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Abstract

Private operation of port facilities is becoming increasingly common worldwide and many governments consider the privatization of public ports as a policy option. We investigate the effect of port privatization in a setting with two ports located in different countries, serving their home market but also competing for transshipment traffic from a third region. Each government chooses whether to privatize its port or to keep port operations public. We show that there exist equilibria in which the two governments choose privatization. In these equilibria, national welfare is higher relative to a situation where both ports are public. Since port charges are strategic complements, privatization can act as a valuable precommitment tool for the two governments and allows for a better exploitation of the third region. However, from the perspective of maximizing the joint national welfare of both port countries, there is an inefficiently low incentive to privatize. It is also shown that a country with a smaller home market has a larger incentive to choose private port operation.

Keywords: Infrastructure competition, privatization, strategic delegation

JEL Classification: L11, L90, L98

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1 Introduction

The hub and spoke system in which hub ports are used to transship cargos from small ships on feeder lines to larger ships on trunk lines is typically adopted in sea transportation. The shares of transshipment traffic at major ports are, for example, 81% in Singapore, 41% in Busan, 30% in Hong Kong (Shibasaki et al., 2005). Carriers benefit from hub and spoke systems because they are useful to fully exploit economies in ship sizes. Operating a hub port can also be beneficial for national economies. This is because (i) importers and exporters in the home country's hinterland may enjoy lower transport cost and shorter lead time due to direct connections from/to major origins/destinations and (ii) port profits contribute to the national income. Hub ports typically possess localized monopoly power, but there still is significant competition between hub ports for transshipment traffic.

Since the 1980s, private operation of port facilities is becoming increasingly common worldwide and many governments consider the privatization of public ports as a policy option to raise the competitive position of their ports (for example, Midoro et al., 2005). One reason frequently discussed is that private port operations might be more cost efficient (Tongzon and Heng, 2005)[1]. However, there might also be strategic reasons for governments to opt for privatization which might rely on higher port profits as part of the national welfare. Our paper tries to explore exactly this effect.

To do so, we consider a two-stage game with two ports located in different countries. These ports are used by domestic customers and, in addition, they compete for transshipment traffic from a third region. In the first stage, each government chooses whether to privatize its port or to keep port operations public, where the government's objective is to maximize the national welfare. In the second stage, ports choose prices (i.e., port charges). A public port chooses the price to maximize national welfare, a private port chooses the price to maximize its profit. We show that if the transshipment market is sufficiently large, both ports are privatized in equilibrium and that the national welfare of the port countries increases compared to a situation where the ports are kept under public operation. Privatization leads to higher port prices (similar to results shown by, e.g., Zhang and Zhang (2003) for the case of airports) and this tends to decrease national welfare due to a lower total surplus in the domestic market. Welfare can however increase due to higher profits from the transshipment market. Due to the transshipment market port prices become strategic complements. Hence, choosing to privatize in the first stage acts like a commitment to charge high prices in stage two. To this, the other port will respond by also choosing higher port prices, allowing for a better exploitation of the transshipment market.

Note that the exploitation of the third region is not sufficient for our result: strategic interaction between competing port operators plays a crucial role of driving them to choose privatization. Since each government accounts only for the own increase in profits from this strategic privatization decision, there is too little privatization from the two countries' perspective. We also show that the smaller a country's domestic market, the larger is the

[1] Oum et al. (2008) investigate cost efficiency of airports for various types of operations, including private, public, and mixed regimes.

incentive to privatize, since the port profits become relatively more important under these conditions.

There is a growing literature on port competition. Veldman and Buckmann (2003) empirically investigate carrier hub choices between European ports. Park et al. (2006) and Anderson et al. (2008) construct a model that incorporates strategic investment decisions between the competing ports of Shanghai and Busan for transshipment cargoes. De Borger et al. (2008) consider a game with pricing and investment decisions of two congested ports that share the same customers and have each a congested link to a common hinterland. In the first stage, local governments independently and simultaneously choose the port and hinterland capacity, while ports independently and simultaneously choose port charges to maximize profits in the second stage. Xiao, Ng and Fu (2010) compare the pricing and investment rules for three types of port ownerships: fully privatized; partially privatized; and government controlled. None of the mentioned studies theoretically analyzes the decision whether to privatize ports.[2]

Most closely related are two recent papers on privatization of hub infrastructures, Matsumura and Matsushima (2012) and Mantin (2012). Both papers investigate privatization decisions and they show that airport privatization may improve national welfare. They assume that airport services are an intermediate input for airline companies, and that the two airports are used as origins and destinations. In this case, the two airports are complementary, which is in contrast to our model where the two ports are substitutes.[3] In their models, the timing of decisions is identical to ours. However, they focus on a situation without a "third region", i.e., all demand for airlines and airport services stems from one of the two countries. In this framework they find that governments have an excessive incentive to privatize, while we find situations where there is an excessive incentive to keep hubs public. The reason for this striking difference in results is the existence of a third region in our model. This implies that there is a *strategic* complementarity arising from the competition for the third region. Governments are in a prisoner's dilemma situation – just the other way around compared to Matsumura and Matsushima (2012) and Mantin (2012): they could increase welfare if they coordinated on privatization, since this can better exploit the transshipment market. But since each government takes into account only the own gain from doing so, the individual incentives to privatize fall short of the joint incentives of doing so.

On a more abstract level, this paper is also related to the literature on "strategic delegation", which explores the effects of contracts between firms in oligopolistic markets and third parties (managers) on profits (e.g. Schelling 1960, Vickers 1985, Fershtman and Judd 1987, Sklivas 1987, Fershtman et al. 1991, Katz 1991, Corts and Neher 2003 and Spagnolo 2005). Das (1997) examines the relationship between strategic delegation and trade policy from the policy viewpoint.

[2]For on an overview over the literature on transport policy competition between governments see De Borger and Proost (2012).

[3]Yuen et al. (2008) consider a scenario with one gateway, oligopolistic carriers and a congested hinterland, where the gateway chooses prices to maximize the sum of gateway and carrier profits, and the road charges are chosen to maximize the hinterland's welfare. This paper abstracts away from oligopolistic carrier markets.

This paper is organized as follows. In Section 2, we present the basic model. Section 3 investigates pricing competition between two ports under public and private operation. In Section 4, we discuss port privatization and welfare effects. Section 5 concludes. Proofs are relegated to the appendix.

2 The Model

Suppose that there are two countries ($i = 1, 2$), where in each country there is a single port, and there is a third region (which might consist of various countries). We assume the spatial structure as in Figure 1 (similar to Takahahi (2004)) where the two countries are points; the third region is a set of locations on a continuous linear space between two countries with the length being equal to b. Each location within the third region is represented by coordinate value, $x \in [0, b]$, whereby the locations of countries 1 and 2 are respectively $x = 0$ and $x = b$.

In each of the two countries there is demand for a transport service to some destination in the rest of the world, for which the usage of one of the two ports is necessary. We assume that local demand in each of the two countries uses the country's local port. The demand for the transport service of port i coming from its home market is given by

$$D_i^H(p_i) = a_i - p_i. \tag{1}$$

Here, $p_i = c_i + \tau_i$ is the "full price" for a local customer of port i, with c_i being operational costs of a customer using port i (which might include time cost for cargo handling, line haul cost on the trunk line, etc.) and τ_i being the port charge of port i. The customer's operational cost c_i can also be interpreted as an inverse measure of the quality of port i; e.g., the shorter handling times or the lower congestion, the lower the cost of usage for the port customers will be. In most of the analysis, we will concentrate on situations where in equilibrium $D_i^H > 0$, for $i = 1, 2$, which holds if, for instance, a_1 and a_2 are sufficiently large.

The two ports also serve as connecting points (hubs) for trades of the third region (cargos are transshipped between feeder lines and trunk lines). There are b customers with unit demand and valuation v for the transshipment service, distributed uniformly on this interval. Customers from the third region also need to use one of the two ports, and they have constant per distance transportation cost from using one of the two hubs of size t, in addition to p_i.We focus on full coverage equilibria, i.e., v is sufficiently large such that always all customers of the third region buy the service. The customer indifferent between both ports is determined by:

$$c_1 + \tau_1 + t\overline{x} = c_2 + \tau_2 + t(b - \overline{x}) \Leftrightarrow \overline{x} = \frac{bt - c_1 + c_2 - \tau_1 + \tau_2}{2t}.$$

We call demand for port services from the third region "transshipment" demand; for port services of port 1 (2) it is given by $D_1^T(\tau_1, \tau_2)$ $\left(D_2^T(\tau_1, \tau_2)\right)$:

$$D_1^T(\tau_1, \tau_2) = \overline{x}, \quad D_2^T(\tau_1, \tau_2) = b - \overline{x}. \tag{2}$$

To ensure that $D_i^T > 0$ in equilibrium, we assume that the transportation cost t is sufficiently high.[4]

There are two modes how to operate a port: private and public. Under public operation, the port will choose the port charge to maximize the national welfare. National welfare can be written as

$$W_i = \int_{\tau_i + c_i}^{a_i} D_i^H(x)\, dx + \tau_i \left(D_i^H + D_i^T \right) \tag{3}$$

and consists of net benefit of local customers (1st term), revenues from port services to local customers and from transshipment demand (2nd and 3rd terms). Alternatively, a private port chooses the port charge to maximize its profits, $\tau_i \left(D_i^H + D_i^T \right)$.[5]

We consider the following two-stage game. First, the governments in both countries simultaneously decide on the mode of port operation (privatization, or no privatization). Given this, port charges will be determined at stage two, to maximize the objective function implemented by the governments' privatization decision. We look for the subgame perfect equilibrium of the game.

It is important to stress that ports charge the same to the home market customers and to customers from the third region. A public port charging different (i.e., lower) prices to home customers would typically violate the rules of the world trade organization (WTO) for free transit. Article 5 of GATT 1994 states: "With respect to all charges, regulations and formalities in connection with transit, each contracting party shall accord to traffic in transit to or from the territory of any other contracting party treatment no less favorable than the treatment accorded to traffic in transit to or from any third country." Private ports that use price discrimination would in many jurisdiction violate non-discrimination obligations.[6] Hence, in practice most ports seem not to use price discrimination.[7]

3 Pricing competition

This section takes the modes of operation (that is, whether ports are public or private) as given and considers the individual ports' best responses to pricing of the rival port. In a further step, equilibrium port charges are derived and discussed.

[4] Private ports may concentrate on the local market when the market for transships is too competitive. This does not occur when transportation cost t are sufficiently high. See Figure 3 for an illustration of the corresponding critical values of t, where private ports are just indifferent between exploitation of the local and the transship markets or the local markets alone.

[5] Since we assume away the cost for port operation, the normal objective, profit maximization is reduced to revenue maximization. If we assumed that port operation cost was proportional to traffic volume, we could interpret τ_i as port charge net of unit operation cost. In this case, $\tau_i \left(D_i^H + D_i^T \right)$ becomes the profit.

[6] E.g., for Europe the EU Treaty requires in Art. 102: A dominant firm (for which the ports in our model would typically qualify) must not apply "dissimilar conditions to equivalent transactions with other trading parties...".

[7] However, non-tariff discrimination seems to play a role, in particular by imposing additional costs on foreign transit customers. See. e.g. WTO G/C/W/22 (September 30, 2002), p. 4. It is obvious that in our setup, neither a private nor a publicly operated port would have an incentive to raise a customer's cost.

3.1 Ports' best responses

The public port operator chooses the port charge to maximize the national welfare W_i defined by (3) with respect to τ_i. The corresponding optimality condition is

$$\tau_i \frac{\partial D_i^H}{\partial \tau_i} + D_i^T + \tau_i \frac{\partial D_i^T}{\partial \tau_i} = 0. \tag{4}$$

The 1st term, $\tau_i \partial D_i^H / \partial \tau_i$, is the effect associated with the market for local customers that is negative in sign, and the sum of 2nd and 3rd terms, $D_i^T + \tau_i \partial D_i^T / \partial \tau_i$, is the marginal revenue from transshipment. If there is no transshipment, the welfare maximizing charge is $\tau_i = 0$. If the port provides transshipment service, the national welfare can be increased by raising the port charge above zero, which is at the expense of a lower welfare from local customers.

The private port operator chooses the port charge to maximize the revenue, $\tau_i \left(D_i^H + D_i^T \right)$, with respect to τ_i. The corresponding first-order condition is

$$D_i^H + \tau_i \frac{\partial D_i^H}{\partial \tau_i} + D_i^T + \tau_i \frac{\partial D_i^T}{\partial \tau_i} = 0. \tag{5}$$

Since we focus on situations for which $D_i^H > 0$, a comparison of (4) and (5) immediately (and unsurprisingly) shows that, for a given level of the rival's port charge, the public port charge is smaller than the private port charge.[8] Using our specification of the demand functions (1) and (2), we can explicitly calculate the best response function of a public port as[9]

$$T_i^G(\tau_j) = \frac{\tau_j + bt - c_i + c_j}{2(1+t)} \tag{6}$$

with slope

$$\frac{\partial T_i^G}{\partial \tau_j} = \frac{1}{2(1+t)} > 0.$$

Likewise, the best response functions of private ports, $T_i^P(\tau_j)$, and their slopes are

$$T_i^P(\tau_j) = \frac{2a_i t + \tau_j + bt - (1+2t)c_i + c_j}{2(1+2t)} \tag{7}$$

and

$$\frac{\partial T_i^P}{\partial \tau_j} = \frac{1}{2(1+2t)} > 0.$$

[8] One can easily check that the second-order conditions for a maximum are satisfied.

[9] The best response function is independent of local-market size measured by a_i. Recall that the corresponding slopes of local demands are one in absolute values by equation (1). Furthermore, best responses do depend on the slopes of local demands. Specifically, a reduction of the slopes in absolute values would reduce the optimal port charges from the social viewpoint of port countries, which is intuitive, since this means that local markets become more important relative to the market for transshipments.

This establishes that prices of public and private port operators are strategic complements.

Furthermore, the slopes of the public ports' best response functions are steeper than their private counterparts, $\partial T_i^G/\partial\tau_j > \partial T_i^P/\partial\tau_j$. Next, at $\tau_j = 0$, we have $T_i^P(0) > T_i^G(0)$.[10] For a given port charge in the other region, the private operator sets a higher port charge than the public operator when $\tau_j < \overline{\tau}_j$ (which ensures that local demands are strictly positive), where $\overline{\tau}_j = 2a_i(1+t) - bt - (1+2t)c_i - c_j$. Figure 2 illustrates the best response functions of public and private ports.

3.2 Equilibrium port charges

There are four combinations of modes of port operation in countries 1 and 2: Case PP in which ports in both countries are operated privately; case GG in which ports in both countries are operated publicly; case PG in which the port in country 1 is privately operated, while the port in country 2 is publicly operated; and vice versa on case GP. Let us denote the equilibrium port charges in country i for the four cases by $\tau_i^{PP}, \tau_i^{GG}, \tau_i^{PG}, \tau_i^{GP}$, respectively. Explicit expressions of the equilibrium port charges are provided in Appendix A.

We start the analysis of the second stage by investigating the effect of the country size a_i and of the operational costs c_i on the equilibrium port charges.

Lemma 1 *The effect of local market size a_i and of operational costs c_i on equilibrium port charges can be described as:*
(i) if $a_1 < a_2$ and $c_1 = c_2$, then $\tau_1^{PP} < \tau_2^{PP}$ and $\tau_1^{GG} = \tau_2^{GG}$.
(ii) if $a_1 = a_2$ and $c_1 < c_2$, then $\tau_1^{PP} > \tau_2^{PP}$ and $\tau_1^{GG} > \tau_2^{GG}$.
(iii) if $c_1 = c_2$, then $\tau_1^{PG} > \tau_2^{PG}$ and $\tau_1^{GP} < \tau_2^{GP}$.

In words: (i) If both ports are privately operated, the port charge in the country with the larger home market is higher, while the size of the home market has no effect on public port charges if both ports are public (the latter hinges upon the assumption that the slope of the demand function is -1; see Footnote 8). (ii) With symmetric market sizes, a reduction of operational costs at port i leads to an increase of i's port charge. This implies that a port with a larger capacity or a higher quality of infrastructure (implying lower operational costs for its customers) would charge a higher price in equilibrium. (iii) If one of the two ports is privatized, and given identical operational costs, the port charge of the privately operated port exceeds those of its publicly operated counterpart. This is independent of the size of the country measured by a_i: For instance, the private port charge in the smaller country is higher than the public port charge in the larger country.

[10] Using (6) and (7), we have

$$T_i^P(0) - T_i^G(0) = \frac{t\,(2a_i(1+t) - bt - (1+2t)c_i - c_j)}{2(1+3t+2t^2)}.$$

When $\tau_i = T_i^P(0)$, we have $D_i^H = (2a_i(1+t) - bt - (1+2t)c_i - c_j)\,/\,(2(1+2t))$. Applying the condition $D_i^H > 0$, we immediately have $T_i^P(0) - T_i^G(0) > 0$.

Next we examine how different combinations of modes of port operation affect the level of port charges. We assume that two countries are symmetric, $a_1 = a_2 = a_s$ and $c_1 = c_2 = c_s$. This leads to:

Lemma 2 *When the two countries are symmetric, the following relations hold:*

$$\tau_1^{PP} > \tau_1^{PG} > \tau_1^{GP} > \tau_1^{GG} \text{ and } \tau_2^{PP} > \tau_2^{GP} > \tau_2^{PG} > \tau_2^{GG}.$$

The above results state that port charges tend to be higher as port privatization is more prevalent. Note that, even though the operator is unchanged, the port charge is higher when the rival port is private ($\tau_1^{PP} > \tau_1^{PG}$ and $\tau_1^{GP} > \tau_1^{GG}$). This is due to the strategic complementarity in pricing decisions. Based on these results, we illustrate in Figure 3 the best response functions and how the port charges differ in equilibrium for the different modes of operation.

4 Welfare effects of port privatization

This section is separated into three parts. The first part derives and discusses equilibrium port operations, while the second part identifies the welfare effects of port privatization. The effect of asymmetries in country sizes on port operations is identified in the third part.

4.1 Privatization as equilibrium policy choice

We turn to the first stage of the game, the selection of modes of port operation by the governments. By doing so, we identify the conditions under which each of the four cases, PP, PG, GP, GG is realized in a subgame perfect equilibrium. Governments choose simultaneously whether to operate their port publicly, or whether to privatize them. Letting $W_i^{PP}, W_i^{GG}, W_i^{PG}, W_i^{GP}$ denote the national welfares for the above four cases, which are obtained by substituting equilibrium port charges into (3), the countries' pay-off matrix can be written as:

	P	G
P	(W_1^{PP}, W_2^{PP})	(W_1^{PG}, W_2^{PG})
G	(W_1^{GP}, W_2^{GP})	(W_1^{GG}, W_2^{GG})

We will find that for large parameter regions, countries will have an incentive to privatize their ports. The reason why privatization can ever increase national welfare and can therefore be part of an equilibrium stems from the strategic interaction in the transshipment market. Port charges are higher under privatization and they are strategic complements. Therefore, privatizing at stage one is a valuable pre-commitment to set higher port charges at stage two. To this, the best response of the other port (whether private of public) is to set a higher port charge, too. Thus, a government can expect much higher prices if it privatizes at stage one.

This leads to a much better exploitation of the third region via the transshipment market, but to a lower consumer surplus in the national market. If the former outweighs the latter, privatization is welfare increasing and therefore the optimal policy choice.

It is important to stress that the exploitation of the third region is not sufficient to derive this result. The presence of competition, or strategic interaction with other country, is essential. To understand this, consider a port that faces no competition. If the port is private, the operator chooses the profit maximizing port charge. On the other hand, the public port operator chooses the national welfare maximizing port charge. In this setting, by definition, national welfare must be higher in the case of the public port. There is no gain from privatization absent strategic interaction.

We first derive the equilibrium results for the choice of the mode of operation for the symmetric case, $a_1 = a_2 = a_s$ and $c_1 = c_2 = c_s$. To understand the equilibrium outcomes, it is useful to characterize the circumstances under which a country is just indifferent between private or public port operations, given the choice of the other country. This will depend on the profitability of the transshipment market, determined by t, and the size of the home markets (a_s) relative to the size of the transshipment market (b), which we measure by $\widehat{a}_s := \frac{2(a_s-c)}{b}$. If country 1 decided at stage one to privatize, then country 2 is indifferent with respect to private or public port operation if

$$\begin{aligned} W_2^{PG}(\widehat{a}_s, t) &= W_2^{PP}(\widehat{a}_s, t) \Rightarrow \\ \widehat{a}_s &= a_s^{PPGP} = \frac{3 + 4t(5 + 4t(3 + 2t(2 + t)))}{1 + 16t(1 + t)^2(1 + 2t)}. \end{aligned}$$

For the case that country 1 chose public port operations, the indifference condition is

$$\begin{aligned} W_2^{GG}(\widehat{a}_s, t) &= W_2^{GP}(\widehat{a}_s, t) \Rightarrow \\ \widehat{a}_s &= a_s^{PGGG} = \frac{3 + 4t(4 + t(7 + 2t(3 + t)))}{2(1 + t)(1 + 2t)(1 + 2t(2 + t))}. \end{aligned}$$

Figure 4 plots these indifference conditions. It illustrates that both are largely downward sloping. To see why this is the case, condsider a point on a_s^{PGGG}. Now imagine that the importance of the home market shrinks. This implies that, if the port is kept public, port charges will remain unchanged (see (6)), but the welfare contribution of the national market becomes less important. Therefore, the government will now opt for privatization since this allows to exploit better the (now relatively more important) transshipment market. Alternatively, consider again a point of a_s^{PGGG} but let the transshipment market become more attractive, i.e., t increases. With such a change the government will now strictly prefer to keep the port public. The reason is that the higher attractiveness of the transshipment market will lead to a steep increase in the private port charge, which will (from the perspective of national welfare) decrease national consumer surplus too much. A similar reasoning holds for a_s^{PPGP}.

Given the two critical values a_s^{PPGP} and a_s^{PGGG}, we can directly identify the subgame perfect privatization decision in Figure 4. We are mainly interested in equilibria in which all fig4s

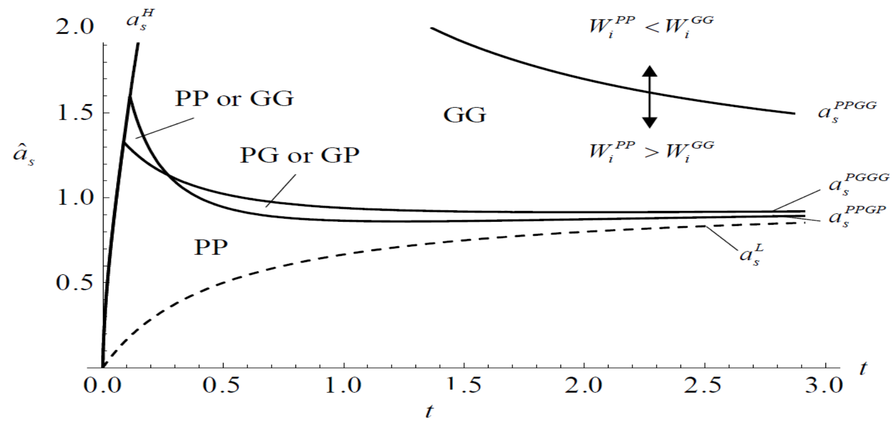

Figure 4 Parameters and equilibrium policy choice

1.pdf

Figure 1: Parameters and equilibrium policy choices

markets (both home markets and the transshipment market) are served, therefore we focus on parameter constellations to the right of the upward sloping line a_s^H and above a_s^L.[11] To the left of a_s^H, the transshipment market is too unattractive, and below a_s^L the home market is too small to be served.[12] The fact that the line a_s^{PGGG} is largely downward sloping, reflects that the national market size and the attractiveness of the transshipment market are in some form "substitutes" for the government, since both favor public port operations. Hence, in the area top-right of Figure 4, keeping the ports public is very attractive indepent of the behavior of the other country, and GG is the equilibrium outcome. Vice versa for low importance of the home market and low attractiveness of the transshipment market, where PP is the equilibrium outcome.

If the home market takes an intermediate size, asymmetric equilibria are possible if t is sufficiently large. If the other country privatized, it is then a best response not to privatize since this would lead to a too strong increase in the port charges. Finally, there are also multiple equilibria possible. If the home market is very important but the transport cost

[11] To construct a_s^H, consider the scenario with one public and one private port. Then calculate the claimed equilibrium which implies that all markets are served. Now calculate the deviation profit that results if the private port would deviate to serving only its home market. The critical value of t which renders this deviation unprofitable is given by the upward sloping line in Figure 3 and is given by:

$$a_s^H = 2\frac{8t\,(1+t)\,(1+2t)(3+2t) + (3+2t)\,(3+4t\,(3+2t))\,\sqrt{2}\sqrt{t\,(1+2t)}}{9+8t\,(5+4t\,(2+t))}$$

A similar line can be constructed for the case of two private ports. The critical value of t is to the left of a_s^H. $a_s^L = \frac{2t}{1+2t}$, which is obtained by solving $q_i^H = 0$. All calculations are available from the authors upon request.

[12] Therefore, below a_s^L the subgame perfect outcome is PP. To the left of a_s^H, our conjecture is that no equillibrium in pure strategies exists.

very small, keeping the port public too is an optimal response, given the large importance of local consumer surplus. However, if the other country had privatized, following suit is optimal: there is a positive gain in terms of better exploiting the transshipment market, but since t is very small, the price increase will be small, too.

These findings discussed for Figure 4 can be made precise in the following proposition.

Proposition 1 *Assume that countries are symmetric and that the transshipment market is sufficiently attractive, $\widehat{a}_s < a_s^H$. (i) For $\widehat{a}_s \leq a_s^{PGGG}$ and $\widehat{a}_s \leq a_s^{PPGP}$, the subgame perfect equilibrium is unique and the outcome is PP. (ii) For $\widehat{a}_s \geq a_s^{PPGP}$ and $\widehat{a}_s \geq a_s^{PGGG}$, the subgame perfect equilibrium is unique and the outcome is GG. (iii) For t sufficiently large, $a_s^{PPGP} < a_s^{PGGG}$. Then, if $\widehat{a}_s$ falls in this range, $a_s^{PPGP} < \widehat{a}_s < a_s^{PGGG}$, the equilibrium outcome is PG or GP. (iv) For low values of t, $a_s^{PPGP} \geq a_s^{PGGG}$. Then, if $\widehat{a}_s$ falls in this range, $a_s^{PGGG} < \widehat{a}_s < a_s^{PPGP}$, the equilibrium outcome is GG or PP.*

4.2 Welfare effects

The previous section has shown that privatization can occur as an equilibrium choice of a welfare maximizing government. Obviously, this need not imply that providing governments with the option to privatize must increase total welfare of both countries. To analyze this we need to compare national welfare levels under PP and GG, W_i^{PP} and W_i^{GG}:

$$W_i^{PP} - W_i^{GG} = \frac{2t^2\left((a_s - c_s)(1+2t) - bt\right)\left(\frac{b(1+4t+2t^2)}{2t} - (a_s - c_s)(1+2t)\right)}{(1+2t)^2(1+4t)^2}. \tag{8}$$

Then we derive the following:

$$W_i^{PP} > W_i^{GG} \iff a_s^L < \widehat{a}_s < a_s^{PPGG}, \tag{9}$$

where $a_s^{PPGG} = \left(1+4t+2t^2\right)/t\,(1+2t)$. The first inequality is always satisfied if $D_i^H > 0$. Figure 4 plots the curve, a_s^{PPGG}, which lies above the maximum of a_s^{PPGP} and a_s^{PGGG}.[13] In other words, the parameter region for case PP to be the outcome of a subgame perfect equilibrium is a strict subset of the region in which $W_i^{PP} > W_i^{GG}$ holds. This directly implies:

Proposition 2 *Suppose that the two countries are symmetric. (i) Whenever privatization PP is a subgame perfect equilibrium of the game, national welfare is higher in both countries, compared to GG, i.e., a situation where both ports remain public. (ii) If the size of the home market, measured by $\widehat{a}_s$, takes on intermediate values in the non-empty range $\left[\max\left\{a_s^{PPGP}, a_s^{PGGG}\right\}, a_s^{PPGG}\right]$, in equilibrium governments decide not to privatize, while both countries are better off by privatizing their ports.*

[13] To see this, calculate $a_s^{PPGG} - a_s^{PPGP} = \frac{b(1+t)(1+4t)^2(1+8t(1+t))}{2t(1+2t)(1+16t(1+t)^2 2(1+2t))} > 0$.

The first part of the proposition implies that providing the governments with the option to privatize, even if they cannot coordinate this decision, increases welfare of both countries. The second part states that their individual incentive to privatize is too small: if the countries could coordinate, they would do so only in order to more often privatize the port infrastructure.

To understand the first part, i.e., why privatization is beneficial, we take a closer look at the relations between port charges and the national welfare. Differentiating (3) with respect to the rival port charge, τ_j, yields

$$\frac{\partial W_i}{\partial \tau_j} = \tau_i \frac{\partial D_i^T}{\partial \tau_j} > 0. \tag{10}$$

An increase in τ_j induces larger transship demand in port i ($\partial D_i^T / \partial \tau_j > 0$), thereby welfare of country i increases.

Based on this result, Figure 5 shows country 1's indifference curves, the locus of combinations of (τ_1, τ_2) that give the same level of national welfare. These indifference curves are upward-sloping for $\tau_1 > T_1^G(\tau_2)$ and downward-sloping for $\tau_1 < T_1^G(\tau_2)$.[14] The welfare level of country 1 is larger since the curve lies to the right (see (10)). Suppose that the rival's port charges are given by τ_2^{PP} and τ_2^{GG} under PP and GG in Figure 5. The best response of country 1 would be $T_1^P(\tau_2^{PP})$ and $T_1^G(\tau_2^{GG})$, thereby pricing equilibria are attained at points P and G in the figure, respectively. The curves W_1^{PP} and W_1^{GG} correspond to these equilibria. In the case of Figure 5, the national welfare of country i under PP is larger than that under GG, since the curves W_1^{PP} lies to the right of W_1^{GG}. Although the national welfare is not maximized at the point P in response to τ_2^{PP}, the point is better than the point G where the welfare is maximized in response to τ_2^{GG}. Privatization of the two ports leads to higher port charges in both countries 1 and 2. In other words, the decision to privatize becomes a commitment to set higher port charge. The two countries enjoy higher welfare at the expense of the third region using transshipment service at one of two ports.

National welfare is not increased by privatization if the size of local demand (transship demand) is relatively large (small) as suggested by (9). In this case, the contribution of the revenue from transshipment in the national welfare is relatively small. The increase in the port charge by privatization does therefore not generate sufficiently large revenues to offset the loss in local customers' welfare in this situation.

That there is an excessive national incentive to keep the ports public results from a simple externality. The decision to privatize has three (direct) welfare effects: (i) It reduces welfare from the own national market, (ii) it increases the own profits from the transshipment market, and (iii) it increases the other countries profits from the transshipment market. Since the individual decision is based only on effects (i) and (ii), the individual incentive to privatize falls short of the joint benefit from doing so.

[14] On the indifference curve, $(\partial W_1/\partial \tau_1)\, d\tau_1 + (\partial W_1/\partial \tau_2)\, d\tau_2 = 0$ should hold. The slope of the curve is $d\tau_1/d\tau_2 = -\left(\partial W_1/\partial \tau_2\right) / \left(\partial W_1/\partial \tau_1\right)$. The numerator of the right-hand side is positive based on (10). On the other hand, the denominator depend on the level of the port charge: since W_1 is maximized at $\tau_1 = T_1^G(\tau_2)$, $\partial W_1/\partial \tau_1$ is positive if τ_1 is smaller than $T_1^G(\tau_2)$ and vice versa.

4.3 Effect of asymmetries between countries

We next consider a situation where the two countries are asymmetric in country size. Without loss of generality, we assume that country 2 is larger. The asymmetry is represented by setting $a_1 = a_s - \rho, a_2 = a_s + \rho$, where $\rho \geq 0$. This setting ensures that total size of the economy is unchanged while asymmetry in size changes. Investigating the condition for each case yields the following result.

Proposition 3 *Suppose that the home market of country 2 is larger than that of country 1. As asymmetry in country size (ρ) increases,*
(i) the case PG is more likely to emerge in equilibrium,
(ii) the cases PP, GG, and GP are less likely to emerge in equilibrium.

The equilibrium with a private port in the smaller country and public port in the larger country is more likely to emerge when the asymmetry in country sizes increases. In the smaller country, the revenue from transshipment makes a relatively large contribution to national welfare. Thereby, the smaller country tends to choose private port operation. This result is consistent with the observations that Busan and Singapore, which are located in small countries, are active in attracting private investment in port development.

Proposition 4 *Suppose that the home market of country 2 is larger than that of country 1. When case PG emerges in equilibrium, both countries attain higher national welfare than in case GG.*

In case PG, country 1 chooses to privatize and this choice also benefits country 2: Due to strategic complementarity, country 2 sets a higher port charge in response to the private port charge in country 1, which leads to higher national welfare in country 2.

5 Conclusions

This paper shows that welfare maximizing governments may choose private operation of their ports in equilibrium, and that national welfare under private port operation can be larger than in the case of public port operation. Choosing private port operation can be perceived as a commitment to charge higher prices; since port charges are strategic complements, the opportunity to commit to higher prices by delegating the pricing decision to a private port operator can be mutually beneficial for port countries. However, a non-cooperative choice of the mode of port operation will lead to too little privatization of port operations since each government does not account for the benefits from privatization to accrue to the other country. Privatization as such is clearly harmful from the viewpoint of the international transshipment market, since its only aim is to better exploit the transshipment customers.

For public policy discussion, our paper implies an additional argument for privatizing port infrastructure, in addition to the well understood argument that private operation might imply lower cost than public operation. Whenever there is a significant transshipment demand from outside the own jurisdiction, from a purely national perspective, a national government should consider privatization. This is true even though privatization as such (i.e., with no cost effect) tends to lead to higher prices and therefore lower domestic consumer surplus.

The gain in national welfare arises in form of larger profits of the port operator. This might be viewed as an undesirable distributional effect within the port country. This distributional effect can, however, easily be avoided if the port operation is privatized in a standard auction (e.g., English auction). Since auction payments are sunk costs for the operator, none of our results would be affected (which would obviously not be true if one would use a non-lump sum tax to correct for the distributional effects). In addition, for national governments with important port facilities it can be useful to coordinate their privatization decision, to overcome the problem of the excessive individual incentive to keep the ports public.

>From the point of view of the transshipment market, the opposite holds true. Clearly, customers from abroad benefit if a port is left public, since public charges are lower, because the operator wants to be soft on national customers. In particular, a coordination of port countries to jointly privatize their hubs should be of concern to customers from the transshipment market.

This paper introduces a number of assumptions to simplify the analysis. First, we assume that perfect competition persists in the carrier market, which might not be compatible with the presence of mega-carriers observed in reality. Second, we ignore scale economies in port operation, which is a driving force behind the adoption of hub-spoke system. It would be useful to examine the effect carrier market power and scale economies on the consequences of transshipment routes and port competition, and the resulting implications on privatization.[15] It may also be beneficial to consider some practical aspects in port development: such as investment in port facilities; intra-port competition where two or more different terminal operators provide the service within the same port; behavior of mega-terminal operators serving at many different ports in the world and so forth.

Appendix A: Equilibrium port charges

Case PP: Equilibrium port charges in the Case PP is the solution for the system of equations, $\left\{\tau_1^{PP} = T_1^P(\tau_2^{PP}), \tau_2^{PP} = T_2^P(\tau_1^{PP})\right\}$. Using (7), we have

$$\tau_1^{PP} = \frac{4a_1t(2t+1) + 2a_2t + bt(4t+3) - c_1(1+8t(1+t)) + c_2(1+2t)}{(4t+1)(4t+3)}, \quad \text{(A1a)}$$

$$\tau_2^{PP} = \frac{4a_2t(2t+1) + 2a_1t + bt(4t+3) + c_1(1+2t) - c_2(1+8t(1+t))}{(4t+1)(4t+3)}. \quad \text{(A1b)}$$

[15] Czerny et al. (2012) analyze the relationship between route choices and scale economies in the context of airline alliances and mergers. The framework developed by Mori and Nishikimi (2002) may also be useful for the analysis of these types of problems.

Case GG:

$$\tau_1^{GG} = \frac{bt(2t+3)-(c_1-c_2)(2t+1)}{4t(t+2)+3}, \tag{A2a}$$

$$\tau_2^{GG} = \frac{bt(2t+3)-(c_2-c_1)(2t+1)}{4t(t+2)+3}. \tag{A2b}$$

Case PG:

$$\tau_1^{PG} = \frac{4a_1t(t+1)+bt(2t+3)-c_1\left(4t^2+6t+1\right)+c_2(2t+1)}{4t(2t+3)+3}, \tag{A3a}$$

$$\tau_2^{PG} = \frac{2t\left(a_1+c_1-2c_2\right)+bt(4t+3)+c_1-c_2}{4t(2t+3)+3}. \tag{A3b}$$

Case GP:

$$\tau_1^{GP} = \frac{2t\left(a_2-2c_1+c_2\right)+bt(4t+3)-c_1+c_2}{4t(2t+3)+3}, \tag{A4a}$$

$$\tau_2^{GP} = \frac{4a_2t(t+1)+bt(2t+3)-c_2\left(4t^2+6t+1\right)+c_1(2t+1)}{4t(2t+3)+3}. \tag{A4b}$$

Appendix B: Proofs

Lemma 1

Using (A1)-(A4) in the Appendix A, we have

$$\tau_1^{PP}-\tau_2^{PP} = \frac{2\left((a_1-a_2)t-(c_1-c_2)\left(t+1\right)\right)}{4t+3} \tag{B1}$$

$$\tau_1^{GG}-\tau_2^{GG} = \frac{2(c_2-c_1)(2t+1)}{4t(t+2)+3} \tag{B2}$$

$$\tau_1^{PG}-\tau_2^{PG} = \frac{2\left(a_1(2t+1)t-bt^2-c_1\left(2t^2+4t+1\right)+3c_2t+c_2\right)}{8t^2+12t+3}. \tag{B3}$$

Part (i) can be immediately shown by setting $c_1 = c_2$ and $a_1 < a_2$ in (B1) and (B2). Part (ii) can be shown in a similar way. To establish part (iii), note that $c_1 = c_2$ implies that the numerator of (B3) becomes $2t((a_1-c_1)(2t+1)-bt)$, which is positive as long as $D_1^H > 0$. ■

Lemma 2

Substituting $a_1 = a_2 = a_s$ and $c_1 = c_2 = c_s$ into (A1a)-(A4a) yields:

$$\tau_1^{PP}-\tau_1^{PG} = \frac{2t\left((a_s-c_s)(1+2t)-bt\right)}{(1+4t)(3+4t(3+2t))},$$

$$\tau_1^{PG}-\tau_1^{GP} = \frac{2t\left((a_s-c_s)(1+2t)-bt\right)}{3+4t(3+2t)},$$

$$\tau_1^{GP}-\tau_1^{GG} = \frac{2t\left((a_s-c_s)(1+2t)-bt\right)}{(1+2t)(3+4t(3+2t))}.$$

It turns out that the signs of the right-hand sides of the above equations all depend on that of $(a_s - c_s)(1+2t) - bt$. To determine the sign, we again use the condition $D_i^H > 0$. Substituting τ_i^{PP}, τ_i^{PG},$\tau_i^{GP}$and τ_i^{GG} in symmetric case for D_i^H, we see that $D_i^H > 0$ is equivalent to $(a_s - c_s)(1+2t) - bt > 0$. Applying this inequality to the above, we have $\tau_1^{GG} < \tau_1^{GP} < \tau_1^{PG} < \tau_1^{PP}$. Since two countries are symmetric, $\tau_1^{PP} = \tau_2^{PP}, \tau_1^{GG} = \tau_2^{GG}, \tau_1^{PG} = \tau_2^{GP}$ and $\tau_1^{GP} = \tau_2^{PG}$. This implies that the inequality for the country 2 holds. ■

Proposition 1

Case PP**:** When two countries are symmetric, $W_1^{PP} = W_2^{PP}$ and $W_1^{GP} = W_2^{PG}$ holds true. The conditions, $W_1^{PP} > W_1^{GP}$ and $W_2^{PP} > W_2^{PG}$ are therefore reduced to $W_1^{PP} > W_1^{GP}$, which can be rewritten as (recall the definition $\widehat{a}_s := 2(a_s - c_s)/b$) :

$$a_s^L < \widehat{a}_s < a_s^{PPGP}, \text{ where } a_s^L = \frac{2t}{(1+2t)} \text{ and } a_s^{PPGP} = \frac{3+4t(5+4t(3+2t(2+t)))}{1+16t(1+t)^2(1+2t)}.$$

Note that the condition above is obtained by supposing $D_i^H > 0$, which is equivalent to $a_s^L < \widehat{a}_s$. If $\widehat{a}_s \leq a_s^L$, $D_i^H = 0$, and the national welfare is reduced to the revenue from transship market. In this case, the national welfare maximization is equivalent to revenue maximization. This situation is also regarded as private operation. So the condition for case PP is simply $\widehat{a}_s < a_s^{PPGP}$.

Case GG**:** The condition for this case is $W_1^{GG} > W_1^{PG}$. In the same way as above, we have the following condition

$$a_s^{PGGG} < \widehat{a}_s, \text{ where } a_s^{PGGG} = \frac{3+4t(4+t(7+2t(3+t)))}{2(1+t)(1+2t)(1+2t(2+t))}$$

Case PG **or** GP**:** The conditions for this case are $W_1^{PP} < W_1^{GP}$ and $W_1^{PG} > W_1^{GG}$, which are equivalent to

$$a_s^{PPGP} < \widehat{a}_s < a_s^{PGGG}.$$

■

Proposition 3

First, we derive the conditions for each case to emerge in equilibrium.

Case PP**:** The conditions, $W_1^{PP} > W_1^{GP}$ and $W_2^{PP} > W_2^{PG}$, are respectively equivalent to $a_1^L < \widehat{a}_s < \ a_1^{PPGP}$ and $a_2^L < \widehat{a}_s < \ a_2^{PPPG}$, where

$$a_1^L = 2\frac{t(3+4t)+(3+14t+8t^2)\frac{\rho}{b}}{3+10t+8t^2} \tag{B4}$$

$$\begin{aligned} a_1^{PPGP} &= \frac{(4t+3)(4t(4t(2t(t+2)+3)+5)+3)}{(4t+3)\left(16t(2t+1)(t+1)^2+1\right)} \\ &\quad + \frac{2(4t+1)(8t(2t(t(2t+7)+8)+7)+9)\frac{\rho}{b}}{(4t+3)\left(16t(2t+1)(t+1)^2+1\right)} \end{aligned} \tag{B5}$$

$$a_2^L = 2\frac{t(3+4t)-(3+14t+8t^2)\frac{\rho}{b}}{3+10t+8t^2} \tag{B6}$$

$$\begin{aligned} a_2^{PPPG} &= \frac{(4t+3)(4t(4t(2t(t+2)+3)+5)+3)}{(4t+3)\left(16t(2t+1)(t+1)^2+1\right)} \\ &\quad - \frac{2(4t+1)(8t(2t(t(2t+7)+8)+7)+9)\frac{\rho}{b}}{(4t+3)\left(16t(2t+1)(t+1)^2+1\right)}. \end{aligned} \tag{11}$$

It is easily shown that $a_2^L < a_1^L$ and $\ a_2^{PPPG} < \ a_1^{PPGP}$ holds true, thereby the above conditions are reduced to $a_1^L < \widehat{a}_s < a_2^{PPPG}$.

Case GG**:** $W_1^{GG} > W_1^{PG}$ and $W_2^{GG} > W_2^{GP}$ are respectively rewritten as $a_1^{PGGG} < \widehat{a}_s$ and $a_2^{GPGG} < \widehat{a}_s$, where

$$a_1^{PGGG} = 2\frac{(4t(t(2t(t+3)+7)+4)+3)}{4(t+1)(2t+1)(2t(t+2)+1)} + 2\frac{\rho}{b} \tag{B8}$$

$$a_2^{GPGG} = 2\frac{(4t(t(2t(t+3)+7)+4)+3)}{4(t+1)(2t+1)(2t(t+2)+1)} - 2\frac{\rho}{b}. \tag{B9}$$

Since $a_2^{GPGG} < a_1^{PGGG}$ hold, the above conditions are reduced to $a_1^{PGGG} < \widehat{a}_s$.

Case PG**:** $W_1^{PG} > W_1^{GG}$ and $W_2^{PG} > W_2^{PP}$ are respectively rewritten as $a_s^L + 2\rho/b < \widehat{a}_s < a_1^{PGGG}$ and $a_2^{PPPG} < \widehat{a}_s$, which are reduced to $a_2^{PPPG} < \widehat{a}_s < a_1^{PGGG}$. Equilibrium of Case PG does not exist when $a_2^{PPPG} > a_1^{PGGG}$.

Case GP**:** $W_1^{GP} > W_1^{PP}$ and $W_2^{GP} > W_2^{GG}$ are respectively rewritten as $a_1^{PPGP} < \widehat{a}_s$ and $a_s^L - 2\rho/b < \widehat{a}_s < a_2^{GPGG}$, which are reduced to $a_1^{PPGP} < \widehat{a}_s < a_2^{GPGG}$. Equilibrium of Case GP does not exist when $a_1^{PPGP} > a_2^{GPGG}$.

(i) From (B8), the upper bound of the region of case PG, a_1^{PGGG}, is increasing with ρ, while the lower bound, a_2^{PPPG} is decreasing with ρ from (B7). Thus, the parameter range of PG is expanded by the increase in the size difference.

(ii) For case PP, $a_1^L < \widehat{a}_s$ should hold from the condition, $D_i^H > 0$. The region of case PP is reduced by increase in size difference since a_2^{PPPG} is decreasing with ρ. Likewise, the region of case GG is reduced since $\ a_1^{PGGG}$ is increasing in ρ. For case GP, the range $a_2^{GPGG} - a_1^{PPGP}$ is decreasing in ρ. ■

Proposition 4

This proposition is proved by showing that $W_1^{PG} > W_1^{GG}$ and $W_2^{PG} > W_2^{GG}$ hold when Case PG emerges in equilibrium. The first inequality is an equilibrium condition for Case

PG. For country 2, $W_2^{PG} > W_2^{GG}$ is equivalent to $a_1^L + 2\rho/b < \widehat{a}_s$, which is satisfied when the condition $W_1^{PG} > W_1^{GG}$ holds (see proof of Proposition 5 above). ■

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