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Modeling port competition from a transport chain perspective

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A B S T R A C T

This paper considers the competition between two ports involving both hinterland shipments and transhipments. Taking a transport chain perspective including deep-sea, port, feeder and inland transportation, we present a static cost model to examine ports' relative competitiveness and justify the development of game models. A non-cooperative game model is then formulated for a two-ports-one-ocean carrier system. The optimal ports' pricing and the carrier's port-of-call decisions are derived. A centralized supply chain model is then discussed. The game model is further extended to uncertain demand situations. A case study of Southampton and Liverpool ports is provided to illustrate the results.

1. Introduction

Port competition is an accepted and important phenomenon, and a key driver of performance improvement, in the shipping industry. This is particularly evident in the container shipping sector where container port operations, cargo handling and equipment are standardized. Competition is intensified as ocean carriers can relatively easily switch their service routes and ports of call (denoted as portcall for simplicity) between different container ports. For example, among the UK container ports, in recent years it was reported that Evergreen moved to Felixstowe from Thamesport; a joint Hapag–Lloyd/OOCL transatlantic service was switched to Southampton from Thamesport; BG Freight Line (a subsidiary of CMA CGM) moved most of its services from Tilbury to Thamesport; the Southern Africa Europe Container Service was switched to London Gateway port from Tilbury (Porter, 2013).

Many factors affect ocean carriers' and shippers' decisions on the selection of ports, e.g. availability of hinterland connections, port tariffs, immediacy of consumers (large hinterland), feeder connectivity, environmental issues and the total portfolio of the port (Wiegmans et al., 2008). From a global supply chain perspective, the total transport chain's cost/profit is regarded as the most significant criterion for port choice (Liu et al., 2014). This paper attempts to address the competitive challenge between two container ports involving both hinterland shipments and transhipments from the transport chain's cost perspective including port prices, deep sea transport cost, hinterland transport cost, and feeder service cost.

There is a rich and varied body of literature on the subject of port competition. Port competition may be classified into three categories: intra-port competition between terminal operators within a single container port, inter-port competition between operators/authorities in neighboring ports, and inter-port competition between operators/authorities in different port ranges. A typical example of the first category is the rivalry among the three major terminals in Rotterdam: the Euromax

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Container Terminal (operated by Hutchison Ports), the Rotterdam World Gateway terminal (operated by DP World), and the APMT MVII terminal (operated by APM Terminals) (Barnard, 2014). Another example has been highlighted by Saeed and Larsen (2010) who studied the intra-port competition among three container terminals located in a port in Pakistan, and examined the different types of coalitions among the container terminals using a two-stage game method.

In the second category, competitive ports are located in the same port region competing for the same hinterland shipments (and may also compete for the same transhipments). For example, Southampton and Liverpool ports compete for the hinterland shipments from England and also compete for the transhipment cargoes from Scotland and Ireland. Cullinane et al. (2005) analyzed the relative competitiveness of the two neighboring container ports of Shanghai and Ningbo with respect to price, quality of service and generalized cost. De Borger et al. (2008) applied a two-stage game to analyze the interaction between the pricing behavior of two competing ports and the capacity investment policies in the ports and hinterland. Both port congestion and hinterland congestion are considered in the model. Li and Oh (2010) studied the competition and cooperation between neighboring ports in a case study of Shanghai port and Ningbo-Zhoushan port. Luo et al. (2012) developed a two-stage game model for a new port and an existing port that serve the same hinterland with different competitive conditions. They focused on port pricing and capacity expansion decisions. The case of Hong Kong and Shenzhen ports was discussed.

In the third category, competitive ports are located in different port ranges and therefore mainly compete for transhipment cargoes. Veldman and Buckmann (2003) applied a logit model to quantify the routing choice among European container hub-ports. Yap and Lam (2006) examined whether there exists a long run relationship between various ports in East Asia using a co-integration test based on historical data. Co-integration refers to a linear combination of variables that are non-stationary with a relationship present between them. Anderson et al. (2008) investigated the competition between two hub ports: Busan and Shanghai. They developed a game-theoretic response model for the purpose of understanding how a competing port would best respond to the development of the focal port, and whether the focal port would be able to capture or defend market share through investment in capacity. Ishii et al. (2013) applied a non-cooperative game theoretic model to examine the effect of inter-port competition between two ports using the case of Busan and Kobe. Working under the assumption that both the levels and timings of capacity investment are pre-determined, they aimed to determine the pricing behavior of the two ports at each time period of port capacity investment. Zhuang et al. (2014) used duopoly games to model the competition between two ports that service two types of cargoes. They found that inter-port competition may lead to port specialization in terms of port service choice and cargo type. Bae et al. (2013) studied container port competition for transhipment cargoes in a duopoly market. A non-cooperative game was applied to a vertical marketing channel consisting of two ports and multiple shipping lines. They showed the existence of the Nash equilibrium including shipping lines' portcall decisions and ports' pricing decisions. A defining contribution of this paper is the joint/interactive decision-making of ports and shipping lines, while most other literature on port competition has primarily focused on the ports' decisions only.

In addition to port competition, there have been a number of empirical studies examining the competitiveness of container ports. For example, Tongzon and Heng (2005) conducted an empirical evaluation of the impact of port privatization on port efficiency and identified the determinants of port competitiveness. Yeo et al. (2008) considered the competitiveness of container ports in the regions of Korea and China. They conducted a regional survey of shipping companies to identify and evaluate the determining factors influencing port competitiveness. Notteboom and Yap (2012) discussed port competition and competitiveness. They introduced the concept of container 'port range', which is defined as a geographically defined area with a number of ports that possess largely overlapping hinterlands and thus serve mostly the same customers. Related to port competition and competitiveness, other researchers have addressed the issues of port cooperation and regionalization. For example, Song (2002) took a strategic perspective to examine the possible competition and cooperation between Hong Kong port and the adjacent container ports in South China. It was reported that port cooperation could be achieved through the same terminal operator or through common ownership. Luo and Grigalunas (2003) presented a simulation model to estimate port-related demand for major US coastal container ports. The demand regionalization was achieved through simulating the multimodal container transportation process based on the shortest path method.

It can be observed that the literature on port competition has focused on either competing for hinterland shipments, or competing for transhipments. Very little research has considered port competition involving both hinterland shipments and transhipments explicitly. Given the fact that the majority of deep sea ports handle both hinterland shipments and transhipment cargoes (although their ratios may vary from port to port), it is appropriate to model port competition by including both types of shipments. More importantly, the port competition models developed so far have primarily concentrated on the port performance and related decisions (e.g. price, investment, congestion); ocean carriers' decisions have been often neglected except in one paper (i.e., Bae et al., 2013). Since ocean carriers are the immediate and primary customers of container ports, and ocean carriers' portcall decisions depend on the entire transport chain, it is desirable to model port competition in the context of the transport chain by considering port pricing, deep sea transport cost, hinterland transport cost, and feeder service cost simultaneously. In addition, it is also useful to investigate the centralized management model for the transport chain in an integrated manner since ports and ocean carriers may seek strategic collaboration and make decisions jointly. A loosely related research stream is shipping network design (Brouer et al., 2014; Meng et al., 2014), which is aimed at designing or selecting shipping service routes, port choice, port rotation, and inland transportation in order to meet customer demands (Tavasszy et al., 2011; Liu et al., 2014). However, this research stream (on shipping network design) has not considered the competition between ports, i.e. port pricing has not been treated as a decision variable. In this study,