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Air cargo revenue management under buy-back policy

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ABSTRACT

Few researches address the application of financial “buy-back” concept in the air cargo revenue management. This paper examines the air cargo booking and execution procedure to measure the applicability of the buy-back policy in the air cargo revenue. By applying buy-back policy during the period of order release and order execution, a revenue model is built which incorporates Hellermann's capacity option model into the Black-Scholes pricing model. The results demonstrated that buy-back policy not only answers the questions of whether to buy-back, when to buy-back and how much to buy-back, but also increases the revenues of both asset provider and intermediary. Further study is extended in the overbooking and partial buy-back scenarios. The buy-back policy showed better performance in these two scenarios compared with current approach.

1. Introduction

According to the forecast of Boeing (2014), global air cargo traffic will grow at an annual rate of 4.7 percent over the next twenty years, with global air freight traffic expected to more than double by 2033. Kasarda et al. (2006) pointed out that air freight represents 35%–40% of advanced economies' total import and exports by value. Significance of air cargo increases as it is related to delivering high value or time sensitive products. Moreover, the cargo space is bid six to 12 months prior to departure (Popescu, 2006), thus when to book the space and how much space to book remain a big challenge for intermediaries.

Generally, three players are considered in the air cargo supply chain: asset providers (airlines), intermediaries (air forwarders) and shippers. As the space is bid in advance so far from the departure time, backlog or overbook happen. To hedge against the risk of wasting the capacity, asset provider usually oversells the capacity. Whenever unexpected demand increases, asset provider still can buy back the required capacity from intermediary. Meanwhile, intermediary can choose to book the capacity either from option contractor or from spot market. Because the cargo space bought from spot market is usually more expensive than that from option contractor, intermediaries would overbook the capacity and return the unwanted capacity to the airlines a few days before the departure time at certain cost. The overselling/overbooking from airlines and intermediaries makes the revenue management complex for the air cargo industry. Scholars have extensively analyzed the elements of cargo revenue management and the underlying philosophy in the air industry. For example, Han et al. (2010); Popescu et al. (2013), and Castelli et al. (2014) all proposed dynamic biding prices to manage the revenue according to the demand forecast. While earlier work focused on using pricing tools, recent contributions highlighted the need for novel approaches. Moreover, pricing tools is used for decision in the period before booking. Study calls for exploring the decisions in the period of booking release and booking execution. To manage the revenue effectively, both asset provider and intermediary need to decide when to book/sell the cargo space, how much space to be reserved, and at what price, so as to increase the total profit?

It is observed that there is limited study in the usage of buy-back tools in air cargo revenue management. As a prevalent financial instrument in the stock market, “buy-back” means repurchasing a portion of its own outstanding shares, either to increase the share value or to prevent hostile takeover. Therefore, our study aims to fill this gap by applying financial concept into the logistic domain. The action of re-obtaining the right of cargo space is executed between asset provider and intermediary. Asset provider can buy back those

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Notations

Variables

$\tilde{D}_c$	Contract market demand
$\tilde{D}_s$	Spot market demand
$\tilde{E}$	Reservation types
K	Option striking price of space at a particular flight
B	The maximum booking that asset provider accepts in the spot market
$\tilde{M}$	Actual bookings in the spot market
N	The reserved capacity by intermediary before knowing the spot price
S	Current space price
c	Reservation cost per unit, $c = r + x$
e	Exponential term
f	Fixed cost per unit
r	Reservation fee per unit from the perspective of intermediary
$\tilde{s}$	Spot price per unit from the perspective of asset provider that charged the intermediary
t	Spot cost per unit from the perspective of asset in the spot market
v	Execution cost per reserved capacity unit to be called
w	Forward-contract market price per unit
x	Execution fee per unit
λ	Intermediary's earnings
$(T\text{-}t)$	The time to the execution date (in year basis)
K	Strike price, which equals to the sum of execution cost and the reservation cost
r'	Annual risk-free rate, $r' = \ln(1+r_0)r' = \ln(1+r_0)$
σ	Daily volatility of the spot market price
$N(\cdot)$	The function of cumulative standard normal distribution

overselling space either to keep the supply promise in the peak season, or to resell at higher price. Intermediary may be more willing to sell back the overbooking space to the asset provider than to the spot market. Because selling back the space to the asset provider can assist building a good relationship with the asset provider. Buy-back makes a win-win situation both for asset provider and intermediary. In the practical case, the financial buy-back is usually applied between the airlines and the large-scale forwarders who have stable and regular business around the year. Exploring the potential application of buy-back policy, asset provider and intermediary can response to the unexpected demand more easily as well as provide more flexible service to the shipper. The utilization of the cargo capacity can be increased as the extra cargo capacity can be bought back and resold which reflecting the market demand. With regard to the policy maker, the buy-back item can be developed as a specific contract version which allows more agile transactions. According to the potential benefit of buy-back policy, this paper intends to explore the application of buy-back policy in the air cargo booking, concerning about whether to buy-back, when to buy-back, how much to buy-back, so as to maximize the total profit of asset provider and intermediary.

Following this introduction, the reminder of the paper is structured as follows. Section 2 reviews related studies of revenue management of air cargo in terms of booking control and buy-back policy. In Section 3, the application of buy-back policy in air cargo revenue management is analyzed: Section 3.1 illustrates the interaction between asset provider and intermediary for capacity reservation, and Section 3.2 describes the exact meaning of buy-back policy. Section 3.3 lists the notations, and Section 3.4 summarizes the related assumptions. Section 3.5 illustrates an overview of the model. The verification of the buy-back policy is conducted in Section 4 which firstly illustrates the application in regular booking condition, and the scenarios of overbooking and partial buy-back are further tested. The conclusions are given in Section 5.

2. Literature review

The following review attempts to delineate the current study of revenue management in the air cargo industry, and summarizes previous research, with the purpose of establishing our underlying model for buy-back policy.

2.1. Booking control of air cargo

Booking control of air cargo is an active area of revenue management research. Kasilingam (1997) modified many traditional passenger yield management models and applied them in the cargo environment. This paper was the first paper that distinguished air cargo yield management from passenger yield management in the aspects of uncertain capacity, three-dimensional capacity, itinerary control and allotments. Since then, air cargo revenue management has been treated as an independent subject of revenue management and has received comprehensive exploration. Slager and Kapteijns (2004) described a pragmatic approach of managing cargo revenue at KLM Royal Dutch airlines by dividing capacity sales into contracts and free-sales. In the model of Sandhu and Klabjan (2006), both passenger and cargo revenues are considered. They applied Benders decomposition to solve the fleeting and bid price based origin-destination revenue management problem. Becker and Kasilingam (2008) described the process of implementing IT-support cargo revenue management solutions in the air cargo domain. Levin et al. (2012)'s value function approximated expected profits from the spot market with desirable monotonic properties. Their control policy focused on the allotment contract for spot market without concerning the option contract. Zhuang et al. (2012) analyzed the impact of the random resource consumptions on optimal single-resource cargo revenue management decisions. They found that the booking limit policy cannot produce the optimal revenue when the demand class exceeded two and thus they proposed two heuristics to deal with this problem.

Several papers concentrated the cargo booking problem on a single flight leg. For instance, the booking problem was formulated by Amaruchkul et al. (2007) as a Markov decision process. In their work, due to the high-dimensional state space, six heuristics were developed to solve the optimal expected revenue. Han et al. (2010) developed a discrete-time Markov chain for the capacity allocation problem, where the booking request decision followed a bid-price control policy and the simulation results outperformed the First Come First Booking (FCFB) algorithm and the algorithm proposed in Pak and Dekker (2004). Following the concept of dynamic capacity control, the general two-dimensional (price and demand intensity) revenue management problems were considered by Xiao and Yang (2010). They derived the structural properties of the optimal solution and proved that the proposed recursive continuous-time model was computational efficient. Moreover,

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