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Effects of risk-aversion on competing shipping lines' pricing strategies with uncertain demands

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ABSTRACT

Container shipping is facing severe overcapacity, fierce price-based competition and high demand uncertainty. It is natural that some shipping lines may adopt a risk-aversion attitude in their pricing strategies. This paper considers the pricing strategies of two competing ocean carriers facing uncertain demand. The first carrier is risk-neutral with sufficient capacity, whereas the second carrier is risk-averse with limited capacity. The conditional value at risk (CVaR) is used to measure the risk-averse attitude of the second carrier. A Nash game model is formulated to model the pricing decisions and the equilibrium solution is obtained. We find that the pricing solution takes two forms, which can be determined by a threshold value of carrier 2's capacity. Under uniformly distributed demand, we show that as the second carrier becomes more risk-averse, both carriers' optimal prices are decreasing, and the threshold value that determines the pricing strategy is also decreasing. We also analyze the impact of price sensitivity and competition intensity parameters on two carriers' price decisions under more specific conditions. A necessary and sufficient condition is established to determine whether two carriers' optimal prices would be positively or negatively affected by the competition intensity parameter. A range of numerical experiments are provided to illustrate the analytical results and explore their validity in more general cases. Moreover, it is shown that the main analytical results in this paper can carry over to the cases when both carriers are risk-averse.

1. Introduction

Maritime transportation plays a vital role in the development of world economy for there is no effective alternative way to transport large scale of goods over a long distance. According to a research conducted by Lloyds Marine Intelligence Unit (Mandryk, 2009), about 75% of the world trade by volume (or 60% of the world trade by value) were carried by sea; among the maritime transport sectors, 52% of cargoes by value were carried by container ships. Container shipping has experienced a rapid growth in the last two decades with the largest containership size increasing from 8000 TEUs in 2000 to 19,000 TEUs in 2015, where TEU stands for twenty-foot equivalent-unit.

Container liner shipping is a capital-intensive industry with long investment lead times (Fransoo and Lee, 2013). A modern containership costs over a hundred million US dollars and takes several years to build. Containerships sail along a published schedule on a regular basis. In order to respect the schedule, a containership may have to depart from a port even

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though it is under-loaded. Nowadays global shipping lines often offer similar shipping services on a weekly basis, e.g. in the Asia-Europe route, Trans-Pacific route, or Trans-Atlantic route, although individual shipping services may differ in terms of port of calls. The capital-intensive nature associated with the requirement of regular shipping services leads to fierce competition between shipping lines. Low service differentiation in liner shipping implies that the competition is mainly on a cost or price (freight rate) basis (Lee and Song, 2017). In addition, the seasonal variations of the shrinking market and the fluctuation of the bunker price drive the volatility of freight rate. For example, Lloyd's List reported that freight rates slumped 40% within a week in November 2015.

Shipping lines face two types of customer demands: long-term contractual demand and spot market demand. The price for the long-term demand is often fixed and contracted once a year, whereas the price for spot market demand may be agreed between shipping lines and shippers (or freight forwarders) dynamically on daily/weekly basis. Since the financial crisis of 2008, economic recession and declining trade demand have led to overcapacity in liner shipping services. The situation is worsened by the fragmented container shipping market and the shipping lines' persistent pursuit of economies of scale (e.g. purchasing larger and larger vessels). In recent years, shippers tend to go for spot market to search for a lower freight rate (Lee et al., 2015). This intensifies the competition between shipping lines and increases the unpredictability of cargo volume for individual shipping lines. Uncertainty in customer demands has been one of the main challenges that shipping lines have to cope with in order to survive in the current highly competitive environment.

The regularity of liner shipping services indicates that liner services are perishable products, which means unutilized vessel slots will lose the opportunity to generate revenue. Therefore, it is vital for a shipping line to seek an appropriate pricing strategy to maximize its revenue in the competitive and uncertain spot market. Understandingly, given the perishable feature of liner services, some shipping lines may adopt a risk-aversion attitude in their pricing strategies. However, there has been no study investigating the effects of risk aversion on the pricing strategies for competing shipping lines.

This paper aims to fill the above research gap by investigating the competition outcome and pricing strategy of shipping lines facing uncertain spot market demand with risk-averse behaviour. We consider a competition between two shipping lines: a larger one and a smaller one. The larger shipping line has sufficient shipping capacity and is risk-neutral, while the smaller shipping line has constrained shipping capacity and is risk-averse. Here the smaller shipping line may be regarded as a freight forwarder or NVOCC (non-vessel operating common carrier) who has purchased a certain number of vessel slots from a shipping line. We would like to address the following questions:

- What are the optimal pricing strategies and the associated profits of two carriers when the smaller carrier is risk-averse in meeting uncertain spot market demand?
- What is the difference between two carrier's pricing strategies? How does the degree of the risk-averse attitude influence the pricing strategies and the profits?
- What is the effect of other parameters, like competition intensity and the spot market price sensitivity, on the decision variables and the profits?

The main contributions of this paper include: (i) to the best of our knowledge, this study is the first to investigate the effects of risk aversion on the pricing strategies for competing shipping lines. We are among the first to introduce the concept of conditional value at risk (CVaR) to measure the risk-averse attitude in the shipping industry. A Nash game model is formulated to model the pricing decisions of two competing carriers (carrier 1 is risk-neutral and carrier 2 is risk-averse) facing uncertain demands; (ii) our model with CVaR takes into account the capacity constraint of the risk-averse carrier. Our model is quite generic and is essentially applicable to other industrial sectors with capacity constraint and perishable products. There has been no similar model in the risk-averse literature. In that sense, our study enriches the literature on CVaR in the broad context; (iii) we solve the Nash game model and obtain the equilibrium solution analytically. We find that the solution takes two forms, which can be determined by a threshold value of carrier 2's capacity; (iv) when the demand uncertainty follows a uniform distribution, we are able to establish the monotone properties of the carriers' optimal prices and the threshold value that determines the pricing strategy, with respect to the second carrier's risk-averse preference; (v) under some specific conditions, we establish analytical results about the impact of price sensitivity and competition intensity on two carriers' optimal price decisions. An interesting finding is that the competition intensity parameter could have either negative or positive impact on two carriers' prices, and more importantly we provide a necessary and sufficient condition to determine whether two carriers' optimal prices would be positively or negatively affected by the competition intensity parameter. Numerical experiments show that some of the above analytical results can carry over to more general cases; (vi) The main analytical results also hold in the cases when both carriers are risk-averse.

The remainder of this paper is organized as follows. In Section 2, we review the literature related to competition and pricing in liner shipping, and some studies related to decision-making with risk-averse behaviour. In Section 3, we describe the problem and formulate a Nash game model. In Section 4, we analyze the model, obtain the equilibrium solution, and establish a series of analytical results. In Section 5, a range of numerical experiments are performed to illustrate the analytical results and explore their validity in more general situations. In Section 6, we extend the model to the cases with both shipping lines are risk-averse. Finally, conclusions and suggestions for further research are drawn in Section 7.