SEAPORT COMPETITION AND STRATEGIC INVESTMENT IN ACCESSIBILITY

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ABSTRACT

We investigate strategic investment decisions of local governments on inland transportation infrastructure in the context of seaport competition. We consider two seaports with their respective catchment areas and a common hinterland for which seaports compete. The two seaports and the common hinterland belong to three independent local governments, each determining the level of investment for its own inland transportation system. We find: (i) increasing investment in the hinterland lowers charges at both ports; and (ii) increasing investment in a port's catchment area will cause severer reduction in charge at its port than at the rival port. We also examine the non-cooperative optimal investment decisions and equilibrium investment levels under various coalitions.

Keywords: Seaport Competition; Inland Accessibility; Strategic Investment; Coordination

1 INTRODUCTION

As a node in the global supply "chain" (Heaver, 2002), a port connects its hinterland – both the local and interior (inland) regions – to the rest of the world by an intermodal transport network. Talley and Ng (2013) deduce that determinants of port choice are also determinants of maritime transport chain choice. Among these determinants, hinterland accessibility is of major concern. It is argued that hinterland accessibility in particular has been one of the most influential factors of seaport competition (e.g. Notteboom, 1997; Kreukels and Wever, 1998; Fleming and Baird, 1999; Heaver, 2006). Empirical studies on major container ports in China and the Asia-Pacific region have found port-hinterland connection as a key factor in determining port competitiveness and productivity (Yuen et al., 2012). Wan et al. (2012, 2013) have found negative correlation between local road congestion and throughput and productivity of sampled container ports in the U.S.

As it is the intermodal chains rather than individual ports that compete (Suykens and Van De Voorde, 1998), seaport competition has been largely affected by the transportation infrastructure around the port as well as the transportation system in the inland. Consequently, plans on local transport infrastructure improvements, such as investment in road capacity, rail system and dedicated cargo corridors, are critical for local governments of major seaport cities as well as inland regions where shippers and consignees locate. Jula and Leachman (2011) study the allocation of import volume between San Pedro Bay Ports (i.e. Los Angelus and Long Beach ports) and other major ports in the U.S. and find that adequate port and landside infrastructure plays a significant role for San Pedro Bay Ports to maintain competitiveness.

Theoretical works discussing the interplay between ports and their landside accessibility are emerging (see De Borger and Proost, 2012, for a comprehensive literature review). One stream of the literature studies a single intermodal chain. Yuen et al. (2008) models a gateway port and a local road connecting the port to the hinterland and investigates the effects of congestion pricing implemented at the port on the hinterland's optimal road pricing, road congestion and social welfare. De Borger and De Bruyne (2011) examine the impact of vertical integration between terminal operators and trucking firms on optimal road toll and port charge, allowing trucking firms to possess market power. The other stream focuses on transport facility investment in the context of seaport or airport competition. De Borger et al. (2008), Zhang (2008), and Wan and Zhang (2013) study the impact of urban road or cargo corridor expansion on the performance of competing seaports. De Borger and Van Dender (2006) and Basso and Zhang (2007) study the investment decisions of two congestible but competing port facilities. The major difference between these two papers is that the former assumes ports face demand from final users (e.g. shippers and passengers) directly, while the later incorporates the vertical structure between the upstream ports and downstream carriers which in turn face demands from final users. One issue which has been overlooked by those papers is that transport infrastructure investment decisions made by individual local governments can affect the well-being of other port regions as well as the inland region through the mechanism of port competition. In the literature of seaport competition, to our knowledge, there is little work investigating the strategic behaviors of and interactions among seaport regions and inland region when making infrastructure investment decisions.

Thus, the focus of the present paper is the strategic investment decisions of local governments on local as well as inland transportation infrastructure in the context of seaport competition. In particular, we consider two seaports with their respective captive catchment areas and a common hinterland for which the seaports compete in prices. The two seaports and the common hinterland belong to three independent local governments, each determining the level of investment for its own regional transportation system. Based on this model, we answer the following questions: (1) how do infrastructure investment decisions affect port competitiveness? (2) How does transport infrastructure improvement affect each region's welfare? (3) How do optimal investment decisions look like under various forms of coordination (coalitions) among local governments? Although some the aforementioned analytical papers also consider duopoly ports competing for a common hinterland, they focus on the competition and welfare effects of road or corridor expansions on the port regions while abstracting away the infrastructure decision of the common hinterland. Our setting is closest to Takahashi (2004) and Czerny and Hoffler (2013), but there are a few major differences: (1) Takahashi does not care about investment decision of the inland region and assume local governments make both price and investment decisions; (2) Czerny and Hoffler focus on port privatization games and ignore facility investment decisions; and (3) the present paper is the first one to examine the infrastructure investment rules under various forms of coordination among local governments of the seaport regions and the inland region.

Our main findings are as follows. Increasing investment in the common hinterland lowers charges of both competing ports. Increasing investment in the captive catchment area of a certain port will cause severer reduction in its port charge than that of the rival port. As a result, an increase in investment in the port region will reduce the welfare of the rival port region but improve the welfare of the common inland region. However, an increase in investment in the inland region will harm the port region with poorer accessibility. We also examine the non-cooperative optimal investment decisions made by local governments as well as the equilibrium investment rules under various coalitions of local governments. In general, for port regions, the incentive of infrastructure investment is the lowest when two port regions collude. They will invest more once at least one of them colludes with the inland region. The inland region, on the other hand, always has higher incentive to invest at lower level of coordination.

The rest of the paper is organized as below. We present the basic model in Section 2. In Section 3, we derive the pricing decision of public seaports and the non-cooperative investment decisions of local governments are derived in Section 4. Section 5 compares the infrastructure decision in non-cooperative scenario with three forms of coalitions among local governments.

2 THE MODEL

We consider a linear continent, with three countries, *B*, *I* and *N*. Countries *B* and *N* have ports, but country *I* does not (Figure 1). The ports are non-congested regarding ship traffic and cargo handling and they deliver the cargoes right in the frontier between their countries and country *I*. We put the origin of coordinates at the boundary between port *B* and country *I*, and country *I* has a length of *d*.

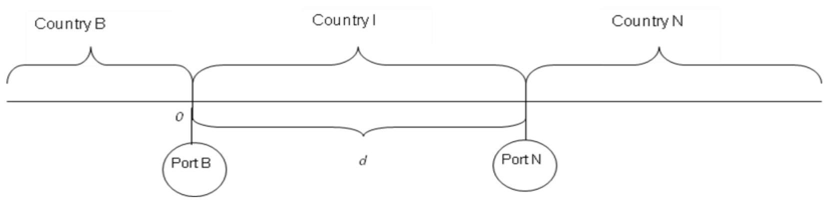

Figure 1 Basic model

For simplicity, we assume that countries *B* and *N* start from the boundary points of country *I* and extent infinitely on the line. In all three countries, shippers, i.e. people or firms that want something shipped in from abroad, are distributed uniformly with a density of one shipper per unit of length. We assume that all shippers desire the same product and each has a demand to ship one unit of containerized cargoes.

Liners and forwarders bring the containers from abroad into the two ports for a fee, but the shippers are the ones that have to decide through which port the containers enter the continent and pay the port fee. Shippers are sensitive to the congestion time costs in the connection section, and have to pay then for an inland transportation service to bring the container to their address. We assume that the inland transportation costs are t_B, t_I, and t_N, per unit of distance in each country's non-congestible transportation network respectively.

Assume that liners and forwarders behave competitively, and hence bringing the containers into one or the other port costs the same. Thus, we will collapse their action to charge a given fee per container, which is set to zero without further loss of generality. The relevant players in this game then are: the two public ports, governments *B*, *N* and *I* and the shippers.

As for objective functions, private ports will maximize profit; while governments or public ports will maximize regional welfare which should include infrastructure expenditure, port profits and national shipper surplus. Shippers are considered because they contribute to a port's traffic and therefore to their profits. Liners and forwarders will not be considered.

The timing of the game is as follows. In the first stage, governments decide investment in accessibility, that is *t*'s. In the second stage, ports decide on prices to maximize a weighted average of profits and consumer surplus. Finally, shippers decide whether they will demand the product or not, and which port to use. This defines the catchment areas of each port (and the market size for the forwarders). The game is solved by backward induction and we start with shippers' decisions.

Shippers have unit demands (per unit of time) and derive a gross-benefit of *V* if they get a container; otherwise their benefit is zero. Shippers care for the full price. Consider a shipper located in country *I* (i.e. at $0 < z < d$). If the shipper decides to use port *B* to bring in the container, she derives a full price of $\rho_B = p_B + t_I z$, and net utility of $U_B = V - \rho_B = V - p_B - t_I z$. Similarly, if she uses port *N*, she derives a net-utility: $U_N = V - \rho_N = V - p_N - t_I(d - z)$. Note that ρ_h is the full price, p_h is the port fee (per container), and t_I is the inland transportation cost that shippers from country *I* have to pay.

We assume that every shipper in country *I* gets a container and that both ports bring in containers for country *I*, then the shipper who's indifferent between using either port is given by $\rho_B = \rho_N$, that is $\tilde{z} = d/2 + (p_N - p_B)/2t_I$. This condition also implies that part of country *B* shippers will demand containers as well and those containers will be brought in through the national port. The same goes for *N*. We define z^l as the last shipper on the left side of port *B* who gets a container. Similarly, we define z^r as the last shipper on the right side of port *N* who gets a container. Hence, taking into account the distribution of shippers along the line, the direct demands that each port faces is given by

$$Q_B = \tilde{z} + \left|z^l\right| = \tilde{z} + \frac{V - p_B}{t_B} \quad \text{and} \quad Q_N = (d - \tilde{z}) + (z^r - d) = (d - \tilde{z}) + \frac{V - p_N}{t_N}$$

Replacing $\tilde{z}$, we obtain the following demands

$$Q_B = \frac{d\,t_B + 2V}{2t_B} + \frac{p_N}{2t_I} - \left(\frac{2t_I + t_B}{2t_I t_B}\right) p_B \quad \text{and} \quad Q_N = \frac{d\,t_N + 2V}{2t_N} + \frac{p_B}{2t_I} - \left(\frac{2t_I + t_N}{2t_I t_N}\right) p_N$$

Let $k_B = 1/t_B$, $k_N = 1/t_N$ and $k_I = 1/2t_I$, and then the these demand functions reduce to:

$$Q_B = (d/2) + k_B V - (k_B + k_I) p_B + k_I p_N \quad \text{and} \quad Q_N = (d/2) + k_N V + k_I p_B - (k_N + k_I) p_N \qquad (1)$$

This is a linear demand system with the standard dominance of own-effects over cross-effects, i.e., $\left|-(k_h + k_I)\right| > \left|k_I\right|$ for $h = B, N$, since $k_B, k_N, k_I > 0$. Furthermore, (1) shows that two ports produce substitutes. The substitutability arises due to the presence of country *I*'s shippers who may use either port for their shipment. To see this, recall that a port obtains its business from two markets: the captured national shippers and the overlapping shippers in country *I*. For port *h* ($h = B, N$) the quantity of the captured market may be denoted as Q_{hh}, and that of the overlapping market Q_{hI}. These quantities can be calculated as,

$$\begin{aligned} Q_{BB} &= k_B (V - p_B), \qquad & Q_{BI} &= (d/2) + k_I (p_N - p_B) \\ Q_{NN} &= k_N (V - p_N), \qquad & Q_{NI} &= (d/2) + k_I (p_B - p_N) \end{aligned} \qquad (2)$$

Clearly, we have $Q_{hh} + Q_{hI} = Q_h$. As can be seen from (2), the port demand of a captured market depends only on the price of its own. On the other hand, the port demand of the overlapping market depends on the prices of both ports: here, the two ports offer substitutable services. In particular, with $Q_{BI} + Q_{NI} = d$ – a fixed number – the gain in demand by one port is the loss in demand of the other port, and vice verse. We shall further assume all the four quantities in (2) are positive, implying that $p_B < V$, $p_N < V$, and p_B and p_N are not too different from each other, i.e. $| p_B - p_N | < d/2k_I$.[1]

3 DECISIONS OF PUBLIC PORTS

Consider first that each port decides on its price to maximize regional welfare. This is the case in which the port is publicly operated: the port authority chooses the region's social surplus as its objective. More specifically, region *B*'s welfare is the sum of region *B*'s consumer surplus and the port's profit, minus the infrastructure cost $c_B(k_B)$.

$$W^B(p_B, p_N; k_B, k_I) = CS^B + \pi^B - c_B(k_B) = (k_B / 2)(V - p_B)^2 + p_B Q_B - c_B(k_B) \tag{3}$$

In (3) region *B*'s consumer surplus is calculated as $CS^B = \int_0^{k_B(V-p_B)} [V - p_B - (z/k_B)]dz$, and the port has zero operating cost and so its profit is just equal to revenue $p_B Q_B$. Also note that k_I enters the $W^B(\cdot)$ function via $Q_B(\cdot)$. Similarly, region N's welfare can be expressed as,

$$W^N(p_B, p_N; k_N, k_I) = CS^N + \pi^N - c_N(k_N) = (k_N / 2)(V - p_N)^2 + p_N Q_N - c_N(k_N) \tag{4}$$

The equilibrium port prices are determined by the following first-order conditions:

$$W_B^B \equiv \partial W^B / \partial p_B = 0, \qquad W_N^N \equiv \partial W^N / \partial p_N = 0 \tag{5}$$

The ports' second-order conditions are satisfied: $W_{BB}^B = -k_B - 2k_I < 0$ and $W_{NN}^N = -k_N - 2k_I < 0$ (subscripts again denoting partial derivatives). Further, the equilibrium is unique and stable, as $\Delta_W \equiv W_{BB}^B W_{NN}^N - W_{BN}^B W_{NB}^N = k_B k_N + 2k_B k_I + 2k_N k_I + 3k_I^2 > 0$.

Using $p^B(k_B, k_N, k_I)$ and $p^N(k_B, k_N, k_I)$ to denote the equilibrium port charges, we obtain, by (5), the identities $W_B^B(p^B, p^N; k_B, k_I) \equiv 0$ and $W_N^N(p^B, p^N; k_N, k_I) \equiv 0$. Totally differentiating these identities with respect to k_B yields,

$$p_B^B \equiv \partial p^B(k_B, k_N, k_I) / \partial k_B = -p^B(k_N + 2k_I) / \Delta_W < 0 \tag{6}$$

$$p_B^N \equiv \partial p^N(k_B, k_N, k_I) / \partial k_B = -p^B k_I / \Delta_W < 0 \tag{7}$$

Thus, an increase in k_B will reduce the equilibrium charges of both ports. The intuition behind this result is as follows. First, it can be easily seen that the first-order conditions (5) generate two upward-sloping reaction functions – noting that $W_{BN}^B = W_{NB}^N = k_I > 0$ and so strategy variables

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[1] Q_{BI} and Q_{NI} are both positive if $| p^B - p^N | = (d/2)(| k_N - k_B | / \Delta_W) < (d/2)(1/k_I)$ and we can prove that for any k_I, k_B and k_N > 0 this inequality condition will hold.

p_B and p_N are strategic complements in the port game. Second, an increase in k_B reduces W_B^B, the marginal welfare increment with respect to p_B, thereby shifting port *B*'s reaction function downward. Given that port *N*'s reaction function remains un-shifted, the price equilibrium moves down along *B*'s reaction function, leading to a fall in both p^B and p^N. Moreover, we have

$$p_B^B - p_B^N = -p^B (k_N + k_I)/\Delta_W < 0 \tag{8}$$

Consequently, the reduction in p^B – following an increase in k_B – is greater than the reduction in p^N, reflecting the fact that port *B*'s reaction function is steeper than port *N*'s.

As for the effects of k_I on port charges p^B and p^N, it can be calculated,

$$\begin{aligned} p_I^B &\equiv \partial p^B (k_B, k_N, k_I)/\partial k_I = -(d/2\Delta_W^2)[(k_N + 3k_I)^2 + k_N(k_N - k_B)] \\ p_I^N &\equiv \partial p^N (k_B, k_N, k_I)/\partial k_I = -(d/2\Delta_W^2)[(k_B + 3k_I)^2 + k_B(k_B - k_N)] \end{aligned} \tag{9}$$

And from (9),

$$p_I^B + p_I^N = -(d/2\Delta_W^2)[(k_N + 3k_I)^2 + (k_B + 3k_I)^2 + (k_N - k_B)^2] < 0 \tag{10}$$

Inequality (10) shows that an increase in k_I will reduce the equilibrium charges for at least one port. Further, by (9), an increase in k_I will reduce the equilibrium charges of both ports if and only if $(k_N + 3k_I)^2 + k_N(k_N - k_B) > 0$ and $(k_B + 3k_I)^2 + k_B(k_B - k_N) > 0$, which hold if the two port regions are not too asymmetric. We shall assume this is the case for the remainder of the paper. The above comparative static results are summarized as follows:

Lemma 1: *Assuming public ports, then (i) an increase in k_B reduces the equilibrium charges of both ports – and here, the reduction in p^B is greater than the reduction in p^N. (ii) The effects of an increase in k_N can be similarly given. (iii) An increase in k_I reduces the equilibrium charges of both ports.*

The intuition behind the positive effect of k_B, k_N, and k_I on port charges may be seen as follows. With the present demand and other specifications, the equilibrium port prices can be calculated as,

$$\begin{aligned} p^B(k_B, k_N, k_I) &= \frac{(k_N + 3k_I)d}{2(k_B k_N + 2k_B k_I + 2k_N k_I + 3k_I^2)} \\ p^N(k_B, k_N, k_I) &= \frac{(k_B + 3k_I)d}{2(k_B k_N + 2k_B k_I + 2k_N k_I + 3k_I^2)} \end{aligned} \tag{11}$$

Assuming symmetric equilibrium, (11) reduces to

$$p^B = p^N = \frac{d}{2(k_H + k_I)}, \qquad k_H = k_B = k_N \tag{12}$$

Therefore, essentially an increase in k_B, k_N, or k_I will make the demands more elastic, and thereby reduce the prices that the ports can charge.

4 NON-COOPERATIVE INFRASTRUCTURE EQUILIBRIUM

This section derives the equilibrium infrastructure investments rules when the social planers for the three countries simultaneously choose the level of infrastructure accessibility which in turn affects regional welfare through subsequent port competition. Taking the ports' price decisions into account, a port region's welfare is given by:

$$\phi^H(k_B, k_N, k_I) \equiv W^H(p^B(k_B, k_N, k_I), p^N(k_B, k_N, k_I); k_H, k_I), \; H = B, N \tag{13}$$

Social surplus of region *I*, the inland country, is just equal to its consumer surplus, CS^I, minus the infrastructure cost $c_I(k_I)$:

$$\phi^I(k_B, k_N, k_I) \equiv CS^I(p^B(k_B, k_N, k_I), p^N(k_B, k_N, k_I); k_I) - c_I(k_I) \tag{14}$$

In (14),

$$CS^I = \int_0^{\tilde{z}} [V - p_B - (z/2k_I)]dz + \int_0^{d-\tilde{z}} [V - p_N - (z/2k_I)]dz \tag{15}$$

where $\tilde{z}$ is the shipper of region *I* who is indifferent between using port *B* and using port *N*, and $\tilde{z} = (d/2) + k_I(p_N - p_B)$.

Governments decide on investment in accessibility, that is, the *k*'s. In particular, the non-cooperative infrastructure equilibrium arises when each government chooses its welfare-maximizing infrastructure investment, taking the investment of the other governments as given at the equilibrium value. Specifically, it is characterized by the following first-order conditions,

$$\phi_B^B \equiv \partial\phi^B / \partial k_B = 0, \qquad \phi_N^N \equiv \partial\phi^N / \partial k_N = 0, \qquad \phi_I^I \equiv \partial\phi^I / \partial k_I = 0 \tag{16}$$

It can be shown that both the governments' second-order conditions and the stability condition are satisfied.

We now take a closer look at each of the marginal effects in (16), starting with port region *B*. The effects of k_N on region *N*'s welfare can be similarly analyzed. As indicated earlier, each port derives its revenue from both its own region and the common (competing) inland market. Since the revenue from the regional market represents an internal transfer, the effects of k_B on region *B*'s welfare consist just of the effect on the inland revenue $p_B Q_{BI}$, the effect on the (gross) benefit of *B*'s shippers, and the effect on infrastructure cost. The benefit function of *B*'s shippers is given by $(V+p_B)Q_{BB}/2$, with $Q_{BB}=k_B(V-p_B)$ given by (2). Thus,

$$\phi_B^B=\frac{\partial}{\partial k_B}[(V+p^B)Q_{BB}/2]+\frac{\partial}{\partial k_B}(p^BQ_{BI})-c_B^{'}(k_B) \tag{17}$$

where

$$\frac{\partial}{\partial k_B}[(V+p^B)Q_{BB}/2]=\frac{(V+p^B)(V-p^B)}{2}-k_Bp^Bp_B^B>0 \tag{18}$$

Therefore, an increase in k_B increases the (gross) benefit of *B*'s shippers. According to (18), this improvement consists of two sources: a direct benefit due to less transport friction (cost) – the first term on the right-hand side (RHS) of (18) – and an indirect benefit via the positive effect of price reduction (recall, by (6), $p_B^B\equiv\partial p^B(k_B,k_N,k_I)/\partial k_B<0$). On the other hand,

$$\frac{\partial}{\partial k_B}(p^BQ_{BI})=k_Ip^B\cdot(p_B^N-p_B^B)+Q_{BI}p_B^B \tag{19}$$

where the first term on the RHS of (19) is, by (8), positive: An increase in k_B will reduce the equilibrium charges of both ports but will reduce own port's charge more, thereby improving own port's market share in the inland market. The second term in (19) is negative: an increase in k_B will reduce the port's price and hence its revenue from the inland market. It turns out, after some lengthy calculation, that the negative price effect dominates the positive market-share effect, leading to a negative net effect on the port's revenue from the inland market.

We next consider the effect of k_I on region *I*'s welfare. From (14)-(15) we obtain,

$$\phi_I^I=[\frac{\partial CS^I}{\partial p_B}p_I^B+\frac{\partial CS^I}{\partial p_N}p_I^N]+\frac{\partial CS^I}{\partial k_I}-c_I^{'}(k_I)=[(-Q_{BI})p_I^B+(-Q_{NI})p_I^N]+\frac{Q_{BI}^2+Q_{NI}^2}{4k_I^2}-c_I^{'}(k_I) \tag{20}$$

where both the first and second terms on the RHS of (20) are, by Lemma 1, positive. While the second term reflects the direct effect of an infrastructure improvement, the first term represents the indirect effect of an infrastructure improvement (via its impact on the port charges, which in turn benefits region *I*'s shippers). The two positive terms are balanced against the cost of infrastructure improvement, $c_I^{'}(k_I)$.

The impact of infrastructure investment on other regions can also be derived. In particular, the effect of k_B on region *N*'s welfare can be written as:

$$\phi_B^N\equiv\partial\phi^N/\partial k_B=W_B^Np_B^B=p^Nk_Ip_B^B<0 \tag{21}$$

Intuitively, an increase in k_B will lower port *N*'s profit due to substantial price-cut by port *B*. Although port *N* responses with lower price as well, but since the price reduction from port *B* is larger than port *N*, eventually, the revenue loss from region *I*'s market cannot compensate the surplus gain of shippers' in region *N*. As a result, the welfare of region *N* will decrease. The effect of k_B on region *I*'s welfare:

$$\phi_B^I = \frac{\partial CS^I}{\partial p_B} p_B^B + \frac{\partial CS^I}{\partial p_N} p_B^N = (-Q_{BI}) p_B^B + (-Q_{NI}) p_B^N > 0 \tag{22}$$

Therefore, an increase in k_B will benefit region *I*'s shippers since the port charges of both ports will decrease. Similarly, the effect of k_N on region *B*'s welfare is negative while that on region *I*'s welfare is positive. The effect of k_I on region *B*'s welfare:

$$\phi_I^B \equiv \partial\phi^B / \partial k_I = W_N^B p_I^N + \partial W^B / \partial k_I = p^B k_I p_I^N + p^B (p^N - p^B) \tag{23}$$

The first term of the RHS of (23) is negative, because increasing the acceptability of the inland region leads to lower charge of port *N* so that some inland shippers will switch to port *N*. When the accessibility of region *B* is worse than region *N*, i.e. $k_B < k_N$, port *B* charges higher than port *N* and hence port *N* has competitive advantage over port *B* for inland shippers. Then, improving the accessibility of region *I* enhances this difference between port *B* and port *N* and more inland shippers will use port *N*; as a result, the second term of the RHS of (23) is negative. However, when $k_B > k_N$, we have $p^N > p^B$ and increasing k_I makes port B more attractive to inland shippers and hence the second term of the RHS of (23) will be positive. We can obtain similar comparative static result for the effect of k_I on region *N*'s welfare. The above discussion leads to Proposition 1.

Proposition 1: *Assuming public ports, then (i) an increase in k_B (k_N) reduces the welfare of region N (region B); (ii) an increase in k_B or k_N raises region I's welfare; and (iii) an increase in k_I reduces the welfare of the port region with less accessible infrastructure, while may or may not increase the welfare of the other port region.*

5 INFRASTRUCTURE EQUILIBRIUM UNDER COALITIONS

This section examines the equilibrium infrastructure investment decisions given that the three regions co-operate in various forms. Without loss of generality, we consider three forms of coalitions.

Coalition 1: region B and region N coordinate while region I remains independent

The social planners of regions *B* and *N* choose k_B and k_N together to maximize the joint welfare of these two regions. The joint welfare of two port regions is $\phi^{BN}(k_B, k_N, k_I) \equiv \phi^B(k_B, k_N, k_I) + \phi^N(k_B, k_N, k_I)$. The optimal investment rule is characterized by:

$$\begin{aligned} &\phi_B^{BN} \equiv \partial\phi^B / \partial k_B + \partial\phi^N / \partial k_B = \phi_B^B + \phi_B^N = 0 \\ &\phi_N^{BN} \equiv \partial\phi^B / \partial k_N + \partial\phi^N / \partial k_N = \phi_N^B + \phi_N^N = 0 \\ &\phi_I^I \equiv \partial\phi^I / \partial k_I = \phi_I^I = 0 \end{aligned} \quad (24)$$

From (21) and (24), we can derive that at equilibrium $\phi_B^B > 0$ and $\phi_N^N > 0$. As the governments' second-order conditions are satisfied, for given levels of k_I and k_N, $\phi_{BB}^B < 0$. As a result, given fixed k_I and k_N (or k_B), k_B (or k_N) will be set below the non-cooperative scenario. This is because under coalition 1, the two port regions internalize the negative externality on each other, as improving accessibility will definitely reduce the other port's profit due to price war. Under this coalition, the optimal investment rule for the inland region remains the same as in section 4 by setting equation (20) equal zero.

Coalition 2: region B and region I coordinate while region N remains independent

The social planners of regions *B* and *I* choose k_B and k_I together to maximize the joint welfare of these two regions. The joint welfare of regions *B* and *I* is $\phi^{BI}(k_B, k_N, k_I) \equiv \phi^B(k_B, k_N, k_I) + \phi^I(k_B, k_N, k_I)$. The optimal investment rule is characterized by:

$$\begin{aligned} &\phi_B^{BI} \equiv \partial\phi^B / \partial k_B + \partial\phi^I / \partial k_B = \phi_B^B + \phi_B^I = 0 \\ &\phi_N^N \equiv \partial\phi^N / \partial k_N = \phi_N^N = 0 \\ &\phi_I^{BI} \equiv \partial\phi^B / \partial k_I + \partial\phi^I / \partial k_I = \phi_I^B + \phi_I^I = 0 \end{aligned} \quad (25)$$

From (22) and (25), we can derive that at equilibrium $\phi_B^B < 0$. Therefore, given a fixed k_N and k_I, k_B will be set above the non-cooperative scenario. This is because under coalition 2, regions *B* and *I* internalize the positive impact of better infrastructure in region *B* on the surplus of shippers in region *I* due to lowered port charge. However, the sign of ϕ_I^I depends on the sign of $(-\phi_I^B)$, which is positive unless k_B is substantially larger than k_N as shown in Section 4. Thus, given fixed k_B and k_N, k_I will be set below the non-cooperative scenario unless region *B*'s accessibility is sufficiently better than region *N*. This is caused by taking into account the impact of increasing k_I on the profit of port *B*. The investment rule for region *N* remains the same as in the non-cooperative case.

Coalition 3: all three regions coordinate

The central planner decides k_B, k_N and k_I to maximize the total welfare across all the three regions. The total welfare of the three regions is $\phi^{BNI}(k_B, k_N, k_I) \equiv \phi^B(k_B, k_N, k_I) + \phi^N(k_B, k_N, k_I) + \phi^I(k_B, k_N, k_I)$. The optimal investment rule is characterized by:

$$\begin{aligned}\phi_B^{BNI} &\equiv \partial\phi^B/\partial k_B + \partial\phi^N/\partial k_B + \partial\phi^I/\partial k_B = \phi_B^B + \phi_B^N + \phi_B^I = 0\\ \phi_N^{BNI} &\equiv \partial\phi^B/\partial k_N + \partial\phi^N/\partial k_N + \partial\phi^I/\partial k_N = \phi_N^B + \phi_N^N + \phi_N^I = 0\\ \phi_I^{BNI} &\equiv \partial\phi^B/\partial k_I + \partial\phi^N/\partial k_I + \partial\phi^I/\partial k_I = \phi_I^B + \phi_I^N + \phi_I^I = 0\end{aligned} \tag{26}$$

Where

$$\phi_B^N + \phi_B^I = \frac{-d}{2\Delta_W} p_B^B (k_B k_N + 2k_B k_I + k_N k_I) - Q_{NI} p_B^N > 0,$$

$$\phi_N^B + \phi_N^I = \frac{-d}{2\Delta_W} p_N^N (k_B k_N + 2k_N k_I + k_B k_I) - Q_{BI} p_N^B > 0, \text{ and}$$

$$\phi_I^B + \phi_I^N = k_I (p^B p_I^N + p^N p_I^B) - (p^N - p^B)^2 < 0.$$

Note that though the effect of k_B on region *N*’s welfare is negative while that on region *I*’s welfare is positive, the positive impact on region *I* dominates and hence the net effect on those two regions is positive. Therefore, it is straightforward to show that given fixed k_N and k_I, the optimal k_B in coalition 3 is higher than the non-cooperative scenario. Note that 0 < $\phi_B^N + \phi_B^I$ < ϕ_B^I implies that given fixed k_N and k_I, ϕ_B^B under coalition 3 is larger than ϕ_B^B under coalition 2. Together with $\phi_{BB}^B < 0$, coalition 3 induces less infrastructure investment in region *B* than coalition 2. Similar analysis applies to the investment rule of region *N*.

Let *NC* denotes non-cooperative case and let *C1*, *C2* and *C3* denote coalitions 1, 2 and 3, respectively. Comparing the investment rules of each region under these four cases, we reveal Propositions 2, 3 and 4.

Proposition 2: *Assuming public ports, given fixed levels of k_N and k_I, $k_B^{C1} < k_B^{NC} < k_B^{C3} < k_B^{C2}$. That is, the infrastructure investment of a port region is the lowest if two port regions collude, followed by non-cooperative case, and both cases invest less than the social optimal level (coalition 3). If one port region colludes with the inland region, this port region will overinvest in infrastructure.*

Proposition 3: *Assuming public ports, given fixed levels of k_B and k_I, $k_N^{C1} < k_N^{NC} = k_N^{C2} < k_N^{C3}$. That is, the infrastructure investment of a port region is the lowest if two port regions collude, followed by the cases that the port region does not collude with any other region and makes decision independently. All the three cases invest less than the social optimal level (coalition 3).*

Proposition 4: *Assuming public ports, given fixed levels of k_B and k_N, $k_I^{C3} < k_I^{NC} = k_I^{C1} < k_I^{C2}$ if k_B is substantially larger than k_N; $k_I^{C3} < k_I^{C2} < k_I^{NC} = k_I^{C1}$ otherwise. That is, the infrastructure investment of the inland region is the lowest if all the three regions collude, followed by the case of no collusion with inland region. If one port region colludes with the inland region, the inland region may invest more or less than the non-cooperative case depending on the difference between k_B and k_N.*

One major implication of the above three propositions is that compared with the social optimum (coalition 3), the port regions are likely to underinvest in infrastructure accessibility while the inland region overinvest, given that full coordination among all the three regions is not achieved. The incentive of underinvestment by port regions comes from the ignorance of inland shippers' welfare improvement when port regions increase their infrastructure accessibility. The incentive of overinvestment by inland region comes from the ignorance of port regions' profit loss when inland region increases its infrastructure accessibility. This is especially the case for *NC* and *C1* where region *B* and region *N* are treated symmetrically. In coalition 2, however, where only one port region will collude with the inland region, the port region in collusion will overinvest while the other port region will underinvest.

6 CONCLUDING REMARKS

This study investigates the strategic investment decisions of local governments on inland transportation infrastructure in the context of seaport competition. In particular, we consider two seaports with their respective captive catchment areas and a common hinterland for which the seaports compete. The two seaports and the common hinterland belong to three independent local governments, each determining the level of investment for its own regional transportation system. This setting is different from any work in the literature in the sense that we consider not only two competing seaports but also the infrastructure decision of the common hinterland that the ports compete for.

We find that increasing investment in the common hinterland lowers charges of both competing ports. Increasing investment in the captive catchment area of a certain port will cause severer reduction in its port charge than that of the rival port. As a result, an increase in investment in the port region will reduce the welfare of the rival port region but improve the welfare of the common inland region. However, an increase in investment in the inland region will harm the port region with poorer accessibility. We also examine the non-cooperative optimal investment decisions made by local governments as well as the equilibrium investment levels under various coalitions of local governments. In general, for port regions, the incentive of infrastructure investment is the lowest when two port regions collude. They will invest more once at least one of them colludes with the inland region. The inland region, on the other hand, always has high incentive to invest for low level of coordination.

The focus of the present paper is on public port. However, ownership plays in a key role in port competition (Yuen et al., 2013) and hence a natural extension of this study is to compare with the infrastructure investment rule under the context that seaports are privatized or even owned by foreign companies. Furthermore, it would also be interest to investigate local governments' incentives to form various types of coalitions and predict with the theoretical model whether and in which forms coalition will occur. Issues such as schedule delay cost and congestion cost can also be incorporated into this model in the future.

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