A game-theoretical model of port competition on intermodal network and pricing strategy

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\textit{ABSTRACT}

This paper develops a game-theoretical model of port competition for the intermodal network design and pricing strategy problem. In the model, port operators determine the dry port locations and pricing strategy to maximize profit considering the shipper's route choice behavior. According to the characteristics of the Nash equilibrium solution for reduced strategy sets, a Nash equilibrium solution algorithm is adapted. We describe a case study involving the competition between Dalian port and Yingkou port in China. We find an obvious link between dry port location and geography. The modal split is related to the number and locations of dry ports.

1. Introduction

Ports are vital in connecting inland and marine areas. In recent years, the global economy has entered a new period characterized by slower economic growth and weak global trade. The development of ports has faced a severe challenge. Meanwhile, an increasing number of small and medium-sized ports in deconcentrated multiple-gateway regions have gradually filled the gap between the markets occupied by the big ports (Feng and Notteboom, 2013). Therefore, the competition between the ports serving overlapping hinterland areas is increasingly fierce. The role of ports extends beyond the building that provides infrastructure facilities for transferring cargo between inland and sea areas; ports have become a critical logistic hub in intermodal transport (Rodrigue and Notteboom, 2009). One of the consequences is that ‘regionalization’ has become an important phase in the port development system (Notteboom and Rodrigue, 2005). In this phase, intermodal transport is important for ports to connect with hinterland. The performance of intermodal transport in overlapping hinterland will become another arena of competition among ports (Monios and Wilmsmeier, 2012; 2013).

To facilitate the development of intermodal transport, dry ports, as nodes connecting rail and roads in transport networks, have received particular attention. With the development of dry ports, long-distance freight transport has been shifted from road to rail, which will relieve congestion at seaport terminals and seaport city roads (Roso, 2007). The implementation of dry ports will also offer...
an opportunity to increase the throughput by attracting shippers, due to a lower inland transport cost and more convenient transport services (Roso, 2013). Moreover, from the perspective of governments, intermodal transport could stimulate regional development by providing cheaper inland transport services (Monios and Lambert, 2013; Monios, 2016). CO2 emissions would also decrease due to the modal shift from road to rail. Thus, in China, the government appears to be encouraging the use of rail-based intermodal transport and supporting the construction of dry ports. With the same purpose, the objective of the European Commission is that '30% of road freight over 300 km should be shifted to other modes such as rail or waterborne transport by 2030, and more than 50% by 2050' (European Commission, 2011). In addition, for shippers, because inland transport costs account for a dominant share (approximately 80%) of the entire cost (Rodrique and Notteboom, 2012), the construction of dry ports could reduce the shippers’ cost burden.

Port operators have become one of the main investors in the construction of dry ports. In China, over 80% of the dry ports have been invested by port operators. In Europe, many ports have also invested in dry ports to expand their capacity (Rodrique et al., 2010; Roso and Lumsden, 2010). Furthermore, port operators play a key role in the operation of intermodal transport. Particularly in China, port operators cooperate with rail companies and are responsible for the operation of rail transport services between the ports and hinterland. Furthermore, considering the strong attractiveness of dry ports for the shippers, trains are preferred to be distributed between the ports and dry ports. For instance, the rail services between Dalian port and its dry port locations account for approximately 80% of the total capacity of rail services between Dalian port and the hinterland. In addition, to seize the market in the overlapping hinterland, the competitive ports tend to locate dry ports in the same city. For example, Dalian port and Yingkou port have both constructed dry ports in Shenyang and Changchun (Zeng et al., 2013; Liu, 2015), while Tianjin port and Qingdao port have constructed dry ports in Zibo (Li et al., 2015; Liu, 2015).

Despite the enormous number of studies on the concept, construction and operation of dry ports (Ng and Gujar, 2009; Roso et al., 2009; Roso and Lumsden, 2010; Bask et al., 2014; Li et al., 2015), very little research has been done on the location design of dry ports simultaneously considering the competition between ports. Meanwhile, in the existing studies, the competition of ports is often assumed to occur at the strategy level (locations of dry ports) and operational level (service prices). In reality, the decisions on the two levels would interact with each other, and the simultaneous consideration of both levels is of value to maximize the profits of players (i.e., ports). Therefore, considering the context of port competition, the following questions will arise: How can we model the competition among ports with respect to dry port locations and price strategies? How can we find the Nash equilibrium solution, if it exists in the competition among ports? How does the construction of dry ports influence the ports’ market shares and the modal shift from road to intermodal transport?

To investigate these problems, we propose a game-theoretical model to find the equilibrium strategies of port operators. In the game-theoretical model, the objective of the port operators is to maximize their own profit by determining the locations of dry ports and service charges of the port and dry ports with the consideration of shipper’s route choice behavior. To obtain the best response for each port operator, a dry port location and pricing strategy optimization model is proposed. In addition, according to the characteristics of the Nash equilibrium solution for reduced strategy sets, we adapt the algorithm proposed by Grauberger (2015) to reduce the calculation requirements. Based on a case study, the impact of the dry port on the port competition is analyzed.

Depending on the proposed model and algorithm, a case study of the competition between Dalian port and Yingkou port in China is described. Some interesting results are revealed by investigating this case. For example, under the equilibrium state, the cities with relatively central locations and large transport demands are more attractive for the construction of the dry port. The construction of the dry port will not always improve the share of intermodal transport, which is also related to the locations of constructed dry ports. The construction of the dry port could help to provide more intermodal routes and result in a decrease in the inland transport cost. However, the influence of the construction of a dry port on port price is related to the constructor. In some instances, although the construction of a dry port improves the competitiveness of the port, the port price decreases due to the intensification of competition.

It seems unusual at first glance that the locations of dry ports and service prices are linked in this paper. However, the fundamental objective of the construction of dry ports is to improve the profit of the port. In turn, the profit is also strongly related to the pricing strategy and the competitive context. Thus, without the consideration of a feasible pricing strategy, it is difficult to make a good decision on the locations of dry ports. In addition, the location design of the dry port depends on the pricing structure. Thus, it may be reasonable to comprehensively consider the change in price caused by the decision on the locations of dry ports. There are a number of emerging studies on the hub location problem with respect to pricing strategies, such as Liuer-Villagrasa and Marianov (2013), O Kelly et al. (2015) and Abbasi and Niknam (2016). In addition, the pricing strategy has been widely considered in the economic studies on location problems, in particular spatial game theoretical problems, such as Combes and Linnemer (2000), Hamoudi and Martín-Bustamante (2011) and Marianov and Eiselt (2016). For an overview over this strand of the literature see Bicaia and Mota (2013).

The remainder of this paper is organized as follows. Section 2 reviews the relevant studies on the dry port location problem and network design with pricing and under competition. Section 3 formulates a game-theoretical model in which the port operator’s decision is determined based on a dry port location and pricing strategy optimization model. Section 4 introduces the adapted algorithm for identifying a pure Nash equilibrium solution of the game-theoretical model. Section 5 provides a case study of northeast China and analyzes in depth the effect of dry port on port competition and the modal split. Finally, conclusions are presented in Section 6.

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6 This number is calculated based on the statistics reported by Zeng et al. (2013).
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