Port competition: The chain approach

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Abstract

Despite extensive research on port competition, little has been done to consider port competition from the supply chain perspective, which this study aims to address. It shows that ports not only have to compete against each other but are involved in strategic games along the supply chain. The study further explains the complexity arising from the co-existence of competition in both dimensions, i.e. between and within the supply chains. Finally implications for policy and business management are also discussed based on the findings.

Key words: transport competition; competition policy; ports; supply chain; oligopoly; game theoretic approach
1. Introduction

Recent economic growth of the global economy has been largely driven by increasing international trade and production outsourcing. This could not be possible without the support of the transport and logistics sector, which also benefits from the increasing demand brought about by globalisation. The need for companies to manage production and distribution activities across countries and regions has made their competitiveness and success much more dependent on transport and logistics than ever before. The above mentioned changes in concert with growing demand, capacity constraints and lack of integration between land and sea side transport inter alia have resulted in inefficient logistics performance and congestions in sea ports.

The traditional/current view on ports is that they are oligopolists/monopolists due to their geographical locations where there are few ports competing for the same hinterland. Furthermore, focus is mainly given to competition between ports against each other. This horizontal view on the port sector completely ignores the vertical relationship between ports and other service providers along the supply chain. The horizontal view of ports and their competition has certainly shaped policies on this sector, including but not limited to competition, privatisation, and economic welfare and efficiency.

It is natural to then ask if the above mentioned policy implications connected with the horizontal view remain valid when ports indeed belong to the supply chains and their vertical connection cannot be ignored. For example, consider the vertical relationship between dry ports and sea port. From the transport and economic development perspective, dry ports are also a natural development/extension of the transport and logistics network in the port hinterland as trade and production activities are intensified. They also help to address the capacity constraints and congestion problems currently faced by sea ports. Moreover, since dry ports also need to achieve economies of scale and scope to be operationally efficient, they offer many similar services currently offered by sea ports including storage, consolidation, container maintenance, customs, and land transport hub service. This generally suggests that dry ports’ and sea ports’ services can be both complements and substitutes. The latter would imply competition between dry ports and sea ports, especially when both offer similar services, for example, intermodal connections, customs and consolidation services. Such relationship between dry ports and sea ports would complicate the relationship along the supply chain.

Despite extensive research on port competition, little has been done to consider port competition in the context of supply chain and connection/relationship within itself. Nor has there been any theoretical framework explaining how such supply chain relationship may affect port competition¹. For example, existing studies on sea-dry port relationship are largely conceptual and descriptive case studies, such as in Walter and Poist (2004) on North America, Tsilingiris and Laguardia (2007) on Spain, Garnwa, Beresford and Pettit (2009) on UK and Nigeria, Roso (2008) on Australia, Roso, Woxenius and Olandersson (2006) on Sweden, Do, Nam and Le (2011) on Vietnam, and Cronje, E.,

¹ See Pallis, Vitsounis, and De Langen (2010) for a comprehensive review of the port economics literature.
Matthee, M. & Krugell (2009) on South Africa. A notable exception is Tsilingiris and Laguardia (2007) that used a Spanish case study on the relationship between dry ports and sea ports. They observed that, while a sea port can survive without collaborating with a dry port, the opposite is not true; dry ports can only substitute certain sea port’s functions but not existence; sea port competition attracts dry port partnership while dry port competition results in partnerships with sea ports; especially no evidence of competition between sea ports and dry ports sea port-dry ports was found, but collaboration is a win-to-win relationship for both. The study however was based on only descriptive and qualitative analysis and did not cover the effect of dry ports on sea ports’ competition and performance.

Since sea ports competition cannot be separated from the supply chains such as one illustrated in Figure 1, the horizontal view on operation and competition between ports, between shipping lines, or between transport service providers is no longer relevant. The current research incorporates the supply chain view into port competition where networking and cooperation become inseparable from companies’ value chain. It is based on the view that the current trend in globalisation is characterised by competition between supply chains rather than between companies. The research focuses on the following key aspects of the chain approach to port competition:

- coopetition between service providers along the supply chain
- coopetition and competition between ports which are parts of a supply chain
- competition between supply chains.

Figure 1: Parallel chains of service providers

![Figure 1: Parallel chains of service providers](image-url)
2. Coopetition in mono-line chains

**Definition:** A *chain* is defined as a line of service providers/productions (SPs) with physical connections between them. The service providers/productions (SPs) can be water/dry ports, terminals and sea/land/rail/air transport service providers. It follows that a mono-line chain such as one shown in Figure 2 has the following characteristics:

- The number of transport objects/products ($Q$) must be the same across the chain: $Q = Q_1 = Q_2 = Q_3 = \ldots$
- The chain users make decisions based on the *total cost/price* of the entire chain: $P = P_1 + P_2 + P_3 + \ldots$

The above chain conditions suggest that it is irrelevant for any SP to control its individual output quantity. All it can do is to adjust its price, which would then affect the demand for the entire chain and hence the other SPs. This interaction along the chain, referred to as “coopetition”, is different from market competition.

Figure 2: A mono-line chain

![Figure 2: A mono-line chain](image)

Note that the interaction between service providers in a mono-line chain further implies that no service providers would gain if they all increased prices. Alternatively, players would gain when they decrease their price. Thus, they can cooperate to decrease their price, but the outcome of this action is unstable because cheating can happen when one service provider decides to increase the price to gain even more than the others. If this happens, the other service provider will also increase its price resulting in a very high aggregate price. Table 1 summarises the outcomes of the interaction along the mono-line chain.

**Table 1: Strategic game in mono-line chains with two service providers**

<table>
<thead>
<tr>
<th>Service provider 2 (SP2)</th>
<th>P1 ↑</th>
<th>P1 ~</th>
<th>P1 ↓</th>
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<tbody>
<tr>
<td>P2 ↑</td>
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<tr>
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The following proposition presents the another result of the chain interaction:

**Proposition 1:** In mono-line chains, prices independently set by service providers are higher than when they act in unison.

**Proof:**

We need to derive the prices set service providers when they act independently, and when they cooperate. To keep the proof intuitively simple, suppose a linear demand function for the mono-line supply chain:

\[ Q = a - b(P_1 + P_2), \]  
\[ P_1 = \frac{a}{2b} + \frac{1}{2}MC_1 - \frac{1}{2}P_2, \]  
\[ P_2 = \frac{a}{2b} + \frac{1}{2}MC_2 - \frac{1}{2}P_1, \]

which result in the following equilibrium prices:

\[ P_1^* = \frac{a}{3b} + \frac{2}{3}MC_1 - \frac{1}{3}MC_2 \]  
\[ P_2^* = \frac{a}{3b} + \frac{2}{3}MC_2 - \frac{1}{3}MC_1 \]  
\[ P_1^* + P_2^* = \frac{2a}{3b} + \frac{1}{3}(MC_1 + MC_2) \]

Substituting (7) and (8) into (1) gives the equilibrium output level when the two service providers act independently:

\[ Q_1^* = Q_2^* = \frac{a}{3} - \frac{b}{3}(MC_1 + MC_2). \]
When the two service providers cooperate, they set the optimal price to maximise their total profit:

\[
\Pi = (P_1 + P_2)Q - (TC_1 + TC_2) = \frac{a}{b} Q - \frac{1}{b} Q^2 - (TC_1 + TC_2). \tag{11}
\]

The corresponding profit-maximising output and price are:

\[
Q^*_c = \frac{a}{2} - \frac{b}{2} (MC_1 + MC_2), \tag{12}
\]

\[
P^*_c = \frac{a}{2b} + \frac{1}{2} (MC_1 + MC_2). \tag{13}
\]

From (10) and (12), we have \( Q^*_I = (2/3)Q^*_c < Q^*_C \). Given the inverse relationship between output and price according to the demand function (1), it must follow that \( P^*_I > P^*_C \). Alternatively, note that \( Q^*_I, Q^*_C > 0 \), therefore \( MC_1 + MC_2 < a/b \). From (10) and (12), we get the same result:

\[
P^*_I - P^*_C = \frac{1}{6} \left[ \frac{a}{b} - (MC_1 + MC_2) \right] > 0
\]

Thus the price set by the service providers when they act independently is lower than the price they would set if they cooperate to maximise the total profit.

End of proof.

3. Coopetition in ramified chains

It is of a natural interest to consider behaviour of companies in an extended chain. Here we consider ramified chain structures.

**Definition**: A ramified chain is a supply chain with parallel links in some but not all of its segments as illustrated in Figure 3. It follows that in a ramified chain both coopetition and competition exist because:

- A change in the price made by any service provider would affect the demand for the entire chain. Therefore there is coopetition along the chain.

- Transport users can choose between parallel links. Therefore there is also competition between these parallel links.

Since SP2 and SP3 have to compete (for the service segment) they could behave according to the Cournot model. However, given the supply chain constraint, the relationship and competition outcome, in no doubt, will not be not the same as in the Cournot model. We can
extend the above chain model to incorporate Cournot behaviour as part of the chain. Note that in this case, the supply chain conditions for price and outputs respectively are \( P = P_1 + P_2 \), and \( Q = Q_1 = Q_2 + Q_3 \).

\[ P_2 = c - d(Q_2 + Q_3) \] (14)

**Figure 3: A ramified chain**

**Proposition 2:** Cournot (output fixing) interactions in parallel branches are independent of price fixing interaction along the supply chain.

**Proof of proposition 2:**

There are two options that parallel SPs can take:

- **When parallel SPs compete over the price:**
  - They tend to undercut the competitors.
  - Price reduction is not only harmful to both, but allows SPs in other links to increase the price making the outcome even worse (see Table 1).
  - Therefore competing over the output would be preferred.

- **When parallel SPs compete over the output:**
  - The output response functions of parallel SPS only take into account each other’s output, but *not* those of other links.
  - Therefore the outcome of such interaction is independent of other SPs in other links.

*End of proof.*

To illustrate the application of the above proposition to the ramified chain shown in Figure 3, first consider the pure Cournot model for the MB segment that includes only SP2 and SP3. Suppose the inverse demand within the segment with the price \( P_2 \) is:

\[ P_2 = c - d(Q_2 + Q_3) \]
The corresponding response functions obtained by solving for the optimal output level for the two service providers are:

\[ Q_2 = \frac{c - MC_2}{2d} - \frac{1}{2} Q_3, \]  
\[ Q_3 = \frac{c - MC_3}{2d} - \frac{1}{2} Q_2, \]  

which imply the following output quantities and price:

\[ Q_2^* = \frac{c}{3d} - \frac{2MC_2}{3d} + \frac{MC_3}{3d}, \]  
\[ Q_3^* = \frac{c}{3d} - \frac{2MC_3}{3d} + \frac{MC_2}{3d}, \]  
\[ P_2^* = \frac{1}{3} (c + MC_2 + MC_3). \]  

Because the response functions (15) and (16) are independent of the market price for the segment \( P_2 \), the strategic game involving SP2 and SP3 is independent of the price fixing game.

To show how the above proposition dictates the outcome of the interaction for the entire a ramified chain shown in Figure 2, we note that the demand function would be similar to the one specified in equation (1):

\[ Q = a - b(P_1 + P_2), \]  
\[ \text{except that in this case:} \quad Q = Q_1 = Q_2 + Q_3. \]  

Rewrite (20) to get the inverse demand function for the service providers SP2 and SP3 treating \( P_1 \) as exogenous:

\[ P_2 = \left( \frac{a}{b} - P_1 \right) - \frac{1}{b} (Q_2 + Q_3). \]  

Noting the similarity in the functional specifications between (14) and (22) with \( c = \left( \frac{a}{b} - P_1 \right) \) and \( d = \frac{1}{b} \), we have the following output quantities and price based on the equations (17), (18) and (19):

\[ Q_2 = \frac{1}{3} (a - bP_1) - \frac{2b}{3} MC_2 + \frac{b}{3} MC_3. \]
\[ Q_3 = \frac{1}{3}(a - bP_1) - \frac{2b}{3}MC_3 + \frac{b}{3}MC_2 \] (24)

\[ P_2 = \frac{1}{3} \left( \frac{a}{b} - P_1 + MC_2 + MC_3 \right) \] (25)

Since SP1 is not affected by the interaction between SP2 and SP3, its response function would be the same as one specified in (5):

\[ P_1 = \frac{a}{2b} + \frac{1}{2}MC_1 - \frac{1}{2}P_2. \] (26)

Solving equations (20), (26)-(29) gives the following prices and quantities for the ramified chain:

\[ P_1^* = \frac{2a}{5b} + \frac{3}{5}MC_1 - \frac{1}{5}(MC_2 + MC_3) \] (27)

\[ P_2^* = \frac{a}{5b} - \frac{1}{5}MC_1 + \frac{2}{5}(MC_2 + MC_3) \] (28)

\[ Q_1^* = \frac{2a}{5} - \frac{2b}{5}MC_1 - \frac{b}{5}(MC_2 + MC_3) \] (29)

\[ Q_2^* = \frac{a}{5} - \frac{b}{5}MC_1 - \frac{3b}{5}MC_2 + \frac{2b}{5}MC_3 \] (30)

\[ Q_3^* = \frac{a}{5} - \frac{b}{5}MC_1 - \frac{3b}{5}MC_3 + \frac{2b}{5}MC_2. \] (31)

The results in (27)-(31) show that despite the independence between competition and competition in a ramified chain, the prices and quantities in ramified chains are indeed linked. SPs in parallel links not only compete but their competition is also affected by interaction along the supply chain.

4. Other chain structures

We consider two extended structures based on the above basic chain structures as illustrated in Figures 4 and 5. Transport network such as one in Figure 4 can be regarded as a network of parallel lines, where competition between SPs is indirectly and depends on the competitiveness of the entire line of SPs they belong to. When there are many parallel links, their competition would drive the total price for the entire link down to its total marginal cost. Chain competition also requires integration between SPs in each chain.

In contrast to the relationship in Figure 4, in the chain structure illustrated by Figure 5 implies users are free to choose SPs. Therefore the chain relationship has little effect on the behaviour of SPs. The network can be seen as a system of different markets.
Figure 4: Parallel chains

Figure 5: Logistics network
5. Conclusions

- As long as chains exist, transport competition is inseparable from supply chain relationship.

- In any markets, SPs do not charge higher than the monopoly price. However, this is not applicable to chains due to chain coopetition.

- Allocative efficiency is critical to chains and can be improved by chain integration.

- The chain approach applies to any markets where a chain structure exists including supply chain or value chain.

References


