FTA member. We believe that this result emerges from being an insider than an outsider in our framework.

This result is somewhat similar to Herguera et al. (2002) who also treat quality as a long-run variable. They show that a domestic firm (i.e. insider) always produces a high quality good when the domestic country sets its optimal tariff against a foreign firm. Unlike their model, however, we introduce a preferential tariff system and consider the insider as a foreign trading partner of the system. Furthermore, we assume that an R&D investment of a firm has a positive spillover effect on the other's product quality level. We show that the quality gap between an FTA and non-FTA members would be reduced (or disappear) when the spillover becomes stronger (or perfect).

Furthermore we show that, given the FTA system and an imperfect spillover of R&D, as the quality gap is larger (so that the FTA-member exporter supplies a better quality product than the non-FTA exporter), the importing country would prefer importing more from its member exporter. The government, then, would optimize its welfare by setting a higher external tariff against the non-FTA exporter.[5] This results in a greater trade diversion toward the FTA-member exporter. Nonetheless, compared to the case without the FTA system, we find that a formation of an FTA yields a higher welfare to the importing country of the FTA because its domestic consumers consume higher quality products as a result of the FTA formation.

Note that, under the FTA system, the FTA member exporter facing a zero tariff becomes a high R&D investor, while the non-FTA member exporter facing a positive tariff becomes a low R&D investor. This is in line with Saggi (2004)'s recent finding for discriminatory tariff system:[6] a higher tariff will be imposed on low cost producers relative to high cost ones. In our model, however, firms are symmetric in production costs and we allow for the firms to choose R&D investment before the production stage. It turns out that the FTA member exporter spends more costs on R&D than the non-FTA member exporter.

To fix the idea of the results, we use a three-country model of trade. Two countries produce differentiated products under a duopolistic structure and the third country imports the products. It is assumed that the firm's optimal choice of R&D investment and thus quality level is undertaken before producing the differentiated products. The importing country sets tariff barriers against each of the duopolists under the two distinct trade regimes — with and without a bilateral free trade agreement (FTA) with one of the exporting countries. The two firms compete each other through quantities. This is a simple model for analyzing quality and welfare changes but the results are quite robust. First, our results hold in a case of price competition between the firms. Second, even in a case when the two firms face a domestic competition in the importing market, the results still hold qualitatively. We did not include

(1997). In their models, firms invest in quality *before* they produce goods and thus quality costs are sunk in the market competition stage. In international context, see Herguera et al. (2000, 2002) and Zhou et al. (2002).

[5] In the literature of preferential free trade analysis, it is known that optimal tariff rates against non-FTA members are decreased as well. This effect is well documented in a various model and termed as 'a tariff complementarity effect' in the literature. For instance, see Bagwell and Staiger (1997) and Bond, Riezman and Syropoulos (forthcoming). In our model, we find that the effect becomes weaker as the quality gap is larger.

[6] Note that, while Saggi (2004) considers Most Favored Nation (MFN) clause as an alternative to the discriminatory tariff system, we do not. We simply compare a trade regime with and without an FTA formation.

these modifications in the paper since no additional or interesting findings were obtained.

The paper is organized as follows. Section II presents the basic model with an optimal trade regime with and without an FTA and compare the results. Section III summarizes the paper.

II. *The Model and Results*

Consider a simple three-country model, one large importing country denoted by l and two exporting countries denoted by 1 and 2. We assume that the importing country has a representative consumer and the utility function takes a quality-augmented version of the standard quadratic function;[7]

$$U_l = q_1 x_1 + q_2 x_2 - x_1^2 - x_2^2 - \theta x_1 x_2 + z. \tag{1}$$

The variables x_1 and x_2 represent the quantities of each variety imported from 1 and 2 respectively. Similarly, the variables q_1 and q_2 show the quality of each variety 1 and 2 respectively. The term z denotes expenditure on numeraires ($z = m - p_i x_i - p_j x_j$ with m as incomes) and the parameter θ is an index of the degree of horizontal product differentiation. As it approaches 0, the goods become independent, while as it increases, the products become more substitutable. In particular, as the parameter approaches 2, the goods become perfect substitutes. For reasons of simplicity, we will assume $0 < \theta < 2$.

Note that the utility function specified in equation (1) is commonly used to analyze in a partial equilibrium that focuses on a particular industrial structure (e.g., a differentiated product market as in this paper). The partial equilibrium analysis ignores the income effects on the particular industry. That is, even when there is a change in income level of each consumer, it does not affect the consumer's consumption choice for the products of the industry. As we will see later in this section, the government's tariff revenues are a part of the government's objective functions and will be redistributed to the consumers as a part of income. The new income generated that comes from the redistribution of tariff revenues will be spent on the numeraires z and will increase the consumer's utility level eventually.

Given equation (1), the inverse demand function for variety $i(\neq j) \in \{1, 2\}$ is;

$$p_i = q_i - 2x_i - \theta x_j. \tag{2}$$

Note that the intercept is increasing in quality variable, which implies a rightward shift of demand in a case of quality improvement.

The duopoly game in the importing market is as follows. At stage 1, the foreign firms simultaneously choose their qualities. The quality level will be determined by R&D investment choice. Note that, following Motta (1992), we assume a spillover effect between the firms' R &D investment. At stage 2, the government of the importing country determines the level of optimal tariffs for countries 1 and 2. In this stage, we consider separately two different trade regimes; no free trade system versus a bilateral free trade agreement with one of the exporting countries. In this sense, a trade regime is exogenously given. Later we will consider an

[7] As a referee suggests, we follow Häckner (2000). Our results hold with other quadratic utility function, for example, $U_l = x_1 + x_2 - x_1^2/q_1^2 - x_2^2/q_2^2 - \theta(x_1 x_2/q_1 q_2) + z$ as in Sutton (1997, 1998) and Symeonidis (1999, 2000).

alternative game where a trade regime is endogenously chosen by the importing government. At stage 3, the two firms export the products to the importing market. The problem is solved by backward induction.

Stage 3: Cournot solution In each of the two exporting countries, there is only one firm that supplies one variety to the importing country. The cost of production is denoted by c for each of the firms. An assumption of $c<1$ is necessary to ensure the existence of a meaningful solution. We assume that the cost of production is industry-specific, so the two firms face the same cost of production. For simplicity, we assume $c=0$. When firm i sells variety i to a consumer of the importing country, it pays a specific tariff τ_i to the country and earns the market price p_i per unit. The profit of each firm is;

$$\pi_i=(p-\tau_i)x_i,\quad i\in\{1,\ 2\}. \tag{3}$$

In the Cournot-Nash equilibrium[8] we have, for $i\in\{1,\ 2\}$ and $i\neq j$;

$$x_i^N=\frac{4(q_i-\tau_i)-\theta(q_j-\tau_j)}{(4-\theta)(4+\theta)}, \tag{4}$$

$$\pi_i^N=2(x_i^N)^2, \tag{5}$$

where N indicates a trade regime without an FTA.

The optimal quantity of each product is determined by quality choices and tariff rates. First, as a quality of a product improves or as the tariff rate declines the optimal quantity of the export increases. This is because the consumer in importing country likes a high-quality and lower-priced product. This is summarized as $\frac{\partial x_i^N}{\partial q_i}>0$ and $\frac{\partial x_i^N}{\partial \tau_i}<0$. Second, as the competing product's quality declines or as the importing country raises tariff rate against the competing product the optimal quantity of the export increases. This is because the consumer is willing to switch to buy a product with a higher quality and a lower price. This can be shown as $\frac{\partial x_i^N}{\partial q_j}<0$ and $\frac{\partial x_i^N}{\partial \tau_j}>0$.

Suppose that the importing country at stage 2 proposed country 2 an FTA and country 2 accepted it, without a loss of generality.[9] Given the FTA with country 2 ($\tau_2=0$), the optimal quantities of each products exported to the importing country will be as follows.

$$x_1^F=\frac{4(q_1-\tau_1)-\theta q_2}{(4-\theta)(4+\theta)} \text{ and } \pi_1^F=2(x_1^F)^2, \tag{6}$$

$$x_2^F=\frac{4q_2-\theta(q_1-\tau_1)}{(4-\theta)(4+\theta)} \text{ and } \pi_2^F=2(x_2^F)^2, \tag{7}$$

where F indicates a trade regime with an FTA.

[8] Bertrand competition does not qualitatively alter our main result, the effect of preferential tariff policy on quality gap.

[9] Due to the symmetry of the model, the results should be the same for a case when the importing country proposed country 1 an FTA and country 1 accepted it.

Note that $\frac{\partial x_i^F}{\partial q_i}=\frac{\partial x_i^N}{\partial q_i}>0$ and $\frac{\partial x_i^F}{\partial q_j}=\frac{\partial x_i^N}{\partial q_j}<0$ for $i\in\{1, 2\}$ and $i\neq j$. When the tariffs are exogenously given, the partial impact of quality change on product quantities is the same before and after the FTA formation. Also from $\frac{\partial x_1^F}{\partial \tau_1}=\frac{\partial x_1^N}{\partial \tau_1}<0$ and $\frac{\partial x_2^F}{\partial \tau_1}=\frac{\partial x_2^N}{\partial \tau_1}>0$, the partial impact of tariff τ_1 (the external tariff against non-FTA member-country 1 if the trade regime is F) on product quantities is also identical before and after the FTA formation since tariff τ_1 is not optimized here. However, $\frac{\partial x_1^F}{\partial \tau_2}$ and $\frac{\partial x_2^F}{\partial \tau_2}$ can not be obtained because the tariff rate for the FTA member (country 2) is fixed at zero.

The optimal quality levels and the optimal tariff rates will be determined by the exporting firms in stage 1 and by the importing country in stage 2 respectively. Next we solve the optimal tariff choices under the two different trade regimes, given the level of quality chosen by the firms in stage 1.

Stage 2: Tariff setting Consider government l choosing tariffs to maximize its national welfare under two different trade regimes: optimal tariff system and a bilateral free trade system. The national welfare is defined as a sum of consumers' surplus (CS_l) and tariff revenues (TR_l).

$$W_l=CS_l+TR_l=\sum_{i\in\{1,\,2\};\, i\neq j}\left(\frac{1}{2}\,(q_i-\theta x_j-p_i)x_i\right)+\sum_{i\in\{1,\,2\}}(x_i\tau_i). \tag{8}$$

The consumer's surplus is defined as an aggregated sum of the consumer's marginal utility level above the expenditure in markets. It measures the degree of the consumer's satisfaction after payments have been made. The tariff revenues are the government's revenues from imports and are redistributed to the consumer in a lump-sum manner, which also increase the consumer's utility level. So, a maximization of the national welfare is tantamount to maximizing consumer' utility.

The first order condition for $i\neq j\in\{1, 2\}$ is obtained as follows:

$$\frac{\partial W_l^N}{\partial \tau_i}=2x_i\frac{\partial x_i}{\partial \tau_i}+2x_j\frac{\partial x_j}{\partial \tau_i}+x_i+\frac{\partial x_i}{\partial \tau_i}\tau_i+\frac{\partial x_j}{\partial \tau_i}\tau_j=0. \tag{9}$$

The second order condition $\left(\frac{\partial^2 W_l^N}{\partial \tau_i^2}<0\right)$ also holds with $\theta\in(0, 2)$. By using (4) and rearranging the first order condition in terms of tariffs τ_i for $i\in\{1, 2\}$ and $i\neq j$, we can obtain the following reduced form.

$$\tau_i=\frac{6\theta^2-32}{10\theta^2-96}q_i-\frac{\theta^3}{10\theta^2-96}q_j+\frac{2\theta(\theta^2-8)}{10\theta^2-96}\tau_j. \tag{10}$$

Note $\frac{\partial \tau_i}{\partial \tau_j}>0$. This implies that the importing country improves the welfare level by changing the tariffs in the same direction. More specifically, suppose that the importing country reduces a tariff for country 2 (maybe due to a free trade agreement). Then the price of the good imported from country 2 becomes lower and the consumption of the good becomes larger. Given a certain degree of substitutability between the two competing products, the other good's demand (i.e. product 1 imported from country 1) will be reduced and thus the importing government suffers welfare loss from reduced consumer's surplus. To prevent any further welfare loss in the other good's market, the government will reduce the tariff so that the price becomes lower. So, it can increase its welfare by reducing the tariff for country 1 as well.

Under the optimal tariff system, the national welfare maximization problem yields the following optimal tariff for $i \in \{1, 2\}$ and $i \neq j$;

$$\tau_i^N = \frac{\theta^2 - 6}{2(\theta+3)(\theta-3)} q_i - \frac{\theta}{2(\theta+3)(\theta-3)} q_j. \tag{11}$$

When a quality of a product is increased, an optimal tariff rate will be raised by the importing country. First, a higher quality product attracts more consumption and thus more imports. Given the larger amounts of imports, the importing government further increases its national welfare by increasing tariff revenue with a higher tariff rate. That is, in (11) $\frac{\partial \tau_i^N}{\partial q_i} > 0$ for $i \in \{1, 2\}$. Second, if the other product, say, product 2 improves its quality, the consumer will consume less of product 1, which will reduce national welfare in the market of product 1. To reduce the loss of national welfare the importing government increases the tariff rate so that it can make up the welfare loss by the increased tariff revenues. That is, in (11) $\frac{\partial \tau_i^N}{\partial q_j} > 0$ for $i \in \{1, 2\}$ and $i \neq j$.

Note that the optimal tariff rates are not MFN-based since the two optimal tariffs may differ if the two firms choose different quality levels.[10] However, since the two countries are symmetric under no-trade agreement, the quality level chosen by each of the countries will be the same and thus the optimal tariffs level will be equalized. We will compare these (non-MFN but symmetrical) optimal tariffs with those under a bilateral free trade agreement. Note that our paper focuses on trade-regime analysis for no-FTA versus an FTA, but not for an MFN versus an FTA. We leave this important topic, MFN, for our future research.

Under the bilateral free trade system with country 2 ($\tau_2 = 0$), the welfare maximization problem yields the following optimal external tariff rate against non-FTA member, country 1.

$$\tau_1^F = \frac{6\theta^2 - 32}{10\theta^2 - 96} q_1 - \frac{\theta^3}{10\theta^2 - 96} q_2. \tag{12}$$

Here we observe $\frac{\partial \tau_1^F}{\partial q_1} > \frac{\partial \tau_1^F}{\partial q_2} > 0$ for all $\theta \in (0, 2)$. Note that the quality levels chosen under the FTA regime are different from those under no-FTA regime. We are going to solve the quality levels under the different trade regime at stage 1 and see that an FTA can generate a quality gap between an FTA member exporting firm and a non-FTA member firm.

More interestingly when we compare (11) and (12), we find that the external tariff

[10] The MFN tariffs can be obtained if we set $\tau_i = \tau_j \equiv \tau$ and maximize the national welfare. After some calculations with $\theta = 1$, we found the MFN tariffs as $-\frac{1}{6} q_j - \frac{1}{6} q_i - \frac{5}{6} + \frac{1}{6}\sqrt{q_i^2 + 2q_i q_j + 40q_i + q_j^2 + 40q_j + 25}$.

against country 1 (τ_1^F) is smaller than the tariff without the FTA regime (τ_1^N).[11] This is so-called tariff complementarity effect of FTA. In fact, this effect has been well-documented in the existing trade theory literature, in particular, regional trade agreement literature. For example, see Bagwell and Staiger (1997). Our paper will investigate how this will be affected by a spillover effect of R&D between the competing firms.

Stage 1: Product R&D and Quality choice Consider the functional relationship between R&D investments, denoted by R, and quality levels; $q_i = 1 + R_i + \epsilon R_j$ for $i \in \{1, 2\}$ and $i \neq j$. The constant term, 1 means that there is a minimum level of quality regardless of R&D. The term ϵ shows a degree of technological spillover, $\epsilon \in [0, 1]$. When it is zero, there is no spillover between the R&D investment, while when it is one, it implies a perfect spillover. The cost of R&D is assumed to be $R^2/2$.

Using the solutions for exports and tariffs at stage 2 and 3, a firm's profit maximization problem is formulated as follows. For $i, j \in \{1, 2\}$ and $i \neq j$;

$$\max_{R_i} \pi_i(x_i(q_i, q_j, \tau_i(q_i, q_j), \tau_j(q_i, q_j))) - (R_i)^2/2 \text{ s.t. } q_i = 1 + R_i + \epsilon R_j. \tag{13}$$

The first and second order conditions are as follows.

$$\frac{\partial \pi_i}{\partial R_i} = 4x_i \frac{\partial x_i}{\partial R_i} - R_i = 0, \tag{14}$$

$$\frac{\partial^2 \pi_i}{\partial R_i^2} = 4\left(\frac{\partial x_i}{\partial R_i}\right)^2 - 1 < 0. \tag{15}$$

The second order condition holds for $\epsilon \in [0, 1]$ and $\theta \in (0, 2)$. The response function can be obtained from the first order condition. The solution for optimal R&D can be obtained by the two response functions of $R_i = r_i(R_j)$ for $i, j \in \{1, 2\}$ and $i \neq j$. By totally differentiating the first order condition we can find out the slope of $R_i = r_i(R_j)$ as follows;

$$\frac{dR_i}{dR_j} = \frac{4\left(\frac{\partial x_i}{\partial R_j}\right)\left(\frac{\partial x_i}{\partial R_i}\right)}{1 - 4\left(\frac{\partial x_i}{\partial R_i}\right)^2}. \tag{16}$$

The denominator is positive from the second order condition. So, the slope of the response function depends on $\frac{\partial x_i}{\partial R_j}$ and $\frac{\partial x_i}{\partial R_i}$. First, in case of no-FTA, the optimal quantity is $x_i^N = x_i(q_i, q_j, \tau_i^N(q_i, q_j), \tau_j^N(q_i, q_j))$. So the effect of R_i on x_i^N is, for $i \in \{1, 2\}$ and $i \neq j$;

$$\frac{\partial x_i^N}{\partial R_i} = A \frac{\partial q_i}{\partial R_i} + B \frac{\partial q_j}{\partial R_i}; \quad \frac{\partial x_i^N}{\partial R_j} = A \frac{\partial q_i}{\partial R_j} + B \frac{\partial q_j}{\partial R_j}, \tag{17}$$

with

[11] That is, since $\left.\frac{\partial W_i^N}{\partial \tau_1}\right|_{\tau_2=0} < 0$ in (9), τ_1 should be smaller when $\tau_2 = 0$ is given.

$$A=\underbrace{\frac{\partial x_i^N}{\partial q_i}}_{+}+\underbrace{\frac{\partial x_i^N}{\partial \tau_i^N}}_{-}\underbrace{\frac{\partial \tau_i^N}{\partial q_i}}_{+}+\underbrace{\frac{\partial x_i^N}{\partial \tau_j^N}}_{+}\underbrace{\frac{\partial \tau_j^N}{\partial q_i}}_{+},\ B=\underbrace{\frac{\partial x_i^N}{\partial q_j}}_{-}+\underbrace{\frac{\partial x_i^N}{\partial \tau_i^N}}_{-}\underbrace{\frac{\partial \tau_i^N}{\partial q_j}}_{+}+\underbrace{\frac{\partial x_i^N}{\partial \tau_j^N}}_{+}\underbrace{\frac{\partial \tau_j^N}{\partial q_j}}_{+}.$$

Note that q_i and q_j affect x_i^N directly and indirectly through τ_i^N and τ_j^N. All signs in A and B are known as shown above and $\frac{\partial q_i}{\partial R_i}=1$ and $\frac{\partial q_i}{\partial R_j}=\epsilon$ for $i\in\{1, 2\}$ and $i\neq j$. As for A, first, when the firm decides to increase its R&D, it will increase the quality of the product by $\frac{\partial q_i}{\partial R_i}=1$. This has a direct positive impact on the optimal quantity of exports that the firm can provide for the importing consumer $\left(\frac{\partial x_i^N}{\partial q_i}>0 \text{ in } (4)\right)$. However, given the rise in imports, the importing government has an incentive to protect the market $\left(\frac{\partial \tau_i^N}{\partial q_i}>0 \text{ in } (11)\right)$ and thus the exports will be affected negatively $\left(\frac{\partial x_i^N}{\partial \tau_i^N}<0 \text{ in } (4)\right)$. The increased quality of the product will also motivate the importing government to protect the market against the competing firm which becomes a relatively low-quality product provider $\left(\frac{\partial \tau_j^N}{\partial q_i}>0 \text{ in } (11)\right)$. This will even further increase the imports of the product $\left(\frac{\partial x_i^N}{\partial \tau_j^N}>0 \text{ in } (4)\right)$. As for B, when the firm decides to increase its R&D, it will also increase the quality of the competing product by $\frac{\partial q_j}{\partial R_i}=\epsilon<1$. This is because of the R&D spillover effect between the two firms. The higher quality of the competing firm's product affects negatively the other firm's export $\left(\frac{\partial x_i^N}{\partial q_j}<0 \text{ in } (4)\right)$ because consumer will buy more of the higher quality product. There is also indirect negative effect: The higher quality of the competing firm's product will give a reason for the importing government to protect against the other firm's product $\left(\frac{\partial \tau_i^N}{\partial q_j}>0 \text{ in } (11)\right)$ and thus the imports of the other firm's product will be decreased $\left(\frac{\partial x_i^N}{\partial \tau_i^N}<0 \text{ in } (4)\right)$. However, as the quality of the competing firm's product is improved, the government can further maximize the national welfare by charging a higher tariff rate $\left(\frac{\partial \tau_j^N}{\partial q_j}>0 \text{ in } (11)\right)$ and then the other firm's export will be increased $\left(\frac{\partial x_i^N}{\partial \tau_j^N}>0 \text{ in } (4)\right)$.

Next, in case of a bilateral FTA with country 2, the optimal quantities, x_1^F and x_2^F is the function of q_1 and q_2 but with $\tau_2=0$. That is, $x_1^F=x_1(q_1, q_2, \tau_1^F(q_1, q_2))$ and $x_2^F=x_2(q_1, q_2, \tau_1^F(q_1, q_2))$. So the effect of R&D on the optimal quantities are;

$$\frac{\partial x_1^F}{\partial R_1} = [A_1]\frac{\partial q_1}{\partial R_1} + [B_1]\frac{\partial q_2}{\partial R_1};\ \frac{\partial x_1^F}{\partial R_2} = [A_1]\frac{\partial q_1}{\partial R_2} + [B_1]\frac{\partial q_2}{\partial R_2},$$
$$\frac{\partial x_2^F}{\partial R_2} = [A_2]\frac{\partial q_2}{\partial R_2} + [B_2]\frac{\partial q_1}{\partial R_2};\ \frac{\partial x_2^F}{\partial R_1} = [A_2]\frac{\partial q_2}{\partial R_1} + [B_2]\frac{\partial q_1}{\partial R_1}, \tag{18}$$

with

$$A_1 = \underbrace{\frac{\partial x_1^F}{\partial q_1}}_{+} + \underbrace{\frac{\partial x_1^F}{\partial \tau_1^F}}_{-}\underbrace{\frac{\partial \tau_1^F}{\partial q_1}}_{+};\ B_1 = \underbrace{\frac{\partial x_1^F}{\partial q_2}}_{-} + \underbrace{\frac{\partial x_1^F}{\partial \tau_1^F}}_{-}\underbrace{\frac{\partial \tau_1^F}{\partial q_2}}_{+},$$
$$A_2 = \underbrace{\frac{\partial x_2^F}{\partial q_2}}_{+} + \underbrace{\frac{\partial x_2^F}{\partial \tau_1^F}}_{+}\underbrace{\frac{\partial \tau_1^F}{\partial q_2}}_{+};\ B_2 = \underbrace{\frac{\partial x_2^F}{\partial q_1}}_{-} + \underbrace{\frac{\partial x_2^F}{\partial \tau_1^F}}_{+}\underbrace{\frac{\partial \tau_1^F}{\partial q_1}}_{+}.$$

First, comparing with A and B in (17) the second (negative) terms in A and B are removed for FTA member (i.e. country 2). Second, the third (positive) terms in A and B are removed for non-FTA member (i.e. country 1). So, it is likely that the impact of quality improvement on the FTA member's export is larger than that on non-FTA member's export. However since $\frac{\partial \tau_1^N}{\partial q_1} > \frac{\partial \tau_1^F}{\partial q_1}$ and $\frac{\partial \tau_1^N}{\partial q_2} > \frac{\partial \tau_1^F}{\partial q_2}$ from (11) and (12), the final effect on FTA member and non-FTA member should be carefully examined. The following Lemma 1 summarizes and compares $\frac{\partial x_i}{\partial R_j}$ and $\frac{\partial x_i}{\partial R_i}$ for both trade regimes. (Proofs of Lemmas will be delegated to the Appendix.)

Lemma 1 *We can rank* $\frac{\partial x_i}{\partial R_j}$ *and* $\frac{\partial x_i}{\partial R_i}$ *under the two different trade regimes as follows. For* $\theta \in (0, 2)$, $\epsilon \in (0, 1)$, $i, j \in \{1, 2\}$ *and* $i \neq j$;

(i) $0 < \frac{\partial x_1^F}{\partial R_1} < \frac{\partial x_1^N}{\partial R_1} = \frac{\partial x_2^N}{\partial R_2} < \frac{\partial x_2^F}{\partial R_2}$;

(ii) $\frac{\partial x_1^F}{\partial R_2} < \frac{\partial x_1^N}{\partial R_2} = \frac{\partial x_2^N}{\partial R_1} < \frac{\partial x_2^F}{\partial R_1}$

where sign $\left(\frac{\partial x_1^N}{\partial R_2}\right)$ = *sign* $\left(\frac{\partial x_2^N}{\partial R_1}\right)$ = *sign* $\left(\epsilon - \frac{\theta}{3}\right)$, *sign* $\left(\frac{\partial x_1^F}{\partial R_2}\right)$ = *sign* $\left(\epsilon - \frac{3\theta}{8}\right)$, *and sign* $\left(\frac{\partial x_2^F}{\partial R_1}\right)$ = *sign* $\left(\epsilon - \frac{4\theta}{24-\theta^2}\right)$ *and* $0 < \frac{4\theta}{24-\theta^2} < \frac{\theta}{3} < \frac{3\theta}{8} < 1$.

From lemma 1(i), we learn that a rise in R&D expenditure of a firm will eventually increase export performances in any trade regime but the relative impact will be larger to the FTA-member exporting firm and smaller to the no-FTA exporting firm, compared to the case of no-FTA regime. Intuitively, by engaging an FTA the exporting firm can effectively remove the negative channel on the export. That is, $\frac{\partial x_2^N}{\partial \tau_2^N}\frac{\partial \tau_2^N}{\partial q_2}<0$ and $\frac{\partial x_2^N}{\partial \tau_2^N}\frac{\partial \tau_2^N}{\partial q_1}<0$ are disappeared in A and B in (17) because of $\tau_2=0$. So, the firm within the FTA can export more from the R &D expenditure. However, if the firm is outside the FTA, the positive channel on the export is eliminated. That is, $\frac{\partial x_1^N}{\partial \tau_2^N}\frac{\partial \tau_2^N}{\partial q_1}>0$ and $\frac{\partial x_1^N}{\partial \tau_2^N}\frac{\partial \tau_2^N}{\partial q_2}>0$ are disappeared in A and B in (17) because of $\tau_2=0$.

Interestingly, lemma 1(ii) tells that, although the ranking of $\frac{\partial x_i}{\partial R_j}$ is still preserved as that of $\frac{\partial x_i}{\partial R_i}$ in lemma 1(i) (using the same reasons as explained above), the signs of $\frac{\partial x_i}{\partial R_j}$ are affected by ranges of spillover effect. This finding is important because the sign of $\frac{\partial x_i}{\partial R_j}$ will eventually determine the sign of $\frac{dR_i}{dR_j}$ in (16). With lemma 1, we are ready to characterize the R&D response functions from (14). We summarize them in the following lemma.

Lemma 2 *Response functions satisfying (14) are all linear and their slopes are as follows. (Refer to Figure 3 for four cases.)*

(i) *If* $0<\epsilon<\frac{4\theta}{24-\theta^2}$, *then* $-1<\frac{dR_1^N}{dR_2}=\frac{dR_2^N}{dR_1}<0$ *and* $-1<\frac{dR_1^F}{dR_2}<0,\ -1<\frac{dR_2^F}{dR_1}<0.$

(ii) *If* $\frac{4\theta}{24-\theta^2}<\epsilon<\frac{\theta}{3}$, *then* $-1<\frac{dR_1^N}{dR_2}=\frac{dR_2^N}{dR_1}<0$ *and* $-1<\frac{dR_1^F}{dR_2}<0,\ 0<\frac{dR_2^F}{dR_1}<1.$

(iii) *If* $\frac{\theta}{3}<\epsilon<\frac{3\theta}{8}$, *then* $0<\frac{dR_1^N}{dR_2}=\frac{dR_2^N}{dR_1}<1$ *and* $-1<\frac{dR_1^F}{dR_2}<0,\ 0<\frac{dR_2^F}{dR_1}<1.$

(iv) *If* $\frac{3\theta}{8}<\epsilon<1$, *then* $0<\frac{dR_1^N}{dR_2}=\frac{dR_2^N}{dR_1}<1$ *and* $0<\frac{dR_1^F}{dR_2}<1,\ 0<\frac{dR_2^F}{dR_1}<1.$

First, consider the trade regime without an FTA formation. Suppose that a response function described in lemma 2 is sloping downward. In other words, when the R&D of a firm increases the other firm reduces its R&D level. This may happen because the rise of R&D of the firm can effectively reduce the other firm's export. The main reason why the other firm's export can be reduced is because of a weak spillover effect of R&D between the two firms. As the spillover effect gets weaker, the positive channel of R&D expenditure on other firm's product quality becomes less effective. (Refer to (17).) As shown in lemma 2, this downward sloping R&D response functions are appeared when ϵ is in a lower range $\left(0<\epsilon<\frac{\theta}{3}\right)$. Likewise, the fact that a response function is positively sloped implies a positive response of a firm's R&D to the other firm's increased R&D level. The rise in R&D of a firm can increase the other firm's export through the stronger spillover effect of the R&D on the other firm's quality of the exports. From lemma 2, this upward sloping R&D response functions are identified when ϵ is in a higher range $\left(\frac{\theta}{3} < \epsilon < 1\right)$.

However, the thresholds of ϵ at which the slope of response functions turns positive are different under the FTA regime. To the FTA member exporting firm, the threshold becomes lower $\left(\frac{4\theta}{24-\theta^2} < \frac{\theta}{3}\right)$. This means that even for a smaller spillover effect than $\frac{\theta}{3}$ (i.e. even in case (ii) in lemma 2), when non-FTA firm increases its R&D expenditure, the FTA exporting firm also does so. This is because one of the negative channel through which the exports may be reduced is eliminated due to the formation of the FTA. To see the eliminated channel, compare B and B_2 for verification. Likewise, to the non-FTA member exporting firm, the threshold becomes higher $\left(\frac{\theta}{3} < \frac{3\theta}{8}\right)$. This means that when the FTA firm increases its R&D expenditure, the non-FTA firm will increases its R&D only when the spillover effects between them are sufficiently high (i.e. in case (iv) in lemma 2). This is because one of the positive channel through which the exports may be increased is eliminated due to the formation of the FTA. Again to see the eliminated channel, compare B and B_2 for verification.

Now we need to show an existence of solution from the response functions. We summarize the results in the following lemma.

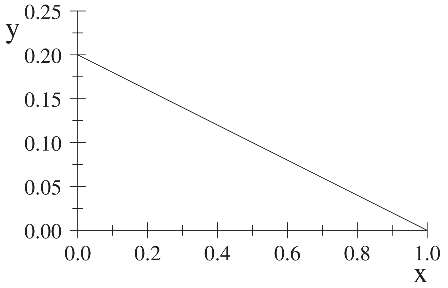
Lemma 3 *There exists a unique solution from the R&D response functions for each of the four cases in lemma 2.*

With lemmas 1, 2 and 3, we provide our first proposition as follows.

Proposition 1 *Under the FTA regime, the exporting firm in the FTA region invests on R&D more than the exporting firm outside the FTA region does.* (i.e. $R_2^F > R_1^F$)

Proof. First, under the no FTA regime, since the firms are symmetric, the choices of the optimal R&D expenditure are identical. This implies that the two firms' response functions cross at a point on the 45-degree line. Now when the importing country and the exporting country (i.e. country 2) formed an FTA, we need to show that the response functions cross at a point below 45-degree line. In doing so, we use the values of intercepts found in the proof in lemma 3. The results are summarized in Figure 3 in the Appendix for each case. For the case of $0 < \epsilon < \frac{4\theta}{24-\theta^2}$, it is now easy to see that $r_1^N|_{R_2=0} > r_1^F|_{R_2=0}$ and $R_1|_{R_2^F=0} > R_1|_{R_2^N=0}$. So the FTA firm's response function shifts downward and the non-FTA firm's function shifts upward. For the case of $\frac{4\theta}{24-\theta^2} < \epsilon < \frac{3\theta}{8}$, it is readily verifiable that $r_1^N|_{R_2=0} > r_1^F|_{R_2=0}$ and the non-FTA firm's response function shifts downward. Although the slope of FTA firm's response function turns positive, the solution exists from lemma 3. For the case of $\frac{3\theta}{8} < \epsilon < 1$, it is shown that $r_1^N|_{R_2=0} > r_1^F|_{R_2=0}$ and $R_1|_{R_2^F=0} > R_1|_{R_2^N=0}$ based on lemma 3 and thus the response functions with positive slopes are all shifted to the right. For all cases, a crossing point of the two response functions under the FTA regime must be located in the area below 45-degree line. ■

FIG. 1. $\dfrac{\partial(q_2^F - q_1^F)}{\partial\epsilon} < 0$ with $\theta = 1$ and $\epsilon \in (0, 1)$



Note that if the spillover effect between the two firms is perfect ($\epsilon = 1$), the resulting levels of product quality would be the same regardless of any chosen optimal level of R&D investments of the two firms. In our model, the FTA member exporter chooses a higher level of R&D than the non-FTA member exporter because the FTA member saves the tariff costs and can afford more R&D. Nevertheless, when the spillover is perfect ($\epsilon = 1$), the benefit of R &D is perfectly transmitted to each other's product quality. So, there would be no gap in qualities between FTA and non-FTA members. The quality gap will exist only when the spillover effect is not perfect. Here we provide our second results when an imperfect spillover effect is assumed in the following proposition.

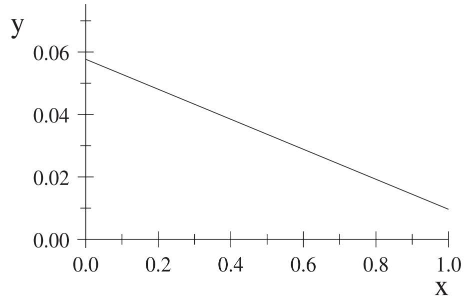
Proposition 2 *Suppose that there is an imperfect spillover effect of R&D investments between the two exporting firms* ($0 < \epsilon < 1$). (*i*) *The FTA formation results in a quality gap in favor of the FTA member's product.* (*ii*) *As the technology spillover becomes smaller* (*larger*) *the quality gap between FTA and non-FTA exporters* ($q_2^F - q_1^F$) *becomes larger* (*smaller*) (*iii*) *As the technology spillover becomes smaller* (*larger*), *the external tariff gap* ($\tau_1^N - \tau_1^F$) *becomes larger* (*smaller*).

Proof. (i) Under no-FTA regime, $q_2^N = q_1^N$ because $R_2^N = R_1^N$ due to the symmetry of the model. However, under an FTA regime, $q_2^F - q_1^F = (1-\epsilon)(R_2^F - R_1^F) > 0$ because $R_2^F > R_1^F$ from proposition 1 and $0 < \epsilon < 1$ as we assumed. (ii) $\dfrac{\partial(q_2^F - q_1^F)}{\partial\epsilon} = -(R_2^F - R_1^F) + (1-\epsilon)\dfrac{\partial(R_2^F - R_1^F)}{\partial\epsilon} < 0$ only if $\dfrac{\partial(R_2^F - R_1^F)/(R_2^F - R_1^F)}{\partial\epsilon/\epsilon} < \dfrac{\epsilon}{1-\epsilon}$. To show if this is the case or not, due to the complexity of the functional relationship between $q_2^F - q_1^F$ and ϵ, we rely on a simulation with numerical values of parameters. Using $\theta = 1$, we can draw $q_2^F - q_1^F$ over $\epsilon \in (0, 1)$ in Figure 1. (Note the y-vertical line is for $q_2^F - q_1^F$ and the x-horizontal line is for ϵ.)

(iii) We need to prove $\dfrac{\partial(\tau_1^N - \tau_1^F)}{\partial\epsilon} < 0$. Due to the complexity of the functional relationship between $\tau_1^N - \tau_1^F$ and ϵ, we rely on a simulation with numerical values of parameters. Using $\theta = 1$, we can draw $\tau_1^N - \tau_1^F$ over $\epsilon \in$ (0, 1) in Figure 2. (Note the y-vertical line is for $\tau_1^N - \tau_1^F$ and the x-horizontal line is for ϵ.)

■

FIG. 2. $\dfrac{\partial(\tau_1^N - \tau_1^F)}{\partial \epsilon} < 0$ with $\theta = 1$ and $\epsilon \in (0, 1)$



Assuming that the imperfect spillover effect is getting weaker, proposition 2 tells that an FTA may bring a higher quality product from its FTA member country and that the importing government becomes relatively more protective against non-FTA country. In other words, the importing country diverts the trade more toward the FTA member by setting a higher external tariff against non-FTA member country.

A trade diversion (toward a high cost country) usually reduces a welfare of the importing country. However, in our model, we assume that the two firms are identical in production costs. So, the trade diversion does not necessarily bring expensive products to the importing market. Instead, in our model, the FTA member's exporting firm invests more on R&D and exports a higher-quality product than the non-FTA member. The product quality improvement will shift the demand curve to the right (see the inverse demand function in (2)) and thus will increase the size of the welfare gain to the consumers in the market. So if a reduction of tariff revenue as a result of FTA formation is not significant, the welfare level of the importing country with the FTA can be higher than the level without the FTA mainly due to the quality improvement. Here we summarize this interesting case in the following corollary.

Corollary 1 *The welfare level of the importing country can be increased as a result of the FTA formation if the welfare benefit from a higher quality of products imported cancels out the reductions of tariff revenues.*

The optimal tariffs in (11) are the welfare-maximizing ones, so any other tariffs should not be able to increase the welfare of the importing country mainly because of the reduced tariff revenues. So, given any level of quality of products imported, an FTA formation should not contribute to the welfare improvement. However, in our model, the quality level of products are determined after the choice of a trade regime. So, it is possible for the importing country to increase its welfare if the welfare benefit from a higher quality of products imported cancels out the reductions of tariff revenues.

So far we treated the FTA formation as a given trade regime between an importing country and one of the exporting countries and thus the FTA formation came before quality choice of the exporting firms. However, since the FTA formation is also a tariff policy just as choosing tariff rates, in a "truly" long-run analysis, firms' quality choice may come even before the government's decision as to whether or not to sign an FTA.[12]

Our definition for the long-run quality variable was meant to take into account a firm's long-term view on the quality of product which will be chosen *before* its production choice. Here, we extend the view to consider a truly long-run case where the quality choice comes even before the importing government's decision on an FTA formation. The timing of this alternative game is as follows.

At stage 1, the two firms simultaneous invest on quality-enhancing R&D. At stage 2, the government l decides whether (i) to propose country 1 to sign an FTA, (ii) to propose country 2 to sign an FTA, or (iii) never to propose any country to sign an FTA. At stage 3, the proposed government, if any, responds as to whether or not to sign an FTA with country l. At stage 4, the government sets optimal tariffs under a chosen trade regime. At stage 5, the two firms competes in the importing country.

One difference between this new game and the old one is that, stage 2 and 3 here are inserted after exporting firms' quality choice and before importing government's tariff choices. In this new game, does the importing government at stage 2 choose to form an FTA in the subgame perfect equilibrium? We doubt it does, mainly because R&D investments are going to be committed at stage 1 in this "truly" long-run model. To simplify the analysis, we modify the model slightly as follows. Let us suppose that a firm in each country at stage 1 has two choices of R&D; a quality-enhancing R&D, R^H or a minimum-quality R&D, R^L. If R^H is chosen by an exporting firm (or both) before an FTA offer, the government l at stage 2 would not need to offer an FTA to the country (or both) because the quality of products will have been already enhanced by the time of an FTA offer. If the minimum quality-induced R&D, R^L is chosen at stage 1, the government l also need not to offer an FTA since it only reduces the tariff revenues. Therefore, at stage 2, government l would not propose any country to sign an FTA. So at stage 1, both firms would choose, R^L, which is less costly in this simple model. Here we summarise the result as follows.

Corollary 2 *In the truly long-run game, no exporting firms would improve the quality of products ex-ante and thus no competition for an FTA occurs. In this case, the importing government would not offer any FTA to an exporting country.*

The above setting is rather specific as we consider only two options, high and low levels of R&D. So, this result should not be interpreted as general one showing 'zero-incentive' for R&D activities at all. In a more general setting, firms are still expected to engage in some R&D. What this corollary tells about is that, the level of R&D of a firm may be 'lower' in a truly long run than that in the case where an importing country is surely expected to offer an FTA to the firm.

This corollary seems interesting since it offers an idea of how exporting firms' choice of quality affects a future FTA formation. According to corollary 2, there is no effect of quality choice on the FTA formation. However this does not necessarily mean that firms would never improve quality of product when its government plans to form FTAs with other countries. As we have seen in the previous game, when a firm is sure about the formation of an FTA (i.e. an FTA is given), the firm will choose the quality-enhanced R&D. So, this suggests that there

[12] I thank a referee to point this out and to suggest an alternative game (as described here) so as to investigate and compare the results under the two games. The result under the alternative game is being presented here.

would be a certain link between a probability of an FTA formation and firm's quality choice. The higher the probability of an FTA formation is, the more a firm invests on R&D activities and thus the higher quality of products will be provided to the FTA region. What might affect the probability of an FTA formation? One possible answer might be a firm's lobby activity, which persuades its government to pre-commit for an FTA formation. This could be an interesting idea and we leave this for a future research topic.

III. *Concluding Remarks*

In this paper, we treated product quality as a long-run variable and analyzed the effect of a preferential trade agreement on the quality gap between the FTA member and non-member. The main result is that, as long as the technology spillover effects are not perfect, the bilateral free trade agreement has a stronger effect on the member country's product quality improvement than that of the non-member country. In a preferential free trade system, its member countries' firms could save their trade costs relatively more than non-members could. So, the member firms can invest the increased profits in R&D so that their product quality can be higher than non-member's. However, the quality gap would disappear if the technology spillover effects are perfect, regardless of the trade regime. In addition, we saw that the FTA formation could be beneficial to the importing country through imported product quality improvement. This result implies that an FTA may have a positive long term effect on its member country. Therefore, a membership in an FTA can be viewed as a long-run strategy for a country.

Appendix

A1: Proof of Lemma 1 (i) Use (4), (6), (7), (11), (12), $\frac{\partial q_i}{\partial R_i}=1$ and $\frac{\partial q_i}{\partial R_j}=\epsilon$ for $i\in\{1, 2\}$ and verify $0<\frac{\partial x_1^F}{\partial R_1}<\frac{\partial x_1^N}{\partial R_1}=\frac{\partial x_2^N}{\partial R_2}<\frac{\partial x_2^F}{\partial R_2}$ where $\frac{\partial x_1^N}{\partial R_1}=\frac{\partial x_2^N}{\partial R_2}=\frac{3-\theta\epsilon}{2(9-\theta^2)}$, $\frac{\partial x_1^F}{\partial R_1}=\frac{8-3\theta\epsilon}{48-5\theta^2}$ and $\frac{\partial x_2^F}{\partial R_2}=\frac{24-\theta^2-4\theta\epsilon}{96-10\theta^2}$. (ii) Again using (4), (6), (7), (11), (12), $\frac{\partial q_i}{\partial R_i}=1$ and $\frac{\partial q_i}{\partial R_j}=\epsilon$, we can see that $\frac{\partial x_1^N}{\partial R_2}=\frac{\partial x_2^N}{\partial R_1}=\frac{3\epsilon-\theta}{2(9-\theta^2)}$, $\frac{\partial x_1^F}{\partial R_2}=\frac{8\epsilon-3\theta}{48-5\theta^2}$ and $\frac{\partial x_2^F}{\partial R_1}=\frac{(24-\theta^2)\epsilon-4\theta}{96-10\theta^2}$. Then for a given value of $\epsilon\in(0, 1)$, we can easily rank them as $\frac{\partial x_1^F}{\partial R_2}<\frac{\partial x_1^N}{\partial R_2}=\frac{\partial x_2^N}{\partial R_1}<\frac{\partial x_2^F}{\partial R_1}$. However, their signs depend on the range of spillover ϵ as follows: $sign\left(\frac{\partial x_1^N}{\partial R_2}\right)=sign\left(\frac{\partial x_2^N}{\partial R_1}\right)=sign\left(\epsilon-\frac{\theta}{3}\right)$; $sign\left(\frac{\partial x_1^F}{\partial R_2}\right)=sign\left(\epsilon-\frac{3\theta}{8}\right)$; and $sign\left(\frac{\partial x_2^F}{\partial R_1}\right)=sign\left(\epsilon-\frac{4\theta}{24-\theta^2}\right)$.

Note that $0<\dfrac{4\theta}{24-\theta^2}<\dfrac{\theta}{3}<\dfrac{3\theta}{8}<1$.

A2: Proof of Lemma 2 The linearity of the response functions can be straightforwardly obtained from (14). For their slopes we propose the following three claims. (Claim I) We claim that $\left|\dfrac{dR_i^N}{dR_j}\right|<1$. (i) If $\dfrac{\theta}{3}<\epsilon<1$, then $0<\dfrac{dR_i^N}{dR_j}<1$. First, it is positive because of $\dfrac{\partial x_i^N}{\partial R_i}=\dfrac{3-\theta\epsilon}{2(9-\theta^2)}>0$ and $\dfrac{\partial x_i^N}{\partial R_j}=\dfrac{3\epsilon-\theta}{2(9-\theta^2)}>0$ from lemma 1. Second, the condition for $\dfrac{dR_i^N}{dR_j}<1$ from (16) yields a condition of $\dfrac{(3+\theta)^2(3-\theta)}{(\epsilon+1)(3-\theta\epsilon)}>1$. This is true for all $\theta\in(0, 2)$ and $\epsilon\in(0, 1)$. (ii) If $0<\epsilon<\dfrac{\theta}{3}$, then $-1<\dfrac{dR_i^N}{dR_j}<0$. First, it is negative because of $\dfrac{\partial x_i^N}{\partial R_i}=\dfrac{3-\theta\epsilon}{2(9-\theta^2)}>0$ and $\dfrac{\partial x_i^N}{\partial R_j}=\dfrac{3\epsilon-\theta}{2(9-\theta^2)}<0$ from lemma 1. Second, the condition for $\dfrac{dR_i^N}{dR_j}>-1$ from (16) yields a condition of $\dfrac{(3+\theta)(3-\theta)^2}{(1-\epsilon)(3-\theta\epsilon)}>1$. This is true for all $\theta\in(0, 2)$ and $\epsilon\in(0, 1)$. (Claim II) We claim that $\left|\dfrac{dR_1^F}{dR_2}\right|<1$. (i) If $\dfrac{3\theta}{8}<\epsilon<1$, then $0<\dfrac{dR_1^F}{dR_2}<1$. First, it is positive because of $\dfrac{\partial x_1^F}{\partial R_1}=\dfrac{8-3\theta\epsilon}{48-5\theta^2}>0$ and $\dfrac{\partial x_1^F}{\partial R_2}=\dfrac{8\epsilon-3\theta}{48-5\theta^2}>0$ from lemma 1. Second, the condition for $\dfrac{dR_1^F}{dR_2}<1$ yields a condition of $\dfrac{(10\theta^2-96)^2}{4(16-6\theta\epsilon)(16-6\theta)(1-\epsilon)}>1$. This is true for all $\theta\in(0, 2)$ and $\epsilon\in(0, 1)$. (ii) If $0<\epsilon<\dfrac{3\theta}{8}$, then $-1<\dfrac{dR_1^F}{dR_2}<0$. First, it is negative because of $\dfrac{\partial x_1^F}{\partial R_1}=\dfrac{8-3\theta\epsilon}{48-5\theta^2}>0$ and $\dfrac{\partial x_1^F}{\partial R_2}=\dfrac{8\epsilon-3\theta}{48-5\theta^2}<0$ from lemma 1. Second, the condition for $\dfrac{dR_1^F}{dR_2}>-1$ yields a condition of $\dfrac{(10\theta^2-96)^2}{4(16-6\theta\epsilon)(16+6\theta)(1-\epsilon)}>1$. This is true for all $\theta\in(0, 2)$ and $\epsilon\in(0, 1)$. (Claim III) We claim that $\left|\dfrac{dR_2^F}{dR_1}\right|<1$. (i) If $\dfrac{4\theta}{24-\theta^2}<\epsilon<1$, then $0<\dfrac{dR_2^F}{dR_1}<1$. First, it is positive because of $\dfrac{\partial x_2^F}{\partial R_2}=\dfrac{24-\theta^2-4\theta\epsilon}{96-10\theta^2}>0$ and $\dfrac{\partial x_2^F}{\partial R_1}=\dfrac{(24-\theta^2)\epsilon-4\theta}{96-10\theta^2}>0$ from lemma 1. Second, the condition for $\dfrac{dR_2^F}{dR_1}<1$ yields a condition of $\dfrac{(10\theta^2-96)^2}{4(\theta^2+4\theta\epsilon-24)(\theta^2+4\theta-24)(1+\epsilon)}>1$. This is true for all $\theta\in(0, 2)$ and $\epsilon\in(0, 1)$. (ii) If $0<\epsilon<\dfrac{4\theta}{24-\theta^2}$, then $-1<\dfrac{dR_2^F}{dR_1}<0$. First, it is negative because of $\dfrac{\partial x_2^F}{\partial R_2}=\dfrac{24-\theta^2-4\theta\epsilon}{96-10\theta^2}>$

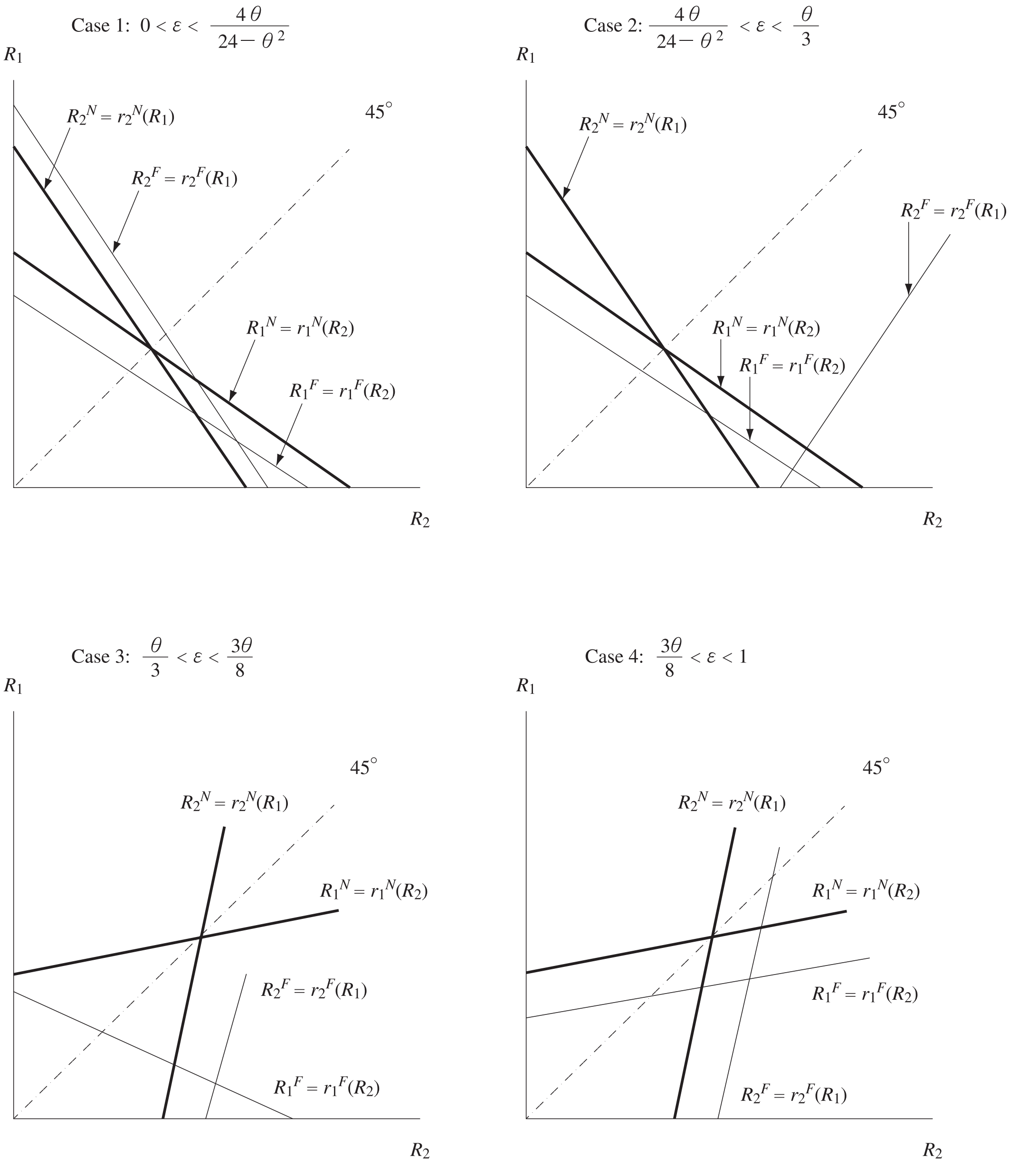
0 and $\dfrac{\partial x_2^F}{\partial R_1} = \dfrac{(24-\theta^2)\epsilon-4\theta}{96-10\theta^2} < 0$ from lemma 1. Second, the condition for $\dfrac{dR_2^F}{dR_1} > -1$ yields a condition of $\dfrac{(10\theta^2-96)^2}{4(\theta^2+4\theta\epsilon-24)(\theta^2-4\theta-24)(1-\epsilon)} > 1$. This is true for all $\theta \in (0, 2)$ and $\epsilon \in (0, 1)$.

A3: Proof of Lemma 3 Since the absolute value of the slopes of the response functions are all less than 1, a solution, if any, should be stable and not diverge. So we only need to observe where the intercepts of the response functions are. (i) First, suppose that there is no FTA formed in the model. Then the firms become symmetric. So, the y-intercept of $R_i^N = r_i^N(R_j)$ is the same as the x-intercept of $R_j^N = r_j^N(R_i)$. The y-intercept of $R_i^N = r_i^N(R_j)$ is the value of R_i^N when $R_j = 0$. From the first order condition in (14), the y-intercept can be calculated as $r_i^N|_{R_j=0} = \dfrac{4\left(\dfrac{1}{2(\theta+3)}\right)\left(\dfrac{\theta\epsilon-3}{2(\theta+3)(\theta-3)}\right)}{1-4\left(\dfrac{\theta\epsilon-3}{2(\theta+3)(\theta-3)}\right)^2} > 0$. The x-intercept of $R_i^N = r_i^N(R_j)$ is the value of R_j when $R_i^N = 0$. Using the same first order condition, the x-intercept can be calculated as $R_j|_{R_i^N=0} = \dfrac{3-\theta}{\theta-3\epsilon}$. So, if $0 < \epsilon < \dfrac{\theta}{3}$, then $R_j|_{R_i^N=0} > 0$ and if $\dfrac{\theta}{3} < \epsilon < 1$, then $R_j|_{R_i^N=0} < 0$. Note that $\left|\dfrac{r_i^N|_{R_j=0}}{R_j|_{R_i^N=0}}\right| = \left|\dfrac{dR_i^N}{dRj}\right|$. So from lemma 2, we can verify that if $0 < \epsilon < \dfrac{\theta}{3}$, then $R_j|_{R_i^N=0} > r_i^N|_{R_j=0} > 0$ and if $\dfrac{\theta}{3} < \epsilon < 1$, then $R_j|_{R_i^N=0} < 0 < r_i^N|_{R_j=0}$. Due to the symmetry of the firms, there must be only one solution for R&D choice for each of the two cases. (ii) Second, suppose that there is an FTA between the importing country and the exporting firm of country 2. Then, the y-intercept of $R_i^F = r_i^F(R_j)$ is not the same as the x-intercept of $R_j^F = r_j^F(R_i)$. For the no-FTA firm, the y-intercept of $R_1^F = r_1^F(R_2)$ is the value of R_1^F when $R_2 = 0$. From the first order condition in (14) with $\tau_2 = 0$, the y-intercept can be calculated as $r_1^F|_{R_2=0} = \dfrac{4\left(\dfrac{3\theta-8}{5\theta^2-48}\right)\left(\dfrac{3\theta\epsilon-8}{5\theta^2-48}\right)}{1-4\left(\dfrac{3\theta\epsilon-8}{5\theta^2-48}\right)^2} > 0$. The x-intercept of $R_1^F = r_1^F(R_2)$ is the value of R_2 when $R_1^F = 0$.

Using the same first order condition, the x-intercept can be calculated as $R_2|_{R_1^F=0} = \dfrac{8-3\theta}{3\theta-8\epsilon}$. So, if $0 < \epsilon < \dfrac{3\theta}{8}$, then $R_2|_{R_1^F=0} > 0$ and if $\dfrac{3\theta}{8} < \epsilon < 1$, then $R_2|_{R_1^F=0} < 0$. Note that $\left|\dfrac{r_1^F|_{R_2=0}}{R_2|_{R_1^F=0}}\right| = \left|\dfrac{dR_1^F}{dR_2}\right|$. So from lemma 2, we can verify that if $0 < \epsilon < \dfrac{3\theta}{8}$, then $R_2|_{R_1^F=0} > r_1^F|_{R_2=0} > 0$ and if $\dfrac{3\theta}{8} < \epsilon < 1$, then $R_2|_{R_1^F=0} < 0 < r_1^F|_{R_2=0}$. (iii) Third, for the FTA firm, the x-intercept of $R_2^F =$

$r_2^F(R_1)$ is the value of R_2^F when $R_1=0$. From the first order condition in (14) with $\tau_2=0$, the x-intercept can be calculated as $r_2^F|_{R_1=0}=\dfrac{4\left(\dfrac{\theta^2+4\theta-24}{10\theta^2-96}\right)\left(\dfrac{\theta^2+4\theta\epsilon-24}{10\theta^2-96}\right)}{1-4\left(\dfrac{\theta^2+4\theta\epsilon-24}{10\theta^2-96}\right)^2}>0$. The y-intercept of $R_2^F=r_2^F(R_1)$ is the value of R_1 when $R_2^F=0$. Using the same first order condition, the y-intercept can be calculated as $R_1|_{R_2^F=0}=\dfrac{24-\theta^2-4\theta}{(\theta^2-24)\epsilon+4\theta}$. So, if $0<\epsilon<\dfrac{4\theta}{24-\theta^2}$, then $R_1|_{R_2^F=0}>0$ and if $\dfrac{4\theta}{24-\theta^2}<\epsilon<1$, then $R_1|_{R_2^F=0}<0$. Note that $\left|\dfrac{r_2^F|_{R_1=0}}{R_1|_{R_2^F=0}}\right|=\left|\dfrac{dR_2^F}{dR_1}\right|$. So from lemma 2, we can verify that if $0<\epsilon<\dfrac{4\theta}{24-\theta^2}$, then $R_1|_{R_2^F=0}>r_2^F|_{R_1=0}>0$ and if $\dfrac{4\theta}{24-\theta^2}<\epsilon<1$, then $R_1|_{R_2^F=0}<0<r_2^F|_{R_1=0}$. (iv) To prove the existence of a unique solution under the FTA trade regime, we compare the intercepts of FTA member's and non-FTA member's response functions. From the obtained intercept values, we can rank them as $r_1^F|_{R_2=0}<R_1|_{R_2^F=0}$ and $r_2^F|_{R_1=0}<R_2|_{R_1^F=0}$ for the case of $0<\epsilon<\dfrac{4\theta}{24-\theta^2}$ and $r_2^F|_{R_1=0}<R_2|_{R_1^F=0}$ for the case of $\dfrac{4\theta}{24-\theta^2}<\epsilon<\dfrac{3\theta}{8}$. For the last case of $\dfrac{3\theta}{8}<\epsilon<1$, the slopes are all positive and $\left|\dfrac{dR_i^F}{dR_j}\right|<1$ from lemma 2. All of these are sufficient conditions for the existence of the solution.

FIG. 3. R&D RESPONSE FUNCTIONS



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