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Transportation Research Procedia 9 (2015) 269 – 282

Transportation Research Procedia

www.elsevier.com/locate/procedia

21st International Symposium on Transportation and Traffic Theory

Strategic Maritime Container Transport Design in Oligopolistic Markets

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Abstract

This paper considers the maritime container assignment problem in a market setting with two competing firms. Given a series of known, exogenous demands for service between pairs of ports, each company is free to design a liner service network serving a subset of the ports and demand, subject to the size of their fleets and the potential for profit. The model is designed as a three-stage complete information game: in the first stage, the firms simultaneously invest in their fleet; in the second stage, they individually design their networks and solve the route assignment problem with respect to the transport demand they expect to serve, given the fleet determined in the first stage; in the final stage, the firms compete in terms of freight rates on each origin-destination movement. The game is solved by backward induction. Numerical solutions are provided to characterize the equilibria of the game.

Peer-review under responsibility of the Scientific Committee of ISTTT21

Keywords: logistics; container assignment model; maritime network; monopoly; duopoly; sequential Games; Backward Induction.

1. Introduction

Over the last 50 years, containerization has grown to account nowadays for roughly 70% of total deep sea trade (by value) and it is now a key component of the global economy (UNCTAD, 2014). The maritime industry has long sought the development of a model that can represent the flow of containers through the global liner shipping network. Such a model would not only assist shipping lines in the design of their services, but would also be useful

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Peer-review under responsibility of the Scientific Committee of ISTTT21

doi:10.1016/j.trpro.2015.07.015

for port operations, governments and international organizations as it could inform investments, strategic and operational planning, and policy design. One of the earliest works to model maritime container flows is the Container World project (reviewed in Newton, 2008), while Perrin et al. (2008) developed one of the earlier macroscopic container assignment models. At the same time, much research has focused on the empty container management problem, which occurs due to the effects of trade imbalances, predominately (e.g., between Western and Asian markets).

Previous work by Bell et al. (2011 and 2013) focused on the development of a container flow assignment framework that acknowledges transshipment operations and capacity constraints in the ports and vessels involved. The resulting optimization algorithms remain linear in nature, are built around the frequency-based structure of liner shipping services and seek to minimize aggregate container travel durations or costs, respectively. Both techniques are capable of simultaneously addressing full and empty container flows – in the past the latter have mostly been examined in isolation and as part of the empty container repositioning problem. Given their linear nature they have modest computational requirements, therefore making them particularly attractive for application in large problem settings that involve hundreds of ports and services.

With a few exceptions, most studies on container flow assignment have relied on predetermined liner service structures, used as inputs to the container assignment problem. Agarwal and Ergun (2008) notably added a network design stage to the container assignment model. In their paper this is referred to as a cargo routing model, therefore reflecting the absence of empty container repositioning from their assignment model. More recently, Mulder and Decker (2014) have enhanced the methodology developed by Agarwal and Ergun. Both studies however take the perspective of a single shipping line or alliance.

The considered academic efforts have provided important results towards the representation of the forces that drive the global flows of containers. However, the existing models still fail to take into account some crucial features of the global shipping market such as: the elasticity of the transport demand to the economic conditions (e.g., travel time and fees) that prevail in the shipping industry at any given moment; and, on the supply side, the effects of competitive actions that are taken by groups of players (e.g., shipping liners or alliances) in the same shipping market.

As regards the effects of competition on network design and service provision, the economic theory of industrial organization highlights two possible outcomes (Tirole, 1988). If competing shipping firms (i.e., liners or alliances) provide services of similar quality (e.g., service reliability) and features (e.g., planned delivery time), competition would take the form of strong price war, reducing profits and, in some cases, preventing the market to find a stable configuration (or medium-term equilibrium). On the other hand, if competing shipping firms are able to determine some form of service differentiation they may reduce the strength of competition and, in this way, increase profits (which nevertheless will remain lower than in the monopolistic case). This case is potentially relevant for the shipping industry, given that firms are able to design different service networks that, in turn, imply diverse delivery times and service features[1]. The policy implications of the two scenarios are quite different: if competition is strong, no regulation of the shipping sector is desirable, given that the market tends to determine the lowest possible prices for shippers; conversely, if competition is weak, prices and profits would tend to increase, and a regulatory remedy could be desirable.

The model introduced in this paper seeks to address this gap in academic literature, by developing an algorithm that could be used to determine an optimal set of liner services, given the presence of a competing shipping firm. The resulting model has game-theoretic elements, whereby the network design strategy of each shipping liner or alliance reacts to the actions of its competitors. Container flow assignment is integral part of this process, as it is used to establish how the market would respond to the simultaneous provision of routes by competing parties.

The types of services considered in the model follow established liner shipping trends, where vessel services are composed by a looped sequence of port visits (commonly referred to as service strings or loops). The resulting model takes into account revenues deriving from a demand for transport services that is distributed between firms in accordance to service costs. The latter include fees charged by the firm operating the chosen service as well as the opportunity cost of travel times. Empty container repositioning is retained in the container assignment model.

The key actors of the model are two firms (i.e., shipping liners or alliances) that seek to maximize their profit by operating in a given region with known transport demands for full containers among a set of ports. To meet this

[1] We can read the considered scenarios in terms of a monopolistic competition model where the degree of substitutability of services provided by different firms is infinite (first scenaro) or finite (second scenario).