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A capacity pricing and reservation problem under option contract in the air cargo freight industry

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ABSTRACT

Option contracts have been increasingly applied in the air cargo freight industry over the last several decades due to its ability to mitigate asset provider's capacity utilization risk. By entering into option contract with an air cargo carrier, freight forwarders reserve a certain amount of capacity upon signing the contract and execute the option partially or completely after the market demand is realized. In this work, we address the capacity pricing and reservation problem under option contract in the air cargo freight industry. A Stackelberg game model is established to simulate the behaviors of air cargo carrier and freight forwarders. We then respectively derive optimal pricing and reservation policy for both parties with the aim to maximize their expected profits. Numerical experiments and sensitivity analysis are subsequently conducted and managerial insights are drawn for both asset provider and freight forwarders to serve as guidelines for industry participators.

1. Introduction

In today's fast-paced economy marked by rapidly developed and increasingly interconnected network for global trade, demand for freight transport across different regions has been growing significantly and product life cycles continue to shorten. With its advantage in efficiency and reliability, air transportation has been adopted as a major delivery option and plays a hugely important role to world trade, carrying approximately 35% of all world trade by value (Airbus, 2016). The international air cargo market has demonstrated a remarkable expansion in the past decades and is forecasted to continue increasing at 4.2% annually over the next 20 years (Boeing, 2016). Meanwhile, as today's global business environment is more complex and uncertain, the demand growth rate of the world air cargo market has become more volatile and no clear pattern can be observed.

The air cargo freight market has long been operated mainly by two groups of players, namely air cargo carriers (or asset providers) and freight forwarding companies (or freight forwarders). Nowadays, approximately 90–95% of air transportation volume is handled by freight forwarding companies who act as intermediaries between end customers and air cargo carriers (Doganis, 2002). Air cargo carriers provide capital-intensive capacity (i.e. air cargo space) which is to be filled by the cargos from freight forwarders or directly from end customers to generate return on its investment. However, due to the unpredictable demand for air cargo capacity, air cargo carriers will inevitably face high capacity utilization risk in reality. In order to reduce such risk, a commonly used approach is to sell a portion of their capacity to freight forwarders in advance through long-term contracts which act as a hedge against future demand fluctuation and help establish a long-term relationship between the two players. On the other hand, freight forwarders also strive to be assured certain amount of air cargo capacity in the future to satisfy the demand from their end customers. However, such long-term agreement is usually not favored by the forwarders because the demand they are facing is volatile and they tend not to bear any risk of advanced capacity sale. As such, certain compensation, usually in terms of favorable price and conditions, for loss of flexibility when entering into long-term agreement with air cargo carriers, must be committed to them.

The traditional practice of such long-term agreement adopted in air cargo industry is fixed-commitment contracts which specify a fixed amount of capacity offered on a particular flight at a predetermined price that is only payable after actual capacity execution by the freight forwarder. Despite a low probability of cancellation, such fixed-commitment contracts are not easily enforceable and the ultimate purpose of a shared utilization risk is more often not achieved (Bazaraa et al., 2001; Hellermann, 2006). As an alternative, a more flexible contract type, capacity-

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option contract, proposed in the recent supply chain management literature (Barnes-Schuster, Bassok, & Anupindi, 2002; Inderfurth, Kelle, & Kleber, 2013; Peng, Erhun, Hertzler, & Kempf, 2012), has been increasingly promoted by airline companies. By engaging in an option contract, a freight forwarder reserves a certain amount of capacity with a reservation fee payable ex-ante on signing the contract and an execution fee payable only if any reserved capacity is exercised. The challenge posed on air cargo carriers under option contract is thus to set optimal prices for reservation and execution of capacity so as to maximize profit and mitigate capacity utilization risk at the same time. On the other hand, freight forwards also need to make decisions on optimal amount of capacity reserved from carriers and optimal price charged on end customers while maximizing its profit.

In this work, the decision-making problem of capacity pricing and reservation under option contract for air cargo carrier and multiple freight forwarders in an air cargo market is addressed. The problem arises from the situation where there is only one airline operating on a particular route and different freight forwarders serve as intermediates between the carrier and end customers. Existence of more than one freight forwarders in the market poses challenges on the decision-making problems because the demand they are facing may be homogeneous or heterogeneous and the competition among different freight forwarding companies may bring certain impacts to the solutions. Hence, in this study, we seek to answer the following questions by studying capacity pricing and reservation models under option contract: What is the optimal capacity pricing decision for an air cargo carrier when facing one or multiple freight forwarders in the market? How does an individual freight forwarder make optimal capacity reservation, execution and pricing decisions given there are other competitors? What is the impact of competition among multiple freight forwarders for contract market demand on both sides? What are the economic implications for the two players when freight forwarders face homogeneous or heterogeneous contract market demands? How will various market parameters influence optimal pricing policy and the profitability of both groups?

The remainder of this paper is organized as follows. Section 2 gives a review on related works. Section 3 introduces the mathematical models for the capacity pricing and reservation problem under option contract. Section 4 presents the results of numerical experiments. Sensitivity analysis is also performed on the multiple freight forwarder models under both homogeneous and heterogeneous settings. Finally, we conclude this study in Section 5.

2. Literature review

This paper studies the capacity pricing problem for the air cargo carrier and capacity reservation problem for freight forwarders under option contract in the air cargo industry which to the best of our knowledge is the first work that involves multiple freight forwarders. The impact of competition among freight forwarders on both sides and the economic implication for these two market players is also investigated when freight forwarders face homogeneous or heterogeneous contract market demand.

There have been many works in the literature studying decision-making problems under flexible capacity contracts. Particularly, our paper is related to those on revenue management or capacity allotment/reservation policy for asset providers and freight forwarders in air cargo industry. Amaruchkul, Cooper, and Gupta (2011) studied capacity contracts between a carrier and a forwarder in which the carrier sells certain amount of capacity to the forwarder and refunds unused capacity at pre-determined refund rate. They identified a set of sufficient conditions under which the carrier can achieve the first-best profit when informational asymmetry exists. Gupta (2008) studied flexible contracts between a forwarder and an airline that faces demands from both the forwarder and end customers. They proposed two contract schemes, in the first of which the carrier determines an upfront fixed fee for reserving capacity but the freight rate is exogenous, whereas in the second scheme, there is no reservation fee, but the carrier chooses the freight rate. Hellermann, Huchzermeier, and Spinler (2013) proposed an options contract for the airline carriers and derived an optimal reservation policy. Overbooking of capacity was allowed in their work and the impact of overbooking on the profit of the cargo capacity provider was analyzed. Amaruchkul and Lorchirachoonkul (2011) considered a capacity allotment problem for an air cargo carrier that allocates its cargo capacity to multiple forwarders. The contractual scheme allowed the forwarder to return unused portion of its allotment and only actual usage is charged. Besides, there is no reservation fee. The option type contract has also been adopted in other industries. Anderson, Davison, and Rasmussen (2004) presented a real options approach to revenue management the car rental business which is not as price sensitive as the airline industry. Under such a contract the capacity buyer takes a certain base supply every week at a preset price and is also able to decide whether or not he would like to buy more at another preset price later. This approach can also be seen in the electricity and gas industries.

Another stream of researches related to this paper is the studies on advance sale and various supply contractual schemes in the context of supply chain management. Tsay, Nahmias, and Agrawal (1999) have identified three main purposes of supply chain contracts which are system-wide performance improvement, risk sharing and facilitation of long-term partnership. Chew et al. (2006) proposed a stochastic dynamic programming model for re-planning of cargo space at various stages when time approaches the actual flight departure date. An optimal cost policy for the freight forwarders was determined based on the economic trade-off between the cost of backlogged shipment and the cost of acquiring additional cargo space. The study was done based on fixed-commitment booking scheme. Flexible supply contracts, in particular, have recently become the center of the focus because they can incorporate uncertainties associated primarily with, but not limited to, demand and prices. Despite being the pioneer in the development of model for bidding strategies considering the existence of both a long-term contract market and a short-term spot market, Wu, Kleindorfer, and Zhang (2002) only managed to incorporate spot price risk. Spinler & Huchzermeier, 2006 later extended the model to include both cost and demand risk. Zhao, Wang, Cheng, Yang, and Huang (2010) considered the coordination issue of a manufacturer–retailer supply chain using an option contract and showed such contract can coordinate the supply chain and achieve Pareto-improvement. Peng et al. (2012) addressed a dual-source procurement problem with option contracts in the semiconductor industry. A firm can reserve a certain number of equipment from the two supply modes and order again based on the updated demand information. The capacity reservation contract considered in Inderfurth et al. (2013) is also a real option contract where a reservation price, proportional with the reserved quantity should be pay when an order is placed. Fu, Lee, and Teo (2010), Fu, Zhou, Chao, and Lee (2012) studied the portfolio procurement problem adopting option contracts.

3. Capacity pricing and reservation model under option contract

3.1. A Stackelberg game model

In the air cargo industry, carriers are the service providers that own airplanes and operate flights to freight goods regionally and globally. Forwarders, which typically do not own any air

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