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PORT PRIVATIZATION IN AN INTERNATIONAL OLIGOPOLY

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Port privatization in an international oligopoly*

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Abstract

We investigate how port privatization affects port charges, firm profits, and welfare. Our model consists of an international duopoly with two ports and two markets. When the unit transport cost is large, privatization of ports *decreases* the prices for port usage, although neither government has an incentive to privatize its port. The equilibrium governmental decisions are inconsistent with the desirable outcome if the unit transport cost is not large enough. The smaller country's government is more likely to privatize its port, although the larger country's government is more likely to nationalize its port to protect its domestic market.

Key words: Port; Privatization; Port charge; Oligopoly; Strategic trade policy.

JEL codes: L33; F12; R48; F13.

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1 Introduction

Ports are an important factor in international trade because they directly influence trade costs through cargo handling charges. About 90% of the international trade by the European Union is performed by sea (González and Trujillo, 2008). The main trade costs include port tariffs, cargo handling charges, and transit time in ports (Trujillo and Nombela, 1999; Limão and Venables, 2001; Tongzon and Heng, 2005). The percentage of the cargo handling charge over the total bill is about 70-90% (Trujillo and Nombela, 1999). That is, this charge is a very important factor in international trade.

Recognizing the importance of port charges in international trade, practitioners and researchers have recently taken a closer look at the important determinants of port charges. For decades, privatization policy has been recognized as one of the most important determinants of port charges because the ownership structure of ports influences their efficiency and how ports' charges are determined. Following the example of the UK, many countries have moved—or are moving—toward the privatization of some public ports. In the UK, many major ports, including Grimsby, Immingham and Teesport are company ports created by their own Act of Parliament (Baird and Valentine, 2007). Furthermore, port practitioners have provided many sound reasons for the move toward the privatization of public ports. The typical reasons are efficiency improvement and trade expansion (Baird, 2002). In fact, several empirical studies have shown that port privatization improves efficiency and increases port trade volumes (Trujillo and Nombela, 1999). As those practitioners implicitly believe, port privatization drastically changes port objectives. We can expect that the changes in port objectives through privatization will influence the port charges levied on many exporters through payments to shippers that use ports. In other words, privatization influences the activities of exporters through the changes in their payments to shippers who are intermediaries of those exporters. We therefore investigate how port privatization affects firm profits and welfare through changes in port objectives. We illustrate how the difference between the objectives under the two different organization regimes, privatization and nationalization, affects port charges, firm profits, and social welfare.

We formulate a simple model that describes the effect of port privatization on social welfare. The model is based on a two-country setting as in Brander and Krugman (1983). The firm in a country supplies its product to both countries, which implies that the two firms compete in each country. The objective of a public port is to maximize domestic welfare, whereas that of a private port is to maximize its own profit.[1] We consider the following three-stage game. First, each government independently decides whether to privatize its port. Second, the ports independently set their port charges to maximize their objectives. Finally, the two firms compete in quantity in the two countries simultaneously.

We show that depending on the per-unit transport cost, several types of organization mode can appear in equilibrium. When the per-unit transport cost is low enough, two outcomes can appear in equilibrium: both ports are privatized or no port is privatized. When the per-unit transport cost is intermediate, both ports are privatized in equilibrium. When the per-unit transport cost is large, no port is privatized in equilibrium, although the port charge would be lowered by the privatization of ports. This result implies that a governmental decision on the ownership structure of ports in its country can be a strategic tool to control trade volume. This provides a new insight in the context of transportation research and strategic trade policy.

We further investigate the welfare property of the equilibrium outcome and how market size asymmetry affects governmental decisions concerning the organization modes of ports. We show that the equilibrium governmental decisions are inconsistent with the socially desirable organization modes of ports if the per-unit transport cost is not large enough. That is, the two governments are in a prisoners' dilemma situation. We also show that the government in the large country is more likely to nationalize its port to protect its domestic market. Finally, we briefly discuss a case in which each port engages in cost-reducing activities after the organization structure of each port is determined by each government.

[1] This follows the model assumption in Zhang and Zhang (2003), Mantin (2012), and Matsumura and Matsushima (2012), who discuss airport privatization.

Theoretically, our paper is closely related to two papers that consider the privatization policy of airports in the context of airline competition (Mantin, 2012; Matsumura and Matsushima, 2012).[2] They consider the following model setting. There are two airlines that supply final products to passengers. Each airline company uses two airports to supply travel services. Each airport monopolistically sets its airport charge. Because the consumer market consists by the international flight services, the number of markets is one in these models. They show the possibility that airport privatization appears in equilibrium. The driving force behind their results is the rent-shifting effect of privatization, which our paper partially shares with theirs. However, these studies do not consider reciprocal trade models, which implies that they do not capture the nature of strategic trade policy. Our paper is also related to the papers that emphasize the market power of agents related to the international transport of products (Francois and Wooton, 2001; Behrens and Picard, 2011; Kleinert and Spies, 2011). Those papers mainly focus on shippers' market power, but they do not explicitly consider the activities of ports, which are gatekeepers for imports and exports.

Czerny et al. (2011) also discuss the effect of port privatization in a Hotelling spatial competition model with local markets (Takahashi, 2004). Two ports compete in a third country market consisted by a Hotelling line. Each port also has a monopoly market in its own country. The port owners compete in port charge for the usage of their ports, which implies that the ports are substitute in the third country market and that the port charges are strategic complements. In Czerny et al. (2011), because a nationalized port takes into account the consumer surplus in its country as well as its own profit, it is more likely to set a lower port charge, which accelerates the competition between the two ports. Because a privatized port does not take into account the consumer surplus in its country, privatization works as a commitment not to set a lower port charge, which mitigate the competition between the ports. This is why privatization can appear in their model. We believe that our paper is a

[2] Our paper is also related to the context of airline competition (Basso, 2008; Basso and Zhang, 2008; Haskel et al., 2013; Zhang and Zhang, 2003, 2006). Zhang and Czerny (2012) provide an excellent survey concerning recent research on airline and airport competition.

complement to Czerny et al. (2011).

The remainder of the paper is as follows. Section 2 presents the model. Section 3 provides the main result. Section 4 extends the basic model. Section 5 concludes the paper. All proofs are available in the Appendix.

2 Model

We consider a two-way oligopolistic trade model with two ports. There are two countries, Home and Foreign, in the world. Each country has a port and a homogeneous manufacturing firm (henceforth, we call it a *firm*). Each firm supplies its product to both markets. When a firm exports, it must use the two ports with payments and incur a per-unit shipping fee for competitive shippers. For simplification, no firm incurs any costs except the costs associated with transportation.

The inverse market demands in Home (H) and Foreign (F) are

$$p_H = a - (q_{HH} + q_{FH}), \quad p_F = a - \frac{1}{b}(q_{FF} + q_{HF}),$$

where p_i is the price in country i, q_{ji} denotes the quantity supplied by a firm in j in market i ($i, j = H, F$), and b is the market size of F compared to that of H. Without loss of generality, we assume that $b \leq 1$, that is, the market size in F is smaller than or equal to that in H. Given the quantities supplied by the firms, the consumer surplus in i is given as

$$CS_H = \frac{(q_{HH} + q_{FH})^2}{2}, \quad CS_F = \frac{(q_{FF} + q_{HF})^2}{2b}.$$

τ (> 0) is the per-unit shipping fee and f_i is the per-unit fee for the usage of the port in i ($i = H, F$).[3] The owner of the port in i maximizes its objective, which depends on whether its ownership structure is private or public (we explain this later). The total per-unit

[3] Hummels and Skiba (2004) empirically show that the transport price is not iceberg type but per-unit type. Hence, this setting is natural.

transportation cost, t, is

$$t \equiv \tau + f_H + f_F.$$

The marginal cost of firm i in i is zero, but that is t in j $(i, j = H, L,\ i \neq j)$.

The profit of firm i (Π_i) is the sum of the profits in the two markets, $\pi_{ii} = p_i q_{ii}$ and $\pi_{ij} = (p_j - t)q_{ij}$; that is,

$$\Pi_i \equiv \pi_{ii} + \pi_{ij} = p_i q_{ii} + (p_j - t)q_{ij}.$$

The owner of the port in i does not incur any operation cost. This port earns its profit from the export from i to j and the import from j to i. The total profit of the port in i is given as

$$R_i \equiv f_i(q_{ij} + q_{ji}) = f_i(q_{HF} + q_{FH}).$$

There are two scenarios related to the objective of each port owner. In the first, it maximizes its own profit; in the second, it maximizes its domestic surplus. The former represents a privatized port and the latter a nationalized port. When the owner of the port in i is a profit maximizer, it maximizes R_i. When the owner of the port in i is a domestic welfare maximizer, it maximizes

$$W_i = R_i + \Pi_i + CS_i. \tag{1}$$

This specification is used in the literature on airport privatization (e.g., Zhang and Zhang, 2003; Basso and Zhang, 2008).

We consider the following four cases: I. Both owners are private; II. Only the owner of the port in H is private; III. Only the owner of the port in F is private; and IV. Both owners are public.

The timing of the game is as follows: first, each government simultaneously determines the ownership structure of the port. Second, each port simultaneously sets the fee f_i to maximize its objective which is determined in the first stage. Third, the firms simultaneously determine their quantities in the two markets. We solve the game by backward induction.

3 Results

In this section, we derive the main results of this paper. To clarify the analysis, in this section, we consider the case in which the market size in the two countries is symmetric, that is, $b = 1$. In the next section, we briefly discuss how market size asymmetry affects the ownership structures of the ports.

The third stage In the third stage, given the fee levels f_H and f_F, each firm simultaneously sets its quantities in the two markets. As in the standard Cournot duopoly outcome, the equilibrium outcome in the third stage is given as

$$q_{ii}(f_H, f_F) = \frac{a + \tau + f_H + f_F}{3}; \quad q_{ji}(f_H, f_F) = \frac{a - 2(\tau + f_H + f_F)}{3}. \tag{2}$$

Substituting these into Π_i, R_i, and CS_i, we have $\Pi_i(f_H, f_F)$, $R_i(f_H, f_F)$, and $CS_i(f_H, f_F)$ in the third stage.

The second stage To discuss the outcome in the second stage, we derive the two reaction functions of the port in i in the two scenarios: private and public.

When the port in i is private, the maximization problem is given by

$$\max_{f_i} \; R_i(f_H, f_F).$$

From the problem, we have the reaction function of the port in i:

$$f_i^P(f_j) = \frac{a - 2\tau - 2f_j}{4}, \tag{3}$$

where the superscript P represents the case of privatization. This is negatively correlated to τ and f_j. Each port earns its profit through the transaction of international shipments, which are negatively correlated to the shipping fee (τ): the number of international transactions decreases as the shipping fee increases. The port fees are also negatively correlated with the international transactions. A port must lower its port fee, given that another port sets a higher fee, which decreases transactions.

When the port in i is public, the maximization problem is given by

$$\max_{f_i} \; R_i(f_H, f_F) + \Pi_i(f_H, f_F) + CS_i(f_H, f_F).$$

From the problem, we have the reaction function of the port in i:

$$f_i^N(f_j) = \frac{2a - \tau - f_j}{13}, \tag{4}$$

where the superscript N represents the case of nationalization. To understand the difference between the two reaction functions, we check the partial derivatives of $\Pi_i(f_H, f_F)$ and $CS_i(f_H, f_F)$ with respect to f_i:

$$\frac{\partial \Pi_i(f_H, f_F)}{\partial f_i} = \underbrace{\frac{\partial \pi_{ii}(f_H, f_F)}{\partial f_i}}_{(+)} + \underbrace{\frac{\partial \pi_{ij}(f_H, f_F)}{\partial f_i}}_{(-)} = -\frac{2(a - 5(\tau + f_H + f_F))}{9}, \tag{5}$$

$$\frac{\partial CS_i(f_H, f_F)}{\partial f_i} = -\frac{2(2a - (\tau + f_H + f_F))}{9} < 0. \tag{6}$$

In the first equation, the positive sign represents the import prevention effect in market i and the negative sign represents the export prevention effect in market j. Rises in consumer prices through the increase in f_i generate the two effects. The effect in each market is stronger as the quantity supplied in the market becomes larger because the effect of a price increase is applied to the total quantity supplied in each market. The shipping fee enhances the import prevention effect but diminishes the export prevention effect. This implies that the former effect dominates the latter one when the shipping fee is large. In fact, the partial derivatives of $\Pi_i(f_H, f_F)$ are positive if the transportation cost, which is the sum of the transportation costs, is larger than $a/5$. In the second equation, a rise in the port fee only increases the marginal cost of the exporter, which reduces the consumer surplus. Because the marginal effect of f_i on the consumer surplus is positively correlated with supply size, a higher shipping fee (τ) weakens the negative effect of the increase in f_i. To sum up, because of the effect of f_i on the profit and the consumer surplus, the shipping fee does not substantially influence the fee schedule of a nationalized port ($f_i^N(f_j)$), meaning that τ does not substantially affect the value of the reaction function's intercept.

The outcomes in the four subgames Using the two types of reaction functions, we draw the equilibrium outcomes in the four subgames. $f_i(f_j)$ is the reaction function of the nationalized port in i and $\hat{f}_i(f_j)$ is that of the privatized port in i. The four intersections generated by the four reaction functions are the equilibrium outcomes in the four subgames. The two curves that pass the intersections generated by the pairs of f_H and f_F and $\hat{f}_H$ and $\hat{f}_F$ are the iso-social surplus curves.

[Figures 1-3 here]

The first stage The first stage decision of each government is to choose one of the reaction functions. Solving the four outcomes, we derive the following proposition:

Proposition 1 *(i) If $0 \leq \tau < a/46$, (P, P) and (N, N) can appear in equilibrium. (ii) If $a/46 \leq \tau < a/11$, only (P, P) appears in equilibrium. (iii) If $a/11 \leq \tau \leq a/4$, only (N, N) appears in equilibrium.*

When τ is small enough, two outcomes can appear in equilibrium: both ports are privatized or they are both nationalized. First, suppose that both ports are nationalized (point A in Figure 1). The trade barrier to firm H is small enough, implying that the demand for each port is large enough. Under the large demand, if a port is privatized, it sets a significantly higher port fee. This implies that the negative effect of privatization is significant. In fact, the privatization of port H substantially moves the reaction function of port H rightward, which changes the intersection from A to B (Figure 1). Second, suppose that both ports are privatized (point C in Figure 1). The trade barrier to firm H is higher because privatized ports set higher port fees. Given their organization forms, the nationalization of port H induces a larger rent shift from port H to port F because of the strategic substitutability of port fees (note that the rent-shifting effect is the main concern in Matsumura and Matsushima (2012) and Mantin (2012)). The negative effect of this rent shift dominates the positive effect of nationalization on the firm profit and the consumer surplus. In fact, the privatization of port H substantially moves the reaction function of port H leftward, which changes the intersection from C to D (Figure 1).

When τ is intermediate, both ports are privatized in equilibrium. To understand the reason nationalized ports are privatized, we first suppose that both ports are nationalized (point A in Figure 2). The trade barrier to firm H is slightly larger than that in the previous case, implying that the demand for each port is not so large. Under moderate demand, if a port is privatized, it does not set a significantly higher port fee. This implies that the negative effect of privatization is not very significant. In fact, privatization of port H moderately moves the reaction function of port H rightward, which changes the intersection from A to B (Figure 2). Second, suppose that both ports are privatized (point C in Figure 2). Under the symmetric market size assumption, the rent shift is relatively large, although the import prevention effect through nationalization is effective. The property of the rent shift is similar to that in the previous case.

When τ is large, both ports are nationalized in equilibrium. First, suppose that both ports are nationalized (point A in Figure 3). The privatization of port H moves the reaction function of port H *leftward*, which changes the equilibrium point from A to B (Figure 3). Because of the import prevention effect through nationalization, the reaction function of nationalized port H is located on the right-hand side. Because $f_F(f_H)$ is downward sloping, through an increase in f_F, privatization always generates a rent shift from country H to country F, which harms social welfare in country H. In fact, point B is located above the iso-welfare curve passing through point A. Second, suppose that both ports are privatized (point C in Figure 3). The nationalization of port H moves the reaction function of port H *rightward*, which changes the equilibrium point from C to D (Figure 3). Through a decrease in f_F, privatization generates a rent shift from country F to country H, which benefits social welfare in country H. In fact, point C is located below the iso-welfare curve passing through point D. To sum up, port nationalization can be a barrier to international trade.

We briefly discuss the relation between the equilibrium organization structure and the welfare ranking. The following proposition and Figure 4 summarize the relation.

Proposition 2 *The welfare ranking between the privatization and nationalization regimes changes twice as the shipping fee goes up: (i) If* $\tau \leq a/11$, $SW_i^{PP} \leq SW_i^{NN}$. *(ii) If* $a/11 < \tau < 55a/227$, $SW_i^{PP} > SW_i^{NN}$. *(iii) If* $55a/227 \leq \tau \leq a/4$, $SW_i^{PP} \leq SW_i^{NN}$, *where* $i = H, F$.

[Figure 4 here]

In the first range ($\tau < a/11$), privatization is more likely to appear in equilibrium although nationalization is preferable. As discussed in Mantin (2012) and Matsumura and Matsushima (2012), privatization of a port causes a rent shift from another country to its country although expanding the total trade volume through the nationalization of ports is beneficial for both countries. That is, the temptation for the rent-shifting benefit through privatization causes the prisoners' dilemma.

In the second range ($a/11 < \tau < 55a/227$), nationalization is more likely to appear in equilibrium, although privatization is preferable. As discussed earlier, when τ is not small, the nationalization of a port *diminishes* the total trade volume because of the import prevention effect, although expanding the total trade volume through the privatization of ports is beneficial for both countries. That is, the temptation for import prevention through nationalization causes the prisoners' dilemma.

In the third range ($55a/227 \leq \tau \leq a/4$), nationalization is more likely to appear in equilibrium, and it is preferable. When τ is large enough, exporters are inefficient firms in each market. As discussed in Lahiri and Ono (1988), eliminating inefficient firms improves welfare. This is because decisions concerning the organization of ports can be beneficial for both countries.

4 Extensions

We further discuss two cases in which the market sizes are heterogenous and in which ports engage in cost-reducing activities.

4.1 Market size asymmetry

We take into account the heterogeneity of market sizes in the two countries. That is, we relax the restriction on b in the previous section and assume that $b \leq 1$. Figure 5 summarizes the result.

[Figure 5 here]

The port in the larger country is more likely to be nationalized, while the one in the smaller country is more likely to be privatized. The main reason for this tendency is that import prevention is more effective for the larger country. Privatized ports do not take into account the benefit of import prevention for the larger country, but only maximize their port revenues. To internalize the import prevention effect, the larger country must nationalize its port. Note that in the non-trade models in Mantin (2012) and Matsumura and Matsushima (2012), an asymmetric privatization mode does not appear in equilibrium. This is because import prevention does not matter in their models although it is one of the main factors in our model.

4.2 Cost-reducing investments

Finally, we briefly discuss a case in which each port engages in cost-reducing activities after the organization structure of each port is determined by each government. This is also an important aspect of privatization policy for ports, as Trujillo and Nombela (1999) have observed that the privatization of ports in Chile has improved efficiency in terms of cargo handling costs.

Based on the basic model, we consider the following game. First, each government simultaneously determines the ownership structure of the port. Second, each port simultaneously sets its effort level e_i to reduce its per-unit operation cost $c - e_i$ and then incurs the effort cost γe_i^2, where c and γ are positive constants.[4] Third, observing the second stage outcome, each port simultaneously sets the fee f_i to maximize its objective which is determined in the first stage. Finally, the firms simultaneously determine their quantities in the two markets.

In the extended model, the nationalized port in the large country mainly focuses on the protection of the domestic market through a higher port fee. Because the pricing schedule decreases the trade volume between the countries, the incentive for the nationalized port to engage in cost-reducing activities is weak. In contrast, the privatized port in the small country does not consider import protection, but focuses on the profit from its port fee. Because increasing the trade volume is important for the privatized port, its incentive to engage in cost-reducing activities is strong. Therefore, the efficiency level of the privatized port is higher than that of the nationalized one under the case in which only the small country's government privatizes its port, which seems consistent with the finding in Trujillo and Nombela (1999).[5]

Proposition 3 *Suppose that only the small country's government privatizes its port. The efficiency level of the privatized port is higher than that of the nationalized one.*

We can numerically show parameter ranges in which only the small country's government privatizes its port in equilibrium, although we do not explicitly mention the problem because of the mathematical complexity. Figure 6 shows an numerical example in which the asymmetric privatization mode appears in equilibrium.

[Figure 6 here]

[4] We appropriately set those exogenous parameters to secure the second-order conditions and the positive per-unit operation costs of the ports.

[5] In the Appendix, we calculate the equilibrium outcome under the subgame in which only the small country's government privatizes its port.

Note that Matsumura and Matsushima (2012) consider the efforts of airports to reduce airport congestions which generate negative externalities on consumer demand. Reducing the negative externalities enhances the demand for airport usage. They show that under an asymmetric privatization mode, the privatized airport has a stronger incentive to reduce airport congestions. The logic behind the result is different from ours. In their model, the rent-shifting effect of privatization, which leads to a higher airport charge of the privatized airport, increases its marginal gain from the effort. In our model, import protection weakens the incentive of the nationalized port to engage in cost reduction even though it sets a higher port charge. Furthermore, an asymmetric privatization mode never appears in Matsumura and Matsushima (2012), although it can appear as an equilibrium outcome in our model.

5 Conclusion

Following the example of the UK, many countries have moved—or are moving—toward the privatization of some public ports. Privatization influences the activities of exporters through the changes in their payments to shippers who are intermediaries of those exporters. We therefore investigate how port privatization affects firm profits and welfare through the changes in the ports' objectives. We formulate a simple model that describes the effect of port privatization on social welfare. The model is based on a two-country setting as in Brander and Krugman (1983). We assume that the objective of a public port is to maximize domestic welfare, whereas that of a private port is to maximize its own profit.

We show that depending on the per-unit transport cost, several types of organization mode can appear in equilibrium. When the per-unit transport cost is low enough, there can be two equilibrium outcomes: either both ports are privatized or neither port is privatized. When the per-unit transport cost is intermediate, both ports are privatized in equilibrium. When the per-unit transport cost is large, no port is privatized in equilibrium, although the port charge would be *lower* by the privatization of ports. This result implies that a governmental decision on the ownership structures of ports in the country can be a strategic tool to control trade volume. This provides a new insight in the context of transportation research and strategic trade policy. We also show that the equilibrium governmental decisions are inconsistent with the socially desirable organization modes of ports if the per unit transport cost is not large enough.

We further investigate the welfare property of the equilibrium outcome and how market size asymmetry affects governmental decisions concerning the organization modes of ports. We show that the government in the large country is more likely to nationalize its port to protect its domestic market. Finally, we have briefly discussed a case in which each port engages in cost-reducing activities after the organization structure of each port is determined by each government. We show that the efficiency level of the privatized port is higher than that of the nationalized one. This seems consistent with the finding in Trujillo and Nombela (1999).

We have used a simple oligopoly model to describe the effect of port privatization on consumer and social welfare. Expanding the simple framework to monopolistic competition models is a considerable work left to future research. Furthermore, we do not consider competition among international ports. As in the literature of airport competition (Pels et al., 2000) and port competition (Czerny et al., 2011), the extension is a considerable work left to future research.

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Appendix

Proof of Proposition 1: By using (3) and (4), we can derive the equilibrium port fees in the four subgames. When both ports are privatized, we use (3). By using the equations, we have the equilibrium port fees:

$$f_H^{PP} = f_F^{PP} = \frac{a - 2\tau}{6},$$

where the subscript PP indicates the subgame in which both ports are privatized. Applying similar procedures to the rest of the cases, we have the equilibrium port fees in the subgames as follows:

$$f_H^{PN} = f_F^{NP} = \frac{3(3a - 8\tau)}{50}, \quad f_H^{NP} = f_F^{PN} = \frac{7a - 2\tau}{50}, \quad f_H^{NN} = f_F^{NN} = \frac{2a - \tau}{14},$$

where PN, NP, and NN respectively indicate the subgame in which only port H is privatized, that in which only port F is privatized, and that in which both ports are privatized. Substituting the outcome in the third stage (equation (2)) and the equilibrium port fees derived above into the equation of the social surplus in (1), we have the following payoff matrix.

Table 1: The payoff matrix of the port privatization game ($b = 1$)

$H \diagdown F$	P	N
P	$SW_F^{PP} = \frac{65a^2 - (26a - 35\tau)\tau}{162}$ $SW_H^{PP} = \frac{65a^2 - (26a - 35\tau)\tau}{162}$	$SW_F^{PN} = \frac{249a^2 - 26(3a - 4\tau)\tau}{625}$ $SW_H^{PN} = \frac{51a^2 - 8(4a - 7\tau)\tau}{125}$
N	$SW_F^{NP} = \frac{51a^2 - 8(4a - 7\tau)\tau}{125}$ $SW_H^{NP} = \frac{249a^2 - 26(3a - 4\tau)\tau}{625}$	$SW_F^{NN} = \frac{20a^2 - 13(a - 2\tau)\tau}{49}$ $SW_H^{NN} = \frac{20a^2 - 13(a - 2\tau)\tau}{49}$

From Table 1,

$$SW_H^{PP} - SW_H^{NP} = SW_F^{PP} - SW_F^{PN} = \frac{(a-11\tau)(287a-457\tau)}{101250},$$
$$SW_H^{NN} - SW_H^{PN} = SW_F^{NN} - SW_F^{NP} = \frac{(a-11\tau)(a-46\tau)}{6125}.$$

From the equations, we find that $SW_H^{PP} > SW_H^{NP}$ if and only if $\tau < a/11$ and that $SW_H^{NN} \leq SW_H^{PN}$ if and only if $a/46 \leq \tau < a/11$.

If $0 \leq \tau < a/46$, (P,P) and (N,N) can appear in equilibrium. If $a/46 \leq \tau < a/11$, only (P,P) appears. If $a/11 \leq \tau \leq a/4$, only (N,N) appears. Q.E.D.

Proof of Proposition 2: From Table 1, simple algebra yields

$$SW_i^{PP} - SW_i^{NN} = \frac{-(a-11\tau)(55a-227\tau)}{7938}.$$

For the equation, we easily find that $SW_i^{PP} - SW_i^{NN} > 0$ if and only if $a/11 < \tau < 55a/227$. Thus, we obtain Proposition 2. Q.E.D.

Equilibrium outcome under country size asymmetry: We discuss the case of country size asymmetry (i.e., $2/9 < b \leq 1$). In the third stage, given the fee levels f_H and f_F, each firm simultaneously sets its quantities in the two markets. As in the standard Cournot duopoly outcome, when the inverse demand function is $p_i = a - (q_{ii} + q_{ji})/b_i$, the equilibrium outcome in the final stage is given as

$$q_{ii}(f_H, f_F) = \frac{b_i(a+\tau+f_H+f_F)}{3}; \quad q_{ji}(f_H, f_F) = \frac{b_i(a-2(\tau+f_H+f_F))}{3}. \tag{7}$$

Note that $b_H = 1$ and $b_F = b(\leq 1)$. Substituting these into π_{ii}, π_{ji}, R_i, and CS_i, we have

$$\pi_{ii}(f_H, f_F) = \frac{b_i(a+\tau+f_H+f_F)^2}{9}, \quad \pi_{ji}(f_H, f_F) = \frac{b_i(a-2(\tau+f_H+f_F))^2}{9}, \tag{8}$$
$$R_i(f_H, f_F) = \frac{f_i(b_i+b_j)(a-2(\tau+f_H+f_F))}{3}, \quad CS_i(f_H, f_F) = \frac{b_i(2a-(\tau+f_H+f_F))^2}{18}. \tag{9}$$

From the maximization problem relevant to ownership structure, we obtain the port fees in each subgame. When all ports are privatized, we obtain

$$f_i(f_{-i}) = \frac{a - 2\tau - 2f_{-i}}{4} \quad (i = H, F,\ i \neq -i) \quad \Rightarrow \quad f_H^{PP} = f_F^{PP} = \frac{a - 2\tau}{6},$$

where $f_i(f_{-i})$ is the reaction function of port i. When only port H is privatized, we obtain

$$\begin{aligned} & f_H(f_F) = \frac{a - 2\tau - 2f_F}{4}, \quad f_F(f_H) = \frac{(3b-1)a + (2-3b)\tau + (2-3b)f_H}{4+9b}, \\ \Rightarrow \quad & f_H^{PN} = \frac{3[(2+b)a - 4(1+b)\tau]}{10(2+3b)}, \quad f_F^{PN} = \frac{(9b-2)a + 2(2-3b)\tau}{10(2+3b)}. \end{aligned}$$

When only port F is privatized, we obtain

$$\begin{aligned} & f_H(f_F) = \frac{(3-b)a - (3-2b)\tau - (3-2b)f_F}{9+4b}, \quad f_F(f_H) = \frac{a - 2\tau - 2f_H}{4}, \\ \Rightarrow \quad & f_H^{NP} = \frac{(9-2b)a - 2(3-2b)\tau}{10(3+2b)}, \quad f_F^{NP} = \frac{3((1+2b)a - 4(1+b)\tau)}{10(3+2b)}. \end{aligned}$$

Finally, when all ports are nationalized, we obtain

$$\begin{aligned} & f_H(f_F) = \frac{(3-b)a - (3-2b)\tau - (3-2b)f_F}{9+4b}, \\ & f_F(f_H) = \frac{(3b-1)a + (2-3b)\tau + (2-3b)f_H}{4+9b}, \\ \Rightarrow \quad & f_H^{NN} = \frac{(5-b)a - 2(3-2b)\tau}{14(1+b)}, \quad f_F^{NN} = \frac{(5b-1)a + 2(2-3b)\tau}{14(1+b)}. \end{aligned}$$

From these results, we obtain the following results in the subgames.

$$
\begin{aligned}
SW_H^{PP} &= \frac{5(12+b)a^2 - 2(3+10b)a\tau + 5(3+4b)\tau^2}{162}, \\
SW_F^{PP} &= \frac{5(1+12b)a^2 - 2(10+3b)a\tau + 5(4+3b)\tau^2}{162}, \\
SW_H^{PN} &= \frac{(16+48b+37b^2+b^3)a^2 - 8(1+b)^3 a\tau + 4(1+b)^2(3+4b)\tau^2}{10(2+3b)^2}, \\
SW_F^{PN} &= \frac{(4+88b+235b^2+171b^3)a^2 - 2(1+b)(2+b)(4+9b)a\tau + 4(1+b)^2(4+9b)\tau^2}{50(2+3b)^2}, \\
SW_H^{NP} &= \frac{(171+235b+88b^2+4b^3)a^2 - 2(1+b)(1+2b)(9+4b)a\tau + 4(1+b)^2(9+4b)\tau^2}{50(3+2b)^2}, \\
SW_F^{NP} &= \frac{(1+37b+48b^2+16b^3)a^2 - 8(1+b)^3 a\tau + 4(1+b)^2(4+3b)\tau^2}{10(3+2b)^2}, \\
SW_H^{NN} &= \frac{(39+b)a^2 - 2(9+4b)a\tau + 4(9+4b)\tau^2}{98}, \\
SW_F^{NN} &= \frac{(1+39b)a^2 - 2(4+9b)a\tau + 4(4+9b)\tau^2}{98}.
\end{aligned}
$$

Using the above outcome, we check the equilibrium outcome in the full game. First, given that the rival country chooses P, the welfare differences between choosing P and N are given as

$$
\begin{aligned}
SW_H^{PP} - SW_H^{NP} &= \frac{[(3-4b)a + (3+8b)\tau][(153+216b+88b^2)\tau - (117+126b+44b^2)a]}{4050(3+2b)^2}, \\
SW_F^{PP} - SW_F^{PN} &= \frac{[(3b-4)a + (8+3b)\tau][(88+216b+153b^2)\tau - (44+126b+117b^2)a]}{4050(2+3b)^2}.
\end{aligned}
$$

From these equations, $SW_H^{PP} - SW_H^{NP} \geq 0$ if and only if

$$
\tau \leq \frac{(4b-3)a}{3+8b}. \tag{10}
$$

$SW_F^{PP} - SW_F^{PN} \geq 0$ if and only if

$$
\tau \leq \frac{(4-3b)a}{8+3b}. \tag{11}
$$

Second, given that the rival country chooses N, the welfare differences between choosing P and N are given as

$$SW_H^{NN} - SW_H^{PN} = \frac{[(1-2b)a + (3+8b)\tau][(22+28b-4b^2)\tau - (2-b^2)a]}{245(1+b)^3},$$
$$SW_F^{NN} - SW_F^{NP} = \frac{[(2-b)a - (8+3b)\tau][(4-28b-22b^2)\tau - (1-2b^2)a]}{245(3+2b)^2}.$$

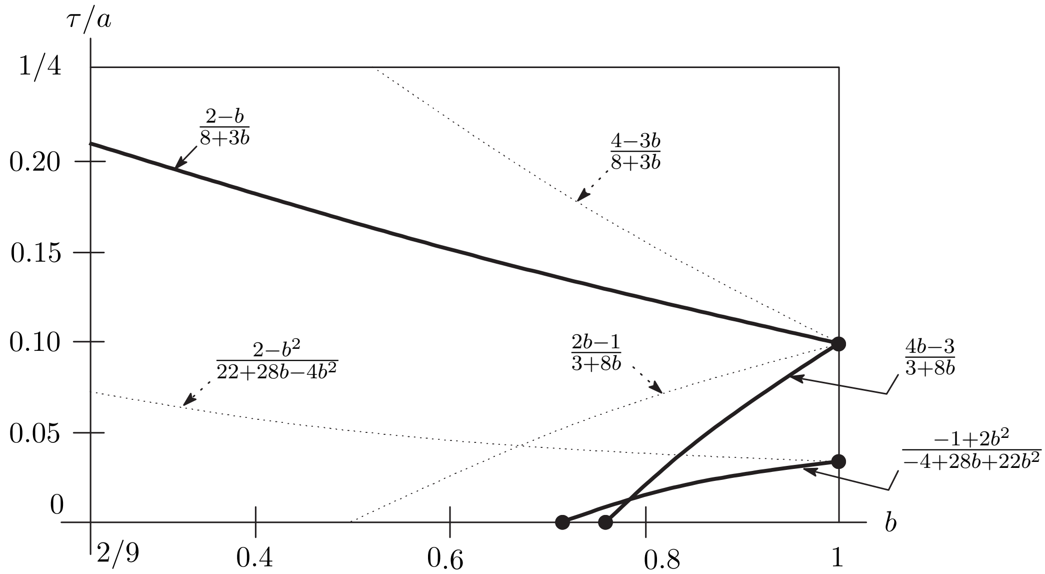
From these equations, $SW_H^{NN} - SW_H^{PN} \geq 0$ if and only if

$$\frac{(2-b^2)a}{22+28b-4b^2} \leq \tau \leq \frac{(2b-1)a}{3+8b}, \quad or \quad \frac{(2b-1)a}{3+8b} \leq \tau \leq \frac{(2-b^2)a}{22+28b-4b^2}. \tag{12}$$

$SW_F^{NN} - SW_F^{NP} \geq 0$ if and only if

$$\frac{(2-b)a}{8+3b} \leq \tau \leq \frac{(-1+2b^2)a}{-4+28b+22b^2}, \quad or \quad \frac{(-1+2b^2)a}{-4+28b+22b^2} \leq \tau \leq \frac{(2-b)a}{8+3b}. \tag{13}$$

From (10) to (13), we have the conditions that PP, NP, PN, and NN can appear as equilibrium outcomes. The following figure summarizes the threshold values of the conditions in (10), (11), (12), and (13).



The threshold curves

PP can appear if and only if both (10) and (11) hold. NP can appear if and only if neither (10) nor (13) holds. PN can appear if and only if neither (11) nor (12) holds. Note that we need to include the case in which τ is equal to the threshold value in the cases of NP and PN. NN can appear if and only if both (12) and (13) hold (see Figure 5).

Cost-reducing investments We now show that the efficiency level of the privatized port is higher than that of the nationalized one under the case in which only the small country's government (country F's government) privatizes its port. We not discuss the outcome in the stage in which the ports set their port charges. We focus on the subgame in which only the small country's government (the government in country F) privatizes its port. The maximization problems of the ports are given by

$$\max_{f_H} \ \pi_{HH}(f_H, f_F) + \pi_{HF}(f_H, f_F) + \tilde{R}_H(f_H, f_F, e_H) + CS_H(f_H, f_F),$$
$$\max_{f_F} \ \tilde{R}_F(f_H, f_F, e_F),$$

where π_{HH} and π_{HF} are in (8), CS_H is in (9), and $\tilde{R}_i(f_H, f_F, e_i)$ is given by

$$\tilde{R}_i(f_H, f_F, e_i) = \frac{(f_i - (c - e_i))(b_i + b_j)(a - 2(\tau + f_H + f_F))}{3}.$$

From the problem, we have the equilibrium outcome in this stage (note that, $b_H = 1$ and $b_F = b$):

$$f_H(e_H, e_F) = \frac{(9 - 2b)a - 2(3 - 2b)(c - e_F + \tau) + 24(1 + b)(c - e_H)}{10(3 + 2b)},$$
$$f_F(e_H, e_F) = \frac{3(1 + 2b)a - 12(1 + b)(c - e_H + \tau) + 2(9 + 4b)(c - e_F)}{10(3 + 2b)}.$$

Substituting the outcome into the objectives of the ports, we have the equilibrium outcome in the subgame.

We now discuss the stage in which the ports set their effort levels. Each port sets its effort level to maximize its objective. Solving the maximization problems, we have

$$\begin{aligned}
e_H &= \frac{(1+b)(9+4b)((1+2b)a-4(1+b)(2c+\tau))}{2(25(3+2b)^2\gamma-2(1+b)^2(21+16b))}, \\
e_F &= \frac{12(1+b)^2((1+2b)a-4(1+b)(2c+\tau))}{2(25(3+2b)^2\gamma-2(1+b)^2(21+16b))}, \\
e_F-e_H &= \frac{(3+8b)(1+b)((1+2b)a-4(1+b)(2c+\tau))}{2(25(3+2b)^2\gamma-2(1+b)^2(21+16b))} > 0.
\end{aligned}$$

Note that the equilibrium trade volume is positive if and only if $(1+2b)a-4(1+b)(2c+\tau) > 0$ and that the denominator is positive if the second-order conditions in the second stage are satisfied. The third equation implies that the *ex post* efficiency level of the privatized port is higher than that of the nationalized one under the case in which only the small country's government (country F's government) privatizes its port. Figure 6 shows an numerical example in which only the small country's government privatizes its port in equilibrium.

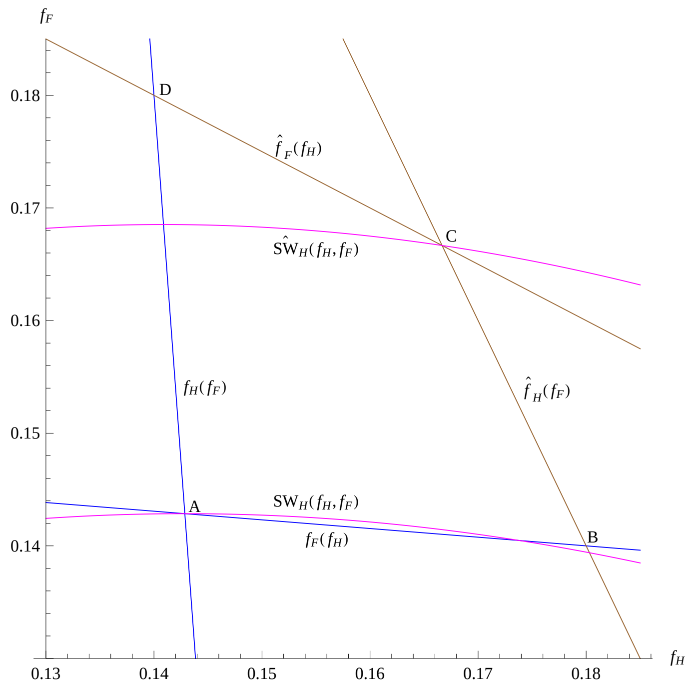


Figure 1: The reaction functions and the iso-surplus curves ($b = 1$, $\tau = 0$)

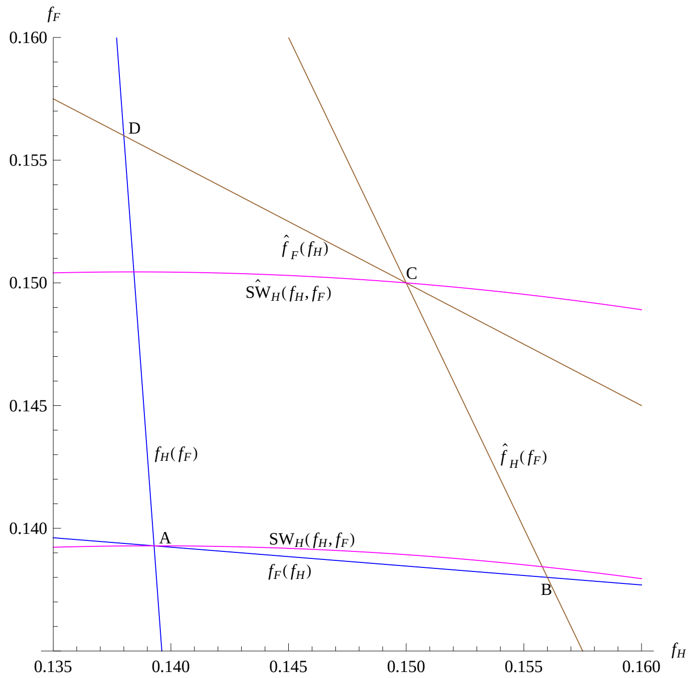


Figure 2: The reaction functions and the iso-surplus curves ($b = 1$, $\tau = 1/20$)

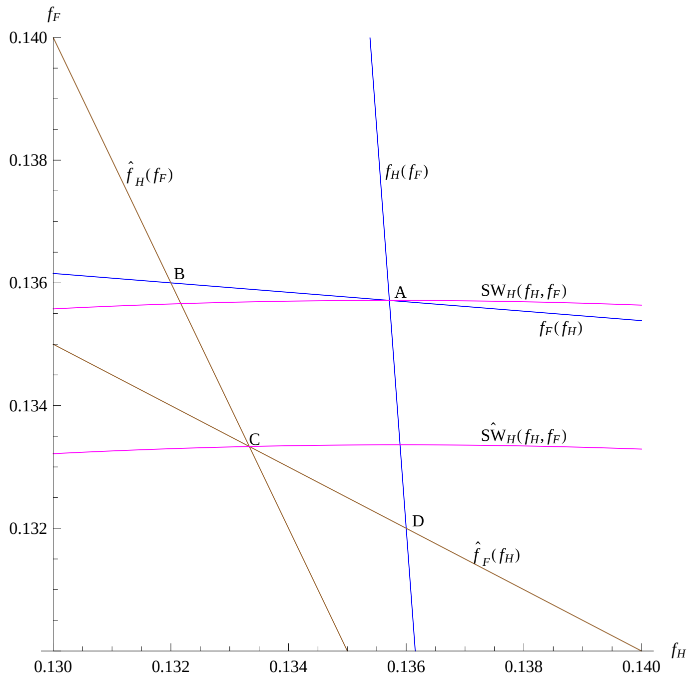


Figure 3: The reaction functions and the iso-surplus curves ($b = 1$, $\tau = 1/10$)

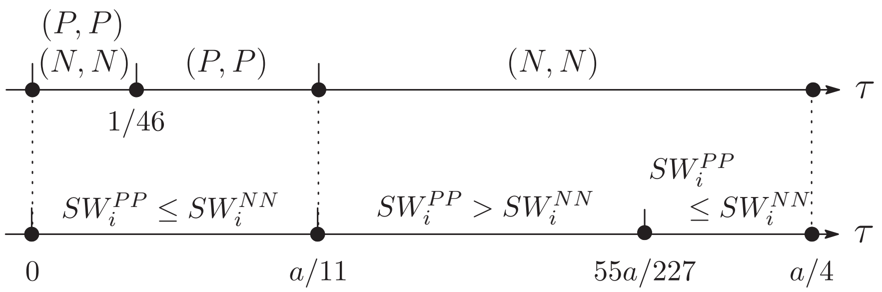


Figure 4: Equilibrium outcomes and welfare ranking under country size symmetry ($b = 1$)

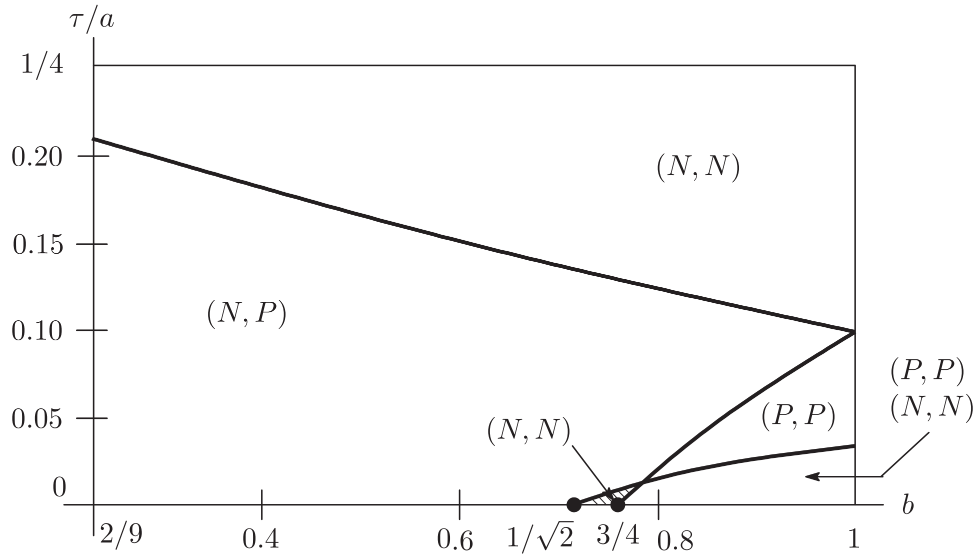


Figure 5: Equilibrium outcomes under country size asymmetry ($2/9 < b \leq 1$)

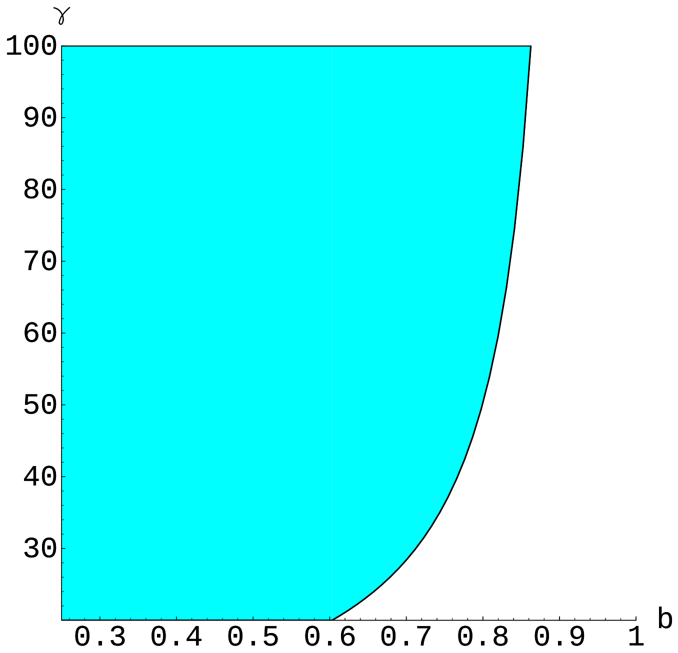


Figure 6: The region in which only the small country's government privatizes its port ($c = a/20$, $\tau = 0$)