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Rules of origin and international R&D rivalry

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Abstract

We study a three-country three-firm free trade area (FTA) trade model with rules of origin (ROO) under international R&D competition. The external tariff is chosen by the country importing final goods in the FTA. If the FTA chooses a higher content rate of ROO, the country importing final goods chooses a higher tariff in order to compensate for lower consumer surplus. We have three results. First, if the FTA raises the content rate, it raises the costs of exporters within the area, but if the R&D cost is sufficiently low, the exporters actually increase exports and their profits also increase. Second, if the firms within the FTA are less efficient than outsiders, the social welfare of countries importing final goods is affected by the content rate in a U-shaped fashion. A tightening of ROO may reduce the social welfare of importing countries since it may replace productive firms outside the FTA with less productive local firms. Third, if the productivity within an FTA is relatively high, the optimal content rate of ROO for the importing country within the FTA is 100%. In that case, the country importing final goods does not need to rely on imports from outside. Since an increase in the content rate of ROO increases external tariff, the most stringent ROO requirement is desirable for that country.

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1 Introduction

In a free trade area (FTA), in order to distinguish between intra-regional trade and external trade, rules of origin (ROO) are necessary, and a majority of FTAs have introduced and imposed one or another form of ROO.[1] Overall, in order to benefit from duty-free access to a member country's market within an FTA, manufacturers of final goods must include a minimum fraction of inputs produced within the region. ROO limit the use of inputs produced outside the region and they protect relatively less efficient countries within the region. In particular, ROO create cost differences between ROO-compliant and non-complaint firms.

Numerous studies in the past have focused on ROO's protective nature, including Krueger (1999), Lopez-de-Silanes *et al.* (1996), Falvey and Reed (2002), and Takauchi (2010a, b). However, these studies primarily examined firms' export activities without adequately considering their R&D activity. ROO considerably influence exporting firms that engage in cost-reducing R&D activity because they create cost differences between ROO-compliant and non-compliant firms. As indicated by Barros and Nilssen (1999) and Lahiri and Ono (1999), a low-cost firm undertakes a more substantial cost-reducing investment than a high-cost one. As a result, a major firm's market share expands owing to cost-reducing R&D competition.[2] Therefore, the welfare implication of ROO is crucial for firms engaged in cost-reducing R&D activity.

This paper examines the manner in which ROO influence firms' behavior and social welfare once the manufacturers of final goods engage in cost-reducing R&D competition and the countries importing final goods within an FTA establish an optimal external tariff. To examine the manner in which ROO influence the social welfare of each country when firms engage in cost-reducing R&D competition, we built a simple three-country (two countries within an FTA and one outside the FTA), three-firm (one firm belonging to each of the abovementioned two countries within the FTA and one belonging to the country outside that FTA), oligopolistic trade model with ROO. We consider the following three-stage game. In the first stage, the country importing final goods within the FTA establishes the external tariff. In the second stage, each firm undertakes R&D investment. Finally, each firm in the country importing final goods within the FTA competes *à la* Cournot.

Considering R&D rivalry, the following three results emerge. First, when the efficiency of R&D is sufficiently high, the output, R&D investment, and profit of the exporting firm within an FTA increase owing to an increase in ROO requirement. An increase in the ROO requirement leads to an increase in optimal external tariff, and this effect of ROO

[1] At least 93 preferential trade agreements (PTAs; including FTAs) have adopted a certain type of ROO (Estevadeordal and Suominen, 2003).

[2] Following the study of Spencer and Brander (1983), several studies examining cost-reducing R&D, competition, and industrial policy (i.e., R&D subsidy) have been conducted. For example, Leahy and Neary (1996, 1999) examined the effects of strategic R&D subsidy on firms' operations and each country's welfare. Furthermore, a recent study identified the initial cost heterogeneity of firms. Ishida *et al.* (2010) focused on the competitive effects of the initial cost differences among firms.

dominates all other effects when the efficiency of R&D is sufficiently high. As pointed out by Lopez-de-Silanes *et al.* (1996), a tightening of ROO shifts rent from complying exporters to non-complying exporters. However, this rent-shifting effect of ROO may help complying exporters in an R&D competition with optimal external tariff. This point has been dropped in the literature of ROO and, therefore, it is worthwhile to consider the role of ROO in firms' competition.

Second, there are ranges of production efficiency within the FTA such that the welfare of a country importing final goods is U-shaped for the ROO requirement. Similar to Lahiri and Ono's (1988) reasoning, the welfare-enhancing production substitution effect of ROO is a key factor. When the productivity of an external firm is relatively high, increasing the stringency of ROO reduces the welfare of a country importing final goods. This is because increasing the stringency of ROO increases the external tariff and, therefore, reduces imports from an external firm. Conversely, when the productivity of an external firm is relatively low, an increase in the ROO requirement improves the welfare of that country. Since the welfare of the importing country within the FTA is U-shaped for the ROO requirement, an intermediate level of the ROO requirement minimizes the welfare of that country.

Third, if the productivity within an FTA is relatively high, the optimal content rate of ROO for the country importing final good within the FTA is 100%. Conversely, if the productivity within the FTA is relatively low, the optimal content rate for the importing country is 0%. When the intra-regional productivity is high, the country importing final good does not need to rely on imports from outside the region. Since a higher content rate corresponds to a higher rate of external tariff, 100% of the ROO requirement is desirable for that country.

In the literature on ROO, many studies emphasize the protective or welfare-enhancing nature of ROO; that is, by introducing and tightening ROO, the national welfare of less efficient countries within an FTA could possibly increase. However, the following question arises: Are ROO always a protective device for the less efficient countries within an FTA? We find a condition that decides whether or not ROO are a protective device. Since this condition depends on the productivity within an FTA, we can say that ROO do not always have a protective nature.

2 Model

Consider an FTA comprising two countries, of which one country has and another country does not have a market for final goods. We identify the member country comprising a market for final goods as country M, the other country without a market for final goods as country E, and the country outside the FTA as country O. We assume that there are two manufacturers of final goods within this FTA, one of which is located in country M (say, firm M) and the other is located in country E (say, firm E). Further, an exporter of final goods is located outside this FTA (say, firm O). Firm E is limited by ROO and, therefore, selects a mixed proportion of intermediate goods produced in countries M and O while exporting the final goods to country M. This is plausible because firm E is exempted from paying external tariff, τ, if it procures over the predetermined quantity stipulated by ROO.[3] Let us denote this ROO requirement as δ $(0 \leq \delta \leq 1)$.

In countries M and O, the intermediate good industries operate under perfect competition. However, the productivity of intermediate goods industry in country M is relatively lower than that of other countries. In other words, $k > k^O (= 0)$, where k and k^O indicate the price of the intermediate goods in country M and country O respectively. Firm E's initial cost is reflected by the following equation: $c^E \equiv c + \delta k$.[4] However, as firm O's initial cost is subject to external tariff, it is reflected by the following equation: $c^O \equiv c + \tau$. Further, we define firm M's initial cost in the following manner: $c^M \equiv c + k$.[5] We assume that firm E is relatively more technologically advanced as compared to firm M. In other words, firm E can employ inputs obtained from multiple sources; however, firm M can employ inputs obtained only from domestic sources. This restraint may be caused by a trade barrier. For example, a sufficiently high import tariff t may be imposed on the imported intermediate good. That is, $k < t + k^O = t$ holds. Then, the firm M never uses the intermediate good originated from the outside. If this trade restriction is relaxed, firm M does not use the domestic intermediate good. This is because, since firm M is a domestic firm and it supplies the final good to the domestic market, it is not constrained by ROO. Therefore, firm M buys cheaper inputs from outside the FTA.

The unit production cost of firm i is represented in the following manner: $c^i - x^i$, $i = M, E, O$, where x^i indicates the degree of cost reduction, that is, it denotes each firm i's R&D level. Therefore, all firms control their input coefficient. We focus on the initial level of unit cost differences among all firms and not on R&D subsidies, taxes, or spillovers. We define R&D cost in the following manner: $\varphi(\gamma, x^i) \equiv \gamma (x^i)^2$, where γ represents a positive constant.

The inverse demand for final goods in country M is reflected by the following equation: $p = a - Q$, with $Q = q^M + q^E + q^O$, where Q and q^i indicate the total sales of the product and firm i's output, respectively. The net profit of firm i is presented in the following manner:

$$\pi^i \equiv \left(p(Q) - (c^i - x^i)\right) q^i - \gamma {(x^i)}^2. \tag{1}$$

Let us consider the following three-stage game. Stage 1: The government of country M establishes the external tariff. Stage 2: Each firm independently and simultaneously determines the quantum of cost reduction, x^i. Stage 3: Each firm independently and simultaneously determines a quantity of product output, q^i.

Final stage. In market competition, each firm i determines q^i in order to maximize $\left(p(Q) - (c^i - x^i)\right) q^i$. From (1), the equilibrium output obtained during the final stage is represented in the following manner:

[3]For simplicity, we assume that firm E constantly complies with ROO throughout the analysis.

[4]The procurement cost is appropriately reflected in the following manner: $\delta k + (1-\delta) k^O$. This definition is the same as that employed by Lahiri and Ono (1998, 2003).

[5]We assume that one unit of the intermediate good is required to produce one unit of the final good.

$$q^i = \frac{\alpha - 3(y^i - x^i) - \sum_{j \neq i} x^j + \sum_{j \neq i} y^j}{4}, \tag{2}$$

where $\alpha \equiv a - c > 0$, $i = M, E, O$, $y^M \equiv k$, $y^E \equiv \delta k$, and $y^O \equiv \tau$.

Second stage. In the R&D stage, each firm i determines x^i in order to maximize π^i. From (1) and (2), the equilibrium R&D level for each firm x^i is reflected by the following equation:

$$x^i = \frac{3[(4\gamma - 3)\alpha - 3(4\gamma - 1)y^i + 4\gamma \sum_{j \neq i} y^j]}{(4\gamma - 3)(16\gamma - 3)}. \tag{3}$$

Substituting (3) into (2) yields the following output:

$$q^i = \frac{4\gamma[(4\gamma - 3)\alpha - 3(4\gamma - 1)y^i + 4\gamma \sum_{j \neq i} y^j]}{(4\gamma - 3)(16\gamma - 3)} = \frac{4}{3}\gamma x^i. \tag{4}$$

The industry output and prices of final goods are reflected by the following equations:

$$Q = \frac{4\gamma(3\alpha - \sum_i y^i)}{16\gamma - 3}, \quad p = \frac{(4\gamma - 3)a + 4\gamma[3c + (1+\delta)k + \tau]}{16\gamma - 3}. \tag{5}$$

In the second stage, the net profit of each firm, $(q^i)^2 - \varphi(\gamma, x^i)$, is presented in the following manner:

$$\pi^i = \gamma(16\gamma - 9)\left[\frac{(4\gamma - 3)\alpha - 3(4\gamma - 1)y^i + 4\gamma \sum_{j \neq i} y^j}{(4\gamma - 3)(16\gamma - 3)}\right]^2 = \frac{16\gamma - 9}{16\gamma}(q^i)^2. \tag{6}$$

Subsequently, we derive the amount of consumer surplus in country M. Consumer surplus is reflected by the following equation: $CS = (1/2)Q^2$. Further, substituting (5) in the consumer surplus equation yields the following result:

$$CS = \frac{8\gamma^2(3a - \sum_i c^i)^2}{(16\gamma - 3)^2}. \tag{7}$$

First stage. In this stage, the government of country M establishes the external tariff. Social welfare W in country M is defined by the sum of consumer surplus (CS), firm M's net profit (π^M), and tariff revenue (τq^O), which is reflected in the following manner:

$$W \equiv CS + \pi^M + \tau q^O. \tag{8}$$

Substituting (2), (6), and (7) into (8) and solving the first-order condition for welfare maximization with respect to τ, country M's optimal external tariff is presented in the following manner:[6]

[6] The welfare function in country M is indicated in the Appendix. See (W.1) and (W.2).

$$\tau^* = \frac{(8\gamma-3)\big[3(2\gamma-1)(4\gamma-3)\alpha - 2\gamma(4\gamma+3)k\big] + 8\gamma(9-51\gamma+56\gamma^2)k\delta}{6(224\gamma^3-276\gamma^2+90\gamma-9)}, \quad \frac{\partial \tau^*}{\partial \delta} > 0. \quad (9)$$

Overall, (9) indicates a positive relationship between τ^* and δ. When δ rises, both productivity of manufacturers of final goods and consumer surplus decreases (anti-competitive effect of ROO). However, since the imports from external firms increase (rent-shifting effect of ROO), country M increases the external tariff in order to maintain domestic welfare levels.

On the basis of equations (3) and (9), each firm's R&D investment and total R&D investment are given by

$$x^M = \frac{3(4\gamma-1)(4\gamma-3)\alpha + [4\gamma(14\gamma-3)\delta - 9 + 66\gamma - 128\gamma^2]k}{224\gamma^3-276\gamma^2+90\gamma-9}, \quad (10)$$

$$x^E = \frac{3(4\gamma-1)(4\gamma-3)^2\alpha + (4\gamma B_1 + B_2\delta)k}{(4\gamma-3)(224\gamma^3-276\gamma^2+90\gamma-9)}, \quad (11)$$

$$x^O = \frac{(4\gamma-3)(3-18\gamma+16\gamma^2)\alpha + 2\gamma(9-56\gamma+64\gamma^2-4\gamma\delta)k}{2(4\gamma-3)(224\gamma^3-276\gamma^2+90\gamma-9)}, \quad (12)$$

$$X = \frac{3(15-82\gamma+80\gamma^2)\alpha - 2k[(4\gamma-3)(14\gamma-3)\delta + B_1]}{2(224\gamma^3-276\gamma^2+90\gamma-9)}, \quad (13)$$

where $X = x^M + x^E + x^O$, $B_1 \equiv 9 - 45\gamma + 40\gamma^2$, and $B_2 \equiv 27 - 234\gamma + 612\gamma^2 - 448\gamma^3$. Therefore, the respective equilibrium outputs for firms M, E, and O are given by $q^M = (4/3)\gamma x^M$, $q^E = (4/3)\gamma x^E$, $q^O = 4\gamma x^O$; further, $Q = (4/3)\gamma X$.

We must assume that $\gamma > 0.786001$ to ensure that the quantities supplied by firms have a finite value. The output and R&D investment of firms possibly diverge when $\gamma > 0.786001$ does not hold.[7]

Subsequently, we impose the following two assumptions on the internal firms' productivity (i.e., k/α).

Assumption 1. $\dfrac{k}{\alpha} > \dfrac{-(4\gamma-3)(3-18\gamma+16\gamma^2)}{2\gamma(9-56\gamma+64\gamma^2)-8\gamma^2\delta} \equiv \epsilon.$

This assumption requires that the optimal external tariff is at least lower than the prohibitive tariff level: it means that $x^O > 0$. We can show that when $\gamma \geq (1/16)(9+\sqrt{33}) \simeq 0.921535$, Assumption 1 always holds since ϵ is negative. In other words, when the efficiency of R&D is not too high, the optimal external tariff is always lower than the prohibitive tariff level. However, when the efficiency of R&D is sufficiently high, the internal firms' productivity should not be too high.[8]

[7] In the second stage of the game, the second-order condition of profit maximization is $\gamma > 9/16 = 0.5625$ for all firms. However, the external tariff is determined in the first stage of the game and the rate of external tariff affects the level of firms' R&D investment (and output). As a result, even if the second order condition ($\gamma > 9/16$) holds, there are values of γ such that firms' R&D investments diverge (e.g., x^E and x^O diverge if $\gamma = 0.75$; all x^i diverge if $\gamma \simeq 0.786001$).

[8] This is because, when the efficiency of R&D is sufficiently high, the effect of production efficiency

Assumption 2. $\dfrac{k}{\alpha} < \dfrac{3(4\gamma-1)(4\gamma-3)}{(9-66\gamma+128\gamma^2)-4\gamma(14\gamma-3)\delta} \equiv \xi.$

Assuming firm M is manufacturing goods under the most stringent conditions with respect to procurement of intermediate goods (i.e., k), then all firms undertake positive production as long as the above assumption holds ($x^M > 0$). Our model needs that $\xi > k/\alpha > \epsilon$. We can show that in our model, there are ranges of k/α such that $\xi > k/\alpha > \epsilon$ (see Appendix).

Hence, we obtain the following lemma:

Lemma 1. *The social welfare in country M is strictly concave with respect to external tariff.*

Proof: Differentiating the welfare function (W.1) twice with respect to τ yields

$$\frac{\partial^2 W}{\partial \tau^2} = \frac{\gamma(216-2160\gamma+6624\gamma^2-5376\gamma^3)}{(9-60\gamma+64\gamma^2)^2}.$$

By numerical calculation, solving $216-2160\gamma+6624\gamma^2-5376\gamma^3 \leq 0$ with respect to γ yields that $\gamma \geq 0.786001$. Therefore, $(\partial^2 W/\partial\tau^2) < 0$. **Q.E.D.**

The net profit of firms is $\pi^M = (1/16\gamma)(16\gamma-9)(q^M)^2$, $\pi^E = (1/16\gamma)(16\gamma-9)(q^E)^2$, and $\pi^O = (1/4\gamma)(16\gamma-9)(q^O)^2$, respectively.

From (10) to (13), we establish the following result.

Proposition 1. *An increase in the content rate of ROO δ [i] increases (decreases) the output, R&D investment, and profit of firm M (firm O); [ii] increases (decreases) the output, R&D investment, and profit of firm E if $\gamma <$ $(>)$ 0.817104; and [iii] is always detrimental to consumers and decreases total R&D investment.*

Proof: See Appendix.

As indicated by Lopez-de-Silanes *et al.* (1996), in a Cournot competitive market, increasing the stringency of ROO requirements shifts rent from ROO-compliant to non-compliant firms. Therefore, Proposition 1 has an interesting feature. The reasoning behind this result is as follows. First, increasing the stringency of the ROO requirement (i.e., an increase in δ) shifts rent from firm E to other firms (M and O). However, as previously mentioned, the optimal external tariff increases with an increase in δ. When the efficiency of R&D is sufficiently high (i.e., $\gamma < 0.81704$), the optimal external tariff rises sharply as δ increases. Second, economies of scale are effective because firms engage in R&D competition. When the efficiency of R&D is not too high (i.e., $\gamma > 0.817104$), the exports of firm E decrease due to an increase in δ, because optimal external tariff does not sufficiently increase due to an increase in δ. In other words, it is considered necessary for country M to concentrate on the production of the domestic firm (firm M) when the efficiency of R&D is not too high.

strengthens extremely. If the internal firms' productivity is too high (i.e., k is too low), the final good importing country does not need to rely on the outside firm and stops importing from the outside.

3 Welfare implications

In this section, we focus on the manner in which a change in the ROO requirement influences a country's welfare. First, we verify the welfare function with respect to the ROO requirement.

Lemma 2. *Second derivative of social welfare in country M with respect to δ is always positive.*

Proof: Differentiating welfare function (W.2) twice with respect to δ yields the following equation:

$$\frac{\partial^2 W}{\partial \delta^2} = \frac{16(k\gamma)^2(9 - 48\gamma + 56\gamma^2)}{3(4\gamma - 3)(224\gamma^3 - 276\gamma^2 + 90\gamma - 9)}.$$

From the numerator of the abovementioned equation, solving $9 - 48\gamma + 56\gamma^2 \geq 0$ with respect to γ yields the following result: $\gamma \geq (3/28)(4+\sqrt{2})$. From the denominator of the abovementioned equation, solving $224\gamma^3 - 276\gamma^2 + 90\gamma - 9 \geq 0$ with respect to γ yields the following result: $\gamma \geq 0.786001$. Thus, Lemma 2 holds. **Q.E.D.**

Lemma 2 and the welfare function in country M (W.2) yield the following result.

Proposition 2. *There exists* $0 < \delta_m < 1$, *which minimizes the welfare in country M if and only if the following equation holds*:

$$\frac{k}{\alpha} > \frac{3(4\gamma - 3)}{9 - 78\gamma + 112\gamma^2},$$

where

$$\delta_m = \frac{(9 - 78\gamma + 112\gamma^2)k - 3(4\gamma - 3)\alpha}{2(9 - 48\gamma + 56\gamma^2)}.$$

Proof: See Appendix.

Proposition 2 demonstrates that the welfare of a country importing final goods within the FTA is U-shaped for the ROO requirement if production efficiency within the FTA is relatively less efficient. This conclusion is comparable to Lahiri and Ono's (1988) reasoning. In other words, the welfare-enhancing (or diminishing) production substitution effect of ROO is a key factor. First, we consider the case in which $\delta \leq \delta_m$. A relatively significant k/α implies that the productivity of firm O is relatively higher than that of other firms. An increase in the ROO requirement (i) increases the optimal rate of external tariff τ^*, and it reduces exports of firm O and (ii) decreases production. In other words, it replaces productive firms outside the FTA with less-productive regional firms engaged in manufacturing final goods. Hence, the welfare level of the importing country decreases.

Next, we consider the case where $\delta \geq \delta_m$. In this case, since δ is sufficiently high, τ^* is sufficiently high, as well. Hence, contrary to $\delta \leq \delta_m$, firm O is less productive in this case.

An increase in δ increases production of firm M. The welfare level of an importing country is enhanced due to an increase in δ because an increase in the profit of the domestic firm dominates all other effects.

Last, we consider the optimal content rate of ROO for country M. From Lemma 2, the welfare is convex with respect to the content rate, so the optimal content rate is either 0% or 100% (hereafter, we refer to the optimal content rate for country M as δ^*). From the welfare of country M (W.2), we obtain the following result.

Proposition 3. *The optimal content rate of ROO for country M is*

$$\delta^* = \begin{cases} 0 & \textit{if} \quad k/\alpha > k_C \\ \{0,1\} & \textit{if} \quad k/\alpha = k_C \\ 1 & \textit{if} \quad k/\alpha < k_C, \end{cases}$$

where $k_C \equiv [3(4\gamma - 3)]/[2\gamma(28\gamma - 15)]$.

Proof: From Lemma 2, the welfare function of country M is convex with respect to δ, so the optimal content rate δ^* is either 0% ($\delta^* = 0$) or 100% ($\delta^* = 1$). Using the welfare function of country M (W.2), we obtain

$$W|_{\delta=0} - W|_{\delta=1} = \frac{8k\gamma^2[-3\alpha(4\gamma-3) + 2\gamma(28\gamma-15)k]}{3(4\gamma-3)(224\gamma^3 - 276\gamma^2 + 90\gamma - 9)}.$$

Since $224\gamma^3 - 276\gamma^2 + 90\gamma - 9 > 0$ for all $\gamma > 0.786001$, the following relation holds:

$$W|_{\delta=1} \begin{cases} \leq W|_{\delta=0} & \text{if} \quad k/\alpha \geq k_C \\ > W|_{\delta=0} & \text{if} \quad k/\alpha < k_C, \end{cases}$$

where $k_C \equiv [3(4\gamma - 3)]/[2\gamma(28\gamma - 15)] > 0$. **Q.E.D.**

Proposition 3 says that if firms within the FTA are more efficient than outsiders (i.e., production efficiency within the FTA is relatively high), a 100% content rate maximizes welfare in country M. The logic is very simple. When production efficiency within the FTA is relatively high, country M does not need to rely on imports from the outside (firm O). The volume of imports from the outside that is accounted to consumer surplus is relatively small, thus it is desirable for country M to set the external tariff as high as possible. Conversely, if the production efficiency within the FTA is relatively low, country M needs to rely on the imports from the outside. In this case, a 0% content rate is the most desirable. This is because a lower content rate corresponds to a lower external tariff rate.

4 Conclusion

This paper focused on examining the R&D activity of firms manufacturing final goods and the manner in which ROO influence the behavior of firms and the welfare of each country. To consider the manner in which ROO influence international R&D competition, we presented a simple three-country three-firm FTA model with ROO.

Considering cost-reducing R&D competition, we obtained three interesting results, which are as follows. First, an increase in the ROO requirement increases the output, R&D investment, and profit of exporting firms within an FTA when the efficiency of R&D investment is sufficiently high. Second, the welfare levels of a country importing final goods within an FTA is U-shaped for the ROO requirement when the efficiency of R&D is not too low and productivity of firms within the FTA is not relatively high. Third, if the productivity within an FTA is relatively high (low), the optimal content rate of ROO for the country importing final goods within the FTA is 100% (0%).

Appendix

Alternative condition of Assumption 1: From (12), we obtain

$$x^O > 0 \;\Leftrightarrow\; (4\gamma - 3)(3 - 18\gamma + 16\gamma^2)\alpha + 2k\gamma(9 - 56\gamma + 64\gamma^2 - 4\gamma\delta) > 0.$$

Therefore, if $\gamma > 0.786001$, $2k\gamma(9 - 56\gamma + 64\gamma^2 - 4\gamma\delta)$ is always positive for all $\delta \in [0,1]$. Thus, if the coefficient of α is positive, $x^O > 0$. $3 - 18\gamma + 16\gamma^2 \geq 0$ for all $\gamma \geq (1/16)(9 + \sqrt{33}\,)$. Therefore $x^O > 0$ if $\gamma \geq (1/16)(9 + \sqrt{33}\,)$.
Next, we consider the case that $\gamma < (1/16)(9 + \sqrt{33}\,)$. In this case, the coefficient of α is negative. Thus,

$$x^O > 0 \quad\Leftrightarrow\quad \frac{k}{\alpha} > \frac{-(4\gamma - 3)(3 - 18\gamma + 16\gamma^2)}{2\gamma(9 - 56\gamma + 64\gamma^2) - 8\gamma^2\delta} \equiv \epsilon.$$

The above condition $k/\alpha > \epsilon$ is equivalent to $\tau_0 - \tau^* > 0$, where τ_0 is a prohibitive tariff level (derived from (4) in the second stage) and $\tau_0 \equiv [(4\gamma - 3)\alpha + 4\gamma(1 + \delta)k]/[3(4\gamma - 1)]$. To see this, we consider the difference between τ_0 and τ^*.

$$\tau_0 - \tau^* = \frac{(16\gamma - 3)\big\{(4\gamma - 3)(3 - 18\gamma + 16\gamma^2)\alpha + k\big[2\gamma(9 - 56\gamma + 64\gamma^2) - 8\gamma^2\delta\big]\big\}}{6(4\gamma - 1)(224\gamma^3 - 276\gamma^2 + 90\gamma - 9)}.$$

Thus, from the numerator, the condition $\tau_0 - \tau^* > 0$ is equivalent to $k/\alpha > \epsilon$.

Welfare function in country M: Substituting (4), (6), and (7) into (8) yields the following welfare function in country M:

$$
\begin{aligned}
W(\tau,\delta) = {} & \gamma\left[\frac{(88\gamma-9)(4\gamma-3)^2(a^2+c^2)+(8\gamma-3)(27-216\gamma+304\gamma^2)k^2}{(4\gamma-3)^2(16\gamma-3)^2}\right] \\
& - 8k\gamma^2\left[\frac{(4\gamma+3)(8\gamma-3)\tau+k(9-108\gamma+160\gamma^2)\delta-4(9-51\gamma+56\gamma^2)\delta\tau}{(4\gamma-3)^2(16\gamma-3)^2}\right] \\
& + 12\gamma\left[\frac{2k^2\gamma(2\gamma-1)(8\gamma-3)\delta^2-(-9+90\gamma-276\gamma^2+224\gamma^3)\tau^2}{(4\gamma-3)^2(16\gamma-3)^2}\right] \\
& - 2\gamma\left[\frac{A\alpha+(27-300\gamma+252\gamma^2)ac}{(4\gamma-3)(16\gamma-3)^2}\right], \qquad \text{(W.1)}
\end{aligned}
$$

where $A \equiv [27+32\gamma^2(9+\delta)-12\gamma(19+3\delta)]k-6(3-14\gamma+16\gamma^2)\tau$.
Under the optimal external tariff, country M's welfare (W.1) becomes

$$
\begin{aligned}
W(\delta) = {} & 6\gamma\left\{\frac{(6-39\gamma+40\gamma^2)(a^2+c^2)+\big[9+64\gamma^2-4\gamma(14+\delta)\big]ck}{3(224\gamma^3-276\gamma^2+90\gamma-9)}\right\} \\
& + \gamma k^2\left[\frac{18\gamma(39-4\delta+4\delta^2)-81+64\gamma^3(25-14\delta+7\delta^2)-27\gamma^2(79-26\delta+16\delta^2)}{3(4\gamma-3)(224\gamma^3-276\gamma^2+90\gamma-9)}\right] \\
& - 6\gamma a\left\{\frac{2(6-39\gamma+40\gamma^2)c+\big[9+64\gamma^2-4\gamma(14+\delta)\big]k}{3(224\gamma^3-276\gamma^2+90\gamma-9)}\right\}. \qquad \text{(W.2)}
\end{aligned}
$$

Proof of Proposition 1: First, differentiating the equilibrium output with respect to δ yields

$$
\frac{\partial q^M}{\partial\delta}=\frac{16(14\gamma-3)\gamma^2k}{3(224\gamma^3-276\gamma^2+90\gamma-9)}, \quad \frac{\partial q^E}{\partial\delta}=\frac{4\gamma(27-234\gamma+612\gamma^2-448\gamma^3)k}{3(4\gamma-3)(224\gamma^3-276\gamma^2+90\gamma-9)},
$$
$$
\frac{\partial q^O}{\partial\delta}=-\frac{16\gamma^3k}{(4\gamma-3)(224\gamma^3-276\gamma^2+90\gamma-9)}, \quad \frac{\partial Q}{\partial\delta}=-\frac{4\gamma(4\gamma-3)(14\gamma-3)k}{3(224\gamma^3-276\gamma^2+90\gamma-9)}.
$$

From these equations, we obtain the following relationships: [i] $(\partial q^M/\partial\delta) > 0$ for all $\gamma > 0.786001$, because, $224\gamma^3-276\gamma^2+90\gamma-9 > 0$ holds for all $\gamma > 0.786001$. [ii] $(\partial q^E/\partial\delta) > (<) 0$ if $\gamma < (>) 0.817104$, because, $27-234\gamma+612\gamma^2-448\gamma^3 > 0$ if $0.314277 < \gamma < 0.817104$ or $\gamma < 0.234691$. In addition, we find that $27-234\gamma+612\gamma^2-448\gamma^3 < 0$ if $0.234691 < \gamma < 0.314277$ or $\gamma > 0.817104$. [iii] $(\partial q^O/\partial\delta) < 0$ for all $\gamma > 0.786001$, because, $224\gamma^3-276\gamma^2+90\gamma-9 > 0$ holds for all $\gamma > 0.786001$. [iv] $(\partial Q/\partial\delta) < 0$ for all $\gamma > 0.786001$, because, $224\gamma^3-276\gamma^2+90\gamma-9 > 0$ holds for all $\gamma > 0.786001$. Subsequently, the following relationships hold. Since $(\partial\pi^i/\partial\delta) = \beta^i q^i(\partial q^i/\partial\delta)$, $\text{sign}\{\partial\pi^i/\partial\delta\} = \text{sign}\{\partial q^i/\partial\delta\}$ holds, where $\beta^h = (1/8\gamma)(16\gamma-9)$ for $h = M, E$ and $\beta^O = (1/2\gamma)(16\gamma-9)$. **Q.E.D.**

Proof of Proposition 2: Differentiating the welfare function of country M (W.2) with respect to δ yields

$$\frac{\partial W}{\partial \delta} = 8k\gamma^2 \times \frac{3(4\gamma-3)\alpha + [2(9-48\gamma+56\gamma^2)\delta - (9-78\gamma+112\gamma^2)]k}{3(4\gamma-3)(224\gamma^3-276\gamma^2+90\gamma-9)}.$$

From the above equation, $224\gamma^3 - 276\gamma^2 + 90\gamma - 9 > 0$ for all $\gamma > 0.786001$. Thus, the denominator is positive. Assuming $\delta = 1$ yields

$$\left.\frac{\partial W}{\partial \delta}\right|_{\delta=1} = \frac{8k\gamma^2\big[3(4\gamma-3)\alpha - 9(2\gamma-1)k\big]}{3(4\gamma-3)(224\gamma^3-276\gamma^2+90\gamma-9)}.$$

From the above equation, $(\partial W/\partial\delta)|_{\delta=1} > 0$ if $(4\gamma-3)/[3(2\gamma-1)] > k/\alpha$. However, $(\partial W/\partial\delta)|_{\delta=1} > 0$ always holds. This is because since ξ is increasing for δ and $\xi|_{\delta=1} = (4\gamma-3)/[3(2\gamma-1)]$, $\xi \leq (4\gamma-3)/[3(2\gamma-1)]$. We can omit the case in which $(4\gamma-3)/[3(2\gamma-1)] \leq k/\alpha$.
Further, assuming $\delta = 0$ yields

$$\left.\frac{\partial W}{\partial \delta}\right|_{\delta=0} = \frac{8k\gamma^2\big[3(4\gamma-3)\alpha - (9-78\gamma+112\gamma^2)k\big]}{3(4\gamma-3)(224\gamma^3-276\gamma^2+90\gamma-9)}.$$

Therefore, $(\partial W/\partial\delta)|_{\delta=0} < 0$ if $[3(4\gamma-3)]/(9-78\gamma+112\gamma^2) < k/\alpha$. We find that

$$\xi|_{\delta=0} - \frac{3(4\gamma-3)}{(9-78\gamma+112\gamma^2)} = \frac{6(4\gamma-3)(224\gamma^3-276\gamma^2+90\gamma-9)}{(9-78\gamma+112\gamma^2)(9-66\gamma+128\gamma^2)} > 0 \;\text{ for all } \gamma > 0.786001.$$

Further, we find that

$$\frac{3(4\gamma-3)}{(9-78\gamma+112\gamma^2)} - \epsilon|_{\delta=0} = \frac{(4\gamma-3)(8\gamma-3)(224\gamma^3-276\gamma^2+90\gamma-9)}{2\gamma(9-56\gamma+64\gamma^2)(9-78\gamma+112\gamma^2)} > 0 \;\text{ for all } \gamma > 0.786001.$$

Thus, $\epsilon|_{\delta=0} < [3(4\gamma-3)]/(9-78\gamma+112\gamma^2) < \xi|_{\delta=0}$.
From the above argument, we obtain the following result: If $[3(4\gamma-3)]/(9-78\gamma+112\gamma^2) < k/\alpha$, then an interior point δ_m $(0 < \delta_m < 1)$ exists and δ_m minimizes the welfare in country M, where

$$\delta_m = \frac{(9-78\gamma+112\gamma^2)k - 3(4\gamma-3)\alpha}{2(9-48\gamma+56\gamma^2)}.$$

Finally, let us verify that the welfare level is positive for sufficiently large γ. Substituting δ_m into (W.2) yields

$$W|_{\delta=\delta_m} = \gamma \times \frac{4(5\gamma-3)(4\gamma-3)\alpha^2 + (16\gamma-9)\big\{3(2\gamma-1)k - 2[a-(4\gamma-3)c]\big\}k}{(4\gamma-3)(9-48\gamma+56\gamma^2)}.$$

If $\gamma \geq 1$, $\alpha \equiv a - c \geq a - (4\gamma-3)c$. Using this equation and the numerator of the above equation yields the following:

$$\begin{aligned} &4(5\gamma-3)(4\gamma-3)\alpha^2 + 3(2\gamma-1)(16\gamma-9)k^2 - 2(16\gamma-9)[a-(4\gamma-3)c]k \\ &\qquad \geq 4(5\gamma-3)(4\gamma-3)\alpha^2 + 3(2\gamma-1)(16\gamma-9)k^2 - 2(16\gamma-9)\alpha k \equiv \Omega. \end{aligned}$$

In the range of $\gamma \geq 1$, $\Omega > 0$. To see this, solving $\Omega \leq 0$ with respect to k/α, we obtain

$$\frac{k}{\alpha} \leq \overline{h}(\gamma) \equiv \frac{16\gamma - 9 + \sqrt{(16\gamma-9)(99 - 524\gamma + 888\gamma^2 - 480\gamma^3)}}{(2\gamma-1)(16\gamma-9)},$$
$$\frac{k}{\alpha} \geq \underline{h}(\gamma) \equiv \frac{16\gamma - 9 - \sqrt{(16\gamma-9)(99 - 524\gamma + 888\gamma^2 - 480\gamma^3)}}{(2\gamma-1)(16\gamma-9)}.$$

In the γ-k/α plane, critical curves $\overline{h}(\gamma)$ and $\underline{h}(\gamma)$ are located in the lower side of $\gamma = 1$ and equalized at a smaller value than $\gamma = 1$. $\overline{h}(\gamma) = \underline{h}(\gamma)$ when $\gamma \simeq 0.856996 < 1$. Thus, if $\gamma \geq 1$, $\Omega > 0$ for all k/α. Provided that $\gamma \geq 1$, $W|_{\delta=\delta_m} > 0$ holds. **Q.E.D.**

Compatibility of Assumptions 1 and 2 ($\xi - \epsilon > 0$): Note that ξ is always larger than ϵ for all $(\delta, \gamma) \in [0,1] \times \left(0.786001, \frac{9+\sqrt{33}}{16}\right)$. If $\epsilon < k/\alpha < \xi$, all firms' outputs are positive. To see $\xi - \epsilon > 0$, we consider the real roots of $\xi - \epsilon = 0$, where

$$\xi - \epsilon = \frac{(4\gamma-3)(-9 + 90\gamma - 276\gamma^2 + 224\gamma^3)[3 + 4\gamma(-4+\delta)]}{2\gamma[9 + 64\gamma^2 - 4\gamma(14+\delta)][-9 + \gamma(66 - 12\delta) + 8\gamma^2(-16 + 7\delta)]}.$$

There exist three real roots:

$$\gamma_1 = \frac{3}{4} < 0.786001, \quad \gamma_2 = \frac{3}{4(4-\delta)} < 0.786001,$$
$$\gamma_3 = \frac{23}{56} + \frac{1}{672}\left(2082240 - 72576\sqrt{89}\right)^{1/3} + \frac{1}{56}\left(1205 + 42\sqrt{89}\right)^{1/3} \simeq 0.786001.$$

Since none of them exceeds 0.786001, $\xi - \epsilon > 0$ for all $(\delta, \gamma) \in [0,1] \times \left(0.786001, \frac{9+\sqrt{33}}{16}\right)$.

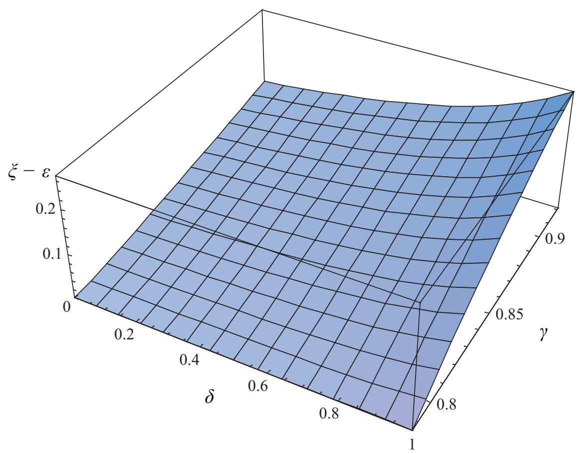

Figure 1: Graph of $\xi - \epsilon$

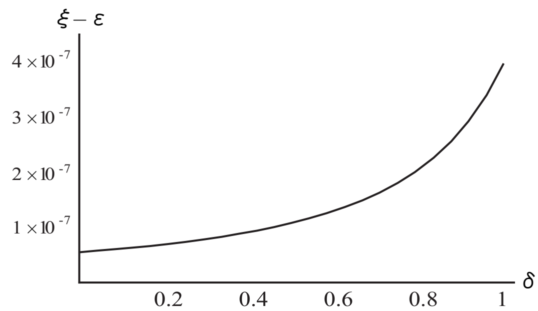

Figure 2: Graph of $(\xi - \epsilon)|_{\gamma=0.786001}$

The function $\xi - \epsilon$ is increasing in both γ and δ, and $(\xi - \epsilon)|_{\gamma=0.786001,\, \delta=0} = 5.48117 \times 10^{-8} > 0$.

References

Barros, P.P. and T. Nilssen (1999) "Industrial Policy and Firm Heterogeneity" *Scandinavian Journal of Economics* **101**, 597-616.

Estevadeordal, A. and K. Suominen (2003) "Rules of Origin: A World Map" *mimeo*, paper presented at the seminar *Regional Trade Agreements in Comparative Perspective: Latin America and the Caribbean and Asia-Pacific*, Washington, D.C., April 22-23, 2003.

Falvey, R. and G. Reed (2002) "Rules of Origin as Commercial Policy Instruments" *International Economic Review* **43**, 393-408.

Ishida, J., T. Matsumura, and N. Matsushima (2010) "Market Competition, R&D and Firm Profits in Asymmetric Oligopoly" forthcoming in *Journal of Industrial Economics.*

Krueger, A.O., (1999) "Free Trade Agreements as Protectionist Devices: Rules of Origin" in *Trade, Theory and Econometrics: Essays in Honor of John Chipman* by J.R. Melvin et al., Eds., Routledge: London, 91-102

Lahiri, S. and Y. Ono (1988) "Helping Minor Firms Reduces Welfare" *Economic Journal* **98**, 1199-1202.

Lahiri, S. and Y. Ono (1998) "Foreign Direct Investment, Local Content Requirement, and Profit Taxation" *Economic Journal* **108**, 444-57.

Lahiri, S. and Y. Ono (1999) "R&D Subsidies under Asymmetric Duopoly: A Note" *Japanese Economic Review* **50**, 104-11.

Lahiri, S. and Y. Ono (2003) "Export-Oriented Foreign Direct Investment and Local Content Requirement" *Pacific Economic Review* **8**, 1-14.

Leahy, D. and P.J. Neary (1996) "International R&D Rivalry and Industrial Strategy without Government Commitment" *Review of International Economics* **4**, 322-38.

Leahy, D. and P.J. Neary (1999) "R&D Spillovers and the Case for Industrial Policy in an Open Economy" *Oxford Economic Papers* **51**, 40-59.

Lopez-de-Silanes, F., J.R. Markusen, and T.F. Rutherford (1996) "Trade Policy Subtleties with Multinational Firms" *European Economic Review* **40**, 1605-27.

Spencer, B.J. and J.A. Brander (1983) "International R&D Rivalry and Industrial Strategy" *Review of Economic Studies* **50**, 707-22.

Takauchi, K. (2010a) "ROO and Strategic Choice of Compliance" in Ph.D. Dissertation, *International Trade and Rules of Origin under Oligopolistic Competition*, Kobe University, Kobe, Japan, 52-72.

Takauchi, K. (2010b) "The Effects of Strategic Subsidies under FTA with ROO" *Asia-Pacific Journal of Accounting and Economics* **17**, 57-72.