Is competition in the transport sector bad? A welfare analysis of cost-reducing R&D rivalry with inter-regional transportation*

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Abstract

We consider the welfare effect of an increase in the number of carriers in a two-region reciprocal market model. While firms engage in cost-reducing R&D investment and employ the transport service to export their products, carriers haul the firms' products and compete a Bertrand fashion in the inter-regional transport market. We show that if the degree of R&D spillover is large, a higher number of carriers harms consumers and always reduces welfare. Hence, policies to restrict competition in transport sector (e.g., by relaxing merger regulation to reduce the number of carriers) may be socially desirable.

Key words: Transport sector; Price competition; Cost-reducing R&D investment; R&D spillovers

JEL classification: F12; L13; R40

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1 Introduction

Today, practitioners and researchers generally accept the idea that promoting competition will benefit consumers. In particular, competition authorities who stress consumer protection may emphasize this idea. For example, Joaquín Almunia, Vice-President and Commissioner for Competition, European Commission 2010-2014, stated, "[O]ur objective is to ensure that consumers enjoy the benefits of competition, a wider choice of goods, of better quality and at lower prices. But competition does not only deliver benefits for consumers. It also delivers benefits for business and the economy as a whole."[1] This assertion undoubtedly possesses a theoretical ground. In standard oligopoly theory, since market power decreases as the number of firms increases, and a higher number of firms lowers prices and raises consumer surplus (Motta, 2004, p. 51). Thus, it is easy to continue to believe that promoting competition, such as by increasing the number of firms, will benefit consumers.

This paper presents a new perspective on the relationship between the promotion of competition and consumer welfare. By considering a market structure consisting of (cargo) carriers and innovative exporting firms, we show that a higher number of carriers may harm consumers.

We base our model on a Brander (1981) and Brander and Krugman (1983)-type reciprocal market. While each region's exporting firm use inter-regional transport services and pays a freight rate to export to the overseas market, it can freely supply its local market. To reduce their unit production costs, two exporters engage in research and development (R&D) investment involving knowledge spillovers.[2] Inter-regional transportation is a homogeneous service, and carriers compete on price *à la* Dastidar (1995).

We show that a higher number of carriers can reduce welfare. First, a rise in the number of carriers reduces consumers surplus if and only if the degree of R&D spillover is large. A higher

[1] Joaquín Almunia (2010) Competition and consumers: The future of EU competition policy, speech at European Competition Day, Madrid, 12 May 2010.

[2] This setting is reasonable because prior studies establish the existence of positive international spillovers from R&D empirically. See, for example, Coe and Helpman (1995) and Keller (1998).

number of carriers lowers transport prices, and its effect becomes stronger as the spillover rate increases. The transport price reduction increases the rival firm's exports and decreases domestic supply. Hence, when the transport price reduction begins to have a large impact on the extent to which domestic supply decreases, total sales fall because the decline in the domestic supply exceeds the rise in the rival firm's exports. Second, a higher number of carriers reduces total surplus in each region through a sharp decline in the domestic supply. Exporting firms must pay a transport price to export their products; thus, export activity is less efficient than supplying domestically. Although a higher number of carriers lowers transport prices and promotes exports, it is equivalent to "fostering inefficient production activity," and it worsens production efficiency, which worsens total surplus.

In particular, the second finding has an important policy implication. While competition authorities regulate horizontal mergers rigorously in the real world, our result indicates that reducing the number of carriers can raise both consumer welfare and total surplus. Therefore, by relaxing regulations and inducing mergers in the transport sector, competition authorities can raise welfare. We believe that our model provides a new insight into the context of competition policy and consumer protection.

This study is most closely related to those of Takauchi (2015) and Takauchi and Mizuno (2018), who use a similar market structure as we do in our study. In their international (or inter-regional) R&D rivalry setting, exporters must pay freight charges to ship their products to their rival's domestic market, but they freely supply to their local market. Takauchi (2015) studies the effect of improving the technical efficiency of R&D on exporters' profit. Takauchi and Mizuno (2018) consider a hold-up problem resulting from carriers' actions of raising prices after observing an exporting firm's investment, and show that the solution to the hold-up problem (i.e., adopting fixed-price contracts for transport prices) can harm all firms. In contrast to these works, we incorporate price competition among carriers into a reciprocal market model and consider the effects of the number of carriers and transport efficiency on welfare.

Our study is also related to research on the transport sector in the context of international trade (Abe et al., 2014; Behrens et al., 2009; Behrens and Picard, 2011; Francois and Wooton, 2001; Ishikawa and Tarui, 2018). Francois and Wooton (2001) incorporate an imperfectly competitive transport sector into a competitive trade model and examine the effect of tariff reductions. Abe et al. (2014) examine trade and environmental policies in a two-way duopoly in which transportation generates pollution. Behrens et al. (2009) and Behrens and Picard (2011) examine the effects of endogenous freight rates on the agglomeration of firms. While Behrens et al. (2009) focus on the role of the carrier's market power, Behrens and Picard (2011) focus on the logistics problem associated with round trips. Ishikawa and Tarui (2018) also examine the logistics problem and consider the role of trade policies in oligopolies. While all of these studies use different models to provide useful insights, they do not consider the price competition among carriers and the R&D activities of exporting firms.

In section 2, we present the baseline model, and in section 3, we derive our results. Section 4 concludes the paper. We provide all proofs in the appendix.

2 Model

We consider two regions, the H (Home) and F (Foreign) regions, whose product market is segmented from each other. Each region has an exporting firm, *firm* i ($i = H, F$), that engages in cost-reducing R&D activity and supplies its product to the local and other markets. The inverse demand in region i is $p_i = a - Q_i$, where p_i is the product price, $Q_i = q_{ii} + q_{ji}$ is total sales, q_{ii} is firm i's domestic supply, q_{ji} is firm j's exports, $i, j = H, F$, $i \neq j$, and $a > 0$. The region i's consumers surplus is $CS_i = Q_i^2/2$.

Firms have no means to carry out long haul transportation, so they pay a per-unit transport price, t, and use a transport service to export their products. The profit of firm i is

$$\Pi_i \equiv (p_i - c_i)q_{ii} + (p_j - c_i - t)q_{ij} - x_i^2 \text{ for } i \neq j,$$

where x_i is firm i's investment level and x_i^2 is the R&D cost. Firm i's production cost after investment is $c_i \equiv c - x_i - \delta x_j$; that is, though firm i invests x_i to reduce the unit cost c, there is a knowledge spillover and the firm i enjoys some part of its rival's developed knowledge, δx_j, without any payments. $\delta \in [0, 1]$ is the spillover rate of R&D and $a - c > 0$.

In the transport sector, there are n (≥ 2) identical cargo transporters, which we refer to as *carriers*. For simplicity, we assume that carriers exist in regions besides the Home and Foreign regions (if carriers exist in the Home or Foreign regions, our main results do not change). In our model, inter-regional transportation is a homogeneous service and carriers compete in a Bertrand fashion. Let the transport price offered by carrier k ($\in \{1, \ldots, n\}$) be t_k, the carrier k's individual transport demand be q_k, and the aggregate demand be $q_{HF} + q_{FH}$. Each firm employs the carriers offering the lowest price, so the individual transport demand of carrier k is $q_k = [q_{HF}(t^l) + q_{FH}(t^l)]/m$ if the carrier offers the lowest price, $t_k = t^l$. Here, m denotes the number of carriers offering the lowest price. If carrier k offers a slightly higher price than t^l, then $q_k = 0$. To obtain explicit solutions, we assume that carrier k has a quadratic operation cost, $(\lambda/2)q_k^2$,[3] where $\lambda > 0$ denotes the transport efficiency. The profit of carrier k is $\pi_k \equiv t_k q_k - (\lambda/2)q_k^2$.

The timing of the game is as follows. In the first stage, each firm independently and simultaneously decides its investment level. In the second stage, the transport price is determined through price competition among carriers. In the third stage, each firm independently and simultaneously decides its level of its local supply and exports. The timing structure corresponds to the difficulty of a change in each decision. R&D generally takes much more time, so its invest-

[3]The quadratic cost is popular in this type of price competition. See, for example, Dastidar (1995 pp. 27), Dastidar (2001 pp. 85), Delbono and Lambertini (2016a, 2016b), Gori et al. (2014), and Mizuno and Takauchi (2018).

ment decision is in the first stage of the game. In contrast, since firms can adjust their outputs frequently, the production decision is in the last stage. Since in the second stage the Nash equilibrium is not unique, we employ subgame perfect Nash equilibrium (SPE) with collusive-price refinement as the equilibrium concept.[4] We solve the game by backward induction. We provide all proofs in Appendix B.

3 Results

In the third-stage of the game, the first-order conditions (FOCs) to maximize the profit of firm i are $0 = a - c - 2q_{ii} - q_{ji} + x_i + \delta x_j$ and $0 = a - c - q_{jj} - 2q_{ij} + x_i + \delta x_j - t$ $(i \neq j)$. These FOCs yield the following third-stage outputs of $q_{ii}(t, \mathrm{x}) = \frac{1}{3}(a - c + t + (2 - \delta)x_i + (2\delta - 1)x_j)$ and $q_{ij}(t, \mathrm{x}) = \frac{1}{3}(a - c - 2t + (2 - \delta)x_i + (2\delta - 1)x_j)$, where $i, j = H, F$, $i \neq j$, and $\mathrm{x} = (x_i, x_j)$.

In the second-stage, the transport price t is determined by carriers' price competition. As Dastidar (1995) shows, if oligopolists with a convex cost engage in a homogeneous price competition, the Nash equilibrium is not unique. In our model, the pure strategy Nash equilibria of transport price has a certain range of $[\underline{t}, \bar{t}]$ derived from the following two conditions: (*carriers do not raise their prices*) $\pi_k(t, \mathrm{x}, n) \equiv t([q_{HF}(t, \mathrm{x}) + q_{FH}(t, \mathrm{x})]/n) - (\lambda/2)([q_{HF}(t, \mathrm{x}) + q_{FH}(t, \mathrm{x})]/n)^2 \geq 0$, and (*carriers do not lower their prices*) $\pi_k(t, \mathrm{x}, n) \geq \pi_k(t, \mathrm{x}, 1) \equiv t[q_{HF}(t, \mathrm{x}) + q_{FH}(t, \mathrm{x})] - (\lambda/2)[q_{HF}(t, \mathrm{x}) + q_{FH}(t, \mathrm{x})]^2$. The first condition yields the lower bound $\underline{t} = \frac{[2(a-c)+(x_H+x_F)(1+\delta)]\lambda}{2(3n+2\lambda)}$, and the second one yields the upper bound $\bar{t} = \frac{(n+1)[2(a-c)+(x_H+x_F)(1+\delta)]\lambda}{2[(3+2\lambda)n+2\lambda]}$.

To narrow the equilibria, we employ the *collusive-price* that maximizes the transport sector's industry profit (i.e., the carriers' joint profit).[5] Since carriers are symmetric, the collusive

[4]More precisely, the equilibrium concept is a subgame perfect Nash equilibrium with payoff-dominance refinement. Some previous studies (e.g., Cabon-Dhersin and Drouhin, 2014; Mizuno and Takauchi, 2018) use this concept. The collusive-price refinement is same as the payoff-dominance refinement if the Nash equilibria contain the strategy that maximizes each players' profit.

[5]To narrow the set of Nash equilibria, studies often employ the "collusive price." See, for example, Dastidar (2001) and Gori et al. (2014).

transport-price is

$$t_{col} = \underset{t}{\operatorname{argmax}}\ \pi_k(t, \mathrm{x}, n) = \frac{[2(a-c) + (x_H + x_F)(1+\delta)](3n+4\lambda)}{8(3n+2\lambda)}.$$

The collusive transport price, t_{col}, is (partially) consistent with the characteristics of the transport sector in the real world. For example, many studies report collusion in the ocean shipping industry (e.g., Sjostrom, 2004; Sys, 2009; Sys et al., 2011). In particular, Sys (2009) shows empirically that the containerized shipping industry operates in an oligopoly market and that the market is tacitly collusive[6]; "$t = t_{col}$" corresponds to such empirical evidence.

The prices $\underline{t}$, $\bar{t}$, and t_{col}, yield Lemma 1.

Lemma 1. *(i)* $t_{col} > \underline{t}$. *(ii)* $t_{col} \leq \bar{t}$ *if and only if* $\lambda \geq \lambda_0 \equiv 3n/[2(n-1)]$.

To ensure $t_{col} < \bar{t}$; that is, $t = t_{col}$, we need the following assumption.

Assumption 1. $\lambda > \lambda_0 \equiv 3n/[2(n-1)]$.

We next define z to facilitate the analysis.

Definition 1. $z \equiv \lambda/n \in [3/2, +\infty)$.[7]

Substituting the outcomes of the third and second stages into the profit of firm i and solving the first-order condition, we obtain the following equilibrium outcomes.

$$x_i^* = \frac{(a-c)[16(3-\delta)z^2 + 16(9-4\delta)z + 113 - 55\delta]}{E}, \tag{1}$$

$$q_{ii}^* = \frac{8(a-c)(2z+3)(4z+5)}{E}; \quad q_{ij}^* = \frac{16(a-c)(2z+3)}{E}, \ i \neq j, \tag{2}$$

$$t^* = \frac{8(a-c)(2z+3)(4z+3)}{E}, \tag{3}$$

where Appendix A reports E and other constants. The variable "$*$" is the SPE outcome.

[6] Hummels et al. (2009) also finds that ocean shipping is an oligopoly market.

[7] Though we need $z > (3/2)(1/(n-1))$ from Assumption 1, because the maximum of $1/(n-1)$ is 1, $\lambda > \lambda_0$ holds for all $z \geq 3/2$.

The profits of carrier k and firm i are

$$\pi_k^* = \frac{256(a-c)^2(2z+3)^3}{nE^2}; \quad \Pi_i^* = \frac{(a-c)^2(4z+5)\,G}{E^2}. \tag{4}$$

To ensure a positive unit production cost after R&D investment, we need Assumption 2.

Assumption 2. $c/(a-c) > [16(3-\delta)z^2 + 16(9-4\delta)z + 113 - 55\delta]/E.$

From Eqs. (1)–(3), we establish Lemma 2.

Lemma 2. *I. If $\delta \geq (<)\ \delta_t \equiv \frac{16z^2+40z+29}{(4z+5)(4z+11)}$, $\partial t^*/\partial\delta$, $\partial q_{ii}^*/\partial\delta$, and $\partial q_{ij}^*/\partial\delta \leq (>)\ 0$.*

II. (i) Suppose $3/2 \leq z < z_1 \simeq 5.90928$; then, $\partial x_i^*/\partial\delta < 0$.

(ii) Suppose $z > z_1$; then, if $\delta < \delta_x$, $\partial x_i^*/\partial\delta > 0$. Otherwise, $\partial x_i^*/\partial\delta \leq 0$. Here, $\delta_x \equiv \frac{48z^2+144z+113-4\sqrt{2}\sqrt{(2z+3)^2(4z+5)(4z+11)}}{(4z+5)(4z+11)}$.

Similarly, Eqs. (1)–(3) yield the following result.

Proposition 1. *(i) Keener competition in the transport sector (i.e., a rise in n) and higher transport efficiency (i.e., a fall in λ) decrease transport prices and domestic supply, but these increase exports. (ii) Keener competition in the transport sector and higher transport efficiency increases the firm's investment if and only if $\delta < 5/(8z+7)$.*

We first consider part (i) of Proposition 1. A higher n and a smaller λ (i.e., a decrease in z) have a similar effect. A higher n lowers transport prices through intensifying competition among carriers, so it increases exports. A smaller λ makes flattens the slope of the carriers' cost curve, which induces a lower transport price, and thereby promotes exports. Because both a higher n and a lower λ expand imports and makes competition in the local market tougher, firm i's domestic supply falls.

Second, we examine the logic behind Lemma 2. A higher δ lowers production costs, facilitates production activities, and thus increases both domestic supply and exports. That is, in our model, δ makes has exactly the same effect on both domestic supply and exports. Since a higher δ leads to an expansion in transport demand, it encourages carriers to set higher prices. (A lower δ yields the inverse result.) Hence, if a higher (lower) δ increases (decreases) transport demand, because it also raises (lowers) transport price, both outputs and transport prices increase (decrease) as δ goes up (down). On the one hand, an increase in transport prices raises the trade barrier, which impedes exports. If δ rises when its level is low enough, because the transport price is low and the positive effects of a reduction in production costs exceeds the export impeding effect of rising transport prices, the firm's exports increase. Conversely, when both δ and transport prices are high, because the export impeding effect becomes large, a rise in δ reduces exports. Then, transport demand falls, so carriers lower their prices as δ rises.[8] Panel (a) in Fig. 1 illustrates part I of Lemma 2.

[Fig. 1 around here]

A rise in δ has positive and negative effects on the R&D motive. A higher δ encourages investment because it reduces the unit production cost and facilitates production (positive effect). If δ increases, because each firm enjoys its rivals developed knowledge without cost, the R&D motive weakens (negative effect). Usually, investment decreases as δ rises because the negative effect is dominant. This is a well-known result illustrated by d'Aspremont and Jacquemin (1988).

Different from the standard result, in our model, the positive effect can be dominant. When λ is large, that is, z is large, transportation is inefficient and its price is high. A high transport price impedes cross-hauling and strengthens the monopolization of the local firm in its market. Suppose that the R&D spillover arises, that is, δ slightly increases from 0 in this case; then, the unit production cost falls and outputs increase, but it also raises transport prices, so the domestic supply increases more rapidly than exports do. This strengthens the degree of the

[8] Additionally, $\partial x_i^*/\partial\delta$ can explain why the transport prices and the firm's outputs have the same change for δ. From the third-stage outputs and $t = t_{col}$, noting that $x_i = x_j$ in equilibrium, the total differentiation of $q_{ii} = q_{ii}(\mathrm{x}, t, \delta)$, $q_{ij} = q_{ij}(\mathrm{x}, t, \delta)$, and $t = t(\mathrm{x}, \delta)$ yields $dt/d\delta = \frac{3n+4\lambda}{4(3n+2\lambda)}\left[x_i + (1+\delta)\frac{dx_i}{d\delta}\right]$, $dq_{ii}/d\delta = \frac{5n+4\lambda}{4(3n+2\lambda)}\left[x_i + (1+\delta)\frac{dx_i}{d\delta}\right]$, and $dq_{ij}/d\delta = \frac{n}{2(3n+2\lambda)}\left[x_i + (1+\delta)\frac{dx_i}{d\delta}\right]$.

local firm's relative monopoly in its market. Because such enlargement in the domestic supply promotes investment and the positive effect becomes dominant, R&D investment increases as δ rises. However, if δ goes above a certain level, since an inflow of the rival firm's developed knowledge becomes large, the negative effect is dominant. Panel (b) in Fig. 1 illustrates part II of Lemma 2.

We next consider part (ii) of Proposition 1, which indicates that to raise investment by lowering transport prices, δ should be small enough. The intuition is as follows. As we show Lemma 2, when δ is sufficiently small, the transport price is also low and the degree of export restriction is weak. Though a higher n and a smaller λ commonly reduce transport prices and increase exports, they decrease the domestic supply. If δ is sufficiently small, because the transport price reduction leads to an increase in exports in excess of the decrease in the domestic supply, a higher n and a smaller λ can encourage investment. In contrast, if δ is large, because the degree of the reduction in domestic supply becomes bigger, a higher n and a smaller λ can never encourage investment. Figure 2 shows this result.

[Fig. 2 around here]

Does an increase in the number of carriers and improved transport efficiency enhance welfares? We next focus on the welfare effects of n and λ. To examine their effects on consumer benefit, we use Eq. (2) and obtain the following result.

Proposition 2. *Keener competition in the transport sector and higher transport efficiency reduces consumer welfare if and only if the R&D spillover rate is high enough; that is,* $\partial Q_i^*/\partial z > 0$ *if and only if* $\delta > \delta_Q$. *Here,* $\delta_Q \equiv -1 + \frac{4\sqrt{2}\sqrt{(2z+3)^2(48z^2+104z+43)}}{48z^2+104z+43} > 0$.

[Fig. 3 around here]

Panel (a) of Fig. 3 depicts Proposition 2. As long as the R&D spillover is not too high, the trade promotion due to the transport price reduction increases total sales, $Q_i = q_{ii} + q_{ji}$, and lowers the product price, so consumer surplus increases. However, Proposition 2 indicates that this promotion of inter-regional trade is not always desirable for consumers. A key to this result is the role of $\partial t^*/\partial z$.

A higher δ lowers the firms' production costs and increases aggregate transport demand. When the aggregate transport demand is high, because carriers are symmetric, each carrier's individual demand is also high. Then, suppose that the number of carriers n increases; that is, z ($\equiv \lambda/n$) decreases. Tougher competition among them reduces each carrier's demand, and the size of the demand that carrier loses increases as the aggregate transport demand increases. Though each carrier lowers its price if it's a reduction in its demand, because the size of the lost demand increases as the aggregate transport demand increases, carriers sharply lower their prices compared to the case of low aggregate transport demand. Hence, a higher δ strengthens $\partial t^*/\partial z$.[9]

Although a higher δ facilitates production, it can raise transport prices (Lemma 2). A higher δ has both export promotion and restriction effects, so a higher δ strengthens $\partial q^*_{ji}/\partial z$ in some cases, but it weakens $\partial q^*_{ji}/\partial z$ in the other cases. On the one hand, as we show in Proposition 1, a higher n (or lower z) reduces domestic supply because transport prices (i.e., the rival firm's trade barrier) fall. If δ is high, because the degree of the reduction in transport prices for an increase in n is large, the degree of reduction in domestic supply for an increase in n is also large. In other words, when δ rises, the "$\partial t^*/\partial z$" effect becomes stronger, which strengthens the "$\partial q^*_{ii}/\partial z$" effect.

We illustrate $\partial q^*_{ii}/\partial z$ and $-(\partial q^*_{ji}/\partial z)$ as functions of δ in Panel (b) of Fig. 3. (Since $\partial q^*_{ji}/\partial z$ has a negative value, we multiply it by -1.) As δ increases above a certain level, $\partial q^*_{ii}/\partial z$ (the increasing curve) exceeds $-(\partial q^*_{ji}/\partial z)$ (the inverted U-shaped curve). Hence, if δ is sufficiently high, $\partial Q^*_i/\partial z$ has a positive value. When δ is high, a higher n (lower z) reduces total sales (i.e.,

[9]Differentiating $\partial t^*/\partial z$ with respect to δ yields $(\partial/\partial\delta)(\partial t^*/\partial z) = (32(a-c)/E^3)R$, where we show R (> 0) in Appendix A. $(\partial/\partial\delta)(\partial t^*/\partial z) > 0$ for all $z \geq 3/2$.

consumer surplus).

z ($\equiv \lambda/n$) and δ have the following effects on the profits of firms and carriers.

Lemma 3. *I.* $\partial\Pi_i^*/\partial z > 0$ *and* $\partial\Pi_i^*/\partial\delta > 0$.

II. (i) $\partial\pi_k^*/\partial n < 0$ *and* $\partial\pi_k^*/\partial\lambda < 0$. *(ii) If* $\delta > (\leq)\ \delta_t \equiv \frac{16\lambda^2+40\lambda n+29n^2}{(4\lambda+5n)(4\lambda+11n)}$, $\partial\pi_k^*/\partial\delta < (\geq)\ 0$.

Lemma 3 is highly intuitive. Since a larger n and a smaller λ promote less efficient production activity, that is, exports, they reduce the firm's profit. On the other hand, a higher δ decreases production costs, and thus increases the firm's profit. The carrier's profit depends on the transport price, so $\partial\pi_k^*/\partial n$ and $\partial\pi_k^*/\partial\delta$ correspond to the changes in the transport price. (See Lemma 2 and part (i) of Proposition 1.) A smaller λ implies an efficiency improvement in transportation, and it therefore increases the carrier's profit.

The social surplus in region i is

$$SW_i^* \equiv CS_i^* + \Pi_i^* = \frac{(a-c)^2}{E^2}\left(K_1 + 256K_2z^4 + 512K_3z^3 + 32K_4z^2 + 32K_5z\right). \tag{5}$$

From Eq. (5), we establish Proposition 3.

Proposition 3. *Keener competition in the transport sector and higher transport efficiency always reduce social surplus; that is,* $\partial SW_i^*/\partial z > 0$.

From the definition of social surplus, the symmetric outcomes ($x_i = x_j$, $q_{ii} = q_{jj}$, $q_{ij} = q_{ji}$, and $p_i = p_j$), and $p_i' = -1$, we can decompose the effects of a change in z (e.g., a change in n or λ) on welfare as follows:

$$\begin{aligned}\frac{\partial SW_i}{\partial z} = & \underbrace{[p_i - (c-(1+\delta)x_i)]\cdot\frac{\partial q_{ii}}{\partial z}}_{\text{(i) Domestic supply effect: }(+)} + \underbrace{[(1+\delta)Q_i - 2x_i]\cdot\frac{\partial x_i}{\partial z}}_{\text{(ii) Investment effect: }(+)/(-)} \\ & + \underbrace{[p_j - (c-(1+\delta)x_i) - t]\cdot\frac{\partial q_{ij}}{\partial z}}_{\text{(iii) Export effect: }(-)} + \underbrace{\left(-q_{ij}\cdot\frac{\partial t}{\partial z}\right)}_{\text{(iv) Transport-price effect: }(-)}.\end{aligned} \tag{6}$$

There are four effects (terms (i)–(iv)) in Eq. (6).[10] The domestic supply effect, term (i), is

[10]For more detail, see Appendix C.

positive because a decrease in z (i.e., an increase in n and a decrease in λ) raises the rival firm's exports and makes the competition in the domestic market tougher. The investment effect, term (ii), hinges on a change in investment $\partial x_i^*/\partial z$, so the effect can be positive when the R&D spillover is low; otherwise, it is negative. Both the export and transport price effects, which correspond to terms (iii) and (iv), respectively, are negative. Since a decrease in z promotes exports, the export effect is negative. A fall in transport prices curtails the inefficiency of cross-hauling, so this effect is also negative.

In our model, the domestic supply effect (term (i)) dominates any other effects because, the production of domestic supply is more efficient than export activities are. The difference in supply efficiencies makes the domestic supply larger than that of exports, and hence, the domestic supply sharply decreases when competition in the local market increases due to the promotion of the rival firm's exports. A fall in z, that is, a rise in n, reduces welfare.

We illustrate this result in Fig. 4. If the spillover rate of R&D is low, the investment effect can be negative. Thus, all terms can be negative except for (i) if the spillover rate is low. Figure 4 depicts each term when $\delta = 1/4$. Even in such a case, we can see immediately that (i) (the curve (i) in Fig. 4) is extremely large compared with the other terms.

[Fig. 4 around here]

Proposition 3 has significant meaning in two regards: the relationship between social surplus and transport prices (cost), and an argument related to competition policy. When the per-unit transport cost is exogenous, the social surplus related to the transport cost is U-shaped in two-way trade oligopoly models (e.g., Brander and Krugman, 1983; Helpman and Krugman, 1985, pp. 107–110). Reducing transport cost from a trade-prohibitive level reduces welfare. However, when the transport cost is low, reducing this cost improves welfare. In our model, a larger n (and a smaller λ) reduces transport prices, so we can indirectly examine the relationship between social surplus and transport prices. However, Proposition 3 shows that a larger n always reduces welfare. This is in sharp contrast to conventional arguments, and thus offers a new insight into intra-industry trade.

The policy implication in Proposition 3 is also significant. As Lemma 3 shows, the carrier's profit decreases as n increases. Thus, whole we did add some carriers into the social surplus, our result does not change. This implies that in the transport sector, by urging horizontal mergers to decrease the number of the existing carriers, a competition regulator can enhance welfare. Therefore, in the context of inter-regional transportation, it may be socially desirable to relax regulations on horizontal mergers (or competition laws) in the transport sector and thereby decrease the number of carriers.

Finally, from Propositions 2 and 3, we obtain the following Corollary.

Corollary 1. *If the R&D spillover is high enough; that is, $\delta > \delta_Q$, reducing the number of carriers enhances both consumer and social surplus.*

4 Conclusion

Many argue that promoting competition, such as by increasing the number of firms in a market decreases each firm's market power and lowers prices, which benefits consumers. On the other hand, this dominant perspective on the relation of competition and consumer benefit is not necessarily robust and may do not hold when we consider the inter-regional transport market. In this study, we show that in a market structure consisting of cargo carriers and innovative exporting firms, a higher number of carriers sharply reduces the firms' domestic supply, and therefore reduces consumer surplus if the degree of R&D spillover is large. We also show that a higher number of carriers promotes less efficient production activity (i.e., exports), so it reduces social surplus.

However, we do not consider other forms of innovations among exporting firms, such as product R&D and quality improving innovation. Although whether our main findings hold or not may be interesting when exporting firms conduct these other R&D activities, this aspect is beyond the scope of our analysis. It may be fruitful for future research to examine this relationship.

Appendices

Appendix A. Constants

$$E \equiv 55\delta^2 - 58\delta + 175 + 16(\delta^2 - 2\delta + 5)z^2 + 16(4\delta^2 - 5\delta + 15)z > 0,$$

$$G \equiv 787 + 2486\delta - 605\delta^2 + 64(7-\delta)(1+\delta)z^3 + 16(101 + 138\delta - 27\delta^2)z^2 + 4(481 + 1018\delta - 231\delta^2)z > 0,$$

$$K_1 \equiv 18047 + 124430\delta - 3025\delta^2 > 0; \quad K_2 \equiv 15 + 6\delta - \delta^2 > 0; \quad K_3 \equiv 43 + 21\delta - 4\delta^2 > 0,$$

$$K_4 \equiv 1505 + 854\delta - 183\delta^2 > 0; \quad K_5 \equiv 1491 + 947\delta - 220\delta^2 > 0,$$

$$R \equiv 5(1280z^4+6016z^3+10752z^2+8840z+2907) + (768z^4-6016z^3-32640z^2-48264z-22923)\delta + 3(4z+5)(4z+11)(16z^2+88z+81)\delta^2 - (4z+5)(4z+11)(112z^2+296z+207)\delta^3 > 0.$$

Appendix B. Proofs

Proof of Lemma 1. (i) Comparing t_{col} and $\underline{t}$ yields $t_{col} - \underline{t} = \frac{3n[2(a-c)+(x_H+x_F)(1+\delta)]}{8(3n+2\lambda)} > 0$. (ii) Comparing $\bar{t}$ and t_{col}, we have $\bar{t} - t_{col} = \frac{3n[2(a-c)+(x_H+x_F)(1+\delta)][2\lambda(n-1)-3n]}{8(3n+2\lambda)[(3+2\lambda)n+2\lambda]}$. From the last formula, $t_{col} \leq \bar{t}$ iff $\lambda \geq 3n/[2(n-1)]$. Q.E.D.

Proof of Lemma 2. I. Differentiating (2) and (3) w.r.t. δ yields

$$\begin{aligned}
\frac{\partial t^*}{\partial \delta} &= \tfrac{16(a-c)(2z+3)(4z+3)}{E^2}[16z^2 + 40z + 29 - (4z+5)(4z+11)\delta], \\
\frac{\partial q_{ii}^*}{\partial \delta} &= \tfrac{16(a-c)(2z+3)(4z+5)}{E^2}[16z^2 + 40z + 29 - (4z+5)(4z+11)\delta], \\
\frac{\partial q_{ij}^*}{\partial \delta} &= \tfrac{32(a-c)(2z+3)}{E^2}\,[16z^2 + 40z + 29 - (4z+5)(4z+11)\delta].
\end{aligned}$$

These yield part I.

II. Differentiating (1) w.r.t. δ yields $\partial x_i^*/\partial \delta = \left(\frac{a-c}{E^2}\right) L$, where $L \equiv 256z^4 - 512z^3 - 4640z^2 -$

$7008z - 3071 - 2\delta(4z+5)(4z+11)(48z^2+144z+113) + \delta^2(4z+5)^2(4z+11)^2$. Solving $L \geq 0$ for δ, we get $\delta \leq \delta_x \equiv \frac{48z^2+144z+113-4\sqrt{2}\sqrt{(2z+3)^2(4z+5)(4z+11)}}{(4z+5)(4z+11)}$; δ_x is increasing for z, $\delta_x \to (3-2\sqrt{2}) \simeq 0.171573$ as $z \to \infty$, and $\delta_x = 0$ iff $z = z_1 \simeq 5.90928$. Q.E.D.

Proof of Proposition 1. (i) Differentiating (2) and (3) w.r.t. z yields

$$\begin{aligned}
\frac{\partial t^*}{\partial z} &= \frac{16(a-c)\left[9(23\delta^2-18\delta+55)+16(7\delta^2-2\delta+15)z^2+8(37\delta^2-22\delta+85)z\right]}{E^2} > 0, \\
\frac{\partial q_{ii}^*}{\partial z} &= \frac{16(a-c)\left[125\delta^2-38\delta+125+16(5\delta^2+2\delta+5)z^2+8(25\delta^2+2\delta+25)z\right]}{E^2} > 0, \\
\frac{\partial q_{ij}^*}{\partial z} &= -\frac{32(a-c)\left[41\delta^2-62\delta+185+16(\delta^2-2\delta+5)z(3+z)\right]}{E^2} < 0.
\end{aligned}$$

(ii) Differentiating (1) w.r.t. z yields

$$\frac{\partial x_i^*}{\partial z} = \frac{128(a-c)(2z+3)}{E^2}[\delta(8z+7)-5],$$

which implies part (ii). Q.E.D.

Proof of Proposition 2. Since $CS_i^* = (Q_i^*)^2/2$, $\text{sign}\{\partial CS_i^*/\partial z\} = \text{sign}\{\partial Q_i^*/\partial z\}$. The differentiation of total sales yields $\partial Q_i^*/\partial z = \frac{16(a-c)}{E^2}\left[(48z^2+104z+43)(\delta^2+2\delta) - 5(4z+7)^2\right]$. Solving $\partial Q_i^*/\partial z \geq 0$ for δ, we have $\delta \geq \delta_Q \equiv -1 + \frac{4\sqrt{2}\sqrt{(2z+3)^2(48z^2+104z+43)}}{48z^2+104z+43} > 0$; δ_Q is decreasing for z and $\delta_Q = 1$ iff $z = \frac{1}{4}(\sqrt{30}-1) \simeq 1.11931$. From $z \geq 3/2$, $\partial Q_i^*/\partial z > 0$ iff $\delta > \delta_Q$. Q.E.D.

Proof of Lemma 3. I. From Π_i^* in (4), we get

$$\frac{\partial \Pi_i^*}{\partial z} = \frac{512(a-c)^2(2z+3)^2}{E^3}[3(47\delta^2-56\delta+25)+16(7\delta^2-4\delta+5)z^2+16(17\delta^2-13\delta+10)z] > 0,$$

and

$$\begin{aligned}
\frac{\partial \Pi_i^*}{\partial \delta} &= \frac{2(a-c)^2(4z+5)}{E^3} \cdot M > 0, \\
\text{where} \quad M &\equiv 29696z^5 + 221952z^4 + 678272z^3 + 1054112z^2 + 829172z + 263171 \\
&\quad + \delta^3(4z+5)^2(4z+11)^3 - 3\delta^2(4z+5)(4z+11)^2(48z^2+144z+113) \\
&\quad - \delta(4z+7)(4z+11)(832z^3+3024z^2+3756z+1563) > 0.
\end{aligned}$$

II. (i) From π_k^* in (4), we get

$$\begin{aligned}
\frac{\partial \pi_k^*}{\partial n} &= -\tfrac{256(a-c)^2(2z+3)^2[3(55\delta^2-58\delta+175)+16(7\delta^2-2\delta+15)z^2+8(31\delta^2-28\delta+85)z]}{n^2E^3} < 0,\\
\frac{\partial \pi_k^*}{\partial \lambda} &= -\tfrac{512(a-c)^2(2z+3)^2[3(9\delta^2-22\delta+65)+16(\delta^2-2\delta+5)z^2+16(2\delta^2-7\delta+15)z]}{n^2E^3} < 0.
\end{aligned}$$

(ii) Differentiating π_k^* w.r.t. δ yields

$$\frac{\partial \pi_k^*}{\partial \delta} = \tfrac{1024(a-c)^2(2z+3)^3}{nE^3}\left[16z^2+40z+29-(4z+5)(4z+11)\delta\right],$$

which implies part (ii). Q.E.D.

Proof of Proposition 3. Differentiating (5) w.r.t. z yields

$$\begin{aligned}
\frac{\partial SW_i^*}{\partial z} &= \frac{128(a-c)^2(2z+3)}{E^3}\cdot N,\\
\text{where}\quad N &\equiv (1088z^3+4272z^2+5292z+1993)\delta^2-2(4z+7)(16z^2+88z+101)\delta\\
&\quad +5(64z^3+112z^2-84z-163).
\end{aligned}$$

Since $N>0$ for $z>1.37301$, $\partial SW_i^*/\partial z>0$ for all $z\geq 3/2$. Q.E.D.

Appendix C. The four effects in Eq. (6)

(i) Domestic supply effect (term (i)) is

$$[p_i-(c-(1+\delta)x_i)]\frac{\partial q_{ii}}{\partial z} = \tfrac{128(a-c)^2(2z+3)(4z+5)}{E^3}\begin{bmatrix}125\delta^2-38\delta+125+16(5\delta^2+2\delta+5)z^2\\ +8(25\delta^2+2\delta+25)z\end{bmatrix} > 0.$$

(ii) Investment effect (term (ii)) is

$$[(1+\delta)Q_i-2x_i]\frac{\partial x_i}{\partial z} = \tfrac{256(a-c)^2(2z+3)[\delta(8z+7)-5]}{E^3}[139\delta-29+16(3\delta-1)z^2+8(21\delta-5)z] \gtreqless 0.$$

(iii) Export effect (term (iii)) is

$$[p_j-(c-(1+\delta)x_i)-t]\,\frac{\partial q_{ij}}{\partial z} = -\tfrac{512(a-c)^2(2z+3)}{E^3}\begin{bmatrix}41\delta^2-62\delta+185+16(\delta^2-2\delta+5)z^2\\ +48(\delta^2-2\delta+5)z\end{bmatrix} < 0.$$

(iv) Transport-price effect (term (iv)) is

$$-q_{ij}\,\frac{\partial t}{\partial z} = -\tfrac{256(a-c)^2(2z+3)}{E^3}\left[\begin{array}{l} 9(23\delta^2 - 18\delta + 55) + 16(7\delta^2 - 2\delta + 15)z^2 \\ +\,8(37\delta^2 - 22\delta + 85)z \end{array}\right] < 0.$$

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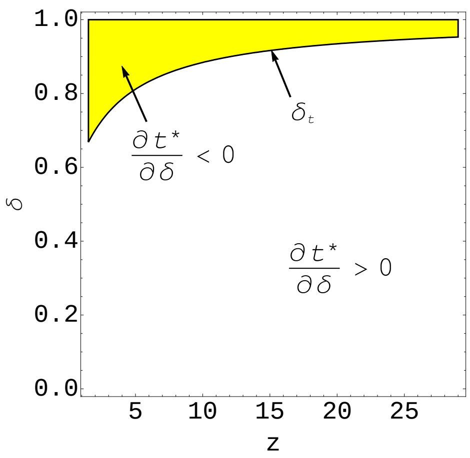
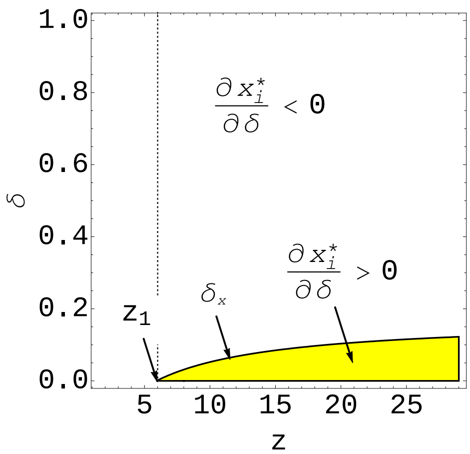


Panel (a): The area "$\partial t^*/\partial\delta < 0$."



Panel (b): The area "$\partial x_i^*/\partial\delta > 0$."

Figure 1: Illustration of Lemma 2.

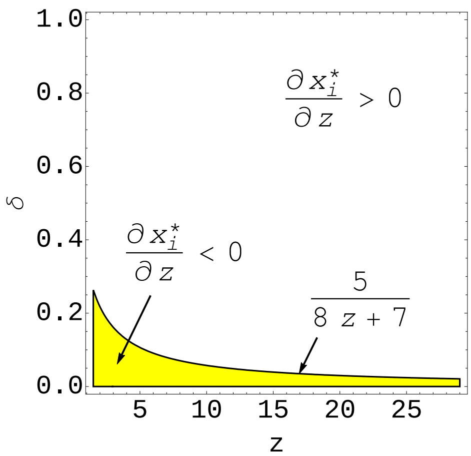
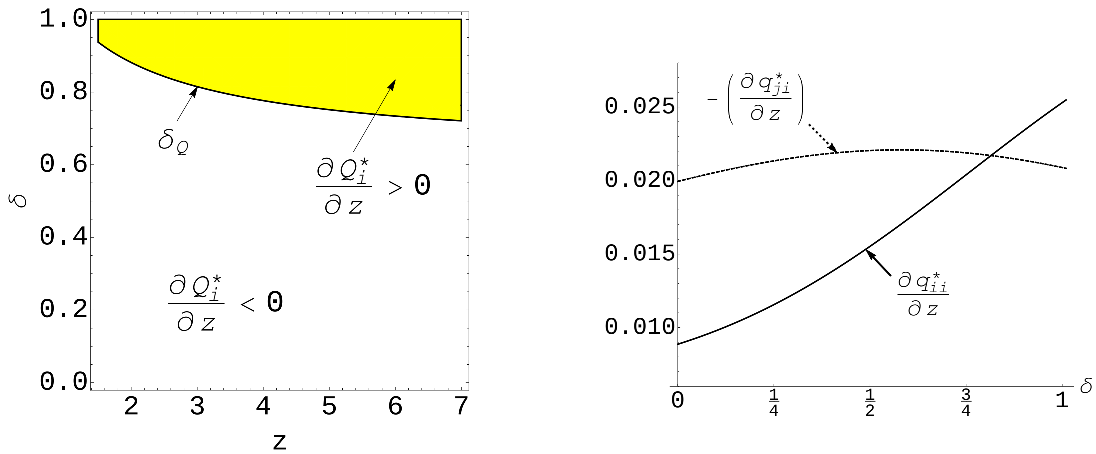


Figure 2: Illustration of (ii) in Proposition 1.



Panel (a): The area "$\partial Q_i^*/\partial z > 0$."

Panel (b): $\partial q_{ii}^*/\partial z$ and $-(\partial q_{ji}^*/\partial z)$ ($z = 3$; $a - c = 1$).

Figure 3: Illustration of Proposition 2.

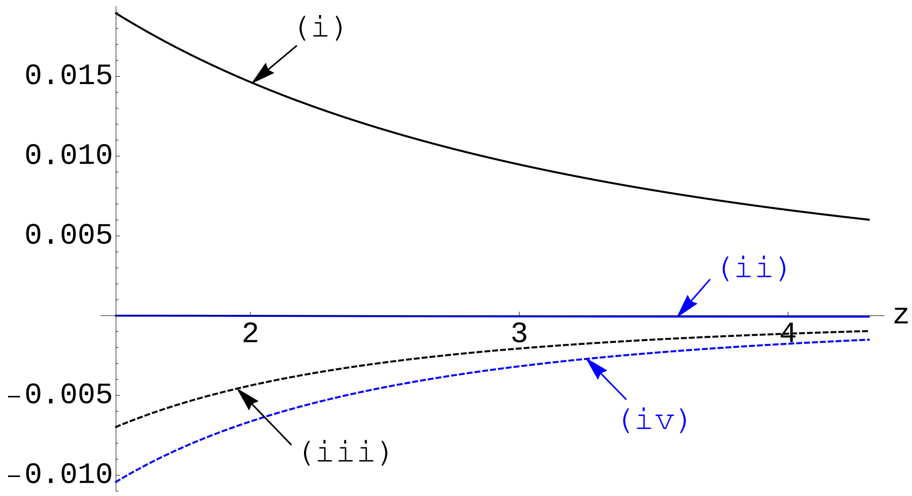


Figure 4: The graph of "(each term)$/(a-c)^2$." ($\delta = 1/4$)