

Responses to the reviewer #1's comments:

We are grateful to Reviewer #1's insightful suggestions and comments.

Reviewer #1:

This study explore a theoretical model to investigate a mixed duopoly competition between a private port and a partially privatized public port. The authors derive the differentiated-goods Cournot equilibrium by two ports as well as that Bertrand equilibrium.

1. In their model, T_i denotes the operational cost of a customer using port i . Originally, as consumers bear the cost, consumer's utility function should include the operation cost. However, in the model, T_i is included into firms' prices and firms can fully levy the operation cost from consumers. As it seems to be quite odd, an appropriate justification is required to the authors.

Response: Thank you for your comment. We are sorry for not explaining the parameter T_i ($i=1,2$) fully to you. T_i refers to the delay cost caused by travel time needed to reach port i or cargo handling in port i , which can also characterize port i 's geographical location or capacity. The larger T_i is, the less capacity port i has and the larger its delay cost is. Thus, the full prices perceived by customers using port i are, respectively:

$$\theta_i = p_i + T_i$$

where p_i is the port charge of port i .

Let T denote the difference (positive or negative) between the delay cost in the two ports, i.e., $T = T_1 - T_2$. Then, the full prices perceived by customers using port i can be rewritten as follows:

$$\begin{aligned}\theta_1 &= p_1 + T \\ \theta_2 &= p_2\end{aligned}$$

As presented by Singh and Vives (1984), consumers using port 1 and 2 maximize a (strictly concave) quadratic utility function as follows:

$$U(q_1, q_2) = \alpha q_1 + \alpha q_2 - \frac{1}{2}(q_1^2 + q_2^2 + 2\beta q_1 q_2)$$

where α is a demand (scale) parameter, q_1 and q_2 denotes the cargo volumes in the port-specific transport chains and the parameter $\beta \in (0,1)$ measures the degree

of horizontal service differentiation between the two ports: a smaller β indicates a larger degree of service differentiation.

Given this specification, the characteristic consumer solves the following problem:

$$\max_{q_1, q_2} U(q_1, q_2) - \theta_1 q_1 - \theta_2 q_2$$

From the first order conditions, it is easy to determine the inverse demand function as follows:

$$\begin{aligned}\theta_1(q_1, q_2) &= \alpha - q_1 - \beta q_2 \\ \theta_2(q_1, q_2) &= \alpha - q_2 - \beta q_1\end{aligned}$$

As a consequence, we have

$$\begin{aligned}p_1(q_1, q_2) &= \alpha - T - q_1 - \beta q_2 \\ p_2(q_1, q_2) &= \alpha - q_2 - \beta q_1\end{aligned}$$

Then, the direct demand function of port i is expressed as:

$$\begin{aligned}q_1(p_1, p_2) &= \frac{p_1 - \beta p_2 + (\beta - 1)\alpha + T}{\beta^2 - 1} \\ q_2(p_1, p_2) &= \frac{p_2 - \beta p_1 + (\beta - 1)\alpha - \beta T}{\beta^2 - 1}\end{aligned}$$

2. The authors should explain the appropriate reason why both Cournot and Bertrand competitions must be examined. Although we can envisage the price competition between ports through port usage fee, we cannot imagine any realistic situations in which ports engage in quantity competition, such as the number of container ships.

Response: Thanks for your comment. We compare the equilibrium statuses where a private port competes with a partial public port with differentiated service in Cournot and Bertrand scenarios. In practice, Cournot competition between two ports is rare since two ports may not adjust their capacities at the same time. Bertrand competition between two ports is quite common and occurs where two ports are competing on price with stable capacity, e.g., in the case of port of Hong Kong (a highly private, but landlord port) competing with the port of Shenzhen (partial public port).

However, the case in which ports engage in Cournot competition has been still examined by many scholars in the field of port operations management. For instance, Chen and Liu (2016) set up a two-period game, allowing two ports first choose their facility investment levels, and then decide their cargo-handling amounts. Cui and Notteboom (2017) compared the equilibrium statuses where a private port competes or cooperates with a partial public port with differentiated service in Cournot, Bertrand and cooperation scenarios. Yip et al. (2014) modeled the effects of Cournot competition on seaport terminal awarding. Chen and Liu (2014) and Liu et al. (2018) considered one port authority and two terminal operators competing in Cournot (or quantity) mode.

Reference

- Chen H.C., Liu S.M. Optimal concession contracts for landlord port authorities to maximize fee revenues. *International Journal of Shipping and Transport Logistics*, 2014, 85: 109-131.
- Chen H.C., Liu S.M. Should ports expand their facilities under congestion and uncertainty. *Transportation Research Part B*, 2016, 85: 109-131.
- Cui H., Notteboom T. Modelling emission control taxes in port areas and port privatization levels in port competition and co-operation subgames. *Transportation Research Part D*, 2017, 56: 110-128.
- Liu S.M., Chen H.S., Han W.Q., Lin Y.H. Optimal concession contracts for landlord port authorities to maximize fee revenues with minimal throughput requirements. *Transportation Research Part E*, 2018, 109: 239-260.
- Yip T.L., Liu J.J., Fu X.W., Feng J.J. Modelling the effects of competition on seaport terminal awarding. *Transport Policy*, 2014, 35: 341-349.

3. The authors should compare Cournot competition with Bertrand competition to explain the effect of social welfare on the difference in competitive forms or strategic variables. In this study, the authors just provide the calculating results of both equilibria.

Response: Thanks for your comment.

First, we found that the optimal level of a partial public port under Cournot and Bertrand competition varies among a fully private, a partially private and a fully public concerned port.

Second, the optimal quantity is lower in Cournot competition than in Bertrand competition.

Third, Bertrand competition yields a larger profit for the private port than Cournot competition. Nevertheless, Bertrand competition yields a higher social welfare than Cournot competition.

4. Readers including the reviewers would like to know the economic implications in more detail. For example, in Figures 1 and 2, we would like to know the economic reason why the difference in the degree of privatization derives and which competition is likely to promote privatization of port.

Response: Thank you for your comment. We are sorry for not explaining the economic reason in Fig. 1 and Fig. 2 fully to you.

Under Cournot competition between the public and private ports, the profit of each port can be expressed as¹:

¹ For convenience, we use the following superscripts for notation: “*” for equilibrium outcomes

$$\Pi_1^C(q_1^C, q_2^C) = [p_1^C(q_1^C, q_2^C) - c_1]q_1^C = (\alpha - T - q_1^C - \beta q_2^C - c_1)q_1^C \quad (1)$$

$$\Pi_2^C(q_1^C, q_2^C) = [p_2^C(q_1^C, q_2^C) - c_2]q_2^C = (\alpha - q_2^C - \beta q_1^C - c_2)q_2^C \quad (2)$$

Then, the social welfare is given by the following equation:

$$W^C(q_1^C, q_2^C) = \Pi_1^C(q_1^C, q_2^C) + \Pi_2^C(q_1^C, q_2^C) + S^C(q_1^C, q_2^C) \quad (3)$$

where $S^C(q_1^C, q_2^C) = \frac{(q_1^C)^2 + (q_2^C)^2 + 2\beta q_1^C q_2^C}{2}$.

As a benchmark, we characterize the socially efficient (first-best) allocation. The first-order conditions for maximizing the social welfare in (3) are:

$$\frac{\partial W^C}{\partial q_1^C} = \alpha - T - q_1^C - \beta q_2^C - c_1 = 0 \quad (4)$$

$$\frac{\partial W^C}{\partial q_2^C} = \alpha - q_2^C - \beta q_1^C - c_2 = 0 \quad (5)$$

The second-order sufficient conditions amount to:

$$\frac{\partial^2 W^C}{\partial q_1^{C2}} = -1 < 0, \quad \frac{\partial^2 W^C}{\partial q_2^{C2}} = -1 < 0, \quad \frac{\partial^2 W^C}{\partial q_1^C \partial q_2^C} = -\beta < 0, \quad \frac{\partial^2 W^C}{\partial q_2^C \partial q_1^C} = -\beta < 0,$$

$$\frac{\partial^2 W^C}{\partial q_1^{C2}} \frac{\partial^2 W^C}{\partial q_2^{C2}} - \left(\frac{\partial^2 W^C}{\partial q_1^C \partial q_2^C} \right)^2 = 1 - \beta^2 > 0.$$

From Eqs. (4) and (5), we derive the following first-best quantities:

$$\begin{aligned} \tilde{q}_1^{C*} &= \frac{(\beta - 1)\alpha + (c_1 + T) - \beta c_2}{\beta^2 - 1} \\ \tilde{q}_2^{C*} &= \frac{(\beta - 1)\alpha - \beta(c_1 + T) + c_2}{\beta^2 - 1} \end{aligned} \quad (6)$$

where the overline “~” denotes the first-best solution.

As previously stated, the private port maximizes its own profit, while the public port maximizes a weighted sum of its profit and consumer surplus. With these specification, the objective function of the public port is:

$$G^C(q_1^C, q_2^C) = \delta \Pi_2^C(q_1^C, q_2^C) + (1 - \delta) (\Pi_2^C(q_1^C, q_2^C) + S^C(q_1^C, q_2^C)) \quad (7)$$

The first-order conditions for maximizing Eqs. (1) and (7) with respect to q_1^C and q_2^C are:

$$\frac{\partial \Pi_1^C}{\partial q_1^C} = \alpha - T - 2q_1^C - \beta q_2^C - c_1 = 0 \quad (8)$$

$$\frac{\partial G^C}{\partial q_2^C} = \alpha - \delta \beta q_1^C - (\delta + 1)q_2^C - c_2 = 0 \quad (9)$$

The second-order conditions respectively are:

$$\frac{\partial^2 \Pi_1^C}{\partial q_1^{C2}} = -2 < 0, \quad \frac{\partial^2 G^C}{\partial q_2^{C2}} = -\delta - 1 < 0, \quad \frac{\partial^2 \Pi_1^C}{\partial q_1^C \partial q_2^C} = -\beta < 0, \quad \frac{\partial^2 G^C}{\partial q_2^C \partial q_1^C} = -\delta \beta < 0.$$

The stability conditions are:

$$\frac{\partial^2 \Pi_1^C}{\partial q_1^{C2}} \frac{\partial^2 G^C}{\partial q_2^{C2}} - \left(\frac{\partial^2 \Pi_1^C}{\partial q_1^C \partial q_2^C} \right)^2 = 2(\delta + 1) - \beta^2 > 0,$$

$$\frac{\partial^2 G^C}{\partial q_2^{C2}} \frac{\partial^2 \Pi_1^C}{\partial q_1^{C2}} - \left(\frac{\partial^2 G^C}{\partial q_2^C \partial q_1^C} \right)^2 = 2(\delta + 1) - \delta^2 \beta^2 > 0.$$

From Eqs. (8) and (9), we derive the following optimal quantities:

$$q_1^{C*} = \frac{-(\delta + 1)(\alpha - c_1 - T) + \beta(\alpha - c_2)}{\delta \beta^2 - 2(\delta + 1)} \quad (10)$$

$$q_2^{C*} = \frac{\delta \beta(\alpha - c_1 - T) - 2(\alpha - c_2)}{\delta \beta^2 - 2(\delta + 1)}$$

When port 2 is purely private, i.e., $\delta = 1$, Eq. (9) can be rewritten as Eq. (11), which is useful in the subsequent analysis.

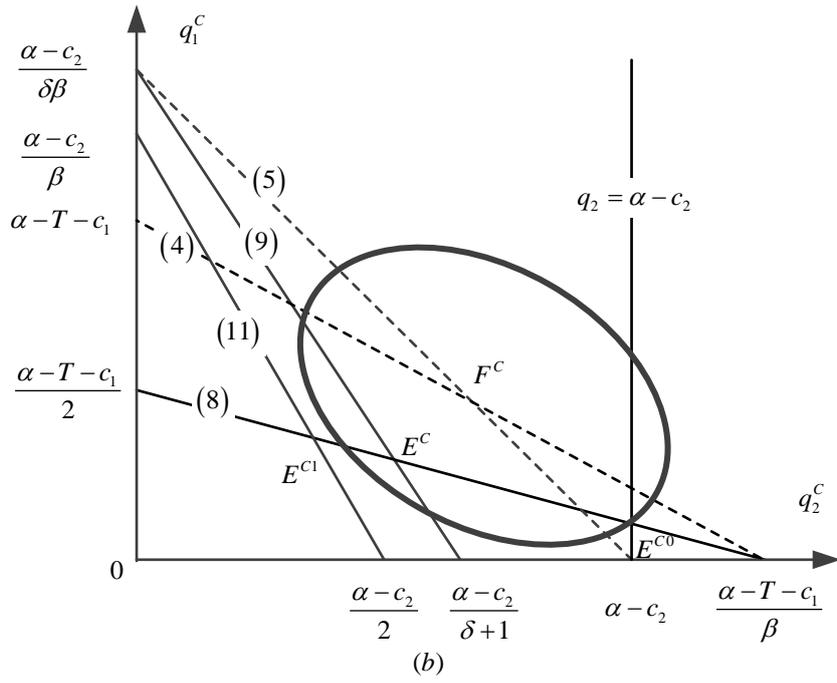
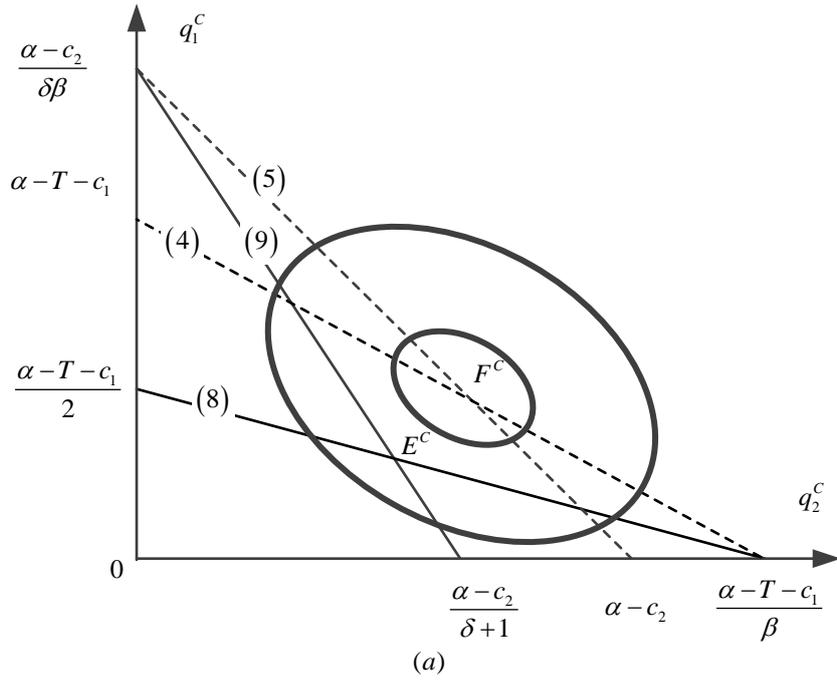
$$\frac{\partial G^C}{\partial q_2^C} = \alpha - \beta q_1^C - 2q_2^C - c_2 = 0 \quad (11)$$

Fig. 1 can be interpreted by the reaction functions (8) and (9) and the best-response functions (4) and (5) in the following Fig. A.

- As is shown in Fig. A(a), the reaction functions (8) and (9) can be depicted in the (q_1^C, q_2^C) plane together with the best-response functions (4) and (5). The two solid lines denote Eqs. (8) and (9) while the two dashed lines indicate Eqs. (4) and (5). According to the definition, the intersection of curves (8) and (9), point E^C , is the Cournot-Nash equilibrium, i.e., (q_2^{C*}, q_1^{C*}) . Besides, the maximum SW is carried out at the intersection of curves (4) and (5), point F^C , i.e., $(\tilde{q}_2^{C*}, \tilde{q}_1^{C*})$. In the surrounding area of point F^C , iso-SW curves can be depicted as contour lines in the figure. As the SW attains the maximum at point F^C , the closer to the point a

contour line is, the larger the SW is.

- As Fig. A(b) shows, curve (9) becomes (11) when $\delta=1$, while it becomes $q_2 = \alpha - c_2$ when $\delta=0$. With the increase of δ , curve (9) deviates from curve $q_2 = \alpha - c_2$ and gets close to curve (11). Therefore, the Cournot-Nash equilibrium under full nationalization of port 2 is obtained at the intersection of curves $q_2 = \alpha - c_2$ and (8), i.e., point E^{C0} in Fig. A(b). An iso-SW curve that passes through point E^{C0} is also drawn in Fig. A(b). With an increase in the level of δ , the equilibrium shifts to the left on curve (8). For example, the equilibrium moves from E^{C0} to E^C in the figure. Thus, the SW goes up because the point is inside the iso-SW contour. That is, the SW can surely be improved by enlarging δ above zero, which obviously shows the non-optimality of full public of port 2.
- The full privatization of port 2 case appears when $\delta=1$, in which the standard Cournot-Nash equilibrium comes true. An iso-SW curve going through the intersection of curves (8) and (11), i.e., point E^{C1} in Fig. A(c), is certainly downward-sloping at E^{C1} . Nevertheless, there are two scenarios: one is that the gradient is larger than that of the best-response curve of the private port (8) in absolute value, and the other is that the gradient is smaller than that of the best-response curve. The figure draws the former case. In this scenario, if port 2 becomes partially nationalized, or δ decreases, then port 2's best response curve moves to the right, from curve (11) to curve (9), which adjusts the equilibrium inside the contour curve, from point E^{C1} to point E^C . In the end, the SW goes up, which indicates that the full privatization of port 2 is not optimal. If, in contrast, the contour's slope at point E^{C1} is lower than that of port 1's best-response curve, thus the full privatization of port 2 is optimal.
- In the case that the full privatization of port 2 cannot be optimal, the possible maximum SW can be reached at the allocation at which an iso-SW contour is fitly tangent to the best response curve of port 1, i.e., point E^{C*} in Fig. A(d). Then, we can derive the optimal degree of partial privatization of port 2 δ^{C*} .



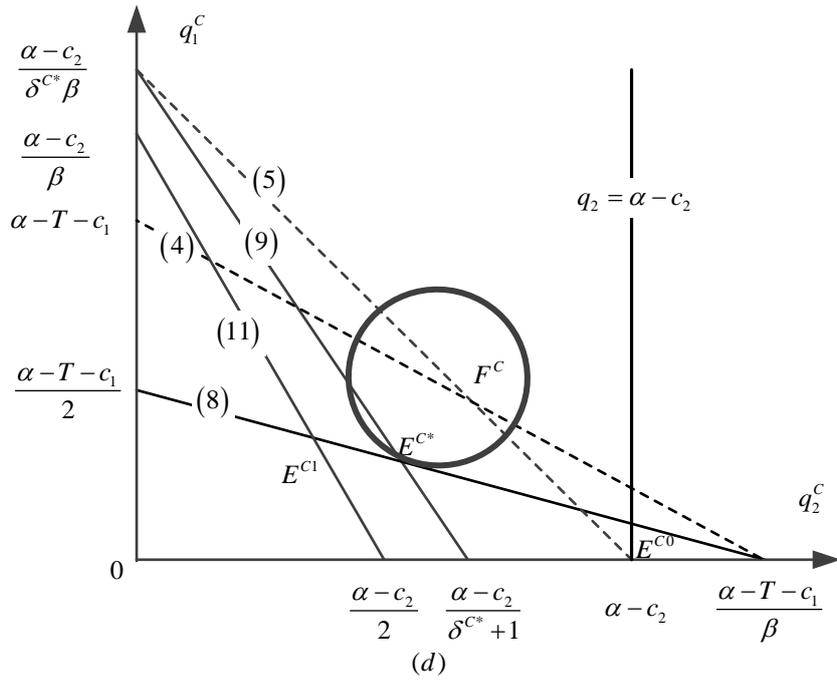
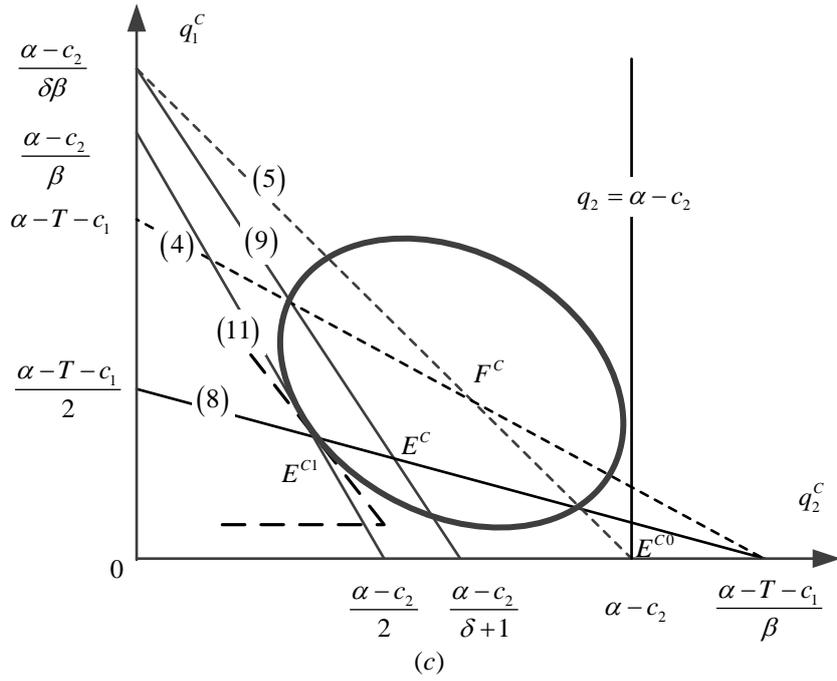


Fig. A The reaction functions of Cournot competition between the two ports.

Special thanks to you for your good comments.

Responses to the reviewer #3's comments:

We are grateful to Reviewer #3's insightful suggestions and comments.

Reviewer #3:

The motivation of the submitted paper is nice given the recent trend of port privatization in the real world. However, the additional contribution and the plausibility of the model are questionable. I would like to comment on the submitted paper.

1. The submitted paper just gives some interpretation to the parameters of the standard duopoly model with firm heterogeneity. The essence of the competition in this paper was discussed by many papers although those related papers do not give concrete contexts to their models (e.g., Fujiwara, 2007 *Journal of Eco-nomics*). The model structure in the submitted paper is quite similar to those related papers in that the market structure in the submitted paper has been discussed in the related papers although the contexts are different. You should refer to those related papers carefully.

Response: Thank you for your comment. We will refer to the relevant literature carefully in the revised paper.

The relevant literature is as follows:

Fujiwara K (2007) Partial privatization in a differentiated mixed oligopoly. *Journal of Economics* 92 (1): 51-65

Heywood JS, Ye GL (2009) Partial privatization in a mixed duopoly with an R&D rivalry. *Bulletin of Economic Research* 61(2): 165-178

Heywood JS, Ye GL (2010) Optimal privatization in a mixed duopoly with consistent conjectures. *Journal of Economics* 101: 231-246

Ishibashi K, Kaneko T (2008) Partial privatization in mixed duopoly with price and quality competition. *Journal of Economics* 95: 213-231

López MC (2007) Price and quantity competition in a differentiated duopoly with upstream suppliers. *Journal of Economics and Management Strategy* 16(2): 469-505

Matsumura T (1998) Partial privatization in mixed duopoly. *Journal of Public Economics* 70: 473-483

Pal R, Jain R (2012) Mixed duopoly, cross-ownership and partial privatization. *Journal of Economics* 107: 45-70

Saha B (2009) Mixed ownership in a mixed duopoly with differentiated products. *Journal of Economics* 98: 25-43

2. In addition, I am not sure whether the demand structure in the submitted paper properly captures the essence of port competition. The representative consumer (the representative port user) in the submitted paper is the only user of the "ports." So, it would be reasonable to interpret the port user as the exporter in the country. I do not think that the demand system does not nicely capture the important aspects of port

competition (e.g., port users from third countries, exporters from foreign countries). In the related papers listed in the submitted paper, for instance, Czerny et al. (2013) incorporates demands for two competing international ports by both domestic users in each country and third-country users who are represented by Hotelling line. I think that the demand structure in the submitted paper is too simple.

Response: Thanks for your comment. For all we know, there are two major categories of the demand function in port competition studying. One is the simple and linear demand function, which has been widely considered in the port competition literature (see Chen and Liu, 2014, 2016; Cui et al., 2017; Liu et al., 2018; Yip et al., 2014). The other one is the demand function derived from the Hotelling model, which has been conventionally used in previous studies (e.g., Czerny et al., 2014; Xing et al., 2018; Wan et al., 2016).

We completely agree with your comment on the important aspects of port competition (e.g., port users from third countries, exporters from foreign countries). However, we employ the conventional Cournot and Bertrand competition model rather than the Hotelling model to explore the port privatization in this paper.

Reference

- Chen H.C., Liu S.M. Optimal concession contracts for landlord port authorities to maximize fee revenues. *International Journal of Shipping and Transport Logistics*, 2014, 85: 109-131.
- Chen H.C., Liu S.M. Should ports expand their facilities under congestion and uncertainty. *Transportation Research Part B*, 2016, 85: 109-131.
- Cui H., Notteboom T. Modelling emission control taxes in port areas and port privatization levels in port competition and co-operation subgames. *Transportation Research Part D*, 2017, 56: 110-128.
- Liu S.M., Chen H.S., Han W.Q., Lin Y.H. Optimal concession contracts for landlord port authorities to maximize fee revenues with minimal throughput requirements. *Transportation Research Part E*, 2018, 109: 239-260.
- Yip T.L., Liu J.J., Fu X.W., Feng J.J. Modelling the effects of competition on seaport terminal awarding. *Transport Policy*, 2014, 35: 341-349.
- Czerny A., Höffler F., Mun S. Hub port competition and welfare effects of strategic privatization. *Economics of Transportation*, 2014, 3: 211-220.
- Xing W., Liu Q., Chen G.J. Pricing strategies for port competition and cooperation. *Maritime Policy & Management*, 2018, 45 (2): 260-277.
- Wan Y.L., Basso L.J., Zhang A.M. Strategic investments in accessibility under port competition and inter-regional coordination. *Transportation Research Part B*, 2016, 93: 102-125.

3. The objective of partially privatized public port is not so standard in the context of mixed oligopoly. The exceptions are Fanti and Buccella (2018 *Japan and the World Economy*) and the papers listed in their paper. You should carefully discuss why you

employ the objective function because such a different formulation of the objective in itself causes different outcomes.

Response: Thank you for your comment. We are sorry for not explaining the “objective of partial public port” fully to you. In this paper, we assume that the private port (port 1) is a profit-seeking port, which is only trying to maximize its own aggregated profit, while the partial public port (port 2) aims at maximizing a combined goal of public and private objectives, in which the private objective is captured by profits while a proxy for the public objective is represented by the consumer surplus. This is a common assumption in literature investigating the optimal privatization policy in a mixed duopoly model.

4. At least, the following two papers in Introduction are not listed in **References**:

- Cui, H., Notteboom, T., 2017. Modelling emission control taxes in port areas and port privatization levels in port competition and cooperation subgames. *Transportation Research Part D: Transport and Environment* 56, 110-128.
- Matsushima, N., Takauchi, K., 2014. Port privatization in an international oligopoly. *Transportation Research Part B: Methodological* 67, 382-397.

Response: We are very sorry for our negligence. We will add the above two papers in the reference list in the revision.

5. There are several typos:

The first line in Section 3.1 (page 6): “Under simultaneous quality” → “Under simultaneous quantity”.

The second line in the second paragraph of Section 3.1 (page 6): “social welfare. With these” → “the consumer surplus. With these”.

The second inequality in Assumption 1 (page 7): $T \leq c_2 - c_1$ would be $T \geq c_2 - c_1$.

Response: It was our carelessness for these expressions. We will improve the writing in the revision.

Special thanks to you for your good comments.