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Abstract

Contrary to the standard belief, we show that a positive transport cost can maximize consumer's surplus if exporting firms engage in product R&D and use their domestic inputs.

Key words: Transport cost; Consumer's surplus; Product R&D

JEL classification: L13; F12; O31

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1 Introduction

It is well-known that, in oligopolistic intra-industry trade, a transport cost reduction increases consumer's surplus. For example, Helpman and Krugman (1985, p. 108) said, "Trade has a procompetitive effect: each firm's exports do not displace an equal volume of shipments from the other firm to its home market, so total output and consumption rise and the price falls." According to such argument, since a decline in transportation cost facilitates exports, it increases total output, reduces price, and puts consumers in an advantageous position. Contrarily, we show that a positive transport cost *can maximize* consumer's surplus, if final-good exporting firms engage in product R&D and use their domestic inputs.

Our result occurs for the following reason. When exporting firms invest, their products become more differentiated and competition declines; this increases the momentum of final-good production, thereby increasing the input demand. After observing demand growth, input suppliers increase prices to extract R&D benefit,[1] which raises firms' production cost. Hence, the total output and consumer's surplus decline with investments by all firms. When transport cost is low, since investment becomes the dominant strategy and all firms invest, the consumer's surplus can drop if transport cost decreases.

In the context of oligopolistic intra-industry trade, Bastos and Straume (2012) and Braun (2008) employ Lin and Saggi (2002)-type product R&D model. However, they focus on the role of skilled and unskilled workers and consider the effects of trade liberalization on wage inequalities and labor demands through the impact on firm's innovation.

By considering a technology transfer through licensing, Kabiraj and Marjit (2003) show the existence of a tariff rate that maximizes consumer's surplus. A high tariff induces foreign firms' technology transfer to local firms and increases the total output, thereby increasing the consumer's surplus more than that in zero tariff case. However, their study analyzes technology

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[1]For detailed arguments on this opportunistic behavior by upstream suppliers, see Takauchi and Mizuno (2019).

transfer in a one-way trade, and it is quite different from our model.

The next section presents the model and results.

2 Model and Results

We consider Brander and Krugman (1983)-type reciprocal market. There are symmetric two countries, H and F, with final-good market. Each country i $(i = H, F)$ has an input supplier (called *supplier i*) and an innovative final-good exporting firm (called *firm i*). To produce one unit of final-good, firms employ one unit of input. We assume that firm i buys its input from an exclusive supplier i.[2] While firms freely supply their products domestically, they incur a per unit transport cost $\tau \geq 0$ to export.

In country i, firms face the following inverse demands:[3]

$$p_{ii} = 1 - q_{ii} - bq_{ji} \quad \text{and} \quad p_{ij} = 1 - q_{ij} - bq_{jj}, \ i \neq j; \ i, j = H, F, \tag{1}$$

where p_{ii} (p_{ij}) denotes firm i's product price in country i (j), q_{ii} (q_{jj}) denotes firm i's $(j$'s) domestic supply, and q_{ij} (q_{ji}) denotes firm i's $(j$'s) exports to country j (i). The parameter $b \in [0, 1]$ measures the degree of product substitutability between final goods of firms H and F. If b becomes to zero, firms become monopolists; while if $b = 1$, firm i's product becomes perfectly substitutable to firm j's product. Following Lin and Saggi (2002),[4] we assume that b is determined by firm i's investment in product R&D, $d_i \in \{0, 1/2\}$, as follows: $b = 1 - (d_H + d_F)$.[5] In our model, firms have two options such that whether to invest in R&D (labeled I) or not (labeled N). If firm i chooses I, $d_i = 1/2$ and it pays the investment cost $k > 0$. If it chooses N, $d_i = 0$ and it has no investment cost. Hence, when all firms invest, $b = 0$; while $b = 1$, when

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[2]When there are high trade barriers for importing inputs, firms also use only their domestic inputs.

[3]A representative consumer's utility function is given by $U_i = y_i + q_{ii} + q_{ji} - \frac{1}{2}(q_{ii}^2 + q_{ji}^2 + 2bq_{ii}q_{ji})$, $i \neq j$, where y_i is the numeraire good. The consumer's surplus CS_i is derived from $U_i - (y_i + p_{ii}q_{ii} + p_{ji}q_{ji})$.

[4]See Bastos and Straume (2012), Braun (2008), and Rosenkranz (2003). For a binary-choice case of investment, see Lambertini and Rossini (1998).

[5]Even if we consider the effectiveness of R&D, $\delta \in (0, 1]$, and assume that $b = 1 - \delta(d_H + d_F)$, a similar analysis is possible and our main results do not alter. However, this setting convolutes algebraic analysis. Hence, to avoid unnecessary complexities, we put $\delta = 1$.

no firm invests. If only one firm invests, $b = 1/2$.

Firm i's gross profit (excluded k) is $\Pi_i \equiv (p_{ii} - w_i)q_{ii} + (p_{ij} - w_i - \tau)q_{ij}$, where w_i is the price of the input produced by supplier i. Supplier i makes a take-it-or-leave-it offer, and its profit is $\pi_i \equiv (w_i - \overline{w})(q_{ii} + q_{ij})$, where $\overline{w}$ is the unit cost. For simplicity, $\overline{w}$ is set equal to zero.[6]

We consider the following three-stage game: In the first stage, each firm independently and simultaneously chooses whether to invest in product R&D (I) or not (N). In the second stage, each supplier decides the level of its input price. In the third stage, firms compete *à la* Cournot in H and F markets. Since firms have two options, four situations—II, IN, NI, and NN—can arise. All firms invest in II. In IN (NI), firm H chooses I (N) and firm F chooses N (I). No one invests in NN. The solution concept is subgame perfect Nash equilibrium (SPNE).

By solving the game using backward induction, we obtain SPNE. The derivation of SPNE is illustrated in the Technical Appendix. The input prices are

$$w_i^{NN} = \frac{2-\tau}{6}; \ w_i^{II} = \frac{2-\tau}{4}; \ w_i^{NI} = w_i^{IN} = \frac{3(2-\tau)}{14}, \tag{2}$$

where the superscript in variables denotes equilibrium regimes.

Firm i's outputs are

$$q_{ii}^{NN} = \frac{4+7\tau}{18}; \ q_{ij}^{NN} = \frac{4-11\tau}{18}; \ q_{ii}^{II} = \frac{2+\tau}{8}; \ q_{ij}^{II} = \frac{2-3\tau}{8},$$
$$q_{ii}^{NI} = q_{ii}^{IN} = \frac{24+23\tau}{105}; \ q_{ij}^{NI} = q_{ij}^{IN} = \frac{24-47\tau}{105}. \tag{3}$$

Firm i's profit are

$$\Pi_i^{NN} = \frac{85\tau^2 - 16\tau + 16}{162}; \ \Pi_i^{II} = \frac{5\tau^2 - 4\tau + 4}{32}; \ \Pi_i^{NI} = \Pi_i^{IN} = \frac{2(1369\tau^2 - 576\tau + 576)}{11025}. \tag{4}$$

To ensure a positive quantity, we assume $\tau < 4/11$.

(2) and (4) yield following lemmas.

Lemma 1. *(i) Suppose that firm j chooses N. Then, if $\phi_l(\tau) > k$, firm i ($i \neq j$) chooses I. Otherwise, it chooses N. (ii) Suppose that firm j chooses I. Then, if $\phi_u(\tau) \leq k$, firm i ($i \neq j$)*

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[6]This setting does not alter our results.

chooses N. Otherwise, it chooses I. Here,

$$\phi_l(\tau) \equiv \Pi_i^{IN} - \Pi_i^{NN} = \frac{1136 - 1136\tau - 54841\tau^2}{198450}; \quad \phi_u(\tau) \equiv \Pi_i^{II} - \Pi_i^{NI} = \frac{7236 - 7236\tau - 32491\tau^2}{352800}.$$

Proof. From (4), $\Pi_H^{IN} - k - \Pi_H^{NN} > (\leq) \; 0 \Leftrightarrow \Pi_F^{NI} - k - \Pi_F^{NN} > (\leq) \; 0 \Leftrightarrow \phi_l(\tau) > (\leq) \; k$ and

$\Pi_H^{II} - k - \Pi_H^{NI} \leq (>) \; 0 \Leftrightarrow \Pi_F^{II} - k - \Pi_F^{IN} \leq (>) \; 0 \Leftrightarrow \phi_u(\tau) \leq (>) \; k$. $\square$

Lemma 2. *(i) $w_i^{II} > w_i^{NI} = w_i^{IN} > w_i^{NN}$. (ii) $\frac{\partial w_i^r}{\partial \tau} < 0$, where $r = II, NI, IN, NN$.*

Proof. (i) From (2), $w_i^{II} - w_i^{NI} = \frac{2-\tau}{28} > 0$ and $w_i^{NI} - w_i^{NN} = \frac{2-\tau}{21} > 0$. (ii) $\frac{\partial w_i^{NN}}{\partial \tau} = -\frac{1}{6}$,

$\frac{\partial w_i^{II}}{\partial \tau} = -\frac{1}{4}$, and $\frac{\partial w_i^{NI}}{\partial \tau} = -\frac{3}{14}$. $\square$

Lemma 1 yields Proposition 1.

Proposition 1. *1. Suppose $\tau < \underline{\tau} \equiv \frac{4(105\sqrt{355} - 142)}{54841}$. (i) If $k < \phi_l(\tau)$, II appears. (ii) If*

$\phi_l(\tau) \leq k \leq \phi_u(\tau)$, NN and II can appear. (iii) If $k > \phi_u(\tau)$, NN appears.

2. Suppose $\tau \geq \underline{\tau}$. (i) If $k < \phi_u(\tau)$, NN and II can appear. (ii) If $k \geq \phi_u(\tau)$, NN appears.

Proof. From Lemma 1, $\phi_u(\tau) > 0 \; \forall \tau \in \left[0, \frac{4}{11}\right]$, $\phi_u(\tau) - \phi_l(\tau) = \frac{46948(1-\tau) + 585037\tau^2}{3175200} > 0$,

$\frac{\partial \phi_l(\tau)}{\partial \tau} = -\frac{568 + 54851\tau}{99225} < 0$, and $\phi_l(0) = \frac{568}{99225} \equiv \underline{k}$. Solving $\phi_l(\tau) = 0$ with respect to τ, we have

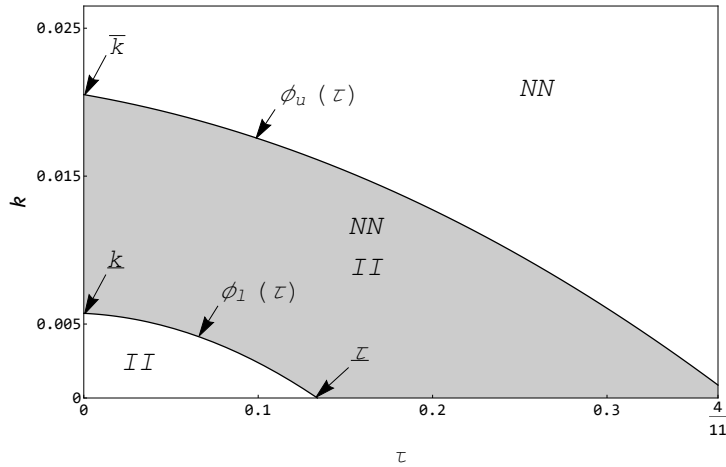$\underline{\tau} \equiv \frac{4(105\sqrt{355} - 142)}{54841} \simeq 0.13394$. $\square$

Figure 1: SPNE of the game

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The input price jumps up by investment (Lemma 2). A decline in competition due to investment facilitates final-good production. However, an increase in the final-good production expands input demands; hence, each supplier increases its price to raise profit. A rise in the transport cost τ continuously reduces input prices. This is because a rise in τ impedes exports and discourages production, thereby reducing the input demand. Therefore, the supplier tries to restore input demand by lowering its price.

Intuition of Proposition 1 is as follows. The R&D motive depends on transport and investment costs. When the investment cost k decreases, because the net benefit of product differentiation increases, the R&D motive intensifies. Further, firms gain the differentiation benefit from both domestic and foreign markets. When τ falls, since it raises exports and relatively increases the differentiation benefit gained from the foreign market, the R&D motive intensifies. Hence, if τ and k are small enough, I becomes the dominant strategy and II appears. If both costs are large enough, N becomes the dominant strategy and NN appears (see Fig. 1).

When τ is high and k is at an intermediate level, NN and II can appear. If firm i deviates from II, w_i falls. However, w_j also falls due to a strategic complementarity. The deviation makes competition tougher and the rival's cost does not increase; hence, firm i does not deviate. Additionally, the deviation from NN raises input price, but it brings differentiation benefit to the deviator. However, in this case, τ is high and the size of foreign market is small, and hence the differentiation benefit gained from the foreign market is small. Since the R&D benefit is relatively small, there is no incentive to deviate.

Let us examine the effects of τ on consumers. The formula of consumer's surplus, $CS_i = \frac{1}{2}(q_{ii}^2 + q_{ji}^2 + 2bq_{ii}q_{ji})$, (1), and (3) yield

$$CS_i^{NN} = \frac{2(2 - \tau)^2}{81}; \quad CS_i^{II} = \frac{4 - 4\tau + 5\tau^2}{64}. \tag{5}$$

From (5), we establish the following.

Proposition 2. *1. Suppose $k \in (0, \frac{9329}{10672200}]$. If NN appears in NN and II, $\phi_l^{-1}(k)$ maximizes consumer's surplus.*

2. Suppose $k \in (\frac{9329}{10672200}, \underline{k})$. (i) If NN appears in NN and II, $\phi_l^{-1}(k)$ maximizes consumer's surplus; (ii) if II appears in NN and II, $\phi_u^{-1}(k)$ maximizes consumer's surplus.

3. Suppose $k \in [\underline{k}, \overline{k})$. If II appear in NN and II, $\phi_u^{-1}(k)$ maximizes consumer's surplus.

Here $\underline{k} \equiv \frac{568}{99225} \simeq 0.00572436$ and $\overline{k} \equiv \frac{201}{9800} \simeq 0.0205102$.

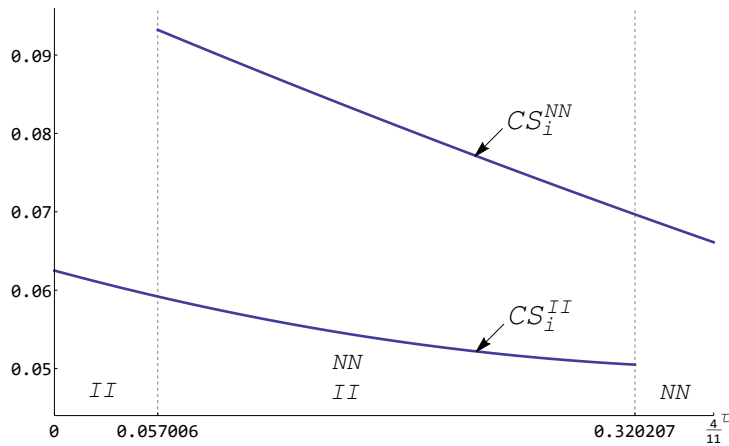*Proof.* See Technical Appendix.

Figure 2: Relationship between CS_i and τ: $k = 0.0045$.

The input price surges if each firm invests. Since this *price rise* sharply increases a firm's production cost, the total output plummets and $\min CS_i^{NN} > \max CS_i^{II}$ holds. For example, when $k < \underline{k}$, the equilibrium transition, $NN\&II \rightarrow II$, arises as τ decreases (see Fig. 1). In any equilibrium, a decrease in τ raises consumer's surplus; hence, the threshold at which the equilibrium switches $NN\&II$ to II maximizes consumer's surplus if NN appears in $NN\&II$ (see Fig. 2).

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Technical Appendix

A. Proof of Proposition 2

First, from Proposition 1 and its proof, $II\&NN$ appears if $k < \overline{k} \equiv \frac{201}{9800} = \phi_u(0)$, whereas only NN appears if $k \geq \overline{k}$.

In the interval $(0, \overline{k})$, the *equilibrium transition* is divided into the following three types: for $k \in (0, \frac{9329}{10672200}]$, "$NN\&II \to II$" as τ decreases; for $k \in (\frac{9329}{10672200}, \underline{k})$, "$NN \to NN\&II \to II$" as τ decreases; and for $k \in [\underline{k}, \overline{k})$, "$NN \to NN\&II$" as τ decreases. Here, $\phi_u(\frac{4}{11}) = \frac{9329}{10672200} \simeq 0.00087414$ and $\overline{k} \equiv \phi_u(0) = \frac{201}{9800} \simeq 0.0205102$.

Second, $\partial CS_i^{NN}/\partial\tau = -\frac{4(2-\tau)}{81} < 0$ and $\partial CS_i^{II}/\partial\tau = -\frac{2-5\tau}{32} < 0$, so the consumer's surplus in both the aforementioned regimes is monotonically decreasing for τ. Simple algebra yields $\max CS_i^{II} = CS_i^{II}\big|_{\tau=0} = \frac{1}{16}$, $\min CS_i^{NN} = CS_i^{NN}\big|_{\tau=4/11} = \frac{8}{121}$, and $\min CS_i^{NN} - \max CS_i^{II} = \frac{7}{1936} > 0$. These imply Proposition 2. $\square$

B. Derivation of firm i's equilibrium profit

3rd stage: The first-order conditions for the profit maximization of firm i are $\partial\Pi_i/\partial q_{ii} = 0 \Leftrightarrow 1 - bq_{ji} - 2q_{ii} - w_i = 0$ and $\partial\Pi_i/\partial q_{ij} = 0 \Leftrightarrow 1 - 2q_{ij} - bq_{jj} - w_i - \tau = 0$ for $i \neq j$. These yield the third-stage outputs: $q_{ii}(w_i, w_j) = \frac{2-b+b(\tau+w_j)-2w_i}{4-b^2}$ and $q_{ij}(w_i, w_j) = \frac{2-b+bw_j-2(\tau+w_i)}{4-b^2}$.

2nd stage: Using the third-stage outputs, the profit maximization problem, $\max_{w_i} \pi(w_i, w_j)$, yields the following best response function of supplier i:

$$w_i = BR_i(w_j, b) \equiv \frac{1}{8}\left((2-b)(2-\tau) + bw_j\right) \text{ for } i \neq j.$$

Hence, the input price has a *strategic complementarity*. This is explained as follows. Suppose that supplier j raises its price. A rise in w_j increases firm j's production cost and reduces outputs. A reduction of the rival's outputs tends to increase firm i's outputs; this increases the input demand of firm i, influencing supplier i to raise its price. Therefore, there is a strategic

complementarity between input prices.

From $BR_i(w_j, b)$, the second-stage input price becomes as $w_i(b) = (2 - b)(2 - \tau)/(2(4 - b))$.

1st stage: Plugging the second-stage outcomes into the profit of firm i, we have

$$\Pi_i(b) = \frac{16(2 - b)^2(1 - \tau) + (b^4 - 4b^3 - 8b^2 + 16b + 80)\,\tau^2}{2(4 - b)^2(4 - b^2)^2}.$$

Substituting $b = 1 - (d_H + d_F)$ in $\Pi_i(b)$ and using the possible four combinations of d_H and d_F,

$(d_H, d_F) = \{(0, 0), (0, 1/2), (1/2, 0), (1/2, 1/2)\}$, we obtain the equilibrium profit (4).