# Port Competition and Hinterland Capacity Investments

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# Overview

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# Issues in sea transport and logistics markets

- For more than ten years, the growth in world seaborne trade is significantly greater than the growth in world GDP (UNCTAD, 2008)
- From a global perspective, asian ports are the most important ones
- Asian ports serve manufacturers located in their own (national) hinterland (e.g. Ducruet, 2006)
- They are in heavy competition for transshipment services (ship-to-quay-to-ship, Baird 2007)
- Private involvement in ports increases (Yuen, Basso and Zhang, 2008)
- Hinterland is used by shippers and cars but not for transshipment services
- Hinterland is frequently congested

# Research question

What's the relationship between the public hinterland and private ports in a context where transshipment services are relevant?

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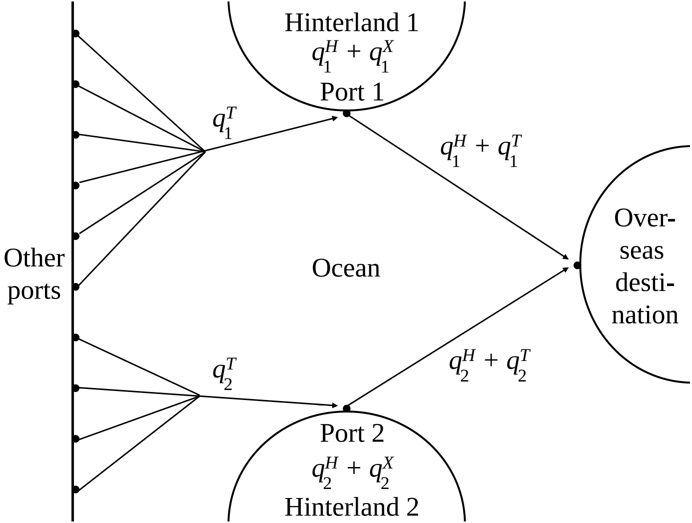
# Literature about the relationship between ports and hinterlands

- De Borger, Proost and van Dender (2005, EER): Congested hinterlands compete for transit services
- De Borger, Dunkerley and Proost (2007, JUE): Similar to 2005, but hinterland capacity choice is also considered
- De Borger, Proost and van Dender (2008, JTEP): Similar to De Borger et al. 2005 and 2007, but private ports and port capacity choice is also considered
- Zhang (2008, ITF working paper): Complementary hinterland infrastructure facilities
- Yuen, Basso and Zhang (2008, JTEP): Vertical structure
- **Our contribution is to consider transshipment services**

# Overview

# The model: network structure



# The model: supply side

- Ports are private, unregulated and uncongested
- Marginal port costs are constant and normalized to zero
- Ports charge a (unit) price $\tau_i \geq 0$ with $i = 1, 2$ to local shippers and for transshipment services
- Market for shipping services is perfectly competitive
- Shippers' costs are fully determined by port charges, hinterland congestion costs, and a road toll $t_i^H$
- Cars' costs are fully determined by hinterland congestion costs and a road toll $t_i^X$
- Hinterland capacity is $k_i \geq 0$ and marginal capacity costs are given by $r > 0$
- Average congestion costs are $C_i = (q_i^H + q_i^X)/k_i$
- Full prices are

$$\rho_i^H = \tau_i + t_i^H + C_i \quad \text{and} \quad \rho_i^X = t_i^X + C_i \tag{1}$$

# The model: demand side

- Benefits of hinterland services, $q_i^H$, and car traffic, $q_i^X$, are

$$B_i^z = a^z q_i^z - \frac{(q_i^z)^2}{2} \tag{2}$$

  with $a^z > 0$ and $z \in \{H, X\}$
- Ports compete for transshipment services according to transport cost a la Hotelling
- Demand for transshipment services hence is

$$D_i^T = \frac{\tau_j - \tau_i + t}{2t} \tag{3}$$

# The model: consumer and total surplus

- Consumer surplus of hinterland $i$ is

$$CS_i = \sum_{z \in \{H,X\}} (B_i^z - \rho_i^z q_i^z) \tag{4}$$

- Total surplus of hinterland $i$ is

$$TS_i = \sum_{z \in \{H,X\}} (B_i^z - q_i^z C_i) + \tau_i D_i^T - rk_i \tag{5}$$

# The model: game structure

We consider a three-stage game:

Stage 1: Jurisdictions/regulators simultaneously choose tolls $t_i^z$ and capacities $k_i$ to maximize national total surplus

Stage 2: Ports simultaneously choose port charges $\tau_i$ to maximize port profits $\tau_i D_i^T$

Stage 3: Shippers, car drivers and customers choose supply and demand

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# National total-surplus maximization

*Setting aside capacity choice*, national total-surplus maximizing behavior is

$$(q_i^{H*}, q_i^{X*}, \tau_i^r(\tau_j)) = \arg \max_{q_i^H, q_i^X, \tau_i} TS_i \tag{6}$$

with

$$\frac{\partial B_i^z}{\partial q_i^z} - \underbrace{\left( C_i + (q_i^{H*} + q_i^{X*}) \frac{\partial C_i}{\partial q_i^z} \right)}_{\text{marginal congestion costs}} = 0 \tag{7}$$

for all $z \in \{H, X\}$ and

$$D_i^T + \tau_i^r \frac{\partial D_i^T}{\partial \tau_i} = 0 \tag{8}$$

Since port charges are unregulated, tolls must be chosen to optimize the use of hinterland capacity *and* the port charge!

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# Third stage

- Inverse demands for hinterland services and car traffic with regard to the full prices, $\rho_i^z$, are $\partial B_i^z / \partial q_i^z$
- The equilibrium conditions are

$$\frac{\partial B_i^H}{\partial q_i^H} - (\tau_i + t_i^H + C_i) = 0 \tag{9}$$

and

$$\frac{\partial B_i^X}{\partial q_i^X} - (t_i^X + C_i) = 0 \tag{10}$$

- Demands as functions of taxes and the port charge, denoted by $D_i^z(t_i^H, t_i^X, \tau_i)$, can be obtained by simultaneously solving these equilibrium conditions

# Second stage

- The port's best responses, indicated by $r$, are

$$\tau_i^r(t_i^H, t_i^X, \tau_j) = \arg\max_{\tau_i} \tau_i(D_i^H + D_i^T). \qquad (11)$$

- The first-order conditions are

$$D_i^H + D_i^T + \tau_i^r \cdot \frac{\partial(D_i^H + D_i^T)}{\partial \tau_i} = 0. \qquad (12)$$

- Simultaneously solving these first-order conditions yields equilibrium port charges, indicated by $N$

# First stage

- Substituting $D_i^H$ for $q_i^H$, $D_i^X$ for $q_i^X$, and $\tau_i^N$ for $\tau_i$ in $TS_i$ gives jurisdiction $i$'s total surplus depending on road taxes $t_i^z$
- jurisdictions' best responses are

$$(t_i^{H\,r}, t_i^{X\,r}) = \arg\max_{t_i^H, t_i^X} TS_i(t_1^H, t_2^H, t_1^X, t_2^X). \tag{13}$$

- The associated first-order conditions are

$$\frac{dTS_i}{dt_i^z} =$$

$$\sum_{m \in \{H,X\}} \left( \frac{\partial B_i^m}{\partial q_i^m} - \frac{\partial C_i}{\partial q_i^m}(D_i^H + D_i^X) - C_i \right) \left( \frac{\partial D_i^m}{\partial t_i^z} + \frac{\partial D_i^m}{\partial \tau_i} \frac{\partial \tau_i^N}{\partial t_i^z} \right)$$

$$+ D_i^T \frac{\partial \tau_i^N}{\partial t_i^z} + \tau_i^N \left( \frac{\partial D_i^T}{\partial \tau_i} \frac{\partial \tau_i^N}{\partial t_i^z} + \frac{\partial D_i^T}{\partial \tau_j} \frac{\partial \tau_j^N}{\partial t_i^z} \right) = 0 \tag{14}$$

# First stage

Simultaneously solving these first-order conditions for tolls yields:

$$t_i^{X,N} = \frac{\partial C_i}{\partial q_i^m}(D_i^H + D_i^X) \tag{15}$$

and

$$t_i^{H,N} = \frac{\partial C_i}{\partial q_i^m}(D_i^H + D_i^X) - \tau_i^N$$
$$-\frac{1}{\frac{\partial D_i^m}{\partial t_i^z} + \frac{\partial D_i^m}{\partial \tau_i}\frac{\partial \tau_i^N}{\partial t_i^z}}\left(D_i^T \frac{\partial \tau_i^N}{\partial t_i^z} + \tau_i^N \left(\frac{\partial D_i^T}{\partial \tau_i}\frac{\partial \tau_i^N}{\partial t_i^z} + \frac{\partial D_i^T}{\partial \tau_j}\frac{\partial \tau_j^N}{\partial t_i^z}\right)\right) \tag{16}$$

$\Rightarrow$ The hinterland shippers' tolls are used to 'control' port charges, which is consistent with the results obtained by Yuen, Basso and Zhang (2008)

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# Conclusions

- (National) Total surplus-maximizing car toll equals marginal external congestion costs
- (National) Total surplus-maximizing road toll for shippers must account for port charges
- The shippers' road toll only is used to optimize transshipment services

# Thank you!