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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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numerical examples confirmed that the proposed model was capable of improving the revenues compared with the heuristics commonly used in practice. Wu (2011) examined the air container renting and loading problem, where the bookings were divided into two types: certain bookings were handled with mixed integer model and uncertain bookings were executed in two stages. However, this paper was analyzed from the perspective of air forwarding company, the optimization was not applied for the whole air cargo participants. Qin et al. (2012) established a dynamic space inventory control model for a single-leg. In the proposed model, the booking lead time was divided into small discrete periods and the simulation results illustrated that the optimal booking limits were time-dependent and nested in the goods classes. This paper considered the overbooking under the conditions of shipping season by involving the penalty cost. After some proofs, the optimal booking-limit policy for each class of goods were deduced. Hoffmann (2013) decomposed the integrated availability of seat and cargo capacity over a single leg. A bid price heuristic was proposed to solve the overbooking problem. The proposed model was further extended to optimize the cargo capacity over an entire network of flights.

2.2. Buy-back policy

In the financial area, the buy-back action is implemented by issuer to repurchase the outstanding shares (stock or bond) to reduce the number of shares outstanding in the market. The reasons for buy-back include increasing the value of shares by reducing supply, and avoiding the takeover risk. Referring to the callable bond, the buy-back action is executed at a predetermined price at specified future date before the bond reaches its maturity, where the call option is embedded in the bond. Technically speaking, there is no tangible product/service movement in the financial buy-back, and the bonds are not really bought and held by the issuer but instead cancelled immediately (Brealey et al., 2014).

The buy-back policy is one of the frequently used instruments in the logistics practice (Padmanabhan and Png, 2004; Mondal and Mukherjee, 2006; Arcelus et al., 2008; Ding and Jian, 2008; Zhao, 2008; Hsieh and Lu, 2010; Wei and Peng, 2013; Zhang et al., 2013). In the supply chain domain, buy-back contract is used to describe the repurchase of a retailer's leftover inventories under demand uncertainty and there is usually no call option in the inventories. Many studies have investigated the buy-back contract where they called return policy. For example, Qin and Xue (2010) extended an initial buy-back contract to maximize the supply chain member's expected profit as well as to satisfy the risk aversion constraint. Based on the combination of risk aversion preferences, the market demand was recognized and the specific contract was offered accordingly (normal buy-back contract or extended buy-back contract). Kleber et al. (2012) analyzed spare parts procurement in the end-of-life phase. The procurement was subjected to different combinations of spare parts' availability condition and the buy-back flexibility, therefore the decision makers need to choose the proper procurement strategy from three buy-back alternatives. However, these researches were based on the fact there was actual tangible product return and the return was happened after the sale was done (i.e. the ownership of the product or service was transferred).

2.3. Research gaps

Thorough review reveals that there are some similarities between the stock and air cargo space: both have no physical asset before implementation, both represent a fraction of the ownership/right from the perspective of the shareholder/intermediary, and both allow selling or buying the right freely. These similarities make "buy-back" tool applicable in the air cargo. However, current work has not extended the financial buy-back policy into supply chain application where the product or service return is happened before the actual ownership transfer.

Because in the air cargo industry, the product is cargo capacity instead of tangible items, and space is reserved till the departure date (maturity date). Moreover, what the intermediary paid is to book the space without entity ownership transfer. It is free and easy to trade the space before the space maturity date. Therefore, the traditional logistics buy-back (i.e. physical return) cannot be applied in the air cargo case, and the booking control of the air cargo should be adjusted during the period of demand reservation and actual trade implementation. Based on the above review, this study is intended to answer the air cargo booking/selling questions of asset provider and intermediary about the time, volume, price so as to increase the total profit by applying financial buy-back policy in the air cargo revenue management domain.

3. The proposed model

3.1. Description of the space procurement process

According to Amram and Kulatilaka (1999), an option is the right, but not the obligation for the holder to buy or sell property at an agreed price. If it is not exercised by a stated date the money is forfeited. Applying the concept 'option' in our context means that the intermediary buys the right to get the air cargo space at an agreed price in the future by paying the option price and to exercise the buying before the expiration date. To exercise the option and to actually buy the space before the expiration date, the intermediary has to pay a defined strike price which acts like a reservation. Asset providers has the corresponding obligation to fulfill the transaction if intermediary exercises the option. To the contrary, intermediaries are not obligated to buy the space as agreement. Therefore, to avoid the potential unexercised action, asset providers usually oversells the option and proposes to buy back certain capacity before the actual exercise. The asset refers to the space of the operating carriers in the application.

We make the following assumptions in order to explain the procedure: a trade with two participants is considered. Single airline is considered in the model to provide cargo space and is recognized as an asset provider (A). The other side of the trade who can access the space of the airlines by buying options is called intermediary (I). The intermediary only sells the space to the end customers without actually operating the airlines.

In practice, the option price represents the value that intermediary pays to asset provider for reserving the cargo space in the airplane, no matter whether it is a cargo plane or a passenger plane. As long as strike price is paid to the asset provider, intermediary is capable to sell the space to the end customers. The sold option can be repurchased by the asset provider at certain price. Therefore, option price and strike price remain valid till the option reaches its maturity. The end customers will not involve in such trade.

One iteration of the trade can be divided into three periods of time: before, during, and after the booking process. Fig. 1 shows the reciprocation between the asset provider and the intermediary.

Before booking any space of a particular flight, ①the asset provider decides how much space to sell to the intermediary in terms of forward contract and option contract, based on the estimated market demand. ②After the asset provider announces the available space and the selling price, e.g. option price, to the intermediary, the intermediary decides how much space to buy and in which form (forward contract or option contract) to buy. The amount of option and the type of option that the intermediary can

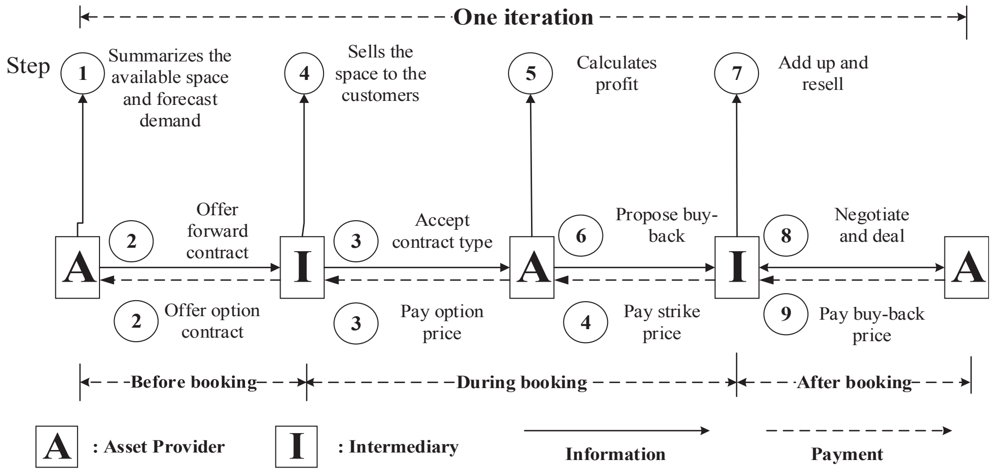

Fig. 1. Reciprocation between the asset provider and intermediary.

buy are subjected to the maximum capacity that the asset provider offers. ③The intermediary in the contract market reserves the space by paying the option price to the asset provider. During the booking process, the intermediary obtains the space by exercising the option. ④To smooth a flexible trade, the asset provider has the right to buy back the unexercised options from the intermediary when the actual demand for space is less than assumed. ⑤When the option price and strike price are fixed, the revenue of the asset provider is fixed (Graf and Kimms, 2013). ⑥When the demand and spot price from the spot market increase, the asset provider tends to sell the space to the spot market for higher profit. In such circumstance, the asset provider can reobtain the reserved space by paying the option and compensation to the intermediary. ⑦The asset provider, however, considers the buy-back alternative only when the estimated buyback revenue is not less than the confirmed revenue (the sum of the strike price and the option price). ⑧After the booking process, the asset provider accumulates the bookings and calculates the spot price according to the summarized demand. In the meanwhile, the intermediary specifies the selling price and communicates with the end customers. ⑨After the demand from the end customers is determined, the intermediary adds up the revenue and decides how much space to book in the future. The interaction between the asset provider and the intermediary restarts and repeats the same steps until the fixed number of iteration is reached.

The application of buy-back is executed during the time of order release and order execution. The goal of the application is to maximize the revenues for the asset provider and the intermediary under the buy-back policy.

3.2. Description of the buy-back

Buy-back policy is offered by asset provider to intermediary to renew the contract with some compensation. The process of buy-back starts with asset provider increasing the original contract price due to the increased expected demand. Then the intermediary negotiates with the asset provider regarding the compensation for future potential loss. Buy-back ends with the release of new contract, after that the intermediary rearranges the previous capacity planning and announces the new price to the end customers. Buy-back occurs only when the sum of the reservation fee and the execution fee is smaller than the potential value of the unexercised options, where the potential value of the unexercised options is calculated by the adjusted Black-Scholes model.

3.3. Assumptions

The assumptions are set with regard to the market and procurement process:

- market is assumed to be efficient, which means the market condition cannot be predicted perfectly;
- both the profit predictions of asset provider and intermediary are performed at the same time;
- there is no overbooking before the order release;
- no commissions are paid during the option life, so the option price will not influence the actual booking;
- the option can only be exercised at the date of expiration;
- the buy-back can happen anytime between the order release and the execution date;
- once buy-back occurs, all the buy-back orders need to be sold;
- risk-free rate and its volatility are applied in the model;
- the cost of the contract (the sum of the reservation price and the execution price) should be less than the mean value of the spot market price, otherwise the intermediary will purchase only from the spot market;

3.4. Overview of the model

Hellermann proposed capacity option (Hellermann, 2006) as an alternative contract type for forwarders to hedge against unforeseen price and uncertain demand. As it refers to the decision before capacity reservation in the forward logistics, it can only provide reference about contract type and capacity price. When buy-back option is concerned, Hellermann's model cannot offer information about whether to buy-back, when to buy-back, how much to buy-back and at what price to buy-back. Therefore, it is necessary to involve other resources that assist the decisions of reverse deal. With well-known for its accuracy and application in the financial market, Black-Scholes pricing model will be incorporated to generate solutions for the above questions and determine buy-back value during the period of order release and order execution.

3.4.1. Capacity options in the Hellermann's model

The environment of the model proposed is similar to that of Hellermann's capacity option model. In this model, there are only one asset provider (A) and one intermediary (I). The single asset provider or intermediary is the aggregation of all asset providers or

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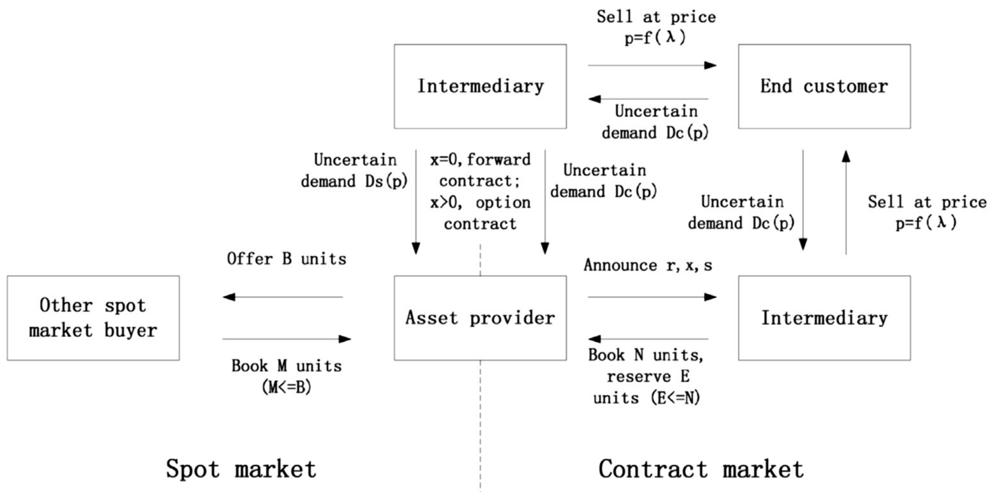

Fig. 2. The booking procedure.

intermediaries with same profit function. The market condition follows the main setting in the operations works (Weatherford and Bodily, 1992; Youyi and Baichun, 1999), such as A and I are risk neutral and prone to maximize the expected profits, and the spot market is assumed to be perfectly competitive. In the market, the asset provider offers a fixed-commitment contract (forward contract) and a spot contract to the intermediary. With regard to the forward contract, the asset provider sells the capacity at a specified future at a price agreed upon today. The intermediary promises to call on all the capacity at the agreed date and at the agreed price. Forward contract will not be discussed further in this paper and the main discussion of the following content is based on the spot contract. In contrast to a forward contract, a spot contract is a contract of buying or selling the underlying item on the settled date which is normally after the trade date. The asset provider announces the strike price which including the reservation fee r and execution fee x, then intermediary starts to book N units of capacity. When the spot price s is recognized, the intermediary would reserve E units ($E \le N$). After the capacity is confirmed, the intermediary would handle the capacity by adding value or directly selling it to the targeted customers at price p, where p includes the markup λ. In this procedure, the asset provider faces uncertain demand $\tilde{D}_c$ from the contract market and $\tilde{D}_s$ from the spot market, where $\tilde{D}_c$ and $\tilde{D}_s$ are independent (Weatherford and Bodily, 1992). Meanwhile, the asset provider offers B units of capacity and receives M bookings ($M \le B$) from other spot market buyers. The detailed procedure can be seen in Fig. 2.

Assume the spot market has unlimited capacity supply (Hellermann, 2006). As the forward contract has already been confirmed, asset provider can only sell up to $\tilde{D}_s$ capacity in the spot market given the total capacity K. Therefore, according to C. F. Mills (1959) and Lau and Lau (1988), the demand in the contract market is formulated as

$$\tilde{D}_C(p) = a - bp + \tilde{\varepsilon} \tag{1}$$

Where $\mu_{D_c} = \varepsilon(a - bp + \varepsilon)$ and $\mu_{D_c} = a - bp$, when. $\sigma_{D_c} = \sigma_\varepsilon$

In equation (1), $a > 0$, $b \ge 0$, and $\tilde{\varepsilon}$ is normally distributed ($\tilde{\varepsilon} \sim N(0, \sigma^2_{\tilde{\varepsilon}})$). The ordinate intercept a is the maximum market size, slope $-b$ is the amount of change that market demand transfers according to the price, and the stochastic error term $\tilde{\varepsilon}$ is the demand uncertainty. Similarly, the normal distributed demand of the spot market is expressed as $\tilde{D}_s \sim N(\mu_{\tilde{D}_s}, \sigma^2_{\tilde{D}_s})$.

As the spot market is independent of the contract market, the actions of the asset provider and intermediary will not influence the market. Therefore, the intermediary will add a certain markup λ to the procurement cost $(\gamma + x)$. The selling price of the intermediary is

$$p = r + x + \lambda \tag{2}$$

In the contract market, the intermediary can maximize profit $\tilde{P}_I$ by selecting the optimal reservations amount $\tilde{E}$ to be exercised on the premise of the realizations of the contract market demand $\tilde{D}_c$ and spot price $\tilde{s}$. Therefore, the objective function is expressed as

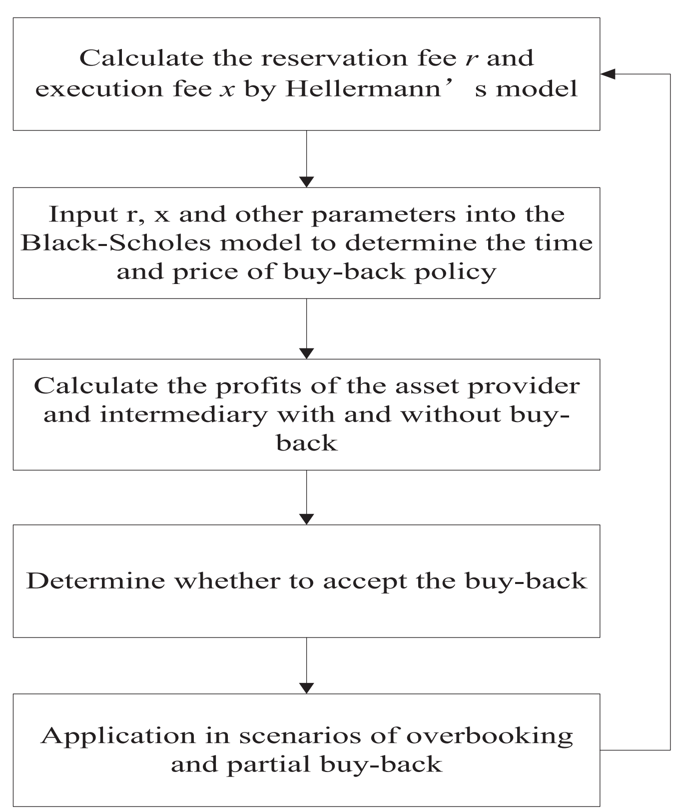

Fig. 3. Testing procedure.

Table 1
One set of input values (Unit: RMB).

Time	Spot market demand	Spot market price	Contract market demand	Contract market price
0.00	144.98	22.35	84.47	23.08
0.05	191.20	18.89	89.64	23.08
0.10	182.69	17.92	106.86	23.08
0.15	192.84	20.87	98.88	23.08
0.20	191.44	20.12	101.66	23.08
0.25	183.71	18.17	124.75	23.08
0.30	196.48	14.32	101.16	23.08
0.35	193.77	16.16	122.46	23.08
0.40	214.05	20.56	105.29	24.16
0.45	176.93	22.23	101.54	24.16
0.50	210.56	21.79	110.84	24.16
0.55	202.77	23.82	111.23	24.16
0.60	195.67	20.09	99.94	24.16
0.65	202.93	22.56	97.35	24.16
0.70	171.11	24.01	85.51	24.16
0.75	181.63	21.24	94.00	24.16
0.80	190.03	18.39	99.85	24.16
0.85	189.33	18.02	119.71	24.16
0.90	178.54	21.27	99.46	24.16
0.95	191.42	22.67	112.51	24.16

$$\max \tilde{P}_I = \max p\tilde{D}_c - rN - x\tilde{E} - \tilde{s}\left(\tilde{D}_c - \tilde{E}\right)^+ \tag{3}$$

$$\text{s.t.} \quad N \geq \tilde{E} \tag{4}$$

$$\tilde{E} \leq \tilde{D}_c \tag{5}$$

$$\tilde{E} \geq 0 \tag{6}$$

Equation (3) demonstrates that the total profit is the difference between the revenue from the sold space and the total cost. The total cost is composed of reservation costs before and after knowing the spot market price, and the spot market cost. Constraint (4) makes sure that the intermediary reserves less than the booked amount. Constraint (5) and (6) ensure the booking amount is no more than the contract market demand and it is positive. In addition, according to Hellermann's lemma, the amount of capacity that intermediary reserves can be expressed as

$$\tilde{E} = \begin{cases} \min\left(\tilde{D}_c, N\right) & if \quad 0 < x \leq \tilde{s}, \\ 0 & if \quad x > \tilde{s}. \end{cases} \tag{7}$$

Equation (7) demonstrates that the space reservation will happen when it is cheaper to book the space from contract rather than from spot market. With the same meaning, the asset provider wishes to maximize the profit $\tilde{P}_A$ which can be expressed as

$$\max \tilde{P}_A = \max \varepsilon\left[(r-c)N + (x-v)\tilde{E} + (s-t)\tilde{M} - fK\right] \tag{8}$$

$$s.t. \; r \geq 0, \; x \geq 0$$

where the profit of the asset provider is the deduction of the fixed capacity cost from the margins (the sum of selling the reservation, the executed reservation in the contract market, and the sales from the spot market).

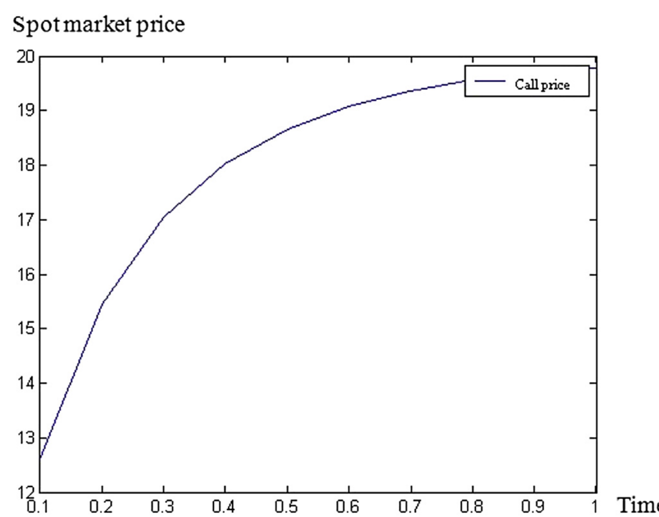

Fig. 4. Call price (Unit: RMB).

Fig. 5. Time for buy-back (Unit: RMB).

3.4.2. The pricing of the call option in the Black-Scholes model

According to Black and Scholes (1973), the call option value for the non-commission-paying underlying asset is expressed as:

$$C(S,t) = N(d_1)S - N(d_2)Ke^{-r(T-t)/365} \tag{9}$$

Table 2
Profit with buy-back vs. profit without buy-back (Unit: RMB).

Time	Asset provider's profit		Intermediary's profit		
	With buy-back	Without buy-back	With buy-back	Without buy-back	
0.00	305.31	478.93	537.96	943.26	
0.05	474.87	619.43	602.39	855.45	
0.10	275.67	323.42	817.01	788.44	
0.15	930.94	940.94	717.55	907.19	
0.20	779.71	856.71	752.18	461.16	
0.25	383.06	383.06	968.95	906.35	
0.30	286.08	206.30	745.99	1136.96	Buyback time and price
0.35	133.33	125.47	1175.80	815.39	196.11
0.40	1193.44	1228.99	955.16	969.43	
0.45	886.64	833.80	907.04	888.35	
0.50	1433.45	1498.97	1026.45	951.58	
0.55	1715.00	1692.74	1031.51	922.12	
0.60	780.32	914.61	886.49	985.28	
0.65	1374.64	1481.83	853.16	865.10	
0.70	989.88	1114.51	701.10	913.12	
0.75	740.19	911.99	810.15	923.71	
0.80	371.80	504.39	885.23	746.73	
0.85	417.65	427.18	1140.41	980.51	
0.90	729.54	815.61	880.22	650.92	
0.95	1290.28	1161.92	1048.00	931.32	

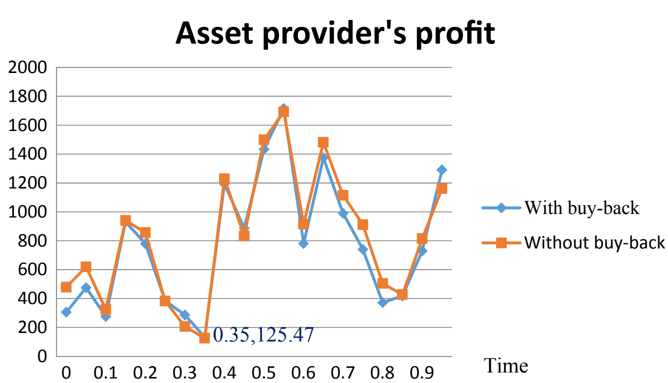

Fig. 6. Asset provider's profit (Unit: RMB).

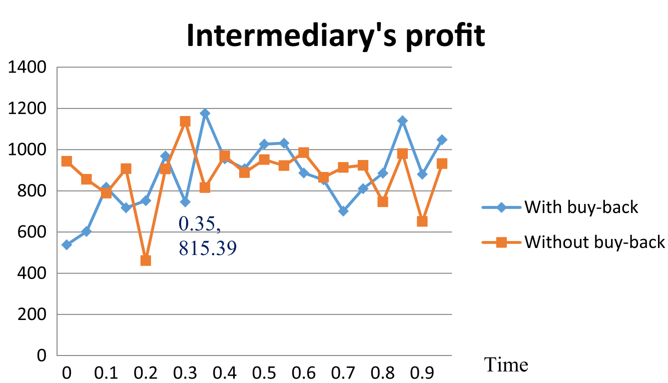

Fig. 7. Intermediary's profit (Unit: RMB).

$$\text{Where } d_1 = \frac{1}{\sigma\sqrt{T-t}}\left[\ln\left(\frac{S}{K}\right) + \left(\frac{r}{365} + \frac{\sigma^2}{2}\right)(T-t)\right]$$

$$d_2 = \frac{1}{\sigma\sqrt{T-t}}\left[\ln\left(\frac{S}{K}\right) + \left(\frac{r}{365} - \frac{\sigma^2}{2}\right)(T-t)\right] = d_1 - \sigma\sqrt{T-t}$$

In Equation (9), the first section demonstrates total spot market value before option maturity and it is the product of unit spot market price and the bought space from spot market, while the second section means the total strike option value. As the buy-back occurs during the order release and the order execution, which is around one year, the daily price of the call option is calculated by dividing the whole price by 365 days.

3.5. *Testing procedure*

Fig. 3 illustrates the incorporation of these two models. In the first step of the testing procedure, the demands and prices in both the spot market and contract market are input into Hellermann's model, and the reservation fee and the execution fee of call option are obtained. These data are passed into the Black-Scholes model, where the time and the corresponding price of the buy-back are determined. After the profits of the asset provider and the intermediary are calculated for the cases of 'buy-back' and 'without buy-back', the asset provider and intermediary can determine whether to accept the buy-back policy. In the same procedure, the applications of the buy-back policy in the scenarios of overbooking and partial buy-back are extended.

4. Experiments and results

Section 3 describes the testing procedure of the buy-back policy where both the Hellermann model and Black-Scholes model are programmed in Matlab. According to the assumption, the data of the demand and price in the spot market are generated based on the fitted normal distributions of practical data (i.e. $\tilde{D}_s \sim N(180,\ 15)$ and $\tilde{D}_p \sim N(20,\ 2.5)$ respectively). Similarly, the demand and price in the contract market are set as $\tilde{D}_c \sim N(103,\ 11)$ and $\tilde{D}_t \sim N(23,\ 0.5)$. This setting reflects the practical situation as the demand in the spot market is generally larger than that in the contract market. Moreover, the price in the spot market is more easily fluctuated by the demand change than that of contract price, so intermediary intends to book the space from asset provider rather than from spot market. Table 1 demonstrates one set of input values. Through the experiment, we expect to find out the relationship between the call price and the spot market price and how does it impact the buy-back decision.

The call price of the spot market is calculated based on the built-

Table 3
Input data in the overbooking scenario (Unit: RMB).

Time	Spot market price	Spot market demand	Contract market demand	Booked capacity
0.00	22.23	191.24	127.76	125.00
0.05	20.16	209.21	148.35	125.00
0.10	18.88	194.17	107.13	125.00
0.15	18.39	204.39	149.38	125.00
0.20	13.10	218.65	123.04	125.00
0.25	27.09	209.41	97.47	125.00
0.30	24.73	190.73	91.88	125.00
0.35	25.08	196.03	120.18	125.00
0.40	23.30	167.22	118.54	125.00
0.45	23.32	176.94	108.29	125.00
0.50	20.22	200.83	114.67	125.00
0.55	14.72	210.53	100.53	125.00
0.60	18.28	228.80	122.54	120.07
0.65	28.77	234.60	74.00	120.07
0.70	25.54	209.43	86.99	120.07
0.75	17.93	207.01	82.49	120.07
0.80	22.21	202.43	67.77	120.07
0.85	21.05	190.16	69.73	120.07
0.90	22.98	185.87	71.83	120.07
0.95	27.46	196.93	104.86	120.07

Table 4
Profit with buy-back vs. profit without buy-back in the overbooking scenario (Unit: RMB).

Time	Asset provider's profit		Intermediary's profit		
	With buy-back	Without buy-back	With buy-back	Without buy-back	
0.00	1354.57	1257.40	1002.35	933.78	
0.05	1232.44	1135.27	1068.09	892.86	
0.10	654.10	521.82	777.34	1010.08	
0.15	797.36	697.82	1114.30	859.99	
0.20	180.96	267.13	975.61	805.39	
0.25	2531.07	2545.80	657.01	913.33	
0.30	1637.68	1709.86	587.36	895.92	
0.35	1968.34	1882.02	939.94	901.21	
0.40	1083.57	1022.69	919.53	911.32	
0.45	1207.14	1203.90	791.75	922.32	
0.50	1058.62	1019.51	871.26	604.65	
0.55	31.64	18.29	695.16	954.59	Buyback price
0.60	1096.32	1001.81	1317.79	976.01	337.50
0.65	3274.79	3539.51	676.85	887.73	
0.70	2101.49	2264.95	851.96	804.35	
0.75	441.86	498.25	791.29	761.29	
0.80	1133.29	1446.58	592.85	840.72	
0.85	716.66	1014.66	619.29	675.01	
0.90	1023.47	1229.71	647.54	923.38	
0.95	2361.32	2286.71	1092.91	862.56	

in function “*normrnd*” in the Matlab 2014b software, and it is positively related with the spot market price (Fig. 4). This is because spot market is always more sensitive than option contract. As time moves on, the actual demand is gradually realized and asset provider has to pay more to redeem the option when the intermediary can choose to sell the option to the spot market. The input price of the spot market is set as: mean value is 20 and standard deviation is 5. The correlation of the spot market price and the call price can further be illustrated in Fig. 5 where the intersection is the time for buy-back. In Fig. 5, both call price and spot market price increase and fluctuate in the same pattern as time moves closer to the departure. In addition, the movement of call price (residual value) is higher than that of spot market price because asset provider need to offer more to beat the spot market. After that, order value keeps almost the same. However, buy-back occurs only when both the asset provider and the intermediary make sure this action will bring more profit.

Table 2 illustrates the profit changes of asset provider and intermediary due to the application of buy-back policy. In this experiment, the initial reservation fee r is set as 4.46, exercise fee $x = 10.62$ and 115.35 units of capacity are booked according to the output from Hellermenn's model. As the tested data are generated by computer following certain distributions, the experiments are run several times and the results are the average profits of twenty runs.

In Fig. 6 and Fig. 7, the intersection is the buy-back time. Though the profits of the cases ‘with buyback’ and ‘without buyback’ fluctuate, at the end of the booking iteration the asset provider can get more than eleven percent $\left(\frac{1290.28-1161.92}{1161.92}*100\%\right)$ profit improvement using buy-back. In the same sense, the intermediary can get around twelve percent more profits by applying the buy-back policy. As a critical portion of airline revenue, the profit benefits in the air cargo represent a promising business growth point that drives asset provider and intermediary. They would enhance the provided value by offering a secure and sustainable service in air cargo supply chain. In the following section, two scenarios will be discussed which represent different strategies of booking in the practical action.

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Table 5
Input data in the partial buy-back scenario (Unit: RMB).

Time	Spot market price	Spot market demand	Contract market demand	Booked capacity
0.00	21.02	218.70	134.00	115.36
0.05	19.07	207.14	123.24	115.36
0.10	22.98	186.90	142.05	115.36
0.15	23.73	202.03	137.68	115.36
0.20	25.51	207.54	143.91	115.36
0.25	21.36	180.05	127.74	115.36
0.30	18.78	201.86	111.04	115.36
0.35	14.46	199.48	106.64	115.36
0.40	16.66	190.03	127.36	115.36
0.45	18.31	208.15	120.89	115.36
0.50	15.79	197.28	110.53	115.36
0.55	18.32	226.07	116.91	115.36
0.60	20.51	194.06	99.82	115.36
0.65	19.48	197.00	104.65	115.36
0.70	18.66	205.39	124.98	115.36
0.75	20.92	201.94	110.36	115.36
0.80	22.52	197.59	137.55	115.36
0.85	21.80	202.99	104.82	115.36
0.90	22.90	203.33	107.60	115.36
0.95	17.72	201.20	139.27	115.36

Table 6
Profit with buy-back vs. profit without buy-back in the partial buy-back scenario (Unit: RMB).

Time	Asset provider's profit		Intermediary's profit		
	With partial buy-back	Without partial buy-back	With partial buy-back	Without partial buy-back	
0.00	1467.39	1438.20	961.20	671.71	
0.05	876.79	876.79	954.50	947.87	
0.10	1322.95	1322.95	925.61	859.92	
0.15	1747.12	1747.12	908.35	577.43	
0.20	2219.67	2219.67	853.46	824.74	
0.25	908.45	793.86	944.18	864.42	
0.30	741.94	716.62	1015.40	919.48	
0.35	53.68	274.66	835.87	954.65	Buy-back price
0.40	320.08	179.14	928.20	1016.64	1.2
0.45	735.71	727.86	1250.46	672.02	
0.50	335.39	91.72	802.72	757.92	
0.55	983.29	974.01	2003.69	804.90	
0.60	485.19	972.51	669.24	959.02	
0.65	695.10	771.30	389.43	974.19	
0.70	707.65	594.30	565.43	957.02	
0.75	1090.29	1133.56	460.60	901.59	
0.80	1363.83	1423.84	707.23	928.94	
0.85	1254.67	1224.81	391.53	936.12	
0.90	1499.00	1602.65	426.15	848.07	
0.95	462.89	439.62	841.06	690.40	

4.1. ***Scenario 1***: *overbooking is allowed*

Overbooking is an intentional practice of the business strategy which sell good or service in excess of actual capacity. In the air cargo industry, overselling is quite common. Asset providers usually oversell the space to maximize return on investment as dead freight cannot fully compensate the opportunity cost. In the meanwhile, intermediaries tend to overbook the space rather than buy the space from the spot market because it is more expensive. Though one of the assumptions in the proposed model is that there is no overbooking, in practice, the intermediary usually uses this approach to hedge against unexpected demand. Therefore, this scenario will test this situation and figure out the influence on the buy-back. In this scenario it is assumed that asset provider will buy back all the extra space from the intermediary.

In the experiment, the price and demand in the spot market are set a little bit higher than the original case ($(\tilde{D}_s \sim N(200,\ 16))$and $\tilde{D}_p \sim N(21,\ 4.1))$, which creates a virtual prosperous market. In addition, the other parameters of the market are set the same as those of the original case. Therefore, the intermediary would overestimate the market condition and overbook the space at 125 units. As time moves on, the demand from end customers is gradually realized and the intermediary will use the proposed method to adjust capacity by applying buy-back. After applying the proposed method, time 0.60 is recognized as the buy-back time, and the intermediary sells the extra capacity (4.93 units) back to the asset provider at a price 337.5. The detailed input of one set of the data is illustrated in Table 3. Table 4 shows the profit differences in the overbooking scenario. In the tested scenario, it is assumed that asset provider bought back the overselling space, and buy-back price in Table 4 depends on the market price.

At the end of the booking iteration, both the asset provider and the intermediary can get more profit by accepting buy-back policy, 75 and 230 RMB respectively. The relative profit improvement of the asset provider is decreased from 11.04% to 3.26%, while that of the intermediary is increased from 12.53% to 26.71%. This is because in the overbooking scenario, the asset provider needs to pay more to buy back the capacity (from 196.11 to 337.5), while in the original case without overbooking, the profit of asset providers mainly comes from the reservation fee. Moreover, due to the overbooking in the intermediary side, which postpones the recognition of the actual market demand for the asset provider (from time 0.35 to time 0.55), the percentage of profit increase of the asset provider will be less than that of the intermediary. Therefore, it can be concluded that in a limited capacity situation, the overbooking may not provide advantage to asset providers. The buy-back price is high, as the asset providers need to pay more to buy back the original reservation which may not be used by the intermediary. On the other hand, the intermediary's profit increases due to the overbooked orders. Normally, the asset provider should have more profit compared with the case without overbooking. Because the capacity is easily controlled by the asset provider, the profit can be managed by adjusting the reservation fee and execution fee. The results are the mean value in 20 runs, where the mean profit of the asset provider is still higher than that without overbooking.

4.2. ***Scenario 2***: *partial buy-back*

Partial buy-back policy means that asset provider buys back only a portion of the extra space from the intermediary. The amount is determined by asset provider when it has other offers. This policy allows the intermediary to cut the loss of overbooking. In this scenario, the positive buy-back is described as the asset provider partially absorbing the overbooked capacity from the intermediary. Therefore, the negative buy-back is executed in the opposite direction. When the contract market demand is high and the intermediary has to reserve more in order to hedge against the risk, negative buy-back occurs. Compared with the input data in the overbooking scenario, the demand and price of the spot market is kept the same, while the demands in the contract market are higher than those in the overbooking scenario. In addition, because the increased demand in the contract market, intermediary has less overbooking capacity to be resold. This kind of setting is to make sure only part of the unexercised space option will be bought back when the overall demand is stable. The following experiment tests the application of partial buy-back policy in such circumstance $((\tilde{D}_s \sim N(200,16), \tilde{D}_p \sim N(21,4.1), \tilde{D}_c \sim N(122,15) and \tilde{D}_t \sim N(115,0.29))$. One set of input data is listed in Table 5 and 6.

Compared with the original case, 12 more units of capacity are reserved in the partial buy-back scenario which increase the profits of the asset provider and intermediary by 23 and 151 RMB respectively. The profit gain is more remarkable for the intermediary compared with that of the asset provider. The reason is that in the upward demand, the intermediary tends to reserve more at the small expense of the reservation fee. However, the asset provider provides capacity for both the contract market and the spot market, and the overbooked capacity from the intermediary is offset by the fluctuation in the spot market. Therefore, the bullwhip effect to the asset provider did not work effectively and the oversold capacity owned by the asset provider did not greatly influence the overall market. In such circumstance, the asset provider will not accept the negative buy-back policy considering the risk that needs to be taken. With regard to the intermediary, the negative buy-back policy is preferential. However, the practical implementation of the partial buy-back still needs to be negotiated by both sides.

5. Conclusions

This paper addresses an air cargo space buy-back problem accounting for demand uncertainties. The buy-back occurs between the order release and order execution period. The idea of asset provider redeeming the space from intermediary comes from financial buyback concept. The similarities of financial concept and logistics application are derived by literature review. Based on the description of cargo procurement process, a buy-back model is proposed which takes advantage of Hellerman's capacity option model and Black-Scholes's pricing model. The proposed model generates the buy-back time and price. Experiments demonstrated that the proposed buy-back model yielded more profits for asset provider and intermediary. The model is further tested under the overbooking and partial buy-back scenarios and both experiments got impressive results. Therefore, implementing buy-back policy can improve revenue for air cargo industry and it is an extended application of financial buy-back concept in the new industry.

Comparing with previous studies, this study proposed a buy-back scenario in which the improvement occur from the perspective of asset provider and intermediary's profit. For the airline and air forwarder companies, it may be a novel approach to effectively manage the revenue and service by introducing the buy-back policy. It is a relatively new concept and it offered a feasible judge point for asset provider to pick up the optimal time.

Future work can adjust the proposed procedure which considering the dependency between the demand and the spot market price, since many real-world problems appear from the assumptions used. Moreover, the application of buy-back policy should be generalized considering more participants. Future research can also explore the model adoption given the imperfect demand forecasting.

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