Vertical Contracting Between Airlines: An Equilibrium Analysis of Codeshare Alliances[*]

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Abstract

This paper studies the competitive effects of airline codeshare alliances. We consider an airline market with two firms offering two differentiated final products: a direct flight and an indirect flight between two destinations. An intermediate (complementary) flight is needed to complete the indirect flight. When the intermediate flight is offered only by a third airline, codesharing between the two complementary airlines eliminates double markup and lowers consumer prices. When the intermediate flight is offered only by the airline that also offers the direct flight, codesharing does not eliminate the double markup, but, interestingly, it again lowers final prices for consumers. However, if both the third and the direct-flight airlines can offer the intermediate flight, then allowing codesharing leads to the exclusion of the third airline and to higher consumer prices.

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1 Introduction

Codeshare alliances between major U.S. airlines have become increasingly popular over the last decade.[1] This has led to much discussion among economists and policy makers about the effects of codesharing on competition and consumer welfare.[2] A prevalent view is that codesharing eliminates double marginalization and hence reduces market prices (Brueckner and Whalen, 2000; Brueckner, 2001; Brueckner, 2003; Bamberger, Carlton, and Neumann, 2004; and Ito and Lee, 2007). This result is predicated on the logic that partners jointly price their codeshare products and therefore will price the intermediate product of any partner airline at the true marginal cost.[3]

In this paper, we provide an equilibrium analysis of the pricing behavior and competitive effects of a codesharing alliance. While we maintain the same assumption as in the theoretical literature that airlines forming a codesharing alliance will jointly price their products, we do not presume that this leads to marginal cost pricing for an intermediate good (flight) in the alliance. Rather, we study the equilibrium pricing incentives for partners in the alliance, and consider the endogenous formation of the alliance when multiple airlines can potentially offer the intermediate flight. We find that codesharing may or may not eliminate double marginalization, depending on whether a codeshare partner also offers a single-carrier product in the concerned market. Specifically, if no codeshare partner offers a single-carrier product, then codesharing indeed leads to true marginal cost pricing for the intermediate good and lowers final prices; otherwise, codesharing does not eliminate double marginalization, and can result in higher market prices.

Codesharing combines the operating services of at least two separate carriers, where only one of the carriers is responsible for marketing and setting the final price for the entire round-trip ticket ("ticketing carrier") and compensating the other carrier ("operating carrier") for their pure operating services on a segment of the trip.[4] For example, in traveling from Hartford, Connecticut,

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[1]For example, U.S. domestic alliances include, United Airlines with US Airways, American Airlines with Alaska Airlines, and Delta Air Lines with Northwest Airlines and Continental Airlines.

[2]For policy discussions on the potential effects of codeshare alliances see, "Aviation Competition: Effects on Consumers From Domestic Airline Alliances Vary," *Report # GAO/RCED-99-37,* U.S. General Accounting Office (1999); and "Termination of review under 49U.S.C. § 41720 of Delta/Northwest/Continental Agreements", U.S. Department of Transportation, Office of the Secretary (2003).

[3]We are concerned with alliances in which partners' routes are complementary; i.e., the codesharing is a form of vertical contracting. If partners' route network overlap prior to formation of the alliance, the alliance is typically referred to as parallel, which tends to have the effect of softening competition and raising market prices (see Park, 1997; Park, Zhang, and Zhang, 2001; Brueckner and Whalen, 2000; Brueckner, 2001; and Gayle, forthcoming).

[4]Within the U.S. domestic market sometimes a ticketing carrier of a product does not provide any operating services for the product. This is referred to as "Virtual" codesharing (see Ito and Lee, 2007; and Gayle, 2007). We do not consider such agreements in our analysis.

to Houston, Texas a passenger may have bought the codeshare round-trip ticket from Northwest Airlines, but the itinerary involves flying on Northwest Airlines from Hartford to Detroit, Michigan, then connecting to a Continental Airlines flight from Detroit to Houston. We can therefore consider codesharing as a vertical contract between ticketing and pure operating carriers. The pure "operating carrier" is equivalent to an upstream supplier that provides an essential input (operate a trip segment) to the downstream "ticketing carrier" who then combines it with other inputs (complementary trip segments) in order to provide the final product to consumers.

In the example above, Continental Airlines also offers non-stop round-trip service between Hartford and Houston. This implies that, in addition to being an "upstream" codesharing partner for the interline product (where a passenger changes airlines at an intermediate stop), Continental is also a vertically integrated firm in this market. In fact, unlike codeshare alliances between different national carriers,[5] it is common for a U.S. codeshare partner to offer both interline connecting service and competing single-carrier service within the same origin-destination market. In a data set that spans 155 U.S. domestic markets, Gayle (2006) found that close to half (44%) of the interline codeshare products are offered by pure operating carriers that simultaneously offer competing single-carrier products. This feature of a codesharing partner, together with whether there is competition for the "intermediate good" in the indirect-flight product, turns out to be crucial in determining the effects of codesharing alliances. As we shall demonstrate, in the presence of a codesharing partner who also offers a direct flight, the price for the codesharing intermediate good will exceed its marginal cost; but, if there is no other firm offering the intermediate good, the final prices will still be below what they would be without codesharing. However, if there is another firm offering the intermediate good, then allowing codesharing raises final prices and harms consumers. The reason for this last result is that, with codesharing, the firm offering the direct flight (the "vertically integrated" firm) will be able to exclude competition for the intermediate good in the indirect flight. This happens because a ticketing carrier will strategically choose to codeshare with a vertically integrated operating carrier in an effort to soften downstream competition; and the vertically integrated operating carrier will indeed compete less aggressively downstream since it takes into account the profit from its intermediate good in the codesharing product.[6]

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[5] For example, American Airlines, British Airways, Finnair, among others are part of the OneWorld alliance, while United, Lufthansa, Air Canada, among others form the Star Alliance.

[6] This is related to the idea in several recent papers in other contexts; see Chen (2001), Chen and Riordan (forthcoming), and Sappington (2005).

The rest of the paper is organized as follows. Section 2 presents our model of an airline market with two firms offering two differentiated final products: a direct flight and an indirect (interline) flight between two destinations. To complete the indirect flight, an intermediate (complementary) flight is needed. The intermediate flight is offered either by a third airline or/and by the airline who is also offering the direct flight. Section 3 studies market equilibrium when only the third airline offers the intermediate flight (in this case, each of the three airlines offers a single product). Section 4 studies market equilibrium when airline 1 offers both a direct flight and the intermediate flight to the other airline, but no other airline offers the intermediate flight. Section 5 studies market equilibrium when a third airline and the direct-flight airline both offer the intermediate good for the indirect-flight product. Section 6 concludes. A linear-demand example is presented in the appendix.

2   The Model

A market is defined as round-trip air travel between an origin and a destination city. A flight itinerary is defined as a specific sequence of airport stops in traveling from the origin to the destination city. Products are defined as a unique combination of airline(s) and flight itinerary.

Our model has up to three airlines, A1, A2, and A3, and three cities, X, Y, and Z. A1 provides non-stop round-trip service between cities X and Z; A2 provides non-stop round-trip service between cities Y and Z; and either A1 or/and A3 provide non-stop round-trip service between cities X and Y. Figure 1 depicts each airlines' route(s) between the cities.
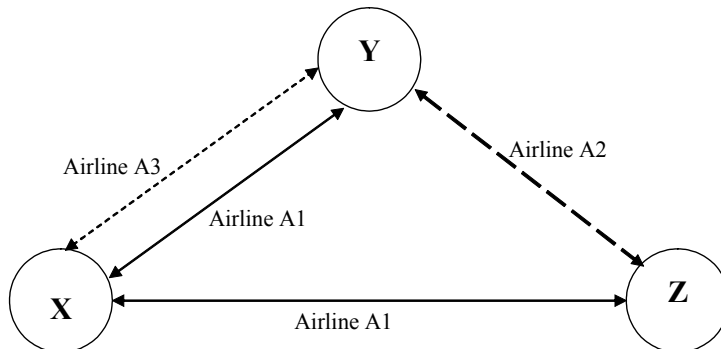

Figure 1

Our focus is on the origin-destination market X-Z. Based on Figure 1, a passenger travelling between X and Z has two differentiated products to choose from: a direct-flight itinerary on A1, D; and a non-direct itinerary N with one intermediate stop in city Y using airlines A2 and Au, where u = either 1 or 3. We can consider product N as consisting of two complementary goods, n_{xy} and n_{yz}. Thus, there are three possible market structures under our consideration: only A1 offers n_{xy}, only A3 offers n_{xy}, and both A1 and A3 offer n_{xy}. Notice that when $u = 1$, A1 is offering both D and an intermediate product to A2, and we use M to denote this (multi-product for A1) market structure. When $u = 3$, each airline is offering a single product, and we use S to denote this (single-product) market structure.[7] When both A1 and A3 offer n_{xy}, the market structure is denoted as B.

Let p_D and p_N be the final prices for the two products (itineraries). Consumer demands for these two products are assumed to be

$$q_D\left(p_D, p_N\right) \text{ and } q_N\left(p_D, p_N\right), \qquad \text{where}$$

$$\frac{\partial q_i}{\partial p_i} < 0 < \frac{\partial q_i}{\partial p_j} \text{ and } \left|\frac{\partial q_i}{\partial p_j}\right| < \left|\frac{\partial q_i}{\partial p_i}\right|, \text{ for } i, j = D, N, \text{ and } i \neq j.$$

Thus, as is usually assumed in the literature, demand for a product is decreasing in its own price but increasing in the other product's (substitute's) price; and demand is more sensitive with respect to its own price change than to price change of the other product.

Under either market structure S or M, there are two potential pricing regimes for Au ($u = 1$ or 3).[8] Without codesharing, Au and A2 choose their prices, r_u and r_2, independently. In this case, $p_N = r_u + r_2$. With codesharing, A2 will set the price for the entire itinerary, p_N, and pay Au a per-ticket price w_u in addition to a fixed payment t_u. For convenience, we assume that n_{xy} is a homogeneous product, whether it is produced by A1 or A3.

Constant marginal costs are $c_D \geq 0$ for D, $c_{xy} \geq 0$ for good n_{xy}, and $c_{yz} \geq 0$ for good n_{yz}. In addition, there are possibly fixed costs: $k_D \geq 0$ for producing D, $k_{xy} \geq 0$ for n_{xy} and $k_{yz} \geq 0$ for n_{yz} if there is no codesharing, and $k_{xyz} \geq 0$ for N if there is codesharing. We assume that none of the fixed costs is so large as to cause any airline to incur negative profits by being in the market.

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[7]Equivalently, we may consider that A1 produces D, a vertically integrated product, while Au produces an essential input for A2 who produces N.

[8]Under market structure B, there is also the issue of which airline, A1 or A3, will be chosen to codeshare with A2. We shall analyze market structure B in Section 5.

The timing of the game under market structures M and S is as follows:

Without codesharing alliance, A1, A2, and Au simultaneously choose p_D, r_2, and r_u.

With codesharing, Au and A2 first negotiate a private contract (w_u, t_u). A1 and A2 then simultaneously choose p_D and p_N.

Market structure M or S, together with or without codesharing, leads to the following four possible combinations of market structure and contracting: (i) Only A3 offers n_{xy} and there is no codesharing; (ii) Only A3 offers n_{xy} but there is codesharing between n_{xy} and n_{yz}; (iii) Only A1 offers n_{xy} and there is no codesharing; (iv) Only A1 offers n_{xy} but there is codesharing between n_{xy} and n_{yz}. In each case, we shall assume that a firm's profit is concave in its own price(s) in the relevant ranges of parameter values, prices are strategic complements (i.e., a firm's marginal profit in a price increases in other prices), and there exists a unique and stable equilibrium. This amounts to assuming that the reaction curves defined by the first-order conditions are upward slopping and have a unique intersecting point (i.e., a unique equilibrium), and that an increase in a reaction function will result in a new equilibrium with higher prices. This will allow us to compare equilibrium prices under different market structures and contracting possibilities.[9]

3   When Only A3 Offers n_{xy}

This situation corresponds to market structure S, with each firm offering a single product (i.e., $u = 3$).

3.1   No Codesharing

We first study the market equilibrium when there is no codesharing between $A2$ and $A3$. Without codesharing, $A1$, $A2$, $A3$ simultaneously choose prices p_D, r_2, and r_3. Let $p_N = r_2 + r_3$. The variable profits of the three firms are, respectively:

$$\pi_1 = (p_D - c_D)\, q_D\,(p_D, p_N), \qquad \pi_2 = (r_2 - c_{yz})\, q_N\,(p_D, p_N), \qquad \pi_3 = (r_3 - c_{xy})\, q_N\,(p_D, p_N).$$

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[9]These assumptions are admittedly strong, and are made to minimize technical details that are not essential for our results. In the Appendix, we give a linear-demand example in which all assumptions are satisfied. Similar assumptions are made in the literature, as, for instance, in Ordover, Saloner, and Salop (1990) and Chen (2001).

The equilibrium prices, $\left(p_D^S, r_2^S, r_3^S\right)$, satisfy the following first-order conditions:

$$q_D\left(p_D, p_N\right) + \left(p_D - c_D\right)\frac{\partial q_D\left(p_D, p_N\right)}{\partial p_D} = 0, \tag{1}$$

$$q_N\left(p_D, p_N\right) + \left(r_2 - c_{yz}\right)\frac{\partial q_N\left(p_D, p_N\right)}{\partial p_N} = 0, \tag{2}$$

$$q_N\left(p_D, p_N\right) + \left(r_3 - c_{xy}\right)\frac{\partial q_N\left(p_D, p_N\right)}{\partial p_N} = 0, \tag{3}$$

and we let $p_N^S = r_2^S + r_3^S$. These first-order conditions implicitly define three reaction functions. Adding equations (2) and (3), we obtain

$$2q_N\left(p_D, p_N\right) + \left(p_N - c_{xy} - c_{yz}\right)\frac{\partial q_N\left(p_D, p_N\right)}{\partial p_N} = 0. \tag{4}$$

Equations (1) and (4) implicitly define the functions of two upward-slopping reaction curves in the p_D-p_N space:

$$p_D = R_D^S\left(p_N\right), \qquad p_N = R_N^S\left(p_D\right).$$

Therefore, the equilibrium prices $\left(p_D^S, p_N^S\right)$ solve equations (1) and (4), with

$$r_2^S = \frac{p_N^S - c_{xy} + c_{yz}}{2}, \qquad r_3^S = \frac{p_N^S + c_{xy} - c_{yz}}{2}.$$

It follows that $r_2^S - c_{yz} = r_3^S - c_{xy}$, or the two complementary goods have the same markups. The equilibrium variable profits are

$$\pi_1^S = \left(p_D^S - c_D\right)q_D\left(p_D^S, p_N^S\right), \qquad \pi_2^S = \left(r_2^S - c_{yz}\right)q_N\left(p_D^S, p_N^S\right), \qquad \pi_3^S = \left(r_3^S - c_{xy}\right)q_N\left(p_D^S, p_N^S\right).$$

3.2 Comparing With Codesharing

We next consider the equilibrium when there is codesharing between A2 and A3. In this case, A3 and A2 first negotiate a private contract (w_3, t_3). A1 and A2 then simultaneously choose p_D and p_N. When A3 and A2 form a codesharing alliance, we follow the existing theoretical literature and assume that they will choose w_3 to maximize their joint profits, which implies that w_3 will equal to the true marginal cost of n_{xy},[10] or $w_3^S = c_{xy}$. The equilibrium value of t_3 will depend on specific assumptions on the bargaining process. For the purpose of this paper, we do not need to know how the surplus is distributed between A3 and A2 through the fixed transfer payment, which does not affect the equilibrium choices of p_D and p_N. Provided that codesharing increases the partners' joint profits so that there is incentive to form the alliance, all we need to know is the equilibrium

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[10] Thus, as in the literature, when each firm offers a single product, codesharing indeed eliminates double markup.

per-unit price for the intermediate good under codesharing, and the resulting equilibrium final prices. We shall follow this approach for the rest of the paper when we analyze equilibrium under codesharing.[11]

The variable profit of A1 and the joint variable profit of A2 and A3 are, respectively:

$$\pi_1 = (p_D - c_D)\, q_D\, (p_D, p_N)\,, \qquad \pi_{23} = (p_N - c_{xy} - c_{yz})\, q_N\, (p_D, p_N)\,.$$

The equilibrium prices, $\left(p_D^{SC}, p_N^{SC}\right)$, solve the first-order conditions:

$$q_D\, (p_D, p_N) + (p_D - c_D) \frac{\partial q_D\, (p_D, p_N)}{\partial p_D} = 0, \tag{5}$$

$$q_N\, (p_D, p_N) + (p_N - c_{xy} - c_{yz}) \frac{\partial q_N\, (p_D, p_N)}{\partial p_N} = 0, \tag{6}$$

which implicitly define two reaction functions:

$$p_D = R_D^{SC}\, (p_N)\,, \qquad p_N = R_N^{SC}\, (p_D)\,.$$

Then, if A2 and A3 form a codesharing alliance, the equilibrium variable profits of A1 and the joint variable profits of A2 and A3 are:

$$\pi_1^{SC} = \left(p_D^{SC} - c_D\right) q_D\left(p_D^{SC}, p_N^{SC}\right), \qquad \pi_{23}^{SC} = \left(p_N^{SC} - c_{xy} - c_{yz}\right) q_N\left(p_D^{SC}, p_N^{SC}\right).$$

Proposition 1. Codesharing between A2 and A3 lowers final prices for both the direct and non-direct products (itineraries). That is, $p_D^S > p_D^{SC}$, and $p_N^S > p_N^{SC}$.

Proof. Since equations (1) and (5) have the same form, while equations (4) and (6) differ only in that (4) contains an extra positive term $q_N\left(p_D^S, p_N^S\right)$, the reaction curves determining $\left(p_D^S, p_N^S\right)$ differ from the reaction curves determining $\left(p_D^{SC}, p_N^{SC}\right)$ only in that $R_N^S\, (p_D)$ is higher than $R_N^{SC}\, (p_D)$ along the p_N axis. Therefore $R_D^S\, (p_N)$ and $R_N^S\, (p_N)$ must intersect at a point that is higher and to the right of the intersection point of $R_D^{SC}\, (p_N)$ and $R_N^{SC}\, (p_N)$, implying $p_D^S > p_D^{SC}$ and $p_N^S > p_N^{SC}$. Q.E.D

Codesharing by A2 and A3 has an allocative efficiency effect: it eliminates a double markup existing between a bilateral monopoly for product N, lowering the final price for N. This further has a strategic effect on A1, motivating A1 to lower its price for D. So in this case codesharing clearly increases competition between D and N, benefiting consumers. Whereas the allocative efficiency

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[11] This is appropriate in the setting of this paper. For general models of vertical contracting that involve multilateral bargaining in which the distribution of surplus is important, see, for instance, de Fontenay and Gans (2005), and Inderst and Way (2003).

effect affects positively the joint profits of A2 and A3, the strategic effect has a negative effect. The incentive for codesharing between A2 and A3 also depends on possible savings in fixed costs.[12] In equilibrium, A2 and A3 will form codesharing alliance if codesharing increases their total joint profits. We thus have:

Remark 1. Assume that A3 is the only provider of n_{xy}. Then, codesharing between A2 and A3 will occur in equilibrium if

$$\pi_{23}^{SC} - k_{xyz} > \pi_2^S + \pi_3^S - k_{xy} - k_{yz}.$$

As our linear-demand example in the Appendix shows, π_{23}^{SC} can be either higher or lower than $\pi_2^S + \pi_3^S$, depending on the parameter values. Thus, A2 and A3 can have the incentive to form an alliance even without cost savings.

4 When only A1 offers n_{xy}

This situation corresponds to market structure M, with A1 offering both D and n_{xy} (i.e., $u = 1$).

4.1 Without Codesharing

We first consider the equilibrium without codesharing. In this case, A1 will choose both p_D and r_1, while A2 will choose r_2; and again the prices are chosen simultaneously. The variable profit functions of the two firms, A1 and A2, are:

$$\pi_1 = (p_D - c_D) \, q_D \, (p_D, r_1 + r_2) + (r_1 - c_{xy}) \, q_N \, (p_D, r_1 + r_2) \,, \qquad \pi_2 = (r_2 - c_{yz}) \, q_N \, (p_D, r_1 + r_2) \,.$$

The equilibrium prices, $\left(p_D^M, r_1^M, r_2^M\right)$, solve the first-order conditions:

$$q_D \, (p_D, p_N) + (p_D - c_D) \frac{\partial q_D \, (p_D, p_N)}{\partial p_D} + (r_1 - c_{xy}) \frac{\partial q_N \, (p_D, p_N)}{\partial p_D} = 0, \qquad (7)$$

$$(p_D - c_D) \frac{\partial q_D \, (p_D, p_N)}{\partial p_N} + q_N \, (p_D, p_N) + (r_1 - c_{xy}) \frac{\partial q_N \, (p_D, p_N)}{\partial p_N} = 0, \qquad (8)$$

$$q_N \, (p_D, p_N) + (r_2 - c_{yz}) \frac{\partial q_N \, (p_D, p_N)}{\partial p_N} = 0, \qquad (9)$$

where $p_N = r_1 + r_2$, and we let $p_N^M = r_1^M + r_2^M$. These first-order conditions again implicitly define three reaction functions.

Notice that equations (2) and (9) have the same form, whereas equations (7) and (8) differ from equations (1) and (3) only in that there is an extra positive term in (7) and in (8). Using the same

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[12] Alliances may result in cost savings since alliance partners often jointly use each others facilities (lounges, gates, check-in counters etc.), and may also practice joint purchase of fuel (Bamberger, Carlton, and Neumann, 2004).

reasoning in obtaining Proposition 1, we have $\left(p_D^M, r_1^M, r_2^M\right) >> \left(p_D^S, r_3^S, r_2^S\right)$. Therefore, without codesharing, the equilibrium prices are higher when n_{xy} is offered by a firm that also offers D, a product competing with N, than when n_{xy} is offered by a single-product firm. This is because A1's incentive to raise prices is higher when it offers both n_{xy} and D than when it only offers D.

Notice also that equations (8) and (9) differ only in that there is an extra positive term in (8), which implies $\left(r_1^M - c_{xy}\right) > \left(r_2^M - c_{yz}\right) > 0$. Thus, unlike when A3 offers n_{xy}, where the price markup for goods n_{xy} and n_{yz} are the same, here the markup for n_{xy} is higher. Furthermore, when A1 offers both n_{xy} and D, we have $r_1^M > c_{xy}$.

The equilibrium variable profits for A1 and A2, without codesharing, are

$$\pi_1^M = \left(p_D^M - c_D\right) q_D\left(p_D^M, p_N^M\right) + \left(r_1^M - c_{xy}\right) q_N\left(p_D^M, p_N^M\right), \qquad \pi_2^M = \left(p_N^M - r_1^M - c_{yz}\right) q_N\left(p_D^M, p_N^M\right).$$

Let $\Pi^M \equiv \pi_1^M + \pi_2^M$ be the equilibrium industry profit under market structure M without codesharing.

4.2 Comparing With Codesharing

Next, we consider the equilibrium with codesharing. The major difference between this case and the case where A3 offers n_{xy} is that, now for the transfer price w_1 in the codesharing agreement, maximizing the joint profits of A1 and A2 is the same as maximizing the industry profit (and hence w_1 need not equal to c_{xy}), while previously w_3 maximizes the joint profits between A2 and A3 (and hence $w_3 = c_{xy}$).

Given any w_1 agreed to by $A1$ and $A2$, the variable profits of A1 and A2 are:

$$\pi_1 = (p_D - c_D) q_D(p_D, p_N) + (w_1 - c_{xy}) q_N(p_D, p_N), \qquad \pi_2 = (p_N - w_1 - c_{yz}) q_N(p_D, p_N).$$

The equilibrium prices $p_D(w_1)$ and $p_N(w_1)$ solve the first-order conditions:

$$q_D(p_D, p_N) + (p_D - c_D)\frac{\partial q_D(p_D, p_N)}{\partial p_D} + (w_1 - c_{xy})\frac{\partial q_N(p_D, p_N)}{\partial p_D} = 0, \qquad (10)$$

$$q_N(p_D, p_N) + (p_N - w_1 - c_{yz})\frac{\partial q_N(p_D, p_N)}{\partial p_N} = 0. \qquad (11)$$

Since the left-hand sides of equations (10) and (11) above are higher with higher w_1, and since w_1 affects p_N directly while affects p_D indirectly, we expect that $p_N'(w_1) \geq p_D'(w_1) > 0$.

The variable industry profit is

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\begin{aligned}
\Pi(w_1) &= (p_D - c_D) q_D(p_D, p_N) + (w_1 - c_{xy}) q_N(p_D, p_N) + (p_N - w_1 - c_{yz}) q_N(p_D, p_N) \\
&= (p_D(w_1) - c_D) q_D(p_D(w_1), p_N(w_1)) + (p_N(w_1) - c_{xy} - c_{yz}) q_N(p_D(w_1), p_N(w_1)).
\end{aligned}
$$

In equilibrium,

$$w_1^{MC} = \arg\max_{w_1} \ \Pi\left(w_1\right),$$

or w_1^{MC} satisfies

$$\left[\left(p_D\left(\cdot\right) - c_D\right)\frac{\partial q_D}{\partial p_N} + \left(w_1^{MC} - c_{xy}\right)\frac{\partial q_N}{\partial p_N}\right]p_N'\left(\cdot\right) + \left(p_N\left(\cdot\right) - w_1^{MC} - c_{yz}\right)\frac{\partial q_N}{\partial p_D}p_D'\left(\cdot\right) = 0. \quad (12)$$

Let $p_D^{MC} \equiv p_D\left(w_1^{MC}\right)$, and $p_N^{MC} \equiv p_N\left(w_1^{MC}\right)$. Then, provided $p_N'\left(w_1\right) \geq p_D'\left(w_1\right) > 0$, we have:

$$
\begin{aligned}
0 &= \left[\left(p_D^{MC} - c_D\right)\frac{\partial q_D}{\partial p_N} + \left(w_1^{MC} - c_{xy}\right)\frac{\partial q_N}{\partial p_N}\right]p_N'\left(\cdot\right) + \left(p_N^{MC} - w_1^{MC} - c_{yz}\right)\frac{\partial q_N}{\partial p_D}p_D'\left(\cdot\right) \\
&< \left[\left(p_D^{MC} - c_D\right)\frac{\partial q_D}{\partial p_N} + \left(w_1^{MC} - c_{xy}\right)\frac{\partial q_N}{\partial p_N}\right]p_N'\left(\cdot\right) - \left(p_N^{MC} - w_1^{MC} - c_{yz}\right)\frac{\partial q_N}{\partial p_N}p_N'\left(\cdot\right) \\
&= \left[\left(p_D^{MC} - c_D\right)\frac{\partial q_D}{\partial p_N} + \left(w_1^{MC} - c_{xy}\right)\frac{\partial q_N}{\partial p_N} - \left(p_N^{MC} - w_1^{MC} - c_{yz}\right)\frac{\partial q_N}{\partial p_N}\right]p_N'\left(\cdot\right). \\
&= \left[\left(p_D^{MC} - c_D\right)\frac{\partial q_D}{\partial p_N} + \left(w_1^{MC} - c_{xy}\right)\frac{\partial q_N}{\partial p_N} + q_N\right]p_N'\left(\cdot\right).
\end{aligned}
$$

where the first inequality is due to $\frac{\partial q_N}{\partial p_D} < -\frac{\partial q_N}{\partial p_N}$ and $p_N'\left(w_1^{MC}\right) > p_D'\left(w_1^{MC}\right) > 0$, and the last equality is due to equation (11). This implies

$$\left(p_D^{MC} - c_D\right)\frac{\partial q_D}{\partial p_N} + \left(w_1^{MC} - c_{xy}\right)\frac{\partial q_N}{\partial p_N} + q_N > 0. \quad (13)$$

Since w_1^{MC} is chosen to maximize $\Pi\left(w_1\right)$, the equilibrium variable profits of A1 and A2, π_1^{MC} and π_2^{MC}, satisfy

$$\pi_1^{MC} + \pi_2^{MC} \equiv \Pi^{MC} = \left(p_D^{MC} - c_D\right)q_D\left(p_D^{MC}, p_N^{MC}\right) + \left(p_N^{MC} - c_{xy} - c_{yz}\right)q_N\left(p_D^{MC}, p_N^{MC}\right).$$

Therefore, when one of the codesharing partners also offers product D, the codeshare partners can negotiate an intermediate-good price that maximizes the industry profit, subject to the constraint that both airlines will independently choose the final prices for D and N. We now turn to the comparison of equilibrium prices.

Proposition 2. Assume $p_N'\left(w_1^{MC}\right) > p_D'\left(w_1^{MC}\right) > 0$. Then codesharing lowers the price for n_{xy}, although it does not eliminate the double markup; and codesharing lowers final-good prices. That is, $c_{xy} < w_1^{MC} < r_1^M$, $p_D^{MC} < p_D^M$, and $p_N^{MC} < p_N^M$. Furthermore, $\Pi^{MC} > \Pi^M$.

Proof. First, from the first-order condition on w_1^{MC}, equation (12), we must have $w_1^{MC} > c_{xy}$; otherwise the left-hand side of equation (12) would be positive, which is a contradiction.

Next, in the equilibrium without codesharing, $\left(r_1^M, p_D^M, p_N^M\right)$ satisfy equations (7)-(9) with $p_N^M = r_1^M + r_2^M$, while in the equilibrium with codesharing, $\left(w_1^{MC}, p_D^{MC}, p_N^{MC}\right)$ satisfy equations (10)-(11) and inequality (13).

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Therefore, the reaction functions determining the two equilibria have the same forms except equation (8) and inequality (13), which determine, respectively, the optimal r_1^M and w_1^{MC}, for given (p_D, p_M). Since $\frac{\partial q_N}{\partial p_N} < 0$, these two conditions imply that the reaction function for w_1^{MC} is lower than that for r_1^M. Consequently, $w_1^{MC} < r_1^M$, $p_D^{MC} < p_D^M$, and $p_N^{MC} < p_N^M$. Furthermore, since w_1^{MC} maximizes $\Pi(w_1)$ but $w_1^{MC} \neq r_1^M$, we have $\Pi^{MC} > \Pi^M$. Q.E.D.

Therefore, even when A1 offers both the direct flight and a segment in the non-direct flight, codesharing between A1 and A2 still alleviates double marginalization and lowers final prices, although it does not eliminate double marginalization. To understand this result, suppose we start at the equilibrium price under codesharing. Without codesharing, a slight increase in r_1 above w_1^{MC} by A1 raises both p_D and p_N, which raises A1's profit from D but lowers both A1 and A2's profits from N; the profit reduction for A2 is not taken into account by A1 when it raises r_1 without codesharing, but is taken into account by A1 and A2 when forming the codesharing agreement. Hence $w_1^{MC} < r^M$. On the other hand, codesharing does not eliminate double markup, because now $w_1^{MC} > c_{xy}$ is chosen to maximize the industry profit, given that A1 and A2 will compete in D and N.

Proposition 3. With codesharing, equilibrium prices are higher when A1 offers both n_{xy} and D than when A3 offers n_{xy}. That is, $w_1^{MC} > w_3^{SC}$, $p_D^{MC} > p_D^{SC}$, and $p_N^{MC} > p_N^{SC}$. Furthermore, industry profit is higher under M than under S, or $\Pi^{MC} > \Pi^{SC}$.

Proof. Since $w_1^{MC} > c_{xy}$ while $w_3^{SC} = c_{xy}$, we have $w_1^{MC} > w_3^{SC}$. Comparing the first-order conditions determining (p_D^{SC}, p_N^{SC}), equations (5) and (6), with the first-order conditions determining (p_D^{MC}, p_N^{MC}), equations (10) and (11), we see that the left-hand sides of (10) and (11) are higher due to an extra positive term in equation (10) and to the fact that $w_1^{MC} > w_3^{SC}$. This implies that the reaction functions defined by equations (10) and (11) are higher than those defined by equations (5) and (6); hence $p_D^{MC} > p_D^{SC}$ and $p_N^{MC} > p_N^{SC}$.

Furthermore, since $w_1^{MC} > c_{xy} = w_3^{SC}$, we have $\Pi^{MC} > \Pi^{SC}$. Q.E.D.

Proposition 3 makes clear that the effects of codesharing depend on who offers n_{xy}, a key insight of our analysis. Compared to the situation where a single-product firm offers n_{xy}, prices are higher if the firm offering n_{xy} also offers D. Also, the fact that $\Pi^{MC} > \Pi^{SC}$ will be important for our analysis later when both A1 and A3 can offer n_{xy} and codeshare partners are chosen endogenously.

When neither codesharing partner offers D, fixed cost saving is sometimes necessary in order for airlines to be willing to form codesharing alliances. In contrast, when a codesharing partner

also offers D, codesharing achieves highest possible industry profit even without cost savings. In fact, since from Proposition 2 $\Pi^{MC} > \Pi^M$, we have:

Remark 2. When A1 offers both n_{xy} and D, there is always incentive for A1 and A2 to form a codesharing agreement, as long as $k_{xyz} \leq k_{xy} + k_{yz}$.

5   Both A1 and A3 Offer n_{xy}

We have so far studied situations where either A1 or A3 can offer the product n_{xy}, but not both of them. We have seen that codesharing benefits consumers by lowering final-product prices. We now consider market structure B, allowing both A1 and A3 to offer the same service for XY, or to produce the homogenous product n_{xy}. As before, we assume that A1 and A3 have the same constant marginal cost of producing n_{xy}, which is equal to c_{xy}; but now we assume $k_{xy} = 0$ so that both firms have incentive to produce n_{xy} even if Bertrand competition between them drives their prices for n_{xy} down to marginal cost.

5.1   Without codesharing

In this case, A1 chooses r_1 for n_{xy} and p_D for D, A3 chooses r_3 for n_{xy}, and A2 chooses r_2 for n_{yz}; and all prices are chosen simultaneously. Competition for n_{xy} between A1 and A3 implies that the only equilibrium price for n_{xy} is $r_1^B = r_3^B = c_{xy}$, despite the fact that A1 also produces D.[13] Therefore the equilibrium prices for D and N are the same as those when only A3 offers n_{xy} and there is codesharing, or $p_D^B = p_D^{SC}$ and $p_N^B = p_N^{SC}$. Interestingly, competition for n_{xy} leads to the same outcome as if A3 codeshares with A2.

5.2   Comparing With Codesharing

With codesharing, A2 first decides with whom to form a codesharing alliance. We assume that A1 and A3 will make simultaneous (two-part tariff) contract offers to A2, and A2 will form alliance with the partner whose offer results in a higher profit for A2.[14] Importantly, the supplier of n_{xy} that is not chosen as A2's codesharing partner will no longer have any demand from consumers and will thus be excluded from the market.

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[13] As is shown in Chen (2001), when a vertically integrated firm competes with another upstream firm in supplying a homogeneous input to a downstream firm, the equilibrium input price will be equal to the marginal cost, if the two competitors have the same marginal cost.

[14] Again, the precise form of bargaining between Au and A2 is not crucial for our results; A2's choice of codesharing partner and the equilibrium prices will be the same under any form of efficient bargaining.

If A2 contracts with A3, their joint variable profit would be π_{23}^{SC}, as in subsection 3.2. In this case, the variable industry profit is $\Pi^{SC} = \pi_1^{SC} + \pi_{23}^{SC}$.

If A2 contracts with A1, they will achieve a joint variable profit that is equal to the industry variable profit, Π^{MC}. Since $\Pi^{MC} > \Pi^{SC}$ from Proposition 3, A1 is willing to offer A2 a contract that yields a higher profit for A2, comparing to the contract that A3 is willing to offer A2. Hence in equilibrium A1 and A2 will form a codesharing alliance, resulting in the equilibrium prices $\left(w_1^{MC}, p_D^{MC}, \ p_N^{MC} \right)$, which are determined by equations (10)-(12). Since $w_1^{MC} > c_{xy}$ and $p_i^{MC} > p_i^{SC}$ for $i = D, N$, we have:

Proposition 4. When both A1 and A3 offer n_{xy}, allowing codesharing leads to a higher price for n_{xy} as well as to higher final prices for both D and N.

When both A1 and A3 can offer n_{xy}, competition between them lowers the price for n_{xy}, resulting in lower final prices for D and N. But if codesharing is allowed, since A1 also offers D, A2's codesharing with A1 leads to a higher industry profit than its codesharing with A3 (i.e., $\Pi^{MC} > \Pi^{SC}$ from Proposition 3). Thus A1 has an advantage in competing with A3 to be selected as A2's codesharing partner.[15] In equilibrium, A2 will codeshare with A1, and their alliance softens competition for D and N, raising final prices.

The possibility that codesharing can increase final prices and harm consumers has been suggested in the literature before. In particular, Brueckner (2003) conjectured that when codesharing partners have overlapping services, "cooperation may result in collusive behavior, which leads to a higher rather than a lower fare" (Brueckner, 2003, page 106). Our analysis provides a formal theory of how anticompetitive codesharing can arise. Interestingly, while in our model codesharing by A1 and A2 does soften price competition, it nevertheless lowers final prices if A1 is the only possible intermediate-good provider (as Propositions 2 and 3 indicate); but when there is competition for the intermediate good, codesharing causes prices to rise. The reason for this difference is that, without codesharing, prices are different under the two market structures: when A1 is the only possible supplier for n_{xy}, the price for n_{xy} is high, leading to higher final prices; whereas when both A1 and A3 compete to supply n_{xy}, the price for n_{xy} is low, leading to lower final prices. Therefore, codesharing causes different price changes under the two different market structures.

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[15] This result shares the similar intuition to the result in Chen and Riordan (forthcoming), where a vertically integrated firm is able to exclude an equally efficient upstream producer through an exclusive supply contract with a downstream competitor.

6 Conclusion

This paper has conducted an equilibrium analysis of codeshare alliances. The pricing incentives and competitive effects of a codesharing alliance depend on both the characteristics of the codesharing partners and the presence (or absence) of competition to become a partner. If no codesharing partner offers a separate single-carrier product in the concerned market, codesharing leads to marginal cost pricing for the intermediate flight; otherwise it does not eliminate double marginalization. On the other hand, if there is only a single potential codesharing partner for the intermediate good (flight), codesharing results in lower final prices for consumers, even when it does not eliminate double marginalization; but if there is competition in providing the intermediate flight, codesharing forecloses the competition and leads to higher final prices for consumers. Our results highlight the importance of endogenizing the formation of codesharing alliances in understanding their competitive effects.[16]

Our findings have interesting policy implications. To the extent that a codesharing alliance can benefit consumers without eliminating double marginalization, policy analysis would need to look beyond the issue of double marginalization in evaluating the competitive effects of codesharing. Our analysis suggests that it is important to consider who the codesharing partners are and what the competitive condition of the market is. In particular, in market segments that are more competitive, there could be more danger that codesharing would harm consumers.

For convenience, our model abstracts from the possibilities that A1 and/or A3 may sell n_{xy} for consumers who just fly between X and Y, and A2 may sell n_{yz} for consumers who just fly between Y and Z. If we were to include these consumers in our model, our analysis would be much more complicated. These consumers could have different demands for n_{xy} from the consumers who purchase n_{xy} to travel between X and Z, and codesharing might have other effects such as enabling airlines to engage in price discrimination. If either A3 or A1 alone offers n_{xy}, our result that codesharing lowers prices likely would continue to hold: when codesharing lowers the price for n_{xyz}, a passenger travelling between X and Z through the indirect flight would choose the codeshare ticket rather than purchase n_{xz} and n_{yz} separately. Additional complication would arise if both A1 and A3 sell n_{xy}. In this case, codesharing between A1 and A2 would still exclude A3 from serving the consumers for whom n_{xy} is an intermediate good, but it could not exclude A3 from serving

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[16]In their study of rivalry between strategic alliances, Zhang and Zhang (2006) also consider a model in which alliance formation is endogenously determined.

the consumers who just fly between X and Y. The separate availability of n_{xy} and n_{yz} could then constrain the ability of A1 and A2 to raise the price for n_{xyz}.[17] It would be interesting for future research to address such issues.

There are other directions for future research. For instance, according to the prediction of our theory, codesharing would lower final prices in markets where no codesharing partner offers a separate single-carrier product or the complementary flight segment lacks competition; and it would raise final prices in markets where the complementary flight segment has multiple competitors prior to codesharing. This is a prediction that can potentially be tested in future empirical work.[18] It would also be desirable for future research to relax our strong simplifying assumption that the intermediate good is homogenous when supplied by competing airlines.

Appendix: A Linear Demand Example

This appendix considers a class of demand functions that take the forms:

$$q_D = 1 - p_D + \beta \left(p_N - p_D \right), \qquad q_N = 1 - p_N + \beta \left(p_D - p_N \right),$$

where $\beta \in (0, \infty)$ is a measure of product differentiation. We have verified that for this example our assumptions made for the paper are all satisfied. In what follows we solve the equilibrium under each game form explicitly, and illustrate the competitive effects of codesharing under different market structures. For convenience of computations, we assume that $c_D = c_{xy} = c_{yz} = 0$.

Analysis under Market Structure S

Solving equations (1) and (4) simultaneously, we obtain,

$$p_N^S = \frac{2 + 3\beta}{6\beta + 2\beta^2 + 3}, \qquad p_D^S = \frac{3 + 5\beta}{2\left(6\beta + 2\beta^2 + 3\right)}. \tag{A1}$$

Similarly, by solving equations (5) and (6) simultaneously we obtain,

$$p_N^{SC} = \frac{2 + 3\beta}{8\beta + 3\beta^2 + 4}, \qquad p_D^{SC} = \frac{2 + 3\beta}{8\beta + 3\beta^2 + 4}. \tag{A2}$$

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[17]However, if our model were further modified so that A3 could earn variable profits from selling n_{xy} as an intermediate good, then not being able to do so due to the codesharing of A1 and A2 might make it not viable for A3 to stay in the market in the presence of fixed costs, and our result that codesharing leads to higher prices would then hold.

[18]Our finding that codesharing does not eliminate double marginalization if a codesharing partner also offers a single-carrier product in the same market is consistent with the empirical evidence in Gayle (2006).

Thus, as in Proposition 1, we have

$$p_D^S - p_D^{SC} = \frac{(\beta + 1)\beta}{2\left(6\beta + 2\beta^2 + 3\right)(\beta + 2)} > 0, \qquad p_N^S - p_N^{SC} = \frac{(\beta + 1)^2}{\left(6\beta + 2\beta^2 + 3\right)(\beta + 2)} > 0.$$

Substituting the equilibrium prices back into each firm's profit function, we obtain:

$$\pi_2^S + \pi_3^S = \frac{(3\beta + 2)^2(\beta + 1)}{2\left(6\beta + 2\beta^2 + 3\right)^2}, \qquad \pi_{23}^{SC} = \frac{(3\beta + 2)^2(\beta + 1)}{(3\beta + 2)^2(\beta + 2)^2}, \qquad \Pi^{SC} = \frac{(\beta + 1)\left(24\beta + 18\beta^2 + 8\right)}{(3\beta + 2)^2(\beta + 2)^2},$$
$$\text{(A3)}$$

$$\pi_{23}^{SC} - \left(\pi_2^S + \pi_3^S\right) = \frac{\left(8\beta^2 + 8\beta + 2 - \beta^4\right)(3\beta + 2)^2(\beta + 1)}{2\left(6\beta + 2\beta^2 + 3\right)^2(\beta + 2)^2(3\beta + 2)^2}. \tag{A4}$$

We note that $\pi_{23}^{SC} - \left(\pi_2^S + \pi_3^S\right) \gtreqless 0$ for $\beta \lesseqgtr 3.261$. Thus, if there is no saving in fixed costs, the incentive for codesharing only exists when $\beta \in (0,\ 3.261)$, consistent with Remark 1.

Analysis under Market Structure M

First, solving equations (7), (8) and (9) simultaneously, we obtain:

$$p_D^M = \frac{1}{2}, \qquad r_1^M = \frac{2 + 3\beta}{6\beta + 6}, \qquad r_2^M = \frac{1}{3\beta + 3}, \qquad p_N^M = r_1^M + r_2^M = \frac{4 + 3\beta}{6(\beta + 1)}. \tag{A5}$$

Next, solving equations (10) and (11) simultaneously, we obtain,

$$p_N^{MC} = \frac{2 + 3\beta + \left(2 + 4\beta + 3\beta^2\right)w_1^{MC}}{8\beta + 3\beta^2 + 4}, \qquad p_D^{MC} = \frac{2 + 3\beta + 3\beta(1 + \beta)w_1^{MC}}{8\beta + 3\beta^2 + 4}. \tag{A6}$$

Next, substituting p_N^{MC} and p_D^{MC} into the industry profit function when A1 and A2 codeshare, we solve for the w_1^{MC} that maximizes the industry profit: $w_1^{MC} = \frac{\beta(3\beta + 2)^2}{2(\beta + 1)(8\beta + 9\beta^2 + 4)}$. We then obtain:

$$p_N^{MC} = \frac{4 + 12\beta + 18\beta^2 + 9\beta^3}{2\left(8\beta + 9\beta^2 + 4\right)(\beta + 1)}, \qquad p_D^{MC} = \frac{4 + 6\beta + 9\beta^2}{2\left(8\beta + 9\beta^2 + 4\right)}. \tag{A7}$$

Thus, as in Proposition 2, we have:

$$w_1^{MC} > c_{xy} = 0, \qquad r_1^M - w_1^{MC} = \frac{(3\beta + 2)(\beta + 2)}{3\left(8\beta + 9\beta^2 + 4\right)(\beta + 1)} > 0,$$

$$p_D^M - p_D^{MC} = \frac{\beta}{\left(8\beta + 9\beta^2 + 4\right)} > 0, \qquad p_N^M - p_N^{MC} = \frac{4\beta + 3\beta^2 + 2}{3\left(8\beta + 9\beta^2 + 4\right)(\beta + 1)} > 0.$$

The industry profits without or with codesharing under market structure M are

$$\Pi^M = \frac{18\beta + 17}{36(\beta + 1)}, \qquad \Pi^{MC} = \frac{\left(24\beta + 33\beta^2 + 18\beta^3 + 8\right)}{4(\beta + 1)\left(8\beta + 9\beta^2 + 4\right)}.$$

We thus have, as in Propositions 2 and 3:

$$\Pi^{MC} - \Pi^M = \frac{2\beta + 1}{9\left(8\beta + 9\beta^2 + 4\right)(\beta + 1)} > 0.$$

$$w_1^{MC} = \frac{\beta\,(3\beta+2)^2}{2\,(\beta+1)\,(8\beta+9\beta^2+4)} > 0 = w_3^{SC},$$

$$p_D^{MC} - p_D^{SC} = \frac{3\,(3\beta+2)\,\beta^2}{2\,(8\beta+9\beta^2+4)\,(\beta+2)} > 0,$$

$$p_N^{MC} - p_N^{SC} = \frac{(4\beta+3\beta^2+2)\,(3\beta+2)\,\beta}{2\,(8\beta+9\beta^2+4)\,(\beta+1)\,(\beta+2)} > 0;$$

$$\Pi^{MC} - \Pi^{SC} = \frac{(3\beta+2)^2\,(2\beta+1)\,\beta^2}{4\,(\beta+2)^2\,(8\beta+9\beta^2+4)\,(\beta+1)} > 0.$$

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