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A mixed wholesale-option-contract to fix the demand imbalance between substitutable air cargo routes: a cooperative game approach

Abstract

In this study, we consider a capacity allocation problem with an airline who sells two substitutable routes to multiple freight forwarders. The airline faces the problem whereby its fixed capacity from one route cannot cover the sum of freight forwarders' orders (hot-selling routes), while the freight forwarders' total orders from the substituting route are much less than its capacity (underutilized routes). To solve this imbalance problem, a sequential cooperative game is performed between the airline and the freight forwarders in which they agree that the airline assigns an amount in the underutilized routes proportional to the forwarder's order from the hot-selling routes. In this game, the players' payoffs are the expected profit from using a mixed-wholesale-option contract between the airline and the freight forwarders. The mixed contract takes advantage of airline power in selling the hot-selling routes at the wholesale price and gives advantage to forwarders by optioning the underutilized routes. The model solution shows that the demand in the underutilized routes follows self-replicating distributions. Also, the mixed wholesale-option model is compared with the pure wholesale and pure option-contract models. The results reveal that the mixed model provides the highest allocations in the underutilized routes, leading to a better demand balance among the substitutable routes.

Keywords: Wholesale contract, Option-contract, Air cargo, Cooperative game, Capacity allocation.

1 Introduction

In the air cargo industry, the relationship between market demand and route capacity is complicated. The market demand is commonly uncertain and the capacity of the route is either uncertain (Wang & Kao, 2008) or fixed (Weatherford & Bodily, 1992). This causes a gap between the routes' demand and capacities, i.e., the freight forwarders demand in certain route may either exceed the airline's fixed capacity "hot-selling routes" or the demand is much less than the airline's capacity in other routes, which can be called "underutilized routes". In this research, we propose a cooperative game theoretical model between a single airline and multiple freight forwarders in order to solve the imbalance between the hot-selling and underutilized routes under uncertain demand and fixed capacity.

The classic capacity allocation approach is commonly used in the hot-selling routes. In these routes, multiple freight forwarders negotiate with the airline in order to purchase the capacity from the hot-selling routes, but the sum of the freight forwarders' orders exceeds the airline's fixed routes capacity. Consequently, the airline needs to dole out the existing route capacity to the freight forwarders with the aim of maximizing profit and keeping the freight forwarders satisfied. In doing this, the airlines may need to use the common allocation techniques or algorithms such as the proportional allocation, lexicographic allocation, FCFS (first come, first served) and price discrimination, among others (Cachon & Lariviere, 1999a). In these methods, different tools have been used to achieve best performance, such as the use of past sales data and turn and earn strategy (Cohen-Vernik & Purohit, 2013; Lu & Lariviere, 2011). Also, it has been reported in the literature that airlines tend to use revenue management techniques to reserve the capacity for the freight forwarders (Hellermann, 2006; Moussawi-Haidar, 2014) and manage it (Han et al., 2010) in the single leg and in the network scales (Barz & Gartner, 2016).

On the other hand, the capacity allocation is severely complicated when the airline provides substitutable routes to the same destination. A problem of demand imbalance between the two substituting routes then occurs in which the freight forwarders order very high quantities of freight space from hot-selling routes, whereas their demand from the substituting routes is much less than the airline's capacity in these routes (underutilized routes) (Feng et al., 2015). This problem is fairly new in the air cargo industry, and it is likely to become severe because of the increasing use of wide-bodied aircrafts (Boeing, 2016). This problem may cause the airline to suffer losses on both routes. In the underutilized routes, the airline may incur the flight's fixed cost for each empty space in the aircraft belly-hold because of the insufficient demand. Further, a loss of profit in the hot-selling routes may be incurred in terms of penalties as a consequence of the overbooked and offloaded freight. These penalties are incurred in two ways: delay costs for each late unit of freight and stocking cost for each offloaded unit.

To solve the afore-mentioned problem, in this study, a sequential cooperative game between a single airline and multiple freight forwarders is performed in the form of a flexible contracting model. This model takes advantage of the wholesale and the option-contracts for the airline and freight forwarders (Y. Zhao et al., 2010). It is used to sell the capacities on the underutilized and hot-selling routes together as one bundle. Because the airline guarantees that the demand on these routes is always high, the model exploits the airline's power to sell the capacity of the hot-selling route in a wholesale contract. With this in mind, the airline suffers from the low demand in the underutilized routes. Consequently, the airline needs to motivate the freight forwarder to buy more quantities of freight space from the underutilized routes, so the option-contract is a perfect incentive to the freight forwarder. Therefore, we suggest that the airline can use the mixed wholesale-option-contract to reach an agreement with the freight forwarders to calculate a ratio from their request in the hot-selling routes which can then be added to the underutilized routes. The cooperative game is played in two phases. In the first phase, it is assumed that the freight forwarders are risk neutral, while in the second phase, the airline offers buyback incentives under the assumption that some freight forwarders are risk-averse (Nagarajan & Sošić, 2008).

Although the mixed wholesale-option-contracting model uses the suitable contracting method in the suitable routes, the airline and the freight forwarders may have different opinions. The airline may prefer to use its full power to impose the wholesale contract to sell the cargo space in the two routes, while, the freight forwarders may only negotiate in optioning for the two substitutable routes. Therefore, we modeled the game in both pure wholesale and pure option contracting forms to show their effect on the capacity allocation process. Then, the mixed wholesale-option-contract model is compared with the pure wholesale and pure option-contract models. The results reveal that the mixed wholesale-option-contract model provides the best quantity allocation in the two-phase game. The pure option models give the smallest allocation to the airline. This confirms the claim of Y. Zhao et al. (2010) that airlines normally prefer wholesale contracts while freight forwarders prefer option-contracts.

The contributions of this research can be summarized as follows: first, to the best of our knowledge, this paper is one of the first studies to use the mixed wholesale and the option-contract in one model. Usually, the wholesale and the option-contracts are used in the literature as alternatives; however, our approach combines the two methods to establish one flexible contract that solves the imbalance in the substitutable routes demand-capacity gaps. Second, as far as we know, this is one of the first studies on the demand imbalance in the substitutable routes which adopts the cooperative game in two phases. These two phases are mainly designated to cope with both risk neutral and the risk-averse freight forwarders, i.e. the freight forwarders are considered as risk neutral in **phase I** and the airline moves to **phase II** when the freight forwarder tends to be risk-averse. In **phase II**, the model uses the buyback policy to deal with the risk aversion problem. Third, in contrast to the previous work in this area, we considered the airline's rivals by using the two-phase game, i.e. the airline moves to **phase II** when an agreement is not reached in **phase I**, thereby assuring the airline that the freight forwarder will not go to the airline's competitors. Indeed, the airline has the upper hand in the negotiation process if we consider a monopolistic game, but this denies the reality that the airline has rivals. It is therefore important that the airline uses its power wisely. In this work, we used the second phase in the game to increase the airline's power and give the freight forwarders more reasons to stay in the game and agree with the airline on the final allocation decision.

The rest of this paper is organized as follows: the literature review and the related capacity allocation games, and wholesale and option-contract are discussed in Section 2. In Section 3, we describe the model and the problem. In Section 4, the two-phase coordination game is formulated and discussed. We then discuss the pure wholesale and pure option balancing models in Sections 5 and 6 respectively. A numerical illustration is presented in Section 7, managerial insights are discussed in Section 8 and the study's conclusions are presented in Section 9.

2 Literature review

This research can be regarded as a study of capacity allocation and the contracting problem using a game theoretic approach. It aims to solve the demand imbalance between the hot-selling and the underutilized routes in the cargo industry. To highlight the contributions of this study, the most relevant studies are discussed based on three themes: capacity allocation and air cargo capacity management and allocation, games applied to airlines, and the wholesale and option-contracts.

2.1 Capacity allocation

A lot of research on capacity allocation has been done in a number of applications and industries. For example, capacity allocation has been studied in operations management, supply chain management, and revenue management. In operations management, turn-and-earn is frequently used to solve the allocation problem of limited and uncertain capacity conditions. (Cachon & Lariviere, 1999a; Lu & Lariviere, 2011) applied the turn-and-earn strategy to fix the classical high demand-low capacity problem. Also, Cohen-Vernik and Purohit (2013) used past sales to apply the turn-and-earn over two periods. However, the turn-and-earn may lead retailers to inflate their orders in the first period to gain more demand in the next period which negatively affects the next period's sales. This occurs when the retailers are not rivals in the markets, but they compete in the seller's limited capacity (e.g. Cachon and Lariviere (1999a)). This worsens among market rival retailers, i.e. competing for the demand as in Liu (2012) who adopted the uniform allocation strategy. However, Cho and Tang (2014) showed that the uniform allocation strategy is not a successful method to stop the gaming between the competing retailers, especially when they are involved in a Cournot competition. Further, the market competition among the retailers can be inhibited by the proportional and lexicographic allocation (Chen et al., 2013). Similarly, Wei et al. (2013) concluded that the competition between the competing retailers in the supply chain can be slowed down when the supplier leads the game.

Cachon and Lariviere (1999b) studied the capacity allocation for a simple supply chain between *n*- retailers and a single supplier. They employed an optimal allocation mechanism to encourage the retailer to tell the truth when ordering from the supplier. However, the results showed that ordering actual quantities is not effective in the supply chain. Moreover, Fan et al. (2017) showed the effect of the post-sales liability of the quality costs on supply chain members' profitability and on the wholesale prices. Although this may introduce some reality, we argue that in the air cargo industry, an airline can use its power to control this by using suitable contracting tools. In our research, we take advantage of the airline power to adopt wholesale contracts in the hot-selling routes, which induces the freight forwarders to tell the truth. At the same time, we also give advantage to the freight forwarders in the underutilized routes by adopting option-contracts and the incentives in buyback form.

Furthermore, as the airline's capacity in the different routes is fixed, the service is perishable, i.e. the route capacity is no more available for sale upon the flight's departure owing to demand fluctuation, resulting in a problem known as revenue management (Weatherford & Bodily, 1992). Revenue management was first introduced by American Airlines and it was called yield management (Smith et al., 1992). Revenue management encompasses different tools such as capacity allocation, overbooking control (capacity management), and pricing (McGill & van Ryzin, 1999). In revenue management, capacity allocation and pricing are correlated and the correlation appears in three situations: first, the product, service or process prices are fixed or determined ahead and the optimal quantities are then estimated (Hosseinalifam et al., 2016). Second, the optimal prices are estimated based on given quantities (Bitran & Caldentey, 2003; Dai et al., 2005; Tsai & Hung, 2009). Third, both price and quantity are jointly optimized (X. Zhao et al., 2017).

Air cargo capacity management and allocation

With regard to the air cargo industry, the literature on capacity allocation and management includes overbooking control, pricing and contracting. Various studies on overbooking control have been conducted in the air cargo sector. For example, Kasilingam (1997b) created a cost-based overbooking model with random continuous and discrete capacity, and stated that the optimal overbooking level can be predicted with the aid of over-sale costs, spoilage costs, and show-up rates. Similarly, a fuzzy reasoning model used the same parameters to obtain overbooking levels (Wang & Kao, 2008). Furthermore, it has been indicated that cancellation rates and shipping information records should be added to these parameters in overbooking calculations (Chalermkiat et al., 2013). Additionally, Kasilingam (1997a) discussed the difference between passenger and cargo overbooking as a revenue management tool. He stated that the complexity of the cargo overbooking problem is derived from the volume and weight dimensions. Hence to ensure better overbooking estimation, the two cargo aspects (weight and volume) should be considered (Luo et al., 2009; Wannakrairot & Phumchusri, 2016). Popescu et al. (2006) customized passengers' overbooking calculation to estimate the optimal cargo overbooking. Further, Hoffmann (2013) developed a heuristic to reduce the calculation complexity in the cargo booking management problem.

Another research direction coped with capacity allocation and contracting processes. An airline needs to decide whether to reject the freight forwarder's order or accept it, resulting in contractual issues. In a single-leg flight, Amaruchkul et al. (2007) developed a Markov decision model for formulating an accept/reject decision under free-sale capacity selling. The authors did not, however, consider cancellations and no-shows in the model. This may reduce the airline's profit because it is possible that the freight forwarder cannot fulfill the reserved capacity. Also, the Markov decision model can be used to calculate a bid pricing threshold to manage the booking process (Han et al., 2010). Amaruchkul et al. (2011) updated the contract from the free-sale pricing to contract-based selling for allotted capacity to a single freight forwarder. Moreover, Amaruchkul and Lorchirachoonkul (2011) upgraded the contract model to include multiple freight forwarders. They used a dynamic programming method to solve the discrete Markov chain model, while the heuristic of Moussawi-Haidar (2014) provided a solution to the guaranteed contracts and spot market price.

In the network scale, (O-D) form, Li and Xianyong (2006) adopted a single period stochastic programming model for the fixed capacity allocation problem in a multi-leg network. Then, Levina et al. (2011) studied the booking requests acceptance and/or rejection policy by network dynamic programming control, and they proposed a simplified linear programming model and heuristics. Moreover, they identified the contracts in both the guaranteed and spot markets. Also, the guaranteed contract was modeled in a series of mixed integer programming models, each representing one spot market case in combination airlines (Levin et al., 2012). Like Levin et al.'s study, Wong et al. (2009) aimed at better cargo capacity allocation by determination of the optimal passenger baggage quantity in combination airlines by using a multi-item newsboy model. Also in the network scale, the optimum overbooking levels can be achieved by using inventory transshipment (Zou et al., 2013). (Barz & Gartner, 2016; Huang & Lu, 2015) solved the revenue management network problem under fixed capacity and random cargo weight, volume, and demand. Feng et al. (2015) discussed the demand imbalance among cargo routes, and solved the problem using the strategic foreclosure model. Their idea was to discriminate their freight forwarders according to their size. Strategic foreclosure necessitates that the forwarders who order a larger quantity of freight space from the hot-selling routes should buy another quantity in the underutilized routes, whereas, small forwarders can be allocated only in the underutilized routes. However, the authors ignored the airline's rivals. If the freight forwarders do not accept the airline allocation, they are free to move to any of the airline's rivals. Moreover, when capacity is allocated according to the discrimination policy, the freight forwarders compete for the capacity by overstating their orders to take priority in the hot-selling routes which may lead to an inaccurate allocation in both routes.

In this research, we model the capacity pre-allocation between a single airline and *n*-freight forwarders in the guaranteed contracts and long-term market. To model this problem, we used a cooperative game between the single player and *n*-freight forwarders.

2.2 Games in airlines

In this research, combination airlines are our focus, as these airlines play multiple games with different players. For example, the airlines play with the airport in slot sales and auctions (Sheng et al., 2015). Also, they engage in cooperative and revenue sharing games (Saraswati & Hanaoka, 2014; Zhang et al., 2010). Moreover, leader-follower (Stackelberg) games are adopted (D'Alfonso & Nastasi, 2012). For the same objectives, the airlines compete with one another to get the highest allocation or revenue share (Xiao et al., 2016).

The games between airlines extend to different modes, such as competing for hub-domination in the network service (Fageda et al., 2011; Hansen, 1990). Furthermore, they compete for passengers in either single period models (Borenstein & Rose, 1994) or dynamic models (Andrew & Lyn, 2013). Grauberger and Kimms (2016) introduced the Nash equilibrium of a competition game between multiple airlines so as to simultaneously estimate the optimum booking quantities and prices in network scale. Furthermore, the airlines may compete to select their partner in making a profitable alliance (Adler & Smilowitz, 2007). The airlines' strategic alliance groups also play among themselves to reach agreements for the revenue share proportions (Çetiner & Kimms, 2013; Hu et al., 2012).

In addition, the combination airlines have a direct relationship with the freight forwarders. Therefore, they play different games, including leader-follower games and bargaining games. Hellermann (2006) used the Stackelberg game to model the long-term and spot market contract between single airline and single freight forwarder. He concluded that the premium pricing policy gives more benefits than the reservation prices. Also, Gupta (2008) adopted the Stackelberg game to design a flexible capacity contract. Tao et al. (2017) used the Stackelberg game to update Hellermann's model by including multiple forwarders, thereby solving the capacity booking and pricing through an option-contract form. Amaruchkul et al. (2011) aimed to estimate the maximum profit for the airline and the forwarder together. On this subject, they adopted the principal-agent game in which the airline was the principal and the freight forwarder was the agent. Although the game was run between the airline and the freight forwarder, the airline leads the game by setting the final allocation and pricing decisions.

2.3 Wholesale and option-contracts

In the literature, both wholesale and option-contracts have been widely used in the supply chain. For example, (Cachon & Lariviere, 1999a; Wei et al., 2013) used the wholesale price to dole the capacity out to multiple retailers. Furthermore, the wholesale contract was used for revenue sharing in the supply chain (Chakraborty et al., 2015; El Ouardighi, 2014). Similarly, the option-contract was widely adopted in capacity allocation and revenue sharing (Cai et al., 2016; Vafa Arani et al., 2016). Also, it has been used to support the buying decision for the balance between the loss-aversion preference and the retailers profits maximization (Xu et al., 2019). Further, it is observed that the wholesale and option-contracts are applied as alternatives (Davis & Leider, 2018; Keyvanloo et al., 2015). For example, Burnetas and Ritchken (2005) showed the effect of using an option-contract on wholesale prices and Y. Zhao et al. (2010) introduced wholesale drawbacks in supply chains and suggest the adoption of the option-contract instead.

Also, the wholesale and option-contracts were implemented in the air cargo industry. For instance, (Gupta, 2008; Levin et al., 2012) used the wholesale pricing in the allotment contract between the airline and the freight forwarders. Whereas (Hellermann, 2006; Hellermann et al., 2013) used the option-contract in the Stackelberg game to allocate the cargo capacities for a single freight forwarder in a single airline and Tao et al. (2017) adopted the option-contract to set the cargo prices and to estimate the optimum quantity reservation. Both contracting methods were used to address similar challenges. In this research, we combine the wholesale and option-contracts to solve the imbalance in the demand-capacity gaps among the substitutable cargo routes.

The literature reviewed above focused on setting the cargo prices and capacities in three different cases: solving the model with fixed prices to determine the optimal quantity allocation, or estimating the optimal prices for a given quantity, or determining the two variables simultaneously. All this work was used only to solve the capacity allocation challenge by assuming either uncertain route capacity or limited capacity. The studies, thus, tried to balance the capacity and demand for a single route. In our study, the capacity allocation problem has a new orientation – i.e. the capacity exceeds the demand on some routes (hot-selling routes); meanwhile, demand does not exceed half of some other routes' capacity (underutilized routes). We establish a sequential cooperative game between a single combination airline and n-freight forwarders. The game combines both wholesale pricing and option-contract mechanisms to solve the unbalanced market demand between the hot-selling and the underutilized routes.

3 Problem and model description

In order to tackle the imbalance between the substitutable hot-selling and the underutilized routes, we propose a negotiation process between the airline and the *n*-freight forwarders. The negotiation process is suggested to be performed through a bargaining game. The bargaining process is subsequently explained.

Twelve months before the flight departure, airlines offer their routes capacity for selling and/or reservation. During this period, large, medium and small freight forwarders go sequentially to the airline to buy or book a space on different routes (Slager & Kapteijns, 2004). Airlines sell the capacity by long-term contract in the first six months from the booking horizon commencement, then they sell the remaining capacity in medium-term contracts until a few days before the flight departure. During these few days, the airline sells this remaining space in free-sale and dynamic pricing – the booking horizon is shown in **Figure 1**. Along the booking horizon, multiple substitutable routes are offered for booking. The capacity and demand differ among these substitutable cargo routes. The imbalance problem occurs because of the demand-capacity-gap in the different cargo routes. These gaps usually happen in particular seasons. The freight forwarders prefer to reserve larger space in some routes, resulting in a positive gap between the demand and the route capacity (hot-selling routes). On the other hand, the freight forwarders reserve very few quantities of freight space in the substituting routes, leading to a negative-gap between the demand and the route capacity (underutilized routes).

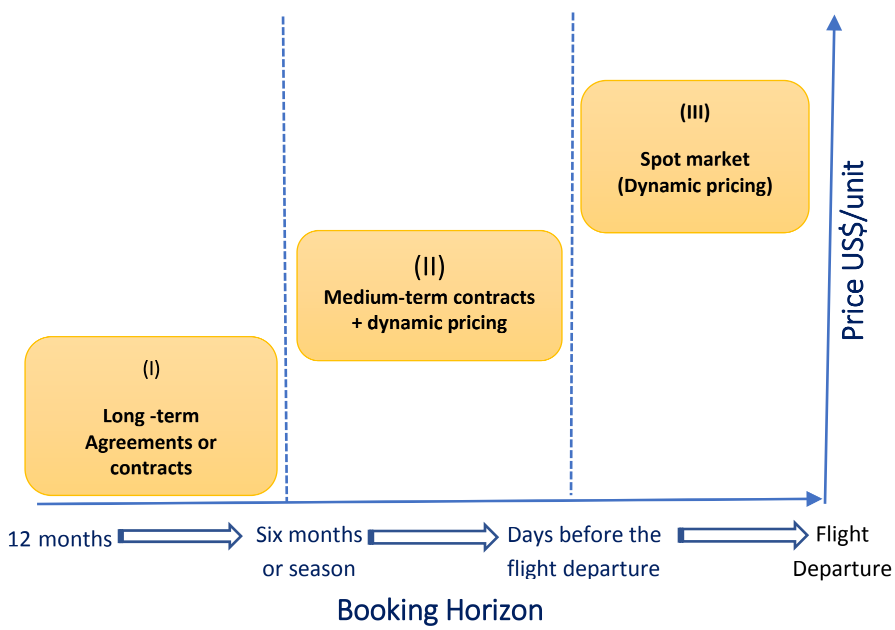

Figure 1 Different capacity reservation periods and type of contracts

Consider an (*n*+1)-player bargaining game, single airline $\mathfrak{A}$ and *n*-freight forwarder $\mathfrak{F}$, for a set of freight forwarders $\mathfrak{F} = \{\mathscr{f}: \mathscr{f} \in \mathbb{N}\}$. Also, let the airline has two sets of routes: first, the routes with hot-selling demand$\mathcal{I}$, where $\mathcal{I} = \{\mathscr{i}: \mathscr{i} \in \mathbb{N}\}$. Second, the routes with underutilization $\mathcal{J} = \{\mathscr{j}: \mathscr{j} \in \mathbb{N}\}$. The airline $\mathfrak{A}$ and each freight forwarder $\mathscr{f}$ negotiate the capacity allocation in the routes $\mathcal{I}$ and $\mathcal{J}$ simultaneously. Because the freight forwarders do not arrive at the same time, the negotiation between the airline and each single freight forwarder is carried out sequentially. Hence, let the capacity of a hot-selling route $\mathscr{i}$ be

$\mathcal{K}_i$, and the capacity of an underutilized route j be $\mathcal{K}_j$. The sum of the capacities in the hot-selling and the underutilized routes are $\sum_i^I \mathcal{K}_i$, and $\sum_j^J \mathcal{K}_j$, respectively. The market demand for the hot-selling route is represented by a random variable X_i . The demand cumulative distribution function of each route is $F(X_i)$ with $x_i \geq zero$, and the random variable of market demand for the underutilized routes is X_j. The demand cumulative distribution function of each underutilized route is $F(X_j)$ with $x_j \geq zero$. The airline and *n*-freight forwarders negotiate the quantities $\boldsymbol{q}$, i.e. the game is a function of this variable, where the current quantity set is $\boldsymbol{q} = \{\boldsymbol{Q_i}, \boldsymbol{Q_j} \in \mathbb{R}^+ : \sum_{i=1}^{I} \boldsymbol{Q_i} \geq \sum_i^I \mathcal{K}_i , \sum_{j=1}^{J} \boldsymbol{Q_j} < \sum_j^J \mathcal{K}_j\}$.

This research gives advantage of the wholesale price contract to the airline and the option-contract to the freight forwarder. Accordingly, the wholesale pricing contract $\mathfrak{w}$ is used to sell the hot-selling routes because the demand for these routes is almost guaranteed. In this vein, the airline needs to induce the freight forwarders to specify the accurate demand instead of inflating their request to guarantee their allocation in the hot-selling routes. The option-contract $\boldsymbol{O}$ is used to sell the underutilized routes because demand is very low on these routes. So, the airline encourages the forwarders to get more space on these routes by exercising higher demand.

The game between the airline and the freight forwarder is run in consecutive steps. In each step, the airline plays with only one freight forwarder, i.e. the forwarder $\boldsymbol{f_1}$ negotiates the quantity of the freight space $\boldsymbol{Q_i}$ in a hot-selling route i at a wholesale unit price w_i, and quantity of the freight space $\boldsymbol{Q_j}$ in an underutilized route j at an option-price Ω_j per unit cargo. Next, the freight forwarder executes the actual market demand in the underutilized routes at an exercise price e_j for each cargo unit**.** We assume that each freight forwarder sells the unit cargo in the hot-selling and underutilized routes at prices p_i and p_j, respectively. Also, it is assumed that the airline incurs a fixed marginal operating cost C_i, C_j for each unit in the hot-selling and the underutilized routes respectively.

4 Two-phase mixed wholesale-option-contract model

Since the airlines control the aircraft and the airport slot, and they own the full freight capacity, we assume that the airline starts the negotiation from the lower incentive levels to the higher incentive levels. Moreover, since the game is performed sequentially, the airline repeats the same approach with each new freight forwarder**,** bringing to the fore the first lemma,

Lemma 1. For identical freight forwarders in a sequential game, the possible capacity allocation for the forwarder $\boldsymbol{f_r}$ from the underutilized routes $\mathcal{J}$, is higher than what is allocated to the forwarder $\boldsymbol{f_{r-1}}$, i.e., $\left(\sum_j^J \boldsymbol{Q_j}\right)_{\boldsymbol{r}} > \left(\sum_j^J \boldsymbol{Q_j}\right)_{\boldsymbol{r-1}}$.

Proof: We follow the logic that each freight forwarder in $\mathfrak{F}$ comes individually and negotiates the capacity allocation in both hot-selling and underutilized routes simultaneously. By the end of the negotiation, the airline and the freight forwarder reach an agreement which cannot be renegotiated, and thus, the contract is binding between the airline and the freight forwarder $\boldsymbol{f_1}$**.** This agreement encompasses the sum of quantities $\left(\sum_j^J \boldsymbol{Q_j}\right)$, and $\left(\sum_j^J \boldsymbol{Q_j}\right)$ from the hot-selling and underutilized routes respectively. Hence, the capacity of both routes decreases by these amounts, and becomes $\sum_i^I \mathcal{K}_i - \left(\sum_i^I \boldsymbol{Q_i}\right)_{\boldsymbol{1}}$ and $\sum_j^J \mathcal{K}_j - \left(\sum_j^J \boldsymbol{Q_j}\right)_{\boldsymbol{1}}$**.** Similarly, the remaining capacity after the $\boldsymbol{r^{th}}$ freight forwarder is $\sum_i^I \mathcal{K}_i - \sum_{f=1}^{r}\left(\sum_i^I \boldsymbol{Q_i}\right)_{f}$ from the hot-selling routes and $\sum_j^J \mathcal{K}_j - \sum_{f=1}^{r}\left(\sum_j^J \boldsymbol{Q_j}\right)_{f}$ from the underutilized routes**.** By following this logic, the airline's bargaining power increases because of the capacity scarcity, and thus, the relation $\left(\sum_{j}^{\mathcal{J}} \boldsymbol{Q}_{j}\right)_{r} > \left(\sum_{j}^{\mathcal{J}} \boldsymbol{Q}_{j}\right)_{r-1}$ holds. ■

In the negotiation process, the freight forwarder starts with incomplete information because the airline does not show the complete offer at the beginning of the game. Moreover, the freight forwarder $\mathfrak{f}_{r}$ has no idea about the current capacity situation after the preceding forwarders' allocations. In this regard, the airline and the freight forwarders negotiate the reservation quantities in the hot-selling and underutilized routes. Both players want to gain maximum profits from getting the best capacity allocation in the unbalanced routes. The airline starts the game with no incentives to the freight forwarder, hoping that they will get the maximum payoffs from the negotiation in the first phase. Therefore, the game in **phase I** is basic in the hot-selling and the underutilized routes.

4.1 Phase I (no incentives)

Suppose that the freight forwarders cannot cancel any of the quantities purchased in any hot-selling route i. Therefore, they incur a loss of v_i for each unsold unit out of the purchased quantity in the hot-selling routes, and hence, each freight forwarder is expected to gain a profit of

$$\left(E\left[\Pi_{\mathfrak{F}}(\boldsymbol{Q}_{\mathfrak{f}i})\right]\right)_{\mathfrak{w}} = (p_i - w_i)\boldsymbol{Q}_{\mathfrak{f}i} - (p_i + v_i)\int_0^{\boldsymbol{Q}_{\mathfrak{f}i}} F(x_i)dx_i \tag{1}$$

upon using the wholesale contract, while each freight forwarder gains an expected profit from the underutilized routes. Moreover, there are no penalties by canceling some of the reserved quantities when the option-contract method is used, See equation (2):

$$\left(E\left[\Pi_{\mathfrak{F}}(\boldsymbol{Q}_{\mathfrak{f}j})\right]\right)_{\boldsymbol{O}} = (p_j - \Omega_j - e_j)\boldsymbol{Q}_{\mathfrak{f}j} - (p_j - e_j)\int_0^{\boldsymbol{Q}_{\mathfrak{f}j}} F(x_j)dx_j \tag{2}$$

Equations (1), (2) lead to the following corollary:

Corollary 1 The expected profit of the freight forwarder in $\mathfrak{F}$ is estimated by equation (3)

$$E\left[\Pi_{\mathfrak{F}}(\boldsymbol{Q}_{\mathfrak{f}i}, \boldsymbol{Q}_{\mathfrak{f}j})\right] = \left(E\left[\Pi_{\mathfrak{F}}(\boldsymbol{Q}_{\mathfrak{f}i})\right]\right)_{\mathfrak{w}} + \left(E\left[\Pi_{\mathfrak{F}}(\boldsymbol{Q}_{\mathfrak{f}j})\right]\right)_{\boldsymbol{O}} \tag{3}$$

Corollary 1 states that the freight forwarder's overall expected profit is the total of two sums; first, the sum of profits from selling quantities $\sum_{i}^{\mathcal{I}} \boldsymbol{Q}_{i}$ in the hot-selling routes by wholesale contract. Second, the sum of profits from selling quantities $\sum_{j}^{\mathcal{J}} \boldsymbol{Q}_{j}$ from the underutilized routes by option-contract.

In each step, solving the imbalance between the underutilized and hot-selling routes necessitates the two parties (airline and freight forwarder) to find a specific condition such that both sides can reach an agreement on the quantities of freight space from the underutilized routes and the hot-selling routes. Therefore, the following proposition describes this condition.

Proposition 1 The freight forwarder's optimum quantity from the hot-selling can be obtained from the following the ***balance ratio***

$$\boldsymbol{\alpha}_{\mathfrak{f}}^{*} = \frac{\boldsymbol{F}(\overline{\boldsymbol{Q}}_{\mathfrak{f}i})(p_i + v_i) + \boldsymbol{F}(\overline{\boldsymbol{Q}}_{\mathfrak{f}j})(p_j - e_j) - (p_i - w_i)}{(p_j - \Omega_j - e_j)} \tag{4}$$

Further, the accompanied quantity from the underutilized route is satisfactory to the freight forwarder.

Proof Equations (1) and (2) are derived from the following two equations which are used to solve the wholesale and the option-contracts for the freight forwarder side respectively:

$$\max_{\boldsymbol{Q}_{\mathfrak{f}i}\geq\boldsymbol{0}}\left(E\left[\Pi_{\mathfrak{F}}(\boldsymbol{Q}_{\mathfrak{f}i})\right]\right)_{\mathfrak{w}} = E\left[p_i \min\{\boldsymbol{Q}_{\mathfrak{f}i}, x_i\} - w_i\boldsymbol{Q}_{\mathfrak{f}i} - v_i\{\boldsymbol{Q}_{\mathfrak{f}i} - x_i\}^{+}\right] \tag{5}$$ [1]

, and

$$\max_{\boldsymbol{Q}_{\mathfrak{f}i}\geq\boldsymbol{0}}\left(E\left[\Pi_{\mathfrak{F}}(\boldsymbol{Q}_{\mathfrak{f}i})\right]\right)_{\mathfrak{w}} = E\left[(p_j - e_j)\min\{\boldsymbol{Q}_{\mathfrak{f}j}, \boldsymbol{x}_j\} - \Omega_j\boldsymbol{Q}_{\mathfrak{f}j}\right] \tag{6}$$

Further, from **Corollary 1**, the overall expected profit can be obtained in Equation (7)

$$\begin{aligned} E\left[\Pi_{\mathfrak{F}}(\boldsymbol{Q}_{\mathfrak{f}i}, \boldsymbol{Q}_{\mathfrak{f}j})\right] \\ &= (p_i - w_i)\boldsymbol{Q}_i - (p_i + v_i)\int_0^{\boldsymbol{Q}_i} F(x_i)dx_i + (p_j - \Omega_j - e_j)\boldsymbol{Q}_j \\ &- (p_j - e_j)\int_0^{\boldsymbol{Q}_j} F(x_j)dx_j \end{aligned} \tag{7}$$

We assume that the airline and each freight forwarder are able to reach an agreement under the condition that the airline gives the freight forwarder an amount in the underutilized routes proportional to the quantity of the hot-selling routes. Equation (8) defines the relation

$$\therefore \boldsymbol{Q}_j \propto \boldsymbol{Q}_i \qquad \therefore \boldsymbol{Q}_j = \boldsymbol{\alpha}_i\boldsymbol{Q}_i \text{ such that } 0 \leq \alpha_i \leq 1 \tag{8}$$

By substituting (8) in (7), the overall expected profit becomes a function of hot-selling quantity $\boldsymbol{Q}_i$. Additionally, it is easy to prove that equation (7) is concave (Y. Zhao et al., 2010). Consequently, the freight forwarder's maximum expected profit is obtainable when the partial derivative of equation (7) w.r.t the hot-selling quantity equals zero, and so, we obtain the value $\boldsymbol{\alpha}_{\mathfrak{f}}^{*}$, and the forwarder will be satisfied. ■

Indeed, it can be said that the solution in **Proposition 1** is realistic. In real life, individual customers send their parcels, packages and freight to freight forwarders to carry them from the country of origin to a certain destination. Regardless of the cargo route followed, the customers need their freight to arrive at the desired destination. Therefore, route identification is one of the freight forwarder's jobs; however, the airline is the party who owns the assets of cargo routes. In this regard, the final decision on assigning routes is achievable by negotiation between the freight forwarders and the airline.

The airline incurs shortage cost s_j for each unit in the underutilized routes. Consequently, by adopting the option-contract, the airline can earn an expected profit of;

$$\left(E\left[\Pi_{\mathfrak{A}}(\boldsymbol{Q}_{\mathfrak{A}j})\right]\right)_{\boldsymbol{O}} = (\Omega_j + e_j - C_j)\boldsymbol{Q}_{\mathfrak{A}j} - (e_j + s_j)\int_0^{\boldsymbol{Q}_{\mathfrak{A}j}} F(x_j)dx_j \tag{9}$$

, and the expected profit from the hot-selling routes when using the wholesale contract is;

$$(E[\Pi_{\mathfrak{A}}(\boldsymbol{Q}_{\mathfrak{A}i})])_{\mathfrak{w}} = (w_i - C_i)\boldsymbol{Q}_{\mathfrak{A}i} - w_i\int_0^{\boldsymbol{Q}_{\mathfrak{A}i}} F(x_i)dx_i \tag{10}$$

---

[1] $\left\{\boldsymbol{Q}_{\mathfrak{f}i} - x_i\right\}^{+} = \max\left\{\boldsymbol{Q}_{\mathfrak{f}i} - x_i, 0\right\}$

Equations (9) and (10) bring to the fore corollary 2, which gives the airline possible profit from the hot-selling and the underutilized routes.

Corollary 2 The airline's overall expected profit is the total of two sums; first, the sold quantities of the freight space $\sum_{i}^{\mathcal{I}} \boldsymbol{Q_i}$ in the hot-selling route by wholesale contract; second, the sold quantities $\sum_{j}^{\mathcal{J}} \boldsymbol{Q_j}$ from the underutilized routes by option-contract.

$$E\left[\Pi_{\mathfrak{A}}\left(\boldsymbol{Q}_{\mathfrak{A}i}, \boldsymbol{Q}_{\mathfrak{A}j}\right)\right] = \left(E\left[\Pi_{\mathfrak{A}}\left(\boldsymbol{Q}_{\mathfrak{A}i}\right)\right]\right)_{\boldsymbol{\mathfrak{w}}} + \left(E\left[\Pi_{\mathfrak{A}}\left(\boldsymbol{Q}_{\mathfrak{A}j}\right)\right]\right)_{\boldsymbol{O}} \tag{11}$$

As the airline aims to maximize the overall expected profit by balancing capacity among the hot-selling and underutilized routes, it leads to the following proposition,

Proposition 2 The optimum quantity of the airline from the hot-selling can be obtained from the following formula:

$$\boldsymbol{\alpha}_{\mathfrak{A}}{}^{*} = \frac{w_i \boldsymbol{F}(\overline{\boldsymbol{Q}}_{\mathfrak{A}i}) + \boldsymbol{F}\left(\overline{\boldsymbol{Q}}_{\mathfrak{A}j}\right)\left(e_j + s_j\right) - \left(w_i - \mathrm{C}_i\right)}{\left(\Omega_j + e_j - \mathrm{C}_j\right)} \tag{12}$$

, and consequently, the underutilized quantity is also estimated.

Intuitively, the decision of $\boldsymbol{\alpha - ratio}$ brings the airline into conflict with the freight forwarder; however, this conflict occurs at different levels. For example, the small freight forwarders prefer to get higher freight space quantities in the hot-selling routes; therefore, they would prefer $\boldsymbol{\alpha - ratio}$ small**,** whereas the airline prefers to use its power to give them a larger $\boldsymbol{\alpha - ratio}$**.** The large freight forwarders and airline very easily agree to the proper ratio. This logic is shown in **Figure 2**, and it is compatible with the model of Feng et al. (2015).

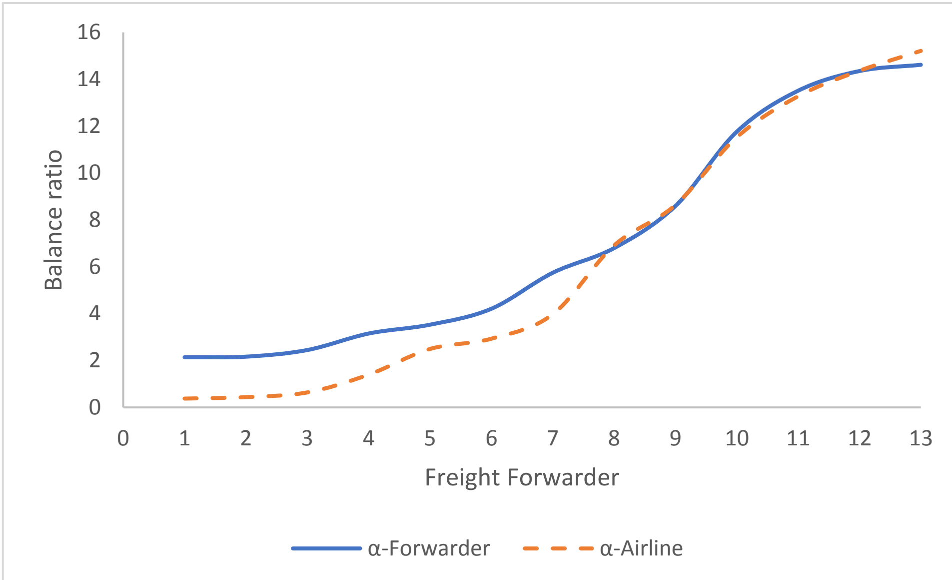

Figure 2 The airline and freight forwarders balance ratios. (The freight forwarders are arranged ascendingly according to the orders from the hot-selling routes).

The proof of **Proposition 2** is similar to **Proposition 1**. Moreover, **Proposition 1** and **Proposition 2** result in a new proposition which describes the relationship between the two types of routes.

Proposition 3 Assuming that both freight forwarders and the airline are risk neural, the optimum quantity allocation to the underutilized route is the inverse of a relocated and scaled cumulative distribution of the quantities in the hot-selling routes. Thus, the cargo quantities allocated to the underutilized routes follow the self-replicating distributions such as normal, gamma and exponential distribution.

$$F\left(\boldsymbol{Q}_j{}^{*}\right) = \{A\, F(\boldsymbol{Q}_i{}^{*}) + B\}^{+} \tag{13}$$

, where

$$A = \frac{(p_i + v_i)\left(\Omega_j + e_j - C_j\right) - w_i\left(p_j - \Omega_j - e_j\right)}{\left(e_j + s_j\right)\left(p_j - \Omega_j - e_j\right) - \left(p_j - e_j\right)\left(\Omega_j + e_j - C_j\right)}$$

, and

$$B = \left[\frac{(w_i - C_i)\left(p_j - \Omega_j - e_j\right) - (p_i - w_i)\left(\Omega_j + e_j - C_j\right)}{\left(e_j + s_j\right)\left(p_j - \Omega_j - e_j\right) - \left(p_j - e_j\right)\left(\Omega_j + e_j - C_j\right)}\right]$$

Proof In real practice, the freight forwarders go to the airline individually to reserve the quantity of freight space in the different routes through negotiation . Usually, the forwarder requests higher quantities of freight space in the hot-selling routes, unlike their orders in the underutilized routes which are very small. In this regard, the airline negotiates to solve the underutilization problem in the underutilized routes. It is assumed that the airline and the freight forwarder agree that the freight forwarder receives a quantity in the underutilized routes proportional to the requested quantity in the hot-selling route. This proportion is derived in **Proposition 1** for the freight forwarder, and in **Proposition 2** for the airline. Therefore, the baragining equilibrium can be achieved when $\boldsymbol{\alpha}_{\mathfrak{A}i}{}^{*} = \boldsymbol{\alpha}_{\mathfrak{f}i}{}^{*}$. Therefore, the freight forwarder and the airline agree on the quantites allocated to underuilized routes, following from equation (13). Furtheromre, when the X_j is the random variable with parameters ($\mu_i = \bar{X}_i$,$\sigma_i{}^2 = s_i{}^2$), then $X_j = AX_i + B$ is a random variable with parameters ($\mu_j = A\bar{X}_i + B$, $\sigma_j{}^2 = A^2 s_i{}^2$). This holds only when the demand follows self-replicated probabilty distribtutions. ■

The statement in **Proposition 3** proves the model's flexibility and validity to the real market, where it is flexible enough to the freight forwarder to get an allocation in the hot-selling , if and only if, the freight forwarder orders a quantity of,

$$\boldsymbol{Q}_i{}^{**} = F^{-1}\left\{\frac{(w_i - C_i)(p_j - \Omega_j - e_j) - (p_i - w_i)(\Omega_j + e_j - C_j)}{(p_i + v_i)(\Omega_j + e_j - C_j) - w_i(p_j - \Omega_j - e_j)}\right\}^{+} \quad (14)$$

, and the capacity is large enough, and in this case, the freight forwarder is considered as the airline's strategic partner. Moreover, **Proposition 3** and **Lemma 1** affirm that the allocated cargo in the underutilized routes increases with the increase in the freight forwarder's order in the hot-selling routes as shown in **Figure 3**. However, the increase is not strictly dominating because the model also considers the high demand to the forwarder and considers the negotiation power. Thus, adding to **Lemma 1**, the airline should give-up the negotiation power from the decreased capacity to the potential freight forwarders.

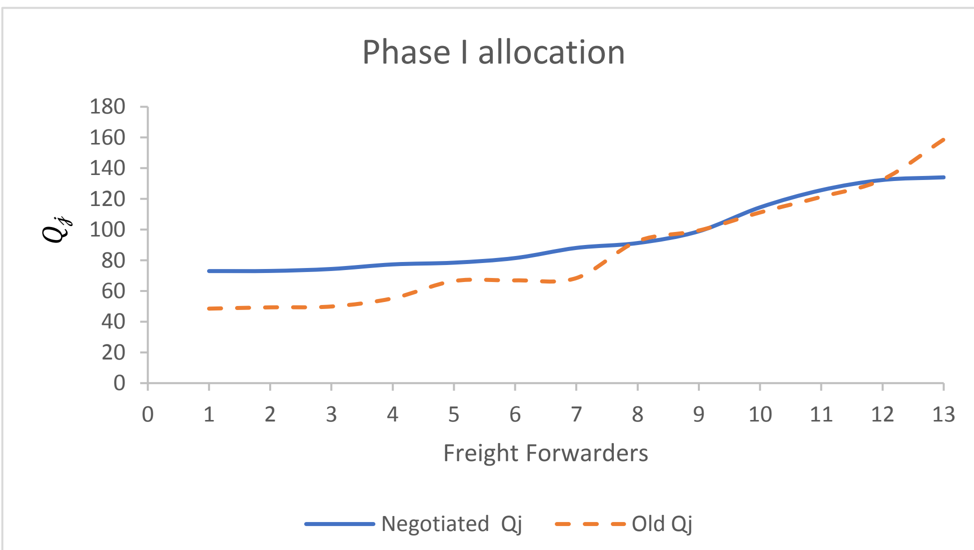

Figure 3 Allocation from negotiated allocation vs. the old allocation[2]

On the other hand, the airline is concerned that the freight forwarders have no penalties upon canceling the booking in the underutilized routes. This means that the airline may experience the underutilization problem because of the cancellations and the no shows. Consequently, our model tackles this issue, i.e. the airline is the only party who knows the routes capacity condition, and it can allocate an amount $F^{-1}(B)$ to the late-freight forwarder in the underutilized routes. At the same time, the allocation of late-

[2] This data is extracted from Feng et al. (2015).

freight forwarder in the hot-selling routes is zero. Therefore, the airline's overall allocation of the underutilized routes is $\sum_{j}^{\mathcal{J}} \mathcal{K}_j + [F^{-1}(B)\,]_{F(\boldsymbol{Q}_i)=0}$. See **Figure 4**.

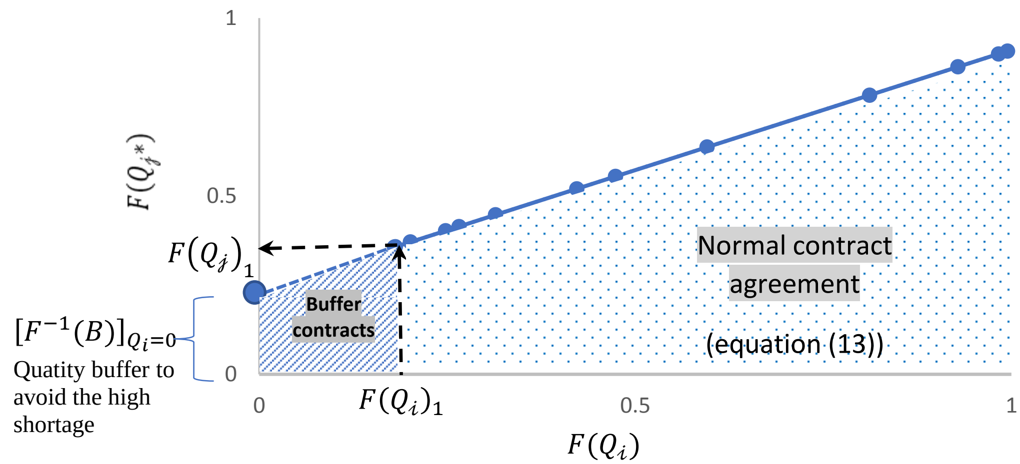

Figure 4 The new allocation of the underutilized routes w.r.t the hot-selling route.

Regarding the cooperation between the airline and the freight forwarder, fixing the imbalance among the underutilized and hot-selling routes can be achieved according to the following theorem:

Theorem 1 In the cooperative game formed between the airline and the freight forwarder, the two parties need to give up some of their profit in the two types of route, i.e. the freight forwarder needs to commit to giving up a small share of the profit in some routes to obtain a better allocation on this route while the airline commits to giving up a small share of profit on the substituting route to make a better mixed allocation in the underutilized and hot-selling routes. This leads to a **Profit balance** between the airline and the freight forwarder, leading to a contractual relation.

Proof The optimum allocation quantity of the underutilized routes is the inverse of the cumulative function scaled by A and relocated to position B. To maintain the property that $1 \geq F(Q) \geq 0$; A and B values may have two different combinations:

- $A = \{a: a < 0\}$, and $B = \{b: b > 0\}$.
- $A \geq 0$, and $0 \leq B \leq 1$.

In the first combination, either the numerator or the denominator in A must be negative, but not both. However, the negative value of the denominator does not make sense because it is completley composed of the underutilized routes variables and it should be positive to avoid the losses in the undeutilized routes. Consequently, to obtain a negative value of A, the condition $\frac{(p_i+v_i)}{w_i} < \frac{(p_j-\Omega_j-e_j)}{(\Omega_j+e_j-C_j)}$ must be achieved. Moreover, since $p_i > w_i$, then $\frac{(p_i+v_i)}{w_i} > 1$, and hence the condition is achieved by $\frac{(p_j-\Omega_j-e_j)}{(\Omega_j+e_j-C_j)} < 1$, and thus, the first part in the theory holds. On the other hand, B is positive when $\frac{(w_i-C_i)}{(p_i-w_i)} > \frac{(\Omega_j+e_j-C_j)}{(p_j-\Omega_j-e_j)}$. This condition is achieved when $\frac{(w_i-C_i)}{(p_i-w_i)} > 1$, and thus, the second part of the theorem holds for this combination.

In the second condition, A is positive when $\frac{(p_{j}-\Omega_{j}-e_{j})}{(\Omega_{j}+e_{j}-C_{j})} > \frac{(p_i+v_i)}{w_i}$**,** and this only occurs when $\frac{(p_{j}-\Omega_{j}-e_{j})}{(\Omega_{j}+e_{j}-C_{j})} > 1$, which means that the airline unit profit is less than the freight forwarder's unit profit on the underutilized route. While, by holding that $\frac{(p_{j}-\Omega_{j}-e_{j})}{(\Omega_{j}+e_{j}-C_{j})} > 1$,the inequality $0 \leq B \leq 1$ is obtainable when $0 < \frac{(w_i-C_i)}{(p_i-w_i)} < 1$, which means that the airline unit profit is higher than the unit profit of the freight forwarder on the hot-selling routes. ■

Stopping the game in **phase I** involves two cases; first, the airline and the freight forwarder agree to the game results or the profit balance amounts. Second, they do not reach an agreement. As soon as the game in **phase I** stops between the airline and the freight forwarder f, etiher by agreement or disagreement, the airline plays the game with a new freight fowarder in a new capacity and a higher negotaiton power. The game is repetitive along *n*-freight forwarders until the airline sells the full capacity on both the hot-selling and underutilized routes, or at least reaches an optimum balance for these routes. This gives the following lemma;

Lemma 2 The game may stop in **phase I**, if and only if

i) The *n*-freight forwarders are risk neutral;
ii) The first r-freight forwarder agree to buy the quantities of

$$\sum_{f=1}^{r}\left(\sum_{i=1}^{\mathcal{I}}(\boldsymbol{Q_i})\right) = \sum_{i}^{\mathcal{I}} \mathcal{K}_i, \text{ and } \sum_{f=1}^{r}\left(\sum_{j=1}^{\mathcal{J}}(\boldsymbol{Q_j})\right) = \sum_{j}^{\mathcal{J}} \mathcal{K}_j + [F^{-1}\{B\}^{+}\,]_{F(\boldsymbol{Q}_i)=0} \tag{15}$$

for hot-selling and underutilized routes respectively.

Proof This lemma holds if one of the two items in (i) and (ii) is achieved. If (i) and (ii) are violated, then the airline and the freight forwarder cannot reach an agreement in **phase I**, so the airline moves to **phase II** with the same freight forwarder. The game starts with a risk-neutral airline and freight forwarders are expected to be a blend of risk neutral and risk-averse players. Since the game is sequential, it may happen that the first r-freight forwarders are risk neutral. Consequently, each freight forwarder f purchases a quantity of $\sum_{i=1}^{\mathcal{I}}(\boldsymbol{Q_i})$, and $\sum_{j=1}^{\mathcal{J}}(\boldsymbol{Q_j})$ from the hot-selling and underutilized routes respectively. The airline continues to receive the freight forwarders' booking requests until they sell the full capacity $\sum_{i}^{\mathcal{I}} \mathcal{K}_i$ on hot-selling routes and the full capacity $\sum_{j}^{\mathcal{J}} \mathcal{K}_j$ plus buffer $[F^{-1}(B)\,]_{F(\boldsymbol{Q}_i)=0}$ on the underutilized routes, as discussed in **proposition 3** – this may only occur in **phase I**. ■

Although the game needs a profit balance between the airline and the freight forwarders, the airline always has the higher negotiation power, and thus, has the ultimate choice to move from **phase I** to **phase II** or stop the game after **phase I**, either by an agreement or disagreement. However, this gives full power to the airline, and the freight forwarder may quit the game in **phase I**. There is a possibility that some freight forwarders are risk averse, i.e. they may not be willing to get the estimated cargo quantities for the underutilized routes. Consequently, they may leave the game and move to the airline's rival. In this regard, we suggest the airline to offer an incentive on the underutilized routes to overcome the risk aversion behavior. In this situation, the airline moves from **phase I** to **phase II**.

4.2 Phase II (buyback incentives)

In this phase, the airline proceeds to the next negotiation level in a cooperative game when the airline and a freight forwarder f cannot reach an agreement in **phase I**. The game rules in **phase I** continue to **phase II**, i.e., each freight forwarder plays the two-phase game only once, but they cannot renegotiate their quantities after **phase II**. The movement from **phase I** to **phase II** relies on the efficiency of the freight forwarder $\mathscr{f}$ in negotiation. If it is an inevitable consequence to move to **phase II**, the airline should try to cope with the risk-averse forwarders. Buyback policy is one of the tools used in the literature to cope with the risk aversion behavior (Nagarajan & Sošić, 2008). We have adopted this policy in **phase II** to deal with the risk-averse freight forwarders.

The buyback policy in **phase II** is involved in the positive and negative demand-capacity gaps or hot-selling and underutilized routes. In the hot-selling routes, the airline offers a buyback for each freight forwarder at a value b_i for each unit of the unsold cargo quantity such that $b_i < w_i < p_i$,moreover, b_j is the buyback value for each unsold cargo unit in the underutilized routes such that $b_j < \Omega_j < e_j < w_i$. In this regard, the freight forwarder's expected profit in **phase II** from the wholesale contract $\overline{\mathfrak{w}}$ is,

$$\left(E\left[\Pi_{\mathfrak{F}}(\boldsymbol{Q_{\mathscr{f}j}})\right]\right)_{\overline{\mathfrak{w}}} = (p_i - w_i)\boldsymbol{Q_{\mathscr{f}j}} - (p_i - b_i + v_i)\int_{\mathbf{0}}^{\boldsymbol{Q_{\mathscr{f}j}}} \boldsymbol{F}(x_i)dx_i \tag{16}$$

on the hot-selling routes under wholesale price w_i, and the expected forwarders profit on the underutilized routes under the option-contract $\overline{\boldsymbol{\mathcal{O}}}$ is,

$$\left(E\left[\Pi_{\mathfrak{F}}(\boldsymbol{Q_{\mathscr{f}j}})\right]\right)_{\overline{\mathcal{O}}} = \left(p_j - \Omega_j - e_j\right)\boldsymbol{Q_i} - \left(p_j - e_j - b_j\right)\int_{0}^{\boldsymbol{Q_j}} \boldsymbol{F}(x_j)dx_j \tag{17}$$

Similar to **Corollary 2**, Corollary 3 can be expressed as follows:

Corollary 3 The expected profit of the freight forwarder $\mathfrak{F}$ is estimated by equation (18),

$$E\left[\Pi_{\mathfrak{F}}(\boldsymbol{Q_{\mathscr{f}i}}, \boldsymbol{Q_{\mathscr{f}j}})\right] = \left(E\left[\Pi_{\mathfrak{F}}(\boldsymbol{Q_{\mathscr{f}i}})\right]\right)_{\overline{\mathfrak{w}}} + \left(E\left[\Pi_{\mathfrak{F}}(\boldsymbol{Q_{\mathscr{f}j}})\right]\right)_{\overline{\mathcal{O}}} \tag{18}$$

In this corollary, the overall expected profit of a freight forwarder is the sum of the expected profit based-buyback from the hot-selling routes which is obtained from the wholesale contract and the expected profit-based buyback from the underutilized routes which is estimated from the option-contract. It is worth noting that the expected profit of the freight forwarder changes from **phase I** and it cancels out the **phase I** results. Thus, the expected profit in **phase II** differs from the expected profit from **phase I**; consequently, the optimal allocation for the two parties changes. This change is described in **Proposition 4** which defines the new allocation ratio based on the use of the buyback policy in **phase II**.

Proposition 4 The freight forwarder balance ratio from the underutilized routes with respect to the priority of the optimal allocation of the hot-selling routes is obtained through,

$$\boldsymbol{\alpha_{\mathscr{f}}}^{**} = \frac{(p_i - b_i + v_i)\boldsymbol{F}\left(\overline{\overline{\boldsymbol{Q}}}_{\boldsymbol{\mathscr{f}i}}\right) + \boldsymbol{F}\left(\overline{\overline{\boldsymbol{Q}}}_{\boldsymbol{\mathscr{f}j}}\right)\left(p_j - e_j - b_j\right) - (p_i - w_i)}{\left(p_j - \Omega_j - e_j\right)}$$

Proof This is similar to **Proposition 1**.

Since the airline plays the same game in **phase II**, the game has a similar objective, but with different game inputs and rationalities. Consequently, the output of the game also changes for the airline. Again, the airline sets its own optimal quantities. Therefore, the airline's optimal balance ratio, which is used to estimate the underutilized route from the optimum hot-selling routes allocation, is:

$$\boldsymbol{\alpha}_{\mathfrak{A}}{}^{**} = \frac{(w_i + b_i + s_i)\boldsymbol{F}\left(\overline{\overline{\boldsymbol{Q}}}_{\mathfrak{A}i}\right) + \left(e_j + b_j\right)\boldsymbol{F}\left(\overline{\overline{\boldsymbol{Q}}}_{\mathfrak{A}j}\right) - (w_i - C_i)}{\left(\Omega_j + e_j - C_j\right)} \tag{19}$$

The buyback value motivates the small forwarders to reset their own allocation balance ratio to be closer to the airlines' ratio. Moreover, if the airline keeps offering buyback to the large sized freight forwarders, the forwarders may bet more quantity of cargo space on the underutilized routes so as to guarantee larger space on the hot-selling routes. Therefore, the larger forwarder's balance ratio exceeds the airline's value as shown in **Figure 5.**

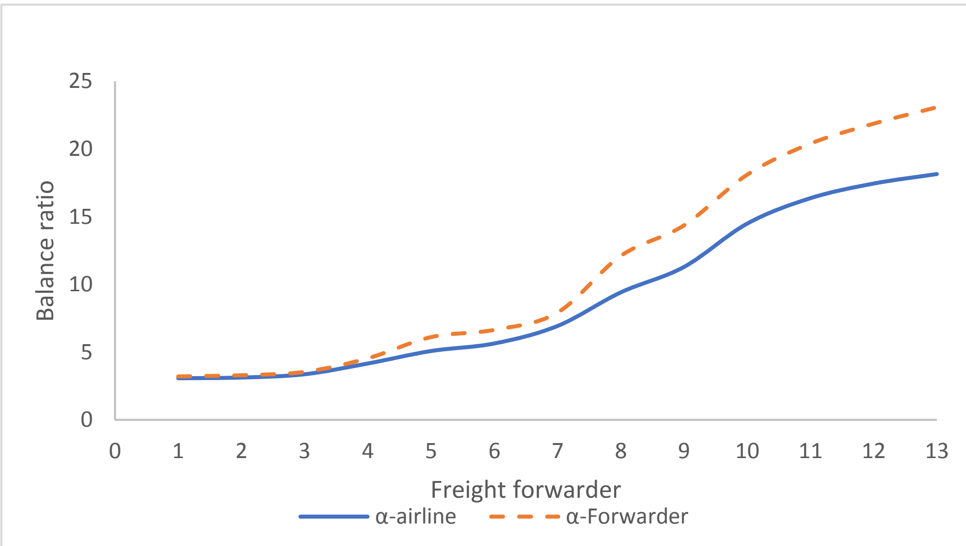

Figure 5 The allocation ratio behavior under buyback policy in phase II

Similar to the Proposition 3, the quantity in the underutilized routes when applying incentives to the wholesale-option-contract is the inverse of the relocation of the scaled cumulative distribution of the allocated quantities to the hot-selling routes,

$$\widehat{\boldsymbol{Q}_j} = F^{-1}\left\{\hat{A}\, F(\boldsymbol{Q}_i{}^{*}) + \hat{B}\right\}^{+} \tag{20}$$

where,

$$\hat{A} = \frac{(p_i - b_i + v_i)\left(\Omega_j + e_j - C_j\right) - (w_i + b_i + s_i)\left(p_j - \Omega_j - e_j\right)}{\left(e_j + b_j\right)\left(p_j - \Omega_j - e_j\right) - \left(p_j - e_j - b_j\right)\left(\Omega_j + e_j - C_j\right)}$$

, and

$$\hat{B} = \frac{(w_i - C_i)\left(p_j - \Omega_j - e_j\right) - (p_i - w_i)\left(\Omega_j + e_j - C_j\right)}{\left(e_j + b_j\right)\left(p_j - \Omega_j - e_j\right) - \left(p_j - e_j - b_j\right)\left((\Omega_j + e_j - C_j\right)}$$

Furthermore, the strategic partner can get an allocation of,

$$\widehat{\boldsymbol{Q}_i}^{*} = F^{-1}\left\{\frac{(w_i - C_i)(p_j - \Omega_j - e_j) - (p_i - w_i)(\Omega_j + e_j - C_j)}{(p_i - b_i + v_i)(\Omega_j + e_j - C_j) - (w_i + b_i + s_i)(p_j - \Omega_j - e_j)}\right\}^{+}$$

When **phase I** and **phase II** allocation ratios are compared, it can be observed that the airline achieves better allocation balance between the underutilized routes and the hot-selling routes in **phase II** than in **phase I**. A numerical experiment based on **phase I** data was used to compare the results between the two phases. To avoid unreasonable results, b_i is selected less than the v_i, and more than s_i. Moreover, to avoid the high drop in the airline's profit, we assumed that $b_j < \Omega_j$. **Figure 6** shows that the allocated quantities on the underutilized routes from **phase II** is higher than the allocated quantities from **phase I**. Furthermore, the freight forwarder allocation increases with the increase in freight forwarders' order quantity of the freight space from the hot-selling routes. The interesting part in **Figure 6** is that the allocation of the smallest freight forwarder in **phase II** is less than its allocation in **phase I**. This may be attributed to the view that the small freight forwarder has very low negotiation power. Consequently, when this forwarder insists on taking the incentives (buyback), the airline reduces its quantity in the underutilized routes because the profit that this freight forwarder gives up in the hot-selling routes may be less than the buyback amount from the underutilized routes.

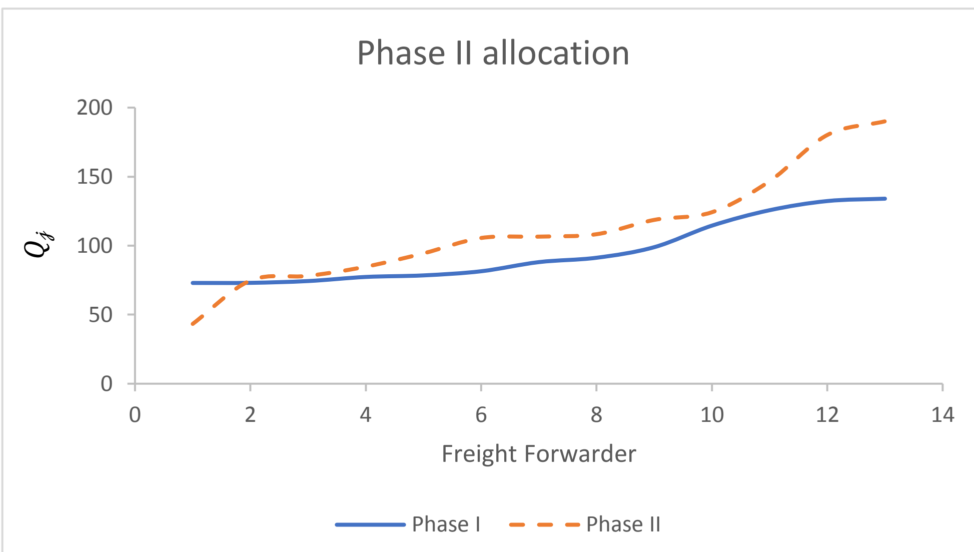

Figure 6 The difference between the Phase I and Phase II allocation in the underutilized allocation

5 Pure wholesale balancing model

Because the airline has the full power to decide the contracting method to sell the cargo capacity, it may sell this capacity in wholesale price or in any other method. In this section, the airline adopts the wholesale price to sell the capacity on underutilized and hot-selling routes; hence, the freight forwarder's allocation ratio in wholesale price is,

$$\boldsymbol{\beta_f} = \frac{(p_i + v_i)\boldsymbol{F}(\boldsymbol{Q_{fi}}) + (p_j + v_j)\boldsymbol{F}(\boldsymbol{Q_{fj}}) - (p_i - w_i)}{(p_j - w_j)} \tag{21}$$

, and the airline allocation ratio is

$$\boldsymbol{\beta}_{\mathfrak{U}} = \frac{w_i \boldsymbol{F}(\boldsymbol{Q}_{\mathfrak{U}i}) + (w_j + s_j)\boldsymbol{F}(\boldsymbol{Q}_{\mathfrak{U}j}) - (w_i - \mathrm{C}_i)}{(w_j - \mathrm{C}_j)} \tag{22}$$

Hence, the optimal allocation for the underutilized routes when applying the wholesale contract to the underutilized and the hot-selling routes is described as follows:

$$(\boldsymbol{Q}_j{}^{*})_{\hat{\mathfrak{w}}} == \boldsymbol{F}^{-1}\{A_{\mathfrak{w}}\boldsymbol{F}(\boldsymbol{Q}_i) + \boldsymbol{B}_{\mathfrak{w}}\}^{+} \tag{23}$$

Where

$$\boldsymbol{A}_{\hat{\mathfrak{w}}} = \frac{(p_i + v_i)(w_j - \mathrm{C}_j) - w_i(p_j - w_j)}{(w_j + s_j)(p_j - w_j) - (p_j + v_j)(w_j - \mathrm{C}_j)}$$

, and

$$\boldsymbol{B}_{\hat{\mathfrak{w}}} = \frac{(w_i - \mathrm{C}_i)(p_j - w_j) - (p_i - w_i)(w_j - \mathrm{C}_j)}{(w_j + s_j)(p_j - w_j) - (p_j + v_j)(w_j - \mathrm{C}_j)}$$

From the wholesale pricing contract properties, it is expected that the model will be advantageous to the airline rather than the freight forwarder, at least in the expected profit, regardless of the allocation balance. Conversely, the option-contract properties make the freight forwarder better-off, making it needful to study the pure option-contract model in order to ensure a fair comparison.

6 Pure option balancing model

As mentioned in the literature review, several scholars adopted the option-contract to sell the cargo capacity to freight forwarders, but they used it only to sell the capacity, regardless of the route type. In this section, the option-contract is used to balance the demand-capacity gap between the substitutable routes. Hence, if the airline decided to adopt the option-contract to sell the capacity to the freight forwarders on the underutilized and the hot-selling routes, the allocation ratio for the freight forwarder side would be:

$$(\boldsymbol{\gamma}_{\mathfrak{f}}{}^{**})_{\hat{\mathcal{O}}} = \frac{(p_i - e_i)\boldsymbol{F}(\boldsymbol{Q}_{\mathfrak{f}i}) + \boldsymbol{F}(\boldsymbol{Q}_{\mathfrak{f}j})(p_j - e_j) - (p_i - \Omega_i - e_i)}{(p_j - \Omega_j - e_j)} \tag{24}$$

It is reasonable that the option-contract favors the freight forwarders because they do not incur any penalties in this contractual agreement. The option-contract is not very attractive to the airline because the solution of the imbalance problem is more challenging under this type of contract. The airline is exposed to shortage in the underutilized routes again. With shortage cost s_j on the underutilized routes, the airline allocation ratio is:

$$(\boldsymbol{\gamma}_{\mathfrak{U}}{}^{**})_{\hat{\mathcal{O}}} = \frac{e_i \boldsymbol{F}(\overline{\overline{\boldsymbol{Q}}}_{\mathfrak{U}i}) + (e_j + s_j)\boldsymbol{F}(\overline{\overline{\boldsymbol{Q}}}_{\mathfrak{U}j}) - (\Omega_i + e_i - \mathrm{C}_i)}{(\Omega_j + e_j - \mathrm{C}_j)} \tag{25}$$

Thus, the underutilized routes' optimal allocation in the pure option-contract is a linear function of the positive route allocation and the equation coefficients are a function of the option and exercise prices as well as the shortage cost on the hot-selling and underutilized routes.

$$(\boldsymbol{Q}_j{}^{**})_{\hat{\mathcal{O}}} = \boldsymbol{F}^{-1}(A_{\mathcal{O}}\boldsymbol{F}(\boldsymbol{Q}_i) + \boldsymbol{B}_{\mathcal{O}}) \tag{26}$$

Where,

$$\boldsymbol{A}_{\widehat{\mathcal{O}}} = \frac{(p_i - e_i)(\Omega_j + e_j - C_j) - e_j(p_j - \Omega_j - e_j)}{(e_j + s_j)(p_j - \Omega_j - e_j) - (p_j - e_j)(\Omega_j + e_j - C_j)}$$

, and

$$\boldsymbol{B}_{\widehat{\mathcal{O}}} = \frac{(p_i - \Omega_i - e_i)(\Omega_j + e_j - C_j) - (\Omega_i + e_i - C_i)(p_j - \Omega_j - e_j)}{(e_j + s_j)(p_j - \Omega_j - e_j) - (p_j - e_j)(\Omega_j + e_j - C_j)}$$

7 Numerical illustration

The three models above are demonstrated in a numerical example and the implementation is performed on one airline and 13 freight forwarders using the data extracted from (Feng et al., 2015). In this example, the fixed capacities of the hot-selling and underutilized routes are 2878 tonnes and 2789 tonnes respectively. Moreover, we consider that the cargo prices on the underutilized and hot-selling routes are fixed and the quantities on the underutilized routes vis-à-vis the hot-selling cargo routes are varied. First, we examine the two-phase mixed wholesale-option-contract game. In phase I, the airline sells the capacity for the hot-selling route at a uniform wholesale price US$ 621.9/tonne and offers the capacity for the underutilized route for reservation at an option price of US$ 25/tonne. Moreover, the freight forwarders execute the actual demand at maximum exercise price US$530 per tonne of the actual demand. The freight forwarders selling prices are US$ 672, US$ 643 for each tonne of the hot-selling and underutilized routes respectively.

Regarding each player's costs, the airline incurs fixed marginal operating costs of US$ 430 per tonne, and US$ 480 per tonne on the hot-selling and underutilized routes respectively. Furthermore, the airline's shortage cost on the underutilized route is US$200/tonne while the freight forwarders incur a leftover cost US$ 560/tonne. On the other hand, in phase II, the buyback values for both route types are added to the airline's costs, where the unit buyback values are US$ 510 and US$ 24.5/tonne on the hot-selling and underutilized routes respectively. Second, the data in the pure wholesale balancing and pure option balancing contracts are shown in **Table 1**.

Table 1 The input parameters of wholesale and the option model

Variables	Wholesale model (US$/tonne)	Option model (US$/tonne)
p_i	672	672
p_j	643	643
w_i	621.9	-
w_j	612.6	-
C_i	430	430
C_j	480	480
Ω_i	-	40
Ω_j	-	25
e_i	-	560
e_j	-	530
s_j	200	200
v_j	560	-

The common parameters between the pure wholesale and the pure option model are the freight forwarder's selling price and the airline's costs for the underutilized and hot-selling routes. Additionally, there is a possibility that the airline incurs shortage cost s_j on the underutilized routes in both models. The difference in the wholesale and the option models can be seen in the freight forwarder's leftover cost v_j on the underutilized routes.

The allocation process was performed on the three models – the mixed wholesale option-model, the pure wholesale model, and the pure option-contract model. **Table 2** summarizes the allocation results from the three models for the underutilized and the hot-selling routes. The allocation results reveal that the mixed model of wholesale-option-contract model gives the highest possible allocations in the underutilized quantities. This shows the advantage of using flexible contracts to sell the different routes to the same destination. Also, taking advantage of the wholesale contract encourages the freight forwarders to use the actual demand in order to avoid high leftover costs. Further, the adoption of the option-contract motivates the freight forwarders to bet on low option prices so as to get more space subsequent to which they execute the quantity according to their actual demand, thereby reducing their losses. The freight forwarders' incentives increase when the airline uses the buyback in **phase II**; therefore, the allocation balancing in **Phase II** improves.

The pure wholesale and the pure option models give almost similar allocation results. The freight forwarder is indifferent to the hot-selling and the underutilized routes, and will, thus, prefer to put most of their demand on the hot-selling routes so as to compete for space.

Table 2 Capacity allocation results (in tonne) from the three models

no.	*Forwarder request*		*Mixed wholesale-option model*				*Wholesale model*		*Option model*	
			phase I		phase II					
	Underutilized route	**Hot-selling route**	**Underutilized route**	**Hot-selling route**	**Underutilized route**	**Hot-selling route**	**Underutilized route**	**Hot-selling route**	**Underutilized route**	**Hot-selling route**
1	48.529	14.657	72.986	0	43.3319	19.8541	56.73912	6.44688	60.84504	2.340961
2	49.365	15.52	73.066	0	74.70423	0	56.87818	8.006818	60.96463	3.920375
3	49.923	29.027	74.352	4.597617	78.10303	0.846965	59.07389	19.87611	62.86535	16.08465
4	55.234	58.055	77.332	35.95708	84.76306	28.52594	63.8989	49.3901	67.11642	46.17258
5	66.508	68.401	78.46003	56.44897	94.43128	40.47772	65.64766	69.26134	68.67914	66.22986
6	66.923	94.555	81.451	80.02681	105.5738	55.90421	70.12117	91.35683	72.72125	88.75675
7	68.438	148.011	88.078	128.3714	106.5428	109.9062	79.42017	137.0288	81.28186	135.1671
8	92.468	172.153	91.237	173.3836	108.2912	156.3298	83.65296	180.968	85.22911	179.3919
9	99.397	229.058	98.901	229.5536	118.6558	209.7992	93.60999	234.845	94.58642	233.8686
10	111.157	348.041	114.494	344.704	124.2134	334.9846	113.5846	345.6134	113.384	345.814
11	121.313	456.679	125.671	452.3206	146.7178	431.2742	128.979	449.013	127.496	450.496
12	132.624	577.387	132.319	577.6925	180.1751	529.8359	139.633	570.378	136.7315	573.2795
13	158.682	662.457	134.033	687.106	190.0861	631.0529	142.7653	678.3737	139.3084	681.8306
total	1120.561	2874.001	1242.381	2770.162	1455.589	2548.792	1159.105	2830.058	1171.209	2823.353

Regarding the profits, it is not surprising that the airline's profits differ among the three models. Furthermore, the results show that the airline's maximum benefit is achievable from the wholesale model. This result is compatible with Y. Zhao et al. (2010) and supports our claim that the wholesale contract is the best for the airline. However, this may affect the freight forwarder's willingness to buy capacity from the airline. On the contrary, the option-contract model provides the minimum expected profit among the three models. This is because the option-contract is more advantageous to the freight forwarder than the airline (Y. Zhao et al., 2010). See **Table 3.**

Table 3 airline profit in (US$) from the three models

	Mixed model	*Wholesale model*	*Option model*
Hot-selling route	516653	523914	466018
Underutilized route	107319	138771	87841
Total	**623972 ***	**662685****	553858

Finally, the mixed wholesale-option model strikes a balance between the profits and the allocation, i.e. the model gives the highest allocation on the underutilized routes, but with 5% less profit than the profit of the wholesale model.

8 Managerial insights

Although we consider the airline in this game as risk-neutral, applying buy-back prices for underutilized routes has a trade-off. This trade-off appears clearly when the freight forwarders collude to enforce the airline to move to **phase II**. Consequently, the airline may experience large amount of buy-back. Moreover, this solution may result in an inaccurate capacity allocation on the underutilized routes. On the other hand, if the airline stops the game in **phase I**, regardless of the forwarder risk behavior, the company will incur shortage costs due to the unused spaces on the underutilized routes. Further, the airline may lose the opportunity to increase the profits from the possible capacity sales when implementing the buyback policy.

Based on Xue et al. (2018) study, the buyback policy will upsurge the competition among the freight forwarders. This may lead them to cheat in order to obtain more space on the hot-selling routes and guarantee them a buyback on the underutilized routes. Therefore, the airline should think of imposing a penalty on the hot-selling routes if the forwarder is not able to fill the reserved capacity in the contract before flight departure.

As shown in the pure wholesale model, the use of wholesale price to sell the capacity to the freight forwarder is valuable to the airline. Nevertheless, this is not the best solution for the airline and the freight forwarders. It gives the maximum profit to the airline but contradicts the game rules. From **Theorem 1** , it has been established that the game uses the profit balance between the airline and the freight forwarder to solve the imbalance among the substitutable routes. This requires one party to give up some profits on a certain route and another to give up some profits on the substituting route. Although the airline does not commit to this rule in the pure wholesale model, the airline tries to maximize its profits regardless of the freight forwarders' profit margin, and thus, the freight forwarders' easiest solution is to go to the airline's rivals. On the contrary, the pure option-contract model offers the lowest allocation and profits to the airline which means that airline power is not used effectively. Finally, the mixed wholesale-option contract model is the most effective of the three models. It optimizes profit sharing and, thus, reduces the double marginalization effect which takes place when the hot-selling routes and the underutilized routes are combined (Vafa Arani et al., 2016).

9 Conclusions

In this study, the demand-capacity gaps between the substitutable cargo routes were classified into two categories, the hot-selling and underutilized. On the hot-selling route, demand was higher than capacity. The underutilized route was found to be the route on which the freight forwarders' demand does not exceed 50% of the capacity. The existence of these two situations in the substitutable routes caused an imbalance problem to an airline. Consequently, we proposed a mixed whole-sale-option-contracting model in a theoretic game form between a single airline and multiple freight forwarders to solve this problem. The model takes advantage of the airline power to adopt a wholesale contract for selling the hot-selling routes, while the option-contract is used to sell the underutilized routes to motivate freight forwarders to buy larger quantities.

The proposed model assumes that the airline and the freight forwarders can agree to allocate an amount on the underutilized routes proportional to their ordered freight space on the hot-selling routes. The game in the mixed wholesale-option-contract model is played in two phases. In **phase I**, the airline tries to reach an agreement with the freight forwarder without incurring any buyback values to the freight forwarders. In **phase II**, the airline considers the risk-aversion of freight forwarders by offering a buyback policy. It was shown that it is important for the airline and the freight forwarders to give up some of their profits on the different routes in order to reach an acceptable agreement.

The model was also compared with pure wholesale and pure option-contract models. Further, the numerical example revealed that the mixed wholesale-option-contract model gives the highest allocation on the underutilized routes among the pure wholesale and the option-contract models. Moreover, the airline's profits from the mixed model were higher than the profits made using the pure option model. The wholesale model gave the greatest profit to the airline; however, the adoption of this model may negatively affect the freight forwarders who may stop the game in disagreement.

This study was performed with fixed prices to set the allocation balance between the routes. Future studies can extend the insights discussed in this study by considering the joint determination of optimum prices and quantities. Moreover, the model was formulated in a single period; hence, future studies can make improvements to it by including dynamic pricing. Additionally, with more investigation, the game can be performed simultaneously if the airline collects the freight forwarders' orders and uses lexicographic, uniform, linear or proportional allocation.

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