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Airline Alliances, Carve-Outs and Collusion

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Abstract

In this paper, we ask how antitrust immunity subject to a carve-out affects collusion incentives in international airline alliances. We show that the gains from economies of density due to higher interline traffic under the alliance strengthen the incentive to collude on the interhub route, while the accompanying revenue gain heightens the incentive to defect from collusive behavior. These two effects exactly cancel in the case of linear demand and linear economies of density. Under this approximation, the incentives for interhub collusion are no different before and after the formation of an airline alliance subject to a carve-out.

Keywords: Airline, Collusion, Competition Policy

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1 Introduction

Despite the existence of a large literature on airline economics and frequent worries about anticompetitive airline behavior on the part of regulators and other industry observers, theoretical analysis that explores the incentives for collusion among carriers is entirely missing from the literature. The purpose of this paper is to remedy this substantial omission by analyzing incentives for a particular type of collusion that may arise in the context of international airline alliances. In being granted antitrust immunity, international alliances are sometimes subject to a regulatory "carve-out" on the routes connecting the alliance partners' hubs. The carve-out forbids anticompetitive collusion on the hub-to-hub route, a possible downside of immunity, while preserving the partners' ability to beneficially cooperate on routes that cross both their networks. The question is whether the alliance enhances incentives for tacit collusion on the interhub route, in violation of the carve-out, relative to the incentives that would exist in the absence of an alliance. If collusion incentives are heightened, the carve-out may contain "the seeds of its own undoing."

To better understand this contribution, recall that the theoretical literature on immunized alliances has shown that the cooperation they foster can have both positive and negative effects.[1] On the one hand, cooperation in

[1]See Brueckner (2001, 2003) and Brueckner and Whalen (2000). A large additional literature on alliances exists. See Bamberger, Carlton and Neumann (2004), Bilotkach (2005), Chen and Gayle (2007), Flores-Fillol and Moner-Colonques (2007), Gayle (2007, 2008), Hassin and Shy (2004), Park (1997), Park, Park and Zhang (2003), Park and Zhang (1998), Park, Zhang and Zhang (2001), and Whalen (2007).

fare setting confers benefits on “interline” passengers, who must travel across the networks of both alliance partners to make their trips. Since an interline trip is a joint product provided by two carriers, the fare is lower when it is set cooperatively than when it is determined by “arm’s length” interaction between the carriers. Cooperation eliminates double marginalization, reducing the interline fare.

However, alliances affect a separate group of passengers, those starting and ending their trips at the hub airports of the alliance partners. In the case of transatlantic travel, one hub would be in the US and the other in the EU, so that the interhub market might be New York-London. In contrast to an interline passenger, whose typical trip between smaller interior US and EU cities cannot be carried out on a single carrier, passengers in a hub-to-hub market can make their trip using one alliance partner or the other, given that both fly between the hubs. With such overlapping service, cooperation in fare setting may lead to anticompetitive collusion, with the result that fares in the interhub market rise. Thus, interhub passengers may be harmed by cooperative pricing.

A carve-out is one remedy for this potential downside to immunized alliances. Under a carve-out, the alliance partners are allowed to cooperate in setting fares in the interline markets, but are prohibited from discussing interhub fares. The expectation is that a carve-out will prevent loss of competition in the interhub market while still reaping the benefits of cooperation for other passengers. Brueckner and Proost (2010) explore this idea in a simple theoretical model.

In practice, carve-outs have been imposed in granting antitrust immunity

(ATI) in some, but not all alliance cases. In granting ATI to United and Lufthansa (founding partners of the Star alliance), the US Department of Transportation imposed carve-outs in the Chicago-Frankfurt and Washington (Dulles)-Frankfurt markets, which connect United and Lufthansa hubs, while allowing the carriers to set fares cooperatively elsewhere. By contrast, in its early grant of ATI to Northwest and KLM, carve-outs were not imposed in the carriers' hub-to-hub markets (Detroit-Amsterdam and Minneapolis-Amsterdam), apparently because of the small size of these markets. Similarly, carve-outs were not imposed in any of the markets connecting the hubs of Delta and Air France, founding members of the SkyTeam alliance (Atlanta-Paris, among others).

The carve-out issue prompted an unusual public debate among the US regulators in a more recent ATI case. In its tentative approval of Star-alliance ATI for Continental (a former SkyTeam member that subsequently merged with United), the Department of Transportation required no new hub-to-hub carve-outs. However, in an advisory opinion, the US Department of Justice recommended a number of such carve-outs as well as other limitations to the extent of ATI. In its final order, the Department of Transportation acquiesced in many of those carve-out recommendations (see USDOJ (2009) and USDOT (2009)). These carve-outs involved routes between the New York area and several secondary Star hubs (Stockholm, Zurich, Copenhagen), and routes between Continental's hubs and Air Canada's Toronto hub. Carve-outs were also considered by the Department of Transportation in its recent grant of ATI to American Airlines and British Airways, but none were imposed despite the large size and importance of the principal hub-to-hub markets (New

York-London and Chicago-London).

A carve-out is expected to maintain the pre-alliance competitive situation in the interhub market, laying to rest anticompetitive concerns regarding this market. However, a factor overlooked in the previous analyses of airline alliances suggests that this conclusion may be premature. The difficulty is that prior work has ignored the possibility of tacit collusion on the interhub route, where carriers provide overlapping service, reflecting a more general failure to analyze collusion incentives in the airline industry. Any appraisal of the competitive state of such a market should include some gauge of the sustainability of collusion in the market. If tacit collusion is sustainable under a wide range of conditions, with competitors having little incentive to defect from a collusive arrangement, then expectations for a competitive outcome are reduced.

While a carve-out is meant to preserve the nominal competitive state of the interhub market, this expectation might not be realized if the existence of the alliance increases the sustainability of collusion in that market. Instead, the alliance could strengthen the incentive for tacit collusion, making the interhub market less competitive despite the imposition of a carve-out. The alliance would exert such an effect through its impact on interline passengers, who make more trips in response to a cooperative reduction in the interline fare. The larger interline traffic volume raises traffic density on the interhub route, reducing the marginal cost of carrying a passenger on this route. The crucial observation is that this cost reduction could affect the incentives for collusion by the alliance partners in the interhub market, strengthening them relative to the prealliance situation.

Using the standard approach to analyzing deviations from collusive behavior, the analysis in this paper explores the effect of interline cooperation on the incentives for interhub collusion. These incentives are measured by the critical value of the discount factor beyond which collusion is sustainable. We show that, as the alliance boosts interline passenger traffic, the resulting cost reduction from economies of density on the interhub segment raises the incentive to collude in the interhub market, validating the previous concern. However, the density-generated interhub cost reduction leads to an expansion of traffic in the interhub market itself, which raises the revenue gain from defection in this market relative to the losses incurred during the retaliation period. Hence, an increase in interline traffic leads to an *ambiguous net effect* on collusion incentives. However, these two effects exactly cancel under functional forms that are widely used in theoretical work on airlines: linear demand and linear, decreasing marginal cost (corresponding to a quadratic cost function). As a result, the incentives for collusion in the interhub market are no different between the pre-alliance situation and an alliance subject to a carve-out. Further analysis shows that, when these functional-form assumptions are locally relaxed (by introducing some curvature in the demand function, for example), collusion incentives remain almost the same as in the pre-alliance situation, establishing the robustness of the main conclusion.

Our result provides encouraging news for airline regulators. In particular, regulators can be confident that a carve-out, which maintains the nominal state of competition in the interhub market, does not worsen actual competitive conditions by increasing the incentives for collusion in that market. The analysis in remainder of the paper establishes this result. In addition to presenting this conclusion, the paper fills a glaring gap in the theoretical airline-economics literature by offering a rare analysis of incentives for collusion in important market context, incentives that have been not a focus of previous theoretical work (although studied in empirical research).[2]

2 Model and Pre-Alliance Case

In the spirit of Brueckner and Proost (2010), we assume two national airlines A and B belonging respectively to countries A and B. Each airline operates a hub in its own country, which also serves as an international gateway. Airline A's hub is denoted h and B's hub is denoted j, and both airlines provide service on the interhub route between h and j. The airlines also provide exclusive service to interior cities in their home countries, a and b respectively. Airline A provides service between a and its hub h, while airline B provides service between b and j. For simplicity, we follow Brueckner and Proost (2010) by assuming that passenger demands exist only for round-trip air travel between the cities a and b and between the hubs h and j. Airlines carry passengers between the hubs on direct flights, whereas they carry passengers between a and b using connections at the two hubs h and j, trips that require use of both airlines.

We denote the trip demand originating from the city h for a return journey to city j by $d_h(P_h)$, while the opposite trip demand is $d_j(P_j)$, where P_h and P_j are the fares. We assume symmetric demands, so that $d_h(\cdot) = d_j(\cdot) \equiv d(\cdot)$.

[2]For empirical studies, see Evans and Kessides (1994), Salvanes et al. (2003), Fang and Sickles (2007), Miller (2010), Ciliberto and Williams (2011), Zhang and Round (2011).

The trip demand originating in city a for a return journey to b is given by $D_a(p_a)$, while the opposite trip demand is $D_b(p_b)$, with p_a and p_b being the fares. For simplicity, we again assume demand symmetry, so that $D_a(\cdot) = D_b(\cdot) \equiv D(\cdot)$.

Airlines incur symmetric costs that depend on the distance and the number of passengers carried on a route segment. For simplicity, we assume that distances are identical for the ah, hj and jb routes. Costs are characterized by economies of density as larger passenger flows imply larger aircraft seat capacities and smaller average costs per passenger. As a result, a carrier's cost for Q return trips on each segment is given by $C(Q)$, where $C' > 0 \geq C''$.

In the interhub market between h and j, we assume that airlines compete by setting their seat capacities Q_h and Q_j. The aggregate demand for travel between h and j is given by $2d(p)$ and the inverse demand by $P(Q)$. The market clears at the price $P(Q_h + Q_j)$.

Airline A has monopoly power over the passengers originating from city a, supplies the two trip legs from a to h and from h to j, but needs a third leg from j and b using a seat on airline B to complete the trip. Let s_a be the seat (access) price paid to airline B, so that airline A gets revenue per passenger of only $p_a - s_a$. The symmetric situation applies for airline B. We assume that passengers flowing between a and b are equally split on the hj segment between airlines A and B. So, the total number of passengers flying from h to j on airline A is equal to $Q_h + \frac{1}{2}\left[D(p_a) + D(p_b)\right]$. As a result, the profit of airline A is given by[3]

$$\pi_A = P(Q_h + Q_j)Q_h - C\left\{Q_h + \frac{1}{2}\left[D(p_a) + D(p_b)\right]\right\}$$
$$+ (p_a - s_a)\,D(p_a) + s_b D(p_b) - C\left[D(p_a) + D(p_b)\right]$$

A symmetric expression applies to airline B.

It is realistic to view the carrier choices in the ab and hj markets as sequential, with interline price choices made in the first stage and interhub choices made in the second.[4] More specifically, in the first stage, airline A chooses p_a and s_a to maximize its profit while airline B chooses p_b and s_b. In equilbrium, these choices are symmetric, with $p_a = p_b \equiv p$ and $s_a = s_b \equiv s$ and interline revenue equal to $pD(p)$ (the access fees cancel). In the second stage, the airlines choose the seat capacities Q_h and Q_j, viewing the first-stage prices as parametric. As usual, the interline fare depends on whether or not the two airlines are alliance partners. In the absence of an alliance, we argue that the interline fare emerges from a competitive process in both the interline and interhub markets. The resulting interline fare is analogous to the IATA fares charged by nonaligned carriers for interline trips, as argued by Brueckner (2003). But since the trip legs are complementary products, the interline fare tends to be higher than the one that maximizes the combined profit of the carriers.

In the presence of an alliance that is subject to a carve-out, the interline fare is the result of competition in the interhub market and cooperation in

[3] Although this setup is superficially different from that of Brueckner and Proost (2010), which relies on "subfares," the two approaches are equivalent.

[4] The outcome is the same as under simultaneous choice, but this structure facilitates the exposition.

the interline market. This setting can be viewed as stemming from the negotiation process between the alliance and the regulators. In this process, the alliance must commit to charging lower interline fares that benefit consumers (eliminating double marginalization) and charging an interhub fare that is close to marginal cost (as expected under the carve-out). In addition, the airlines have to stick to such prices; otherwise the regulator would investigate the alliance and find reasons to waive the immunity it has granted. This commitment justifies the present sequential choice model, and it also precludes any retailation possibilities through the interline market in the tacit collusion analysis below.

We denote by $\widehat{p}$ and p^* the symmetric interline prices with and without alliance. As shown by Brueckner and Proost (2010), cooperative interline pricing in the presence of a carve-out leads to a lower interline fare, so that $\widehat{p} < p^*$.[5] With p equal to either $\widehat{p}$ and p^*, airline A's profit is written

$$\pi_A = P(Q_h + Q_j)Q_h - C\left[Q_h + D(p)\right] + v(p)$$

where

$$v(p) = pD(p) - C\left[2D(p)\right]$$

equals interline revenue minus the cost of operating the aj segment.

In the second stage, the interline price p is set to either $\widehat{p}$ or p^*. To study how an alliance changes the incentives for tacit collusion, we just need to investigate how a drop in the price p changes these incentives. Collusion incentives can therefore be simultaneously analyzed in the pre-alliance and

[5]Note that this conclusion need not be true when the airlines are instead allowed to cooperate in both the hj and ab markets, as argued by Brueckner (2001).

alliance cases. For conciseness we now drop the explicit reference to price p in $D(p)$ and $v(p)$. Henceforth, the variable D represents the interline passenger traffic, which is expected to increase under airline alliance, and v interline revenue net of aj costs.

3 Airline alliance structure and collusion

In this section, we compare the incentives for collusion in the interhub market in the pre-alliance and alliance cases (with a carve-out). We first establish the profits under competition, cooperation, and deviation from collusion. We then discuss how the interline price, which determines interline traffic, affects the sustainability of collusion.

When firms compete in the interhub market, airline A chooses Q_j in Cournot fashion to maximize its profit taking Q_h as given, satisfying the first-order condition

$$P(Q_h^* + Q_j^*) + P'(Q_h^* + Q_j^*)Q_h^* - C'\left(Q_h^* + D\right) = 0, \qquad (1)$$

while airline B's choice is determined by a symmetric condition. Because of cost symmetry, these conditions yield the competitive seat capacities $Q_h^* = Q_j^* \equiv Q^*$, with airline A's profit given by

$$\pi_A^* \equiv P(2Q^*)Q^* - C\left(Q^* + D\right) + v$$

and airline B's by a symmetric expression. The level of Q^* generated by this condition depends on the value of D and hence on the level of p, which was chosen in the first stage and differs between the pre-alliance and alliance cases. To analyze the effect of these alternate p values, we can simply differentiate as needed with respect to p, recognizing that the derivatives allow us to compare outcomes between the case where p is high (pre-alliance) and p is low (alliance).

Differentiating the profit function, we get

$$\frac{\mathrm{d}\pi_A^*}{\mathrm{d}p} = v' - C'\left(Q^* + D\right)D' + \left[P\left(2Q^*\right) + P'\left(2Q^*\right)2Q^* - C'\left(Q^* + D\right)\right]\frac{\mathrm{d}Q^*}{\mathrm{d}D}D'$$

where $D' = \mathrm{d}D/\mathrm{d}p < 0$ and $v' = \mathrm{d}v/\mathrm{d}p$. Using (1), we have

$$\frac{\mathrm{d}\pi_A^*}{\mathrm{d}p} = v' - C'\left(Q^* + D\right)D' + \left[P\left(2Q^*\right) - C'\left(Q^* + D\right)\right]\frac{\mathrm{d}Q^*}{\mathrm{d}D}D' \qquad (2)$$

Hence, a fall in p induces an increase in interline traffic and in profits in the interline market (first two terms). It also generates economies of density that allow airlines to reduce their interhub fares and to earn a positive markup on additional passengers (last term).

When firms collude, they jointly set the seat capacity $Q_h + Q_j$ so as to maximize their joint profits $\pi_A + \pi_B$. The first-order condition for Q_h is given by

$$P(Q_h^o + Q_j^o) + P'(Q_h^o + Q_j^o)(Q_h^o + Q_j^o) - C'\left(Q_h^o + D\right) \qquad (3)$$

A symmetric condition holds for Q_j. Because of symmetry, we have that $Q_h^o = Q_j^o \equiv Q^o$. It is straightforward to show that $Q^o < Q^*$. Airline A's profit is given by

$$\pi_A^o \equiv P(2Q^o)Q^o - C\left(Q^o + D\right) + v$$

and can be shown to be larger than π_A^*. Coordination in the interline segment affects the profit π_A^o through the effect on D and v. Differentiating the profit function gives

$$\frac{\mathrm{d}\pi_A^o}{\mathrm{d}p} = v' - C'\left(Q^o + D\right) D' + \left[P\left(2Q^o\right) + P'\left(2Q^o\right) 2Q^o - C'\left(Q^o + D\right)\right] \frac{\mathrm{d}Q^o}{\mathrm{d}D} D'$$

However, by (3), the last term vanishes. Changes in interline traffic bring no first-order changes in the profits of the interhub segment because the cooperating airlines have set the seat capacities that yield zero marginal profit. So, the above expression simplifies to

$$\frac{\mathrm{d}\pi_A^o}{\mathrm{d}p} = v' - C'\left(Q^o + D\right) D' \tag{4}$$

Since interhub traffic has already been optimized, a fall in p only affects profit in the interline market itself. So, despite the existence of economies density, cooperation in the interline market therefore brings no gains in the interhub market.

When airline A deviates from the collusive outcome, it chooses its seat capacity $Q_h^d \equiv Q^d$ to maximize profit taking as given $Q_j = Q^o$. The first-order condition is

$$P(Q^d + Q^o) + P'(Q^d + Q^o)Q^d - C'\left(Q^d + D\right) = 0 \tag{5}$$

It can be shown that $Q^d > Q^* > Q^o$. Airline A's profit is given by

$$\pi_A^d \equiv P(Q^d + Q^o)Q^d - C\left(Q^d + D\right) + v$$

which can be shown to be higher than π_A^o. Differentiating the profit function with respect to p and using (5) gives

$$\frac{\mathrm{d}\pi_A^d}{\mathrm{d}p} = v' - C'\left(Q^d + D\right) D' + \left[P(Q^d + Q^o) - C'\left(Q^d + D\right)\right] \frac{\mathrm{d}Q^o}{\mathrm{d}D} D' \tag{6}$$

As in the case of the Nash equilibrium, a fall in the interline fare p increases interline traffic and brings additional traffic and profit to the interhub segment (second term).

Collusion incentives are determined as follows. We assume that the above choice of interhub seat capacity is repeated from time $t = 0$ to infinity. To anchor our analysis in the standard literature, we focus on tacit collusion with the grim strategy: that is, a deviation is followed by a reversion to the Cournot-Nash equilibrium forever (Friedman 1971). This assumption can be relaxed with little effect on the analysis. Collusion is then sustainable if and only if the long-run gain from collusion outweighs the short-run gain from deviating. In time period 0, this condition is satisfied if

$$\sum_{t=0}^{\infty} (\delta)^t \pi_A^o \geq \pi_A^d + \sum_{t=1}^{\infty} (\delta)^t \pi_A^*$$

where δ is the discount factor of airlines. An analogous condition applies for any other time period and for airline B. The above inequality implies that collusion is sustainable if and only if

$$\delta \geq \overline{\delta} \equiv \frac{\pi_A^d - \pi_A^o}{\pi_A^d - \pi_A^*}$$

where the numerator is the *deviation gain* and the denominator is *punishment cost*.

We are now in a position to discuss how the fare p for interline trips between a and b affects airline collusion in the interhub market hj. Lower fares increase the demand D and augment airline profits under collusion, deviation and competition provided that the price p lies above the sum of marginal costs on the three route segments, which we assume in the sequel.

Collusion is more easily sustained if the *deviation gain* $\pi^d - \pi^o$ decreases faster than *punishment cost* $\pi^d - \pi^o$ when p falls. In other words,

$$\begin{aligned} \frac{\mathrm{d}\overline{\delta}}{\mathrm{d}p} \geq 0 \iff & \frac{\mathrm{d}}{\mathrm{d}p} \ln\left(\pi^d - \pi^o\right) \geq \frac{\mathrm{d}}{\mathrm{d}p} \ln\left(\pi^d - \pi^*\right) \\ \iff & \frac{\mathrm{d}}{\mathrm{d}p}\left(\pi^d - \pi^o\right) \geq \overline{\delta}\, \frac{\mathrm{d}}{\mathrm{d}p}\left(\pi^d - \pi^*\right) \end{aligned} \tag{7}$$

Using (2), (4) and (6), the change in the deviation gain is given by

$$\frac{\mathrm{d}}{\mathrm{d}p}\left(\pi^d - \pi^o\right) = |D'| \begin{bmatrix} C'\left(Q^d + D\right) - C'\left(Q^o + D\right) \\ +\left[P(Q^d + Q^o) - C'\left(Q^d + D\right)\right] \frac{\mathrm{d}Q^o}{\mathrm{d}D} \end{bmatrix} \tag{8}$$

while the change in the punishment cost is

$$\frac{\mathrm{d}}{\mathrm{d}p}\left(\pi^d - \pi^*\right) = |D'| \begin{bmatrix} C'\left(Q^d + D\right) - C'\left(Q^* + D\right) \\ +\left[P(Q^d + Q^o) - C'\left(Q^d + D\right)\right] \frac{\mathrm{d}Q^o}{\mathrm{d}D} \\ -\left[P\left(2Q^*\right) - C'\left(Q^* + D\right)\right] \frac{\mathrm{d}Q^*}{\mathrm{d}D} \end{bmatrix} \tag{9}$$

where $|D'| = -\mathrm{d}D/\mathrm{d}p > 0$.

It is instructive to first discuss the case where economies of density are absent, with C' equal to a constant c. In this case, the traffic D does not appear in the above first-order conditions (1) to (5), so that seat capacity decisions (Q^o, Q^*, Q^d) in the hj market are unaffected by passenger traffic D between a and b. Therefore, the profits under collusion, deviation and competition are each increased by the same exogenous profit that is earned from interline passengers. For airline A, this profit is equal to net revenue from interline passengers, $(p_a - s_a)\, D_a(p_a) + s_b D_b(p_b)$, minus the cost of carrying them from/to the airport a, $c\left[D_a(p_a) + D_b(p_b)\right]$, and the cost of carrying them between hubs h and j, $c\left[D_a(p_a)+D_b(p_b)\right]/2$. This profit is actually equal to $v-cD$. As a result, a larger demand D increases the profits π^o, π^* and π^d by the same amount and therefore does not change the profit differences $\pi^o-\pi^*$ and $\pi^d-\pi^*$ in expressions (8) and (9). So, *without economies of density, the fare level in the interline market ab has no impact on collusion incentives in market hj.*

The impact of p on collusion therefore stems from the economies of density generated by the resulting change in ab traffic on the hj segment. Accordingly, suppose now that $C''<0$. The impact of ab traffic then includes a direct and an indirect effect. The direct effect is presented in the first lines of the bracketed terms in expressions (8) and (9) and stems from economies of density, as higher traffic between a and b reduces marginal costs on the hj segment. Because $Q^*>Q^o$ and $C''<0$, we get

$$C'\left(Q^d+D\right)-C'\left(Q^o+D\right)<C'\left(Q^d+D\right)-C'\left(Q^*+D\right)<0$$

So, with economies of density, an increase in D tends to decrease the deviation gain more than the punishment cost. Therefore, from a cost perspective, collusion is more likely to be sustained with an increase in ab traffic.

The indirect effect stems from the revenue effects of an increase in traffic D and is presented in the second and third lines of the bracketed terms in expressions (8) and (9). This effect results from the price decline in the interhub market hj that follows from the drop in marginal costs due to the density effect. The price decline emerges because the lower marginal costs on the interhub segment increases hj traffic ($\mathrm{d}Q^o/\mathrm{d}D>0$ and $\mathrm{d}Q^*/\mathrm{d}D>0$).

Given these increases, it is easily seen that

$$\left[P(Q^d + Q^o) - C'\left(Q^d + D\right)\right] \frac{\mathrm{d}Q^o}{\mathrm{d}D} >$$
$$\left[P(Q^d + Q^o) - C'\left(Q^d + D\right)\right] \frac{\mathrm{d}Q^o}{\mathrm{d}D} - \left[P\left(2Q^*\right) - C'\left(Q^* + D\right)\right] \frac{\mathrm{d}Q^*}{\mathrm{d}D}$$

Therefore, referring to (5) and (6), the indirect effect of the additional ab traffic increases the deviation gain by more than the punishment cost. So from a revenue perspective, collusion is less likely to be sustained with additional ab traffic. Hence, an increase in ab traffic leads to direct and indirect effects on deviation gains and punishment costs that have opposite signs, making the net effect on collusion incentives ambiguous. These effects, however, exactly cancel under functional forms that are widely used in theoretical models of the airline industry and are likely to represent a close approximation to actual demand and cost functions.

In particular, suppose that demands are linear and symmetric between markets and that cost is quadratic. Normalizing the units of output and specifying the numeraire, we can assume $P = 1 - Q$ while cost is given by $C(Q) = cQ - dQ^2/2$, where $c, d \in (0, 1)$. We successively get

$$Q^* = \frac{2}{3 - 2d}\left(1 - c + d\,D\right)$$
$$Q^o = \frac{1}{2 - d}\left(1 - c + d\,D\right)$$
$$Q^d = \frac{(3 - 2d)}{2\left(1 - d\right)\left(2 - d\right)}\left(1 - c + d\,D\right)$$

The profit differentials become

$$\pi^d - \pi^o = \frac{1}{8\left(1 - d\right)\left(2 - d\right)^2}\left(1 - c + d\,D\right)^2$$
$$\pi^d - \pi^* = \frac{17 - 24d + 8d^2}{8\left(1 - d\right)\left(3 - 2d\right)^2\left(2 - d\right)^2}\left(1 - c + d\,D\right)^2$$

The profit differentials thus have the common factor $(1-c+d\,D)^2$. As a result, critical value $\overline{\delta}$ of the discount factor, above which collusion is sustainable, is invariant to traffic in the ab market. It can be computed as

$$\overline{\delta}=\frac{(3-2d)^2}{17-8\,(3-d)\,d}$$

which increases in d. It can be shown that this result generalizes to a setup where demand is linear but asymmetric across markets, although it does not generalize to the case of quadratic costs that are asymmetric across route segments. We summarize the above results as follows:

Proposition 1 *The incentives for collusion in the hj market are independent of the level of traffic ab market and thus independent of the price p in that market (i) under linear costs and (ii) under linear demand and symmetric quadratic costs.*

Thus, the nature of pricing in the interline ab market has no impact on the incentives for collusion on the interhub hj market. The reason is the resulting change in ab traffic has effects on costs and revenues in the hj market that effectively balance out.

4 Checking Robustness

Since Proposition 1 relies on the linearity of demand and cost functions, it important to check how the incentives for collusion are altered with nonlinear functions. We first consider the case of a quadratic demand function $P(Q)=1-Q+aQ^2/2$, where a measures demand convexity, while keeping the cost function $C(Q) = cQ - dQ^2/2$. Since profits become cubic functions of Q, the equilibrium outputs are the roots of quadratic first-order conditions. Although the profit expression become intractable, we can assess the effect of nonlinear demand on the incentives to collude using the following approximation for small enough a, d: [6]

$$\overline{\delta} \simeq \frac{(3-2d)^2}{17-8\,(3-d)\,d} - \frac{a(10-49d)}{4(17-24d)^2}\,(1-c+Dd)$$

Computing the derivative of the natural log of this approximation with respect to $\ln D$ and then setting a and d equal to zero except where they multiply D, the result is $\mathrm{d}\ln\overline{\delta}/\mathrm{d}\ln D \simeq -(5/306) * aDd$. So, the incentives to collude fall ($\overline{\delta}$ rises) as interline traffic rises marginally above zero when the demand is concave (when $a < 0$) and rise when demand is convex (when $a > 0$). But this effect is very small since 5/306 is a small value and both a and d are small in this approximation.

The same conclusion applies for a broader set of a and d values. Indeed, Figure 1 shows that the discount factor that sustains collusion is not very sensitive to D for a fairly wide range of a values around 0 (d is set to 0.1 and c to 0.5). It should be noted that the maximum D value of 1.0 in Figure 1 represents a traffic volume significantly larger than the interhub traffic itself, which reaches this value only a fare of zero. Therefore, collusion incentives are hardly affected even when the magnitude of D is large.

INSERT FIGURE 1 HERE

[6] This approximation is obtained by developping a Taylor series of $\overline{\delta}$ around $a = 0$ to the first order and suppressing terms in d of order higher than 2 in the second term.

We also check the robustness of Proposition 1 for the case of iso-elastic demand and cost: $P = Q^{-1/\varepsilon}$ and $C = cQ^{\theta}$, where $\theta \in (0, 1]$. In this case, economies of density are absent when $\theta = 1$ but present for smaller θ values. Results are displayed in the two panels of Figure 2 (default parameter values are $c = 0.2$, $\varepsilon = 1.2$ and $\theta = 0.9$). The incentives to collude are again almost independent of traffic D. Since this conclusion is true for empirically relevant demand elasticities (ε between 1 and 2) and cost elasticities (θ between 0.7 and 1), we may again conclude that Proposition 1 represents a reasonable benchmark as a statement about collusion incentives.

INSERT FIGURE 2 HERE

5 Further Discussion

First, one may argue that airlines use the multi-market contacts to enforce their collusive behavior. Multi-market contacts allow firms to retailate in adjacent markets. However, in the present setting, the interhub market is the only common market in which two airlines of the same alliance may compete. So, in practice, multi-market retaliation strategies must be performed in the inland market on which each airline is a monopoly. However, as explained earlier, the alliance negotiates its immunity with carve out with regulators. In doing this, it makes explicit to regulators its price strategy in the interline market and has incentives to stick to it for the sake of maintaining the approval for the alliance. This therefore precludes retailation possibilities through the interline market. So, the collusion incentives seem immune to multi-market contacts.

Second, our analysis assumes that no other airline competes with the two alliance partners. In a few rare cases there may exist another airlines flying between alliance hubs. For example, Virgin Atlantic offers flights between London and New York along with the Oneworld alliance partners American Airlines and British Airways. Two views on this issue can be elaborated. First, suppose that the outside airline never participates in tacit collusion. Then, the structure of competition changes from three players under the competitive setting imposed by the carve-out to two players (alliance versus outsider) under collusion. As shown by Salant, Switzer and Reynolds (1983) for the case of linear demands and costs, cooperation is profitable in this setting only if the alliance is able to reap more than 80% of the interhub traffic. If the three airlines have symmetric cost structures, then this threshold cannot be reached in the linear case, making collusion unprofitable. Cooperation is profitable only if the third airline has a significantly higher cost structure and thus a low market share. The presence of economies of density has the additional effect of reducing collusion profits. Indeed, the higher collusive price reduces interhub passenger traffic, which raises the allied carriers' marginal costs, benefiting the third airline.

Second, suppose that the outside airline participates in tacit collusion. It is known that collusion is more difficult to sustain among three firms than two because the firms get a lower share of the collusive profit and because retaliation requires coordination (see Belleflamme and Peitz 2010 for a summary). However, our question is whether the incentives for collusion are fostered by the increase in the alliance partners' interline traffic. If we assume again that the three airlines have symmetric cost structures and face linear demand, we can repeat the above analysis and compute the profit under collusion, Nash equilibrium and deviation. Although the firms in the alliance incur lower marginal costs because of their interline traffic and economies of density, we assume in this example that they equally share the interhub market. For low enough interline traffic D and economies of density, we can again approximate the discount factor sustaining tacit collusion and now show that it increases with D. Figure 3 confirms this result for larger ranges of economies of density and D values (c is set at 0.5). In this case, the incentives to collude decrease ($\bar{\delta}$ increases) as the interline traffic volume rises. In this example, profits are more responsive to interline traffic under competition than under collusion, making the loss from reverting to Nash competition lower when D is high. Although the presence of a third, nonaligned airline on the interhub route is rare, this case is still worthy of analysis in further research.

INSERT FIGURE 3 HERE

6 Conclusion

Proposition 1 and the subsequent robustness analysis provide welcome news for airline regulators. The implication of these findings is that that the incentives for collusion in an alliance's interhub market under a carve-out are virtually the same as in the prealliance situation, where interline traffic is lower, in the usual case where no other interhub competitors are present. Thus, the carve-out's nominal preservation of competition in the interhub market is not undermined by a worsening of actual competitive conditions, as measured by the incentives for collusion. If regulators believe that a carve-out is worth imposing, their decision will not be undone by a greater incentive for tacit collusion between the alliance partners.

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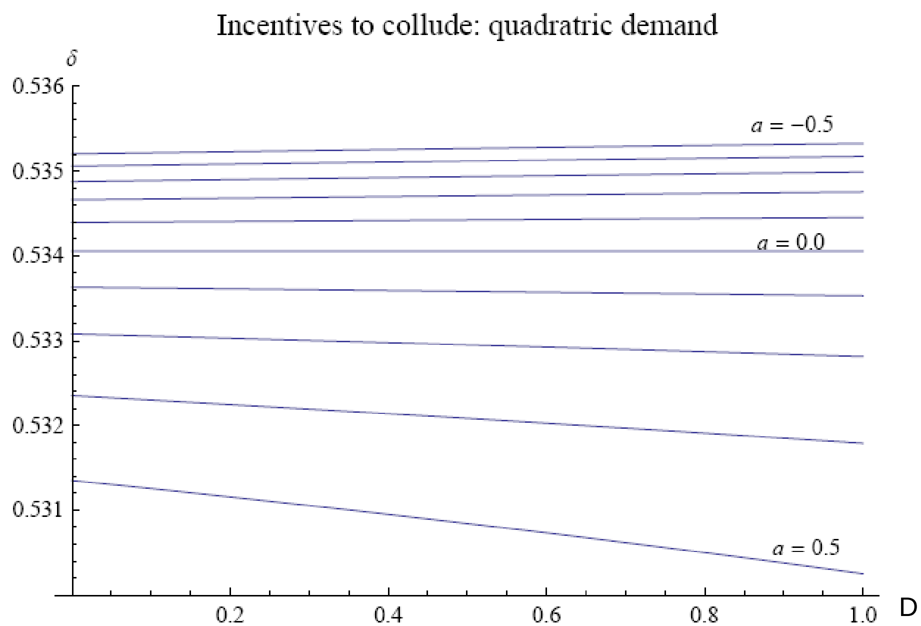

Figure 1: Incentives to collude: quadratic demand function

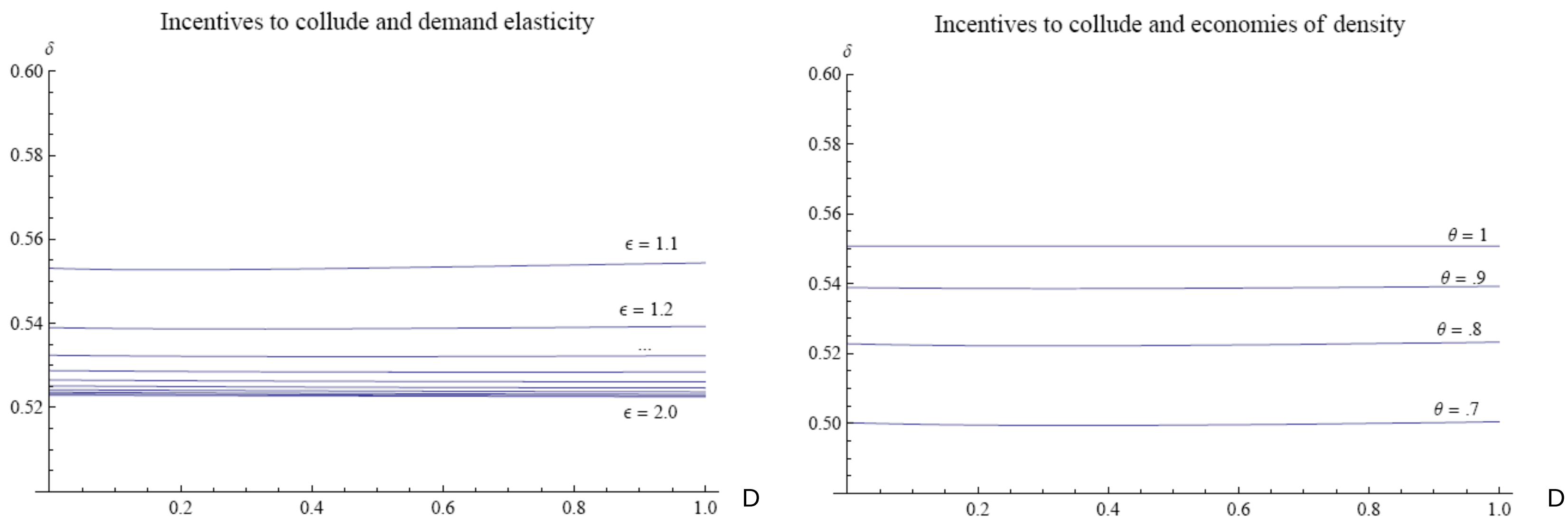

Figure 2: Incentives to collude: iso-elastic demand and cost functions

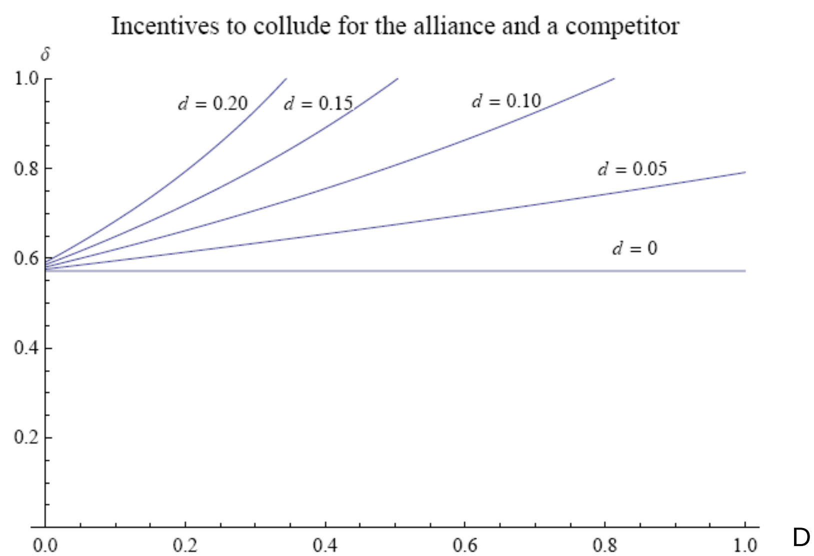

Figure 3: Incentives to collude for alliance and competitor