Complementary vs. Semi-Complementary Airline Partnerships

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Abstract

As low-cost airlines or carriers excluded from international markets by regulation may seek to expand internationally in an indirect way through code-sharing agreements, they can choose partner airlines from among domestic or international carriers. The former case results in a semi-complementary partnership, while in the latter a classic complementary alliance is formed. This paper compares welfare properties of the two types of partnerships under economies of traffic density. Semi-complementary partnerships yield higher total welfare (but not necessarily lower prices) when economies of traffic density are strong, demand is more price-sensitive, or where a carrier feeding domestic traffic to international routes is a lower-cost one.

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Keywords: Code-sharing, airline alliances, complementary alliances, low-cost airlines

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I. Introduction

The global airline market currently consists of a number of largely deregulated domestic markets, connected by the regulated international routes. The so-called legacy carriers (on the US market) or flag carriers (in the EU), while playing a major role on the international routes, are gradually losing their 'domestic' markets to the low-cost competition. Whether the low-cost airlines will ever enter the long-haul international routes following their success on domestic markets is an open question. Two obstacles to such an entry are regulation and the low-cost carriers' business model. And the second one is more important than the first. Indeed, bilateral air services agreements do not specify *which* carrier can be designated to perform services between the two countries; therefore, if a legacy or flag carrier should exit an international route, a low-cost airline can replace it. Moreover, 'open skies' agreements United States has with a number of countries effectively remove entry barriers for low cost carriers on many international routes. Yet, a typical 'low-cost product' may not be received well by customers on long-haul markets, simply because it is much easier to tolerate a two-three hour flight than an eight-plus hours' journey without 'frills'. In addition, entering the long-haul markets will require the low-cost airlines to effectively abandon their single-aircraft-type strategy and/or decrease aircraft utilization rates. Single aircraft type strategy and high aircraft utilization rates are said to have brought about a significant chunk of cost savings.

If an airline is unable or unwilling to enter a market directly, it can do so indirectly, through a code-sharing agreement with some other airline. That is, a low-cost airline may choose to feed traffic to international services of one or the other carrier. Such arrangements are currently uncommon (a 'prototype' was a limited code-sharing agreement between America West and British Airways to feed passengers to BA's services out of Phoenix and Los Angeles[2]), but may become more possible as low-cost airlines fly to more places more often and if tougher competition on the domestic U.S. market will force those carriers to seek ways to more fully exploit economies of traffic density.

A low-cost airline choosing to feed traffic to international routes can choose its partners from among domestic or foreign carriers. The difference between these two cases is that in the former one the partnership will be 'semi'-complementary (a low-cost and its domestic partner will most likely have overlapping domestic networks), while in the latter the code-sharing

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[2] This partnership has been dismantled on December 31, 2005.

agreement will be strictly complementary. Currently many U.S. carriers are engaged in complementary partnerships with foreign airlines (mostly related to their participation in global airline alliances). An example of ‘semi’-complementary partnership is the code-sharing agreement between US Airways and United Airlines, if international dimension of this arrangement is considered. US Airways does operate a limited number of international departures to European and Caribbean destination. Yet, it also feeds traffic to a much wider network of United Airline’s international services. And, the two carriers’ networks within the United States overlap, especially if we consider segments to/from airports from which United Airlines’ international services originate.

This paper compares price and welfare effects of these two types of airline partnerships, where technology exhibits increasing returns to traffic density. With constant returns to traffic density the analysis is rather trivial, as all markets can be analyzed independently. And, complementary alliance will produce higher welfare gains than a semi-complementary one. Yet, when economies of traffic density are introduced, the answer to the question of which partnership is better from the society’s point of view stops being self-evident. Economies of traffic density is a widely recognized feature of the airline industry (Caves et al., 1984, Berry et al., 1996, Brueckner and Spiller, 1991, Brueckner, 2001, Brueckner and Pels, 2005). Unfortunately, with economies of traffic density even the simple quantity-competition model becomes analytically intractable, requiring us to resort to numerical simulations.

We find that as the extent of economies of traffic density increases, and demand becomes more price sensitive, society is more likely to be better off in case of a partnership between the two domestic carriers. Another interesting and rather unexpected finding is that a partnership producing lower prices is not necessarily the one resulting in higher total welfare – an outcome produced by substantial cost savings due to economies of traffic density. Also, if the domestic carrier feeding traffic to a partner’s international routes is a lower cost one, our simulations show that a semi-complementary partnership is more likely to yield higher welfare than a complementary one, as compared to a scenario with symmetric costs. Finally, the split of interline revenue in the semi-complementary partnership can also affect welfare implications of our analysis.

It has been previously shown (Park, 1997, Brueckner, 2001, Brueckner and Whalen, 2000, Bilotkach, 2005) that code-sharing agreements without overlaps in partners’ networks reduce prices and produce welfare gains, due to complementary nature of products. Semi-complementary arrangements like the one we consider here have not been examined; yet, they are likely to appear, as discussion above suggests. Moreover, the setup we offer in this paper is not that uncommon on the global market. Airlines do have varying degree of access to international routes, and some domestically operating carriers are excluded from international markets by restrictive bilateral air services agreements. Governments also are very reluctant to open domestic markets (however deregulated otherwise) to foreign competition (European Union is an exception that proves the rule). We thus are likely to see foreign carriers looking for a partner to effectively expand their presence in a certain country, and it could be either a big flag carrier with extensive international presence, or a smaller airline excluded from most international routes. Small domestic airlines may (and sometimes do) partner with either a big domestic or a foreign carrier to feed passengers to international services they cannot provide because of the regulatory restrictions.

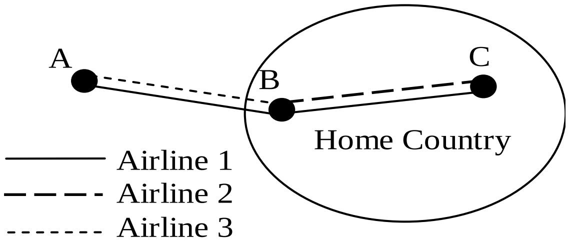
The rest of the paper is organized as follows. Section II outlines the framework used in numerical simulations. Section III describes simulation results; Section IV discusses implications of our analysis and concludes.

II. Model

2.1 Setup

This section presents the modeling exercise, involving a rather simple yet realistic setup, as presented on Figure 1. We have three markets (AB, BC, and AC) and three airlines (1, 2, and 3). For the sake of presentation, we assume that market BC is domestic, while markets AB and AC are international. airline 1 can be considered either a ‘legacy’ (flag) carrier, as discussed in the introduction, or an airline not restricted by regulation from servicing any of the markets within our network. Airline 2 is domestic (relative to airline 1) carrier, either restricted by regulation from flying internationally, or a (low-cost) carrier seeking to indirectly expand its services. Airline 3 is a foreign (again, relative to airlines 1 and 2) carrier, designated to fly only on the AB route. Each airline carries passengers only within its network or within the network covered by the code-sharing agreement, if present. This way, absent code-sharing agreements, a passenger on the AC market can only travel with airline 1.

Figure 1 Network Structure



Inverse demands will be assumed linear:

$$p^{ij} = A - \alpha Q^{ij} \tag{1}$$

(where Q^{ij} is the total traffic between cities i and j, A is a measure of market size, and α is the price sensitivity parameter) and symmetric across markets.

Throughout the paper, we will assume airlines (airline partnerships) compete in quantities. This is the simplest possible representation, which will allow us to draw a tractable and a rather realistic picture of the market. Yet, this simplicity comes at certain cost. Namely, airline partnerships often involve setting of *sub-fares*, or fares for each airline's portion of an interline itinerary. In our model, however, code-sharing will involve airlines setting quantities of interline passengers, with total fares determined by the inverse demand function. Eventually, each carrier involved will be assumed to obtain half of the fare paid by an interline passenger[3]. A point in defense of using Cournot setup in spite of the above mentioned fact is the existence of *block space arrangements*, or agreements whereby an airline allocates certain number of seats on its flights to be sold by a partner carrier. These arrangements are more in line with quantity competition. Plus, quantity-setting has been assumed in previous models of airline partnerships (Park, 1997, Brueckner, 2001, Brueckner and Pels, 2005).

Technically, our exercise should consider three different scenarios. The first one involves no partnerships. This means that airline 1 is the monopolist on the AC market, and markets AB and BC are duopolies. The second case will involve partnership between airlines 2 and 3, or a purely complementary alliance. This agreement effectively creates competition on the AC market. The third case involves a partnership between airline 1 and either airline 2 or 3 (a semi-complementary partnership), which only allows the partners to cooperate on the AC market.

Hence, overlapping portions of the partner airlines' networks are not covered by such an alliance. Such a non-overlapping partnership between, for example, carriers 1 and 2 means that carrier 2 can sell tickets to passengers traveling on the AC market; this effectively expands network of airline 2. Further in this paper we will refer only to the partnership between carriers 1 and 2 as an illustration of this scenario. The market where both carriers are present (the BC market) remains a duopoly, and no coordination between the partners is allowed. Yet, the focus of the study is comparing the welfare properties of the two latter scenarios. Clearly, since in both the second and the third cases we create some competition on AC market without decreasing competition on markets AB and BC, either of the two partnerships will be welfare-increasing as compared to the case with no code-sharing agreements. Further, absent regulatory restrictions, airline 1's monopoly on the AC market is unsustainable; carriers 2 and/or 3 will have a strong incentive to enter some sort of a partnership. A carrier indirectly entering the AC market through a partnership will be able to earn extra money as compared to the no partnership case, and will also gain cost savings, which will allow it to better compete with airline 1 on either AB or AC market.

On the cost side, we assume technology exhibiting economies of traffic density, or lower per passenger cost per flight segment with an increase in traffic. In fact, analysis assuming constant returns to traffic density is straightforward, as all three markets can be analyzed independently of each other. In that case, if we compare a complementary partnership between airlines 2 and 3 to the semi-complementary one between carriers 1 and 2, we can say the following. In the latter case, the partnership between airlines 1 and 2 competes with the single-airline service by carrier 1 on AC market. Thus, airline 1 effectively competes against itself. This means that adding a non-overlapping semi-complementary partnership between carriers 1 and 2 suggests higher fares on the AC market comparing to the partnership between airlines 2 and 3. The Appendix shows this formally.

With economies of traffic density, the analysis becomes more complicated and less trivial, but some intuitive generalizations can be offered. Namely, if the semi-complementary partnership between carriers 1 and 2 is considered, on the AC market we can talk about two effects working in the opposite directions. First, the above-mentioned 'lower competition' effect (airline 1 competing against itself) will imply higher fares (lower welfare) on the AC market as opposed to the complementary partnership. In fact, when airline 1 allies with airline 2, its best

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[3] The assumed symmetry of demands facilitates validity of this assumption. We will relax it in section 3.3 for semi-

response to an increase in AC traffic supplied by its partner is decreasing the number of its passengers on the market (see Appendix). On the other hand, economies of traffic density create the 'cost savings' effect, which should, other things equal, be stronger for the partnership between carriers 1 and 2. This is so primarily because all of the AC traffic will go through AB segment of airline 1's network. While airline 1 reduces its own AC traffic, its partner airline 2 compensates for it by supplying twice as many passengers as carrier 1. In equilibrium with economies of traffic density and symmetric costs, airline 2's traffic on AC market will be twice that of airline 1. This implies substantial cost savings for airline 2's BC segment. When airline 2 partners with carrier 3, it effectively carries one half of AC traffic, as compared to two thirds in partnership with airline 1. Thus, for interline passengers the benefit of partnership between carriers 1 and 2 appears to be growing with the extent of economies of traffic density. Yet, for the international AB market the benefits of a semi-complementary partnership between airlines 1 and 2 appear rather uncertain. It is true that airline 1 will gain a huge cost advantage over airline 3, due to economies of traffic density on this segment. It is also true, however, that airline 3 is squeezed out of the AB market, and airline 1 gets more opportunities to exercise its market power on the route. The expected results with economies of traffic density are summarized in Table 1 below.

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complementary partnerships.

Table 1 Expected results with economies of traffic density

	Changes relative to the case without partnerships		Expected difference between partnerships
	Complementary partnership (airlines 2 and 3)	Semi-complementary partnership (airlines 1 and 2)	
AB market	Cost savings to airline 3 due to AC traffic. Higher cost of airline 1 due to lower AC traffic. Still two competitors with symmetric costs (airlines 1 and 3).	Substantial cost savings to airline 1 due to higher AC traffic. Airline 1 obtains cost advantage over airline 3.	With semi-complementary partnership, airline 1 can squeeze out airline 3, especially when economies of density are substantial. Yet, reduction in airline 1's cost can bring lower fares with semi-complementary partnership.
BC market	Cost savings to airline 2 due to AC traffic. Higher cost of airline 1 due to lower AC traffic. Still two competitors with symmetric costs (airlines 1 and 2).	Lower cost to airline 2 due to high AC traffic. Airline 1's AC traffic down (cost up) due to airline 1 effectively competing against itself. Airline 2 obtains cost advantage over airline 1, as it carries two times more AC passengers.	Substantial reduction in airline 2's cost can bring lower fares with semi-complementary partnership, when economies of density are high.
AC market	Effectively, a new competitor is created; costs of both competitors are similar. Airline 1's AC traffic is down, costs are up.	Airline 1 competes with a partnership, which includes airline 1. Airline 1 responds to increase in AC traffic by airline 2 by reducing its AC traffic. Yet, because all AC traffic passes through airline 1's AB segment, substantial cost reduction is generated.	With semi-complementary partnership, airline 1 retains more market power than with complementary one. Yet, when economies of traffic density are substantial, cost savings can lead to lower fares with semi-complementary alliance.

Formally, we will follow such studies as Brueckner and Spiller (1991) and Brueckner (2001) and adopt the following cost function for a segment of an airline's network:

$$C(T) = T - \tfrac{1}{2}\theta T^2 \tag{2}$$

where T is the airline's total traffic on the segment and θ is a positive parameter. Note that the cost is segment-specific, not market-specific. Thus, for example, a passenger traveling on AC route with airline 1 will enter AB and BC segment cost functions. We keep symmetry of costs, even though one of the practical applications of our analysis involves low-cost carrier's choice of partner airline. This assumption will be relaxed later on to provide a comparison of the case with symmetric costs to a scenario where airline 2 is indeed a lower cost carrier.

2.2 Formalizing Two Types of Partnerships

Consider first a complementary partnership between carriers 2 and 3 on the AC market. The agreement between carriers stipulates that airline 3 can sell tickets on the BC flight serviced by airline 2 to a passenger flying from A to C (obviously, such a passenger flies from A to B with carrier 3). Airline 2 obtains similar rights. We assume that the partners choose the number of interline passengers jointly. This seems to better correspond to the situation where the partnership members are granted antitrust immunity for their operations. Yet, the Appendix shows equivalence of the case we consider here to the one where partner airlines choose interline passengers in an uncoordinated fashion. Bilotkach (2005) notes that Cournot-type models of complementary airline partnerships are unable to formally distinguish between the cases of code-sharing with coordinated and uncoordinated decision making by the partner airlines.

In this scenario, we effectively have two competitors (we will call them competitor 1 and competitor 2+3) setting quantities taking each other's choices as given. The competitors' revenues are given by:

$$R_1 = p\left(q_1^{AB} + q_3^{AB}\right)q_1^{AB} + p\left(q_1^{BC} + q_2^{BC}\right)q_1^{BC} + p\left(q_1^{AC} + q_{2+3}^{AC}\right)q_1^{AC} \tag{3}$$

$$R_{2+3} = p\left(q_1^{AB} + q_3^{AB}\right)q_3^{AB} + p\left(q_1^{BC} + q_2^{BC}\right)q_2^{BC} + p\left(q_1^{AC} + q_{2+3}^{AC}\right)q_{2+3}^{AC} \tag{4}$$

where $p = A - \alpha \sum q$, as before. The cost functions are:

$$\begin{aligned} TC_1(q_1^{AB}, q_1^{BC}, q_1^{AC}) &= C_1^{AB} + C_1^{BC} \\ &= q_1^{AB} + q_1^{AC} - \tfrac{1}{2}\theta\left(q_1^{AB} + q_1^{AC}\right)^2 + q_1^{BC} + q_1^{AC} - \tfrac{1}{2}\theta\left(q_1^{BC} + q_1^{AC}\right)^2 \end{aligned} \tag{5}$$

$$\begin{aligned} TC_{2+3}(q_2^{BC}, q_3^{AB}, q_{2+3}^{AC}) &= C_2^{BC} + C_3^{AB} \\ &= q_2^{BC} + q_{2+3}^{AC} - \tfrac{1}{2}\theta\left(q_2^{BC} + q_{2+3}^{AC}\right)^2 + q_3^{AB} + q_{2+3}^{AC} - \tfrac{1}{2}\theta\left(q_3^{AB} + q_{2+3}^{AC}\right)^2 \end{aligned} \tag{6}$$

The competitors' costs in (5) and (6) are broken down by network segments, according to (2). Note that AC traffic enters cost functions for two segments of each of the two competitors.

The first-order conditions of a model defined by (3)–(6) give a system of six linear equations with six unknowns. The closed-form solution to this system of equations can be found, but both the expressions and the related comparative statics are rather intractable, requiring us to resort to numerical simulations to explore properties of equilibrium.

Next we consider the semi-complementary partnership between carriers 1 and 2. As noted above, we are talking about the partnership whereby airline 1 will pick up AC passengers from airline 2 at airport B and carry them to endpoint A. At the same time, cooperation on BC route is not allowed, which means that we cannot allow for partner airlines' joint profit maximization as in the previous scenario.

To offer a tractable model of the code-sharing agreement between airlines 1 and 2 we assume that airline 1 does not transfer its own passengers to its partner. This means that airline 2 only carries those AC passengers to which it sells the tickets. Airline 1, however, carries all airline 2's AC passengers on the AB segment of their itinerary. Symmetry of AB and BC markets introduced above allows us to initially assume airlines 1 and 2 will split the total fare paid by the interline passenger on AC market equally. We will later relax this assumption. All the above-stated suggests the following revenue functions for the carriers.

$$R_1 = p\left(q_1^{AB} + q_3^{AB}\right)q_1^{AB} + p\left(q_1^{BC} + q_2^{BC}\right)q_1^{BC} + p\left(q_1^{AC} + q_2^{AC}\right)\left(q_1^{AC} + \tfrac{1}{2}q_2^{AC}\right) \tag{7}$$

$$R_2 = p\left(q_1^{BC} + q_2^{BC}\right)q_2^{BC} + p\left(q_1^{AC} + q_2^{AC}\right)\tfrac{1}{2}q_2^{AC} \tag{8}$$

$$R_3 = p\left(q_1^{AB} + q_3^{AB}\right)q_3^{AB} \tag{9}$$

Note the factor ½ appearing in (7) and (8) – revenue functions of airlines 1 and 2, respectively. The part $p\left(q_1^{AC} + q_2^{AC}\right)\left(q_1^{AC} + \tfrac{1}{2}q_2^{AC}\right)$ of airline 1's revenue function tells that this carrier charges full price to all its AC passengers, and obtains half of the full price paid by AC passengers supplied by airline 2. In the same way, airline 2 retains only half of the revenue on each AC ticket it sells. The airlines' cost functions are:

$$\begin{aligned} TC_1\left(q_1^{AB}, q_1^{BC}, q_1^{AC}, q_2^{AC}\right) &= C_1^{AB} + C_1^{BC} \\ &= q_1^{AB} + q_1^{AC} + q_2^{AC} - \tfrac{1}{2}\theta\left(q_1^{AB} + q_1^{AC} + q_2^{AC}\right)^2 + q_1^{BC} + q_1^{AC} - \tfrac{1}{2}\theta\left(q_1^{BC} + q_1^{AC}\right)^2 \end{aligned} \tag{10}$$

$$TC_2(q_2^{BC}, q_2^{AC}) = q_2^{BC} + q_2^{AC} - \tfrac{1}{2}\theta\left(q_2^{BC} + q_2^{AC}\right)^2 \tag{11}$$

$$TC_3\left(q_3^{AB}\right) = q_3^{AB} - \tfrac{1}{2}\theta\left(q_3^{AB}\right)^2 \tag{12}$$

Note two differences between (10)–(12) and (5)–(6) (cost functions for complementary partnership). First, cost functions of airlines 2 and 3 include only one segment. Second, AC traffic supplied by airline 2 enters airline 1's cost function, albeit only for AB segment.

Construction of profit functions from equations (7)–(12) is a trivial task, as is solving for first-order conditions, taking the assumed linear form of inverse demand relationship. As before, the first-order conditions are represented by a system of six linear equations with six unknowns and an analytically intractable closed-form solution. The objective of the simulation exercise discussed in the next section is comparison of numerical solutions in the two cases described here.

III. Simulation Results

3.1 General

The three main parameters we can vary are A (equivalent to the market size), α (price sensitivity of demand), and θ (the extent of economies of traffic density). It should be noted that previous similar exercises varied primarily the first and the third of the above parameters, paying little attention to responsiveness of results to price sensitivity of demand (α was typically set equal to one). This is understandable; as such studies used simulation exercises mostly as illustrative examples.

Based on intuition outlined above, semi-complementary partnership between airlines 1 and 2 is more likely to be superior (in terms of total welfare) to the complementary one between carriers 2 and 3 the higher the extent of economies of traffic density, and the larger the market size. In the former case, each additional passenger will bring higher cost savings, and in the latter, more traffic will be generated, other things equal, suggesting higher cost savings for otherwise equal extent of economies of traffic density.

In our simulations we varied A from 2 to 16, while θ was varied from 0.05 until the solution was outside the feasibility limits. Feasibility in our case required that resulting prices, profit, marginal revenue and marginal cost of all market participants be non-negative in equilibrium. The price sensitivity parameter α was varied between 0.7 and 1.2.

Let us first describe the findings in a nutshell. As we varied three parameters, it is not easy to represent the results graphically in such a way as to obtain a meaningful comparison. Therefore, for the start let us take a look at the following table, which gives a summary of selection of simulation results. This table tells us, for each combination of price sensitivity (α) and degree of economies of traffic density (θ), over what percentage of feasible range of market size parameter (starting from $A=2$ and ending at $A=16$ unless feasibility bound was lower) the partnership between carriers 2 and 3 resulted in higher simulated total welfare. In other words, for each pair of α and θ, we determine how large the market has to be for the semi-complementary partnership between airlines 1 and 2 to start yielding higher welfare as compared to the other alternative.

Table 2 Percentage of feasible range of A where partnership between airlines 2 and 3 yields higher total welfare than a partnership between airlines 1 and 2

Theta	Alpha					
	0.7	*0.8*	*0.9*	*1.0*	*1.1*	*1.2*
0.05	100	100	100	100	100	100
0.10	100	100	100	100	100	100
0.15	44.3	79.8	100	100	100	100
0.20	22.2	28.6	36.0	65.1	100	100
0.25	6.18	24.5	31.5	42.3	48.0	67.2
0.30	0.00	5.43	9.24	15.4	17.4	20.0
0.35	0.00	0.00	3.15	7.89	10.0	18.2
0.40	0.00	0.00	0.00	1.45	3.12	5.32

As expected, lower extent of economies of traffic density is associated with higher welfare gains from partnership between airlines 2 and 3. Also, at higher price sensitivity of demand (lower α)[4] a semi-complementary partnership between airlines 1 and 2 started dominating that between carriers 2 and 3 in terms of welfare at lower values of θ, other things equal. Yet, the feasibility region was also shrinking with lower values of α (higher price sensitivity of demand) and higher values of θ. For example, if we fix α and ask the question about the percentage of feasible region of values of A and θ over which partnership between carriers 2 and 3 yields higher simulated total welfare, the answer will be 60% for $\alpha = 0.7$ and almost 80% for $\alpha = 1.2$. The reason for this is wide feasible range for A for low values of θ, and narrower one for higher economies of traffic density, combined with the fact that complementary partnership between carriers 2 and 3 very often results in higher welfare for lower values of θ. In fact, if we only look at values of θ equal to or greater than 0.15, the percentage of feasible combinations of A and θ, where partnership between carriers 2 and 3 is better for the society shrinks to 15% for $\alpha = 0.7$ and 58% for $\alpha = 1.2$.

A somewhat surprising finding was that higher prices under one or the other scenario did not necessarily mean higher total welfare with the same partnership type. Namely, in almost two thirds of instances where partnership between airlines 1 and 2 resulted in higher welfare, it also yielded higher prices. Moreover, for theta below 0.25 higher total welfare with semi-complementary partnership between carriers 1 and 2 always went hand in hand with higher prices. Likewise, for some combinations of parameter values partnership between carriers 2 and 3 yielded higher prices and higher welfare, but such occurrences were infrequent.

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[4] Recall that in our exercise α is the slope coefficient of the *inverse* demand function. Therefore, the price sensitivity of demand, or $\frac{\partial Q}{\partial P}$ is inversely proportional to the value of alpha

The source of this seeming anomaly is simple. A partnership between carriers 1 and 2 creates less competition and leaves more room for exercising market power on the AC route, suggesting higher prices and higher profit[5] than with the other scenario (unless economies of traffic density are substantial). At the same time, airline 1 carries all AC traffic through its AB segment, resulting in very low per passenger cost. We therefore have a tradeoff between (substantially) higher profit and lower consumer surplus. It is however useful to note that differences in simulated total welfare across the partnership types are rather small, while differences in prices (and therefore in consumer surplus) on the AC market appear substantial. To give an idea of what 'small' and 'substantial' in the above sentence mean, the difference in simulated total welfare across the two scenarios was within 2% for $\theta = 0.05$; while for the same value of θ the difference in simulated prices on AC market was up to 17%.

Higher fares and higher welfare under complementary partnership between carriers 2 and 3 appear at low values of A and high values of θ. Here semi-complementary partnership between airlines 1 and 2 gives lower fares since economies of density are substantial; yet, the level of demand is not high enough for airlines 1 and 2 to obtain high profit. In fact, as long as we remain within the feasible region, an increase in demand level (A) keeping other things constant brings us from the case described above to the one where semi-complementary partnership between carriers 1 and 2 produces both lower prices and higher welfare gains as compared to the other alternative.

Where a partnership between carriers 1 and 2 outperforms the other kind of airline consolidation in terms of simulated total welfare, we often observe decreasing prices on the AC market with the increase in market size[6].

We speculated in the previous section that partnership between carriers 1 and 2 could potentially be harmful to consumers on AB route, as airline 3 will effectively be squeezed out of the market by carrier 1, taking advantage of lower costs due to economies of traffic density. We did not actually observe such an effect in our simulations. Even though airline 3 does get a lower market share on AB market, the simulated equilibrium prices on AB and BC markets are the same. In fact, the situation on AB and BC markets is somewhat similar: airline 1 loses BC

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[5] In fact, semi-complementary alliance always results in higher total profit for carriers 1 and 2 than the complementary one.

[6] Such a negative relationship between AC prices and market size (A) is not necessarily present; yet, where partnership between carriers 2 and 3 yields higher total welfare, the relationship between price on AC route and A is always positive.

market share to airline 2. This happens because airline 2 takes better advantage of economies of traffic density on this segment by carrying more AC passengers on BC segment than airline 1.

Throughout this sub-section, we compared simulated total welfare throughout the entire network. Yet, if we consider potential policy implications of our analysis, a regulator choosing whether to approve a complementary or a semi-complementary partnership may be more concerned with welfare effects of such alliances in the home country alone. This means that a domestic regulator may not take into account profit received by the foreign to it airline 3 when making its decision[7]. In this respect, semi-complementary partnership may look still better than the complementary one, as airline 3 receives lower profit in the former case than in the latter. It pays to note, however, that semi-complementary alliance provides distribution of total welfare, which is more biased towards the airlines, as compared to the complementary one. This is evidenced by many combinations of parameter values which give higher total welfare but lower consumer surplus with semi-complementary partnership.

3.2 Making Airline 2 a Lower Cost Carrier

Since one of the practical applications of our research involves potential indirect entry of low-cost airlines on the international market, it is interesting to see what happens to our simulation results if we indeed make one of our market players a lower cost airline. Namely, let airline 2 be such a carrier. As before, this airline can choose to partner either with the domestic carrier 1, or the international airline 3. The only difference between the previously considered cases will be that the cost function of airline 2 is now modified as:

$$C_2(T) = \beta\left(T - \tfrac{1}{2}\theta T^2\right) \tag{13}$$

Where β is a positive parameter strictly less than one. Thus, per segment total cost of airline 2 is a fraction of costs of any of the other carriers. To keep a long story short, varying the new parameter β changes our simulation results in the following ways. First, the feasible region of other parameters (A and θ, keeping α constant) shrinks. Moreover, the region of feasible values of A shrinks from below; the latter happens because in case of the semi-complementary partnership, airline 2 carries many more AC passengers than airline 1, and for low values of A the simulated equilibrium quantity of AC passengers carried by airline 1 turns out negative. Second, other things equal, a partnership between carriers 1 and 2 starts yielding higher simulated total

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[7] Consumer surplus on AC market will clearly be taken into account, as domestic passengers travel on it

welfare for lower values of θ. Illustration of this is provided in Table 3. There we fix the value of A at four (this value fits comfortably within the admissible range of A for most combinations of other parameter values) and search for the value of θ above which semi-complementary partnership between carriers 1 and 2 starts dominating the other one in terms of total welfare (keeping in mind higher total welfare may not necessarily mean lower prices) for certain combinations of α and β. It is visible from the table that once airline 2 becomes a relatively lower cost carrier, lower extent of economies of traffic density is needed for its partnership with the domestic (airline 1) carrier to yield higher welfare as compared to allying with the foreign airline (airline 3). That is, other things equal, a semi-complementary partnership is more likely to yield higher total welfare than a complementary one, if airline 2 is a lower cost carrier.

Table 3 Cutoff values of θ for cases with symmetric cost and lower-cost airline 2 (A=4)

Alpha	Symmetric Costs $(\beta = 1)$	Airline 2 as Lower-Cost Carrier $(\beta = 0.9)$	Airline 2 as Lower-Cost Carrier $(\beta = 0.8)$
0.7	0.147	0.136	0.122
0.8	0.165	0.154	0.141
0.9	0.183	0.173	0.162
1.0	0.204	0.192	0.176
1.1	0.230	0.212	0.195
1.2	0.252	0.231	0.214

Note: For values of θ below those reported here, complementary partnership between carriers 2 and 3 yields higher total welfare (for given combination of α, β, and A). For values higher than those in the table, semi-complementary partnership between carriers 1 and 2 yields higher simulated total welfare.

The intuition behind this result is as follows. When airline 2's cost falls relative to that of other competitors, its share of interline passengers increases faster under the semi-complementary partnership than under a complementary one. This happens because in the complementary alliance airline 1 sets its quantity on AC market taking the competitors' one as given; whereas under the semi-complementary one airline 1 decreases its number of AC passengers following an increase in this number by carrier 2. Thus, competition intensifies more with the semi-complementary alliance, other things equal.

Combined with shrinking feasible regions, we can say that with airline 2 being the lower cost carrier, the percentage of the feasible region where partnership between carriers 1 and 2 will yield higher total welfare increases quite substantially, and more so the lower the cost of airline 2 compared to other market players.

3.3 Varying Revenue Split in the Semi-Complementary Partnership

Our analysis has thus far assumed that with the semi-complementary partnership the revenue from the interline passengers on the AC market is equally divided between airlines 1 and 2. In this sub-section, we will relax this assumption and see how our results will change. Actually, changing the revenue split between the airlines is likely to affect welfare implications of our analysis, as it directly impacts the degree to which airline 1 effectively competes against itself on the AC market under the semi-complementary partnership. If airline 2 receives lower share of the price paid by each AC passenger it carries within the partnership, it decreases the carrier's incentives to sell AC tickets. This will strengthen airline 1's market power on the route. Thus, airline 1 will aim for keeping bigger share of revenue from interline passengers to itself, while giving a larger share to airline 2 appears more in line with that carrier's and social welfare interests.

The extent to which the two carriers will be able to bargain for shares of interline revenue will be determined by the profit the airlines are able to obtain under the complementary alliance scenario. Since with semi-complementary alliance and equal split of the revenue from interline passengers carriers 1 and 2 both get higher profit than with the complementary partnership[8], the range of the interline revenue split over which the airlines will be able to bargain will be non-empty. Further, as with the complementary alliance airlines 2 and 3 maximize joint profit, and since changing the interline revenue split in that case does not affect welfare implications of our analysis, assuming they split interline revenue equally is reasonable (especially in light of assumed symmetry of markets). Hence, as we vary the split of interline revenue on the AC market under the semi-complementary partnership, we will compare the carriers' profits to that under the complementary partnership scenario with equal revenue split.

Formally, let $\delta \in [0,1]$ be the share of revenue from an interline AC passenger, retained by airline 2. In that case, revenue functions (7) and (8) will be modified as follows:

$$R_1 = p\left(q_1^{AB} + q_3^{AB}\right)q_1^{AB} + p\left(q_1^{BC} + q_2^{BC}\right)q_1^{BC} + p\left(q_1^{AC} + q_2^{AC}\right)\left(q_1^{AC} + (1-\delta)q_2^{AC}\right) \qquad (14)$$

$$R_2 = p\left(q_1^{BC} + q_2^{BC}\right)q_2^{BC} + p\left(q_1^{AC} + q_2^{AC}\right)\delta q_2^{AC} \qquad (15)$$

with all other airlines' revenue and cost functions under the semi-complementary partnerships scenario remaining unchanged. Note that values of δ close to zero are likely to be infeasible as it will make no sense for airline 2 to offer AC tickets for sale, as such interline passengers will be adding very little to the revenue relative to cost. In the most extreme case of δ equal to zero, an AC passenger traveling on airline 2 for part of its trip will add nothing to the carrier's revenue, but will generate positive marginal cost, for all otherwise feasible combinations of other parameters[9]. We therefore determined the lower limit of δ as the value of this parameter which gives airline 2 the same profit under the semi-complementary partnership as the one it will be able to obtain under the complementary alliance with airline 3. The upper limit of δ defined the interline revenue split which gave airline 1 the same total profit as that it obtained under the complementary alliance scenario.

This modification of our analysis leads to the following results. First, for all otherwise feasible combinations of other model's parameters, increasing δ decreases equilibrium prices on all markets. The decrease of price on AC market is a direct result of higher competition between the on-line service of airline 1 and the interline service by airlines 1 and 2, as described above. Prices on AB and BC markets fall due to economies of traffic density resulting from higher AC traffic. Second, higher δ yields higher profit for airline 2, and lower profit for airline 1, which is also understandable. The net welfare effect of increasing δ is positive.

The general results reported above have very interesting implications. First, if higher δ increases total welfare, there is a possibility that increasing the value of δ above 0.5, as in all preceding analysis, we can make the semi-complementary alliance yield higher welfare where it previously did not. Yet, such occurrences are more likely the stronger the economies of traffic density. In fact, for $\theta = 0.05$ changes in revenue split which made semi-complementary partnership to yield higher total welfare as compared to the complementary one also gave airline 1 lower profit compared to what it would be able to obtain with the complementary alliance. With higher values of θ we can give airline 2 higher share of interline revenue, reverse the welfare comparisons in favor of semi-complementary partnership, and still give airline 1 higher total profit than under the complementary alliance. For example, for combination of parameter values $\theta = 0.15, A = 6, \alpha = 1, \beta = 1$, giving airline 2 between 60 and 88 percent of the interline revenue reverses the welfare comparison between semi-complementary and complementary partnership in favor of the former, while still giving airline 1 higher profit than under the complementary alliance (yet, for the semi-complementary partnership to also start yielding lower

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[8] This is so primarily because with semi-complementary alliance airlines 1 and 2 squeeze carrier 3 out of the market.

prices, airline 2 needs to receive at least 75 percent of the interline revenue). Second, where with equal revenue split semi-complementary alliance resulted in both higher welfare and prices as compared to the complementary one, increasing δ can result in both higher welfare and lower prices. Third, by decreasing δ below 0.5, it is possible to lose welfare dominance of semi-complementary alliance. Thus, δ effectively becomes a policy variable.

IV. Implications and Conclusions

Two phenomena currently characterize the global airline market. First, international routes are largely more regulated than domestic markets (deregulated EU market being a notable exception). Second, flag or legacy carriers, which play the major role on regulated international markets, appear to be losing the deregulated domestic markets to low-cost competitors. As a typical low-cost airline's product is unlikely to be welcomed on most currently regulated long-haul international routes, it seems possible that low-cost carriers may start feeding traffic to international markets and entering into partnerships with 'traditional' carriers. One question we explore here is whether it is better from the society's point of view for such a low-cost airline to partner with a domestic or an international carrier. Partnership with the domestic carrier can be called semi-complementary since, even though the agreement only stipulates that low-cost carrier feeds interline traffic to international service of its partner, partners' networks do overlap; whereas agreement with the international carrier creates a classic complementary partnership. With constant returns to traffic density, a complementary partnership creates lower prices and higher welfare than a semi-complementary one. Yet, with economies of traffic density one cannot unambiguously conclude which partnership is better in terms of consumer and total welfare.

The setup we offer in this paper is not as uncommon currently as previous paragraph suggests. Airlines do have varying degree of access to international routes, and some domestically operating carriers are excluded from international markets by restrictive bilateral air services agreements. Governments also are very reluctant to open domestic markets (however deregulated otherwise) to foreign competition. We thus are likely to see foreign carriers looking for a partner to effectively expand their presence in a country, and it could be either a big flag carrier with extensive international presence, or a smaller airline excluded from most

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[9] Recall that positive marginal cost in equilibrium is one of requirements for feasibility of a given combination of

international routes. Small domestic airlines may (and sometimes do) partner with either a big domestic or a foreign carrier to feed passengers to international services they cannot provide because of the regulatory restrictions.

We find that the semi-complementary partnership is more likely to dominate the complementary one in terms of total welfare when economies of traffic density are strong and demand is more price sensitive (other things equal). Yet, dominance in terms of (simulated) welfare gains does not necessarily mean lower equilibrium prices, suggesting a possibility that not all cost savings are passed on to consumers. A similar result shows empirically in the work of Brueckner and Spiller (1994), who suggest that only about half of cost savings due to economies of traffic density translate into lower fares. Also, if a domestic carrier feeding traffic to a partner's international routes is a lower cost one; our simulations show that a semi-complementary partnership is more likely to yield higher welfare than a complementary one, as compared to a scenario with symmetric costs. Finally, where economies of traffic density are strong, varying the split of interline revenue in the semi-complementary partnership from the originally assumed equal one can reverse welfare comparisons between the two scenarios, effectively making the revenue split a policy variable.

It would be nice to be able to match empirical findings on price elasticity of demand and extent of economies of traffic density to results of our simulations. Yet, studies by Caves et al. (1984), Brueckner and Spiller (1994), and Berry et al. (1996) offer diverse estimates of economies of traffic density. Brueckner and Spiller suggest stronger economies of density as compared to Caves et al. Berry et al. find no economies of traffic density on thin and mid-size short-haul markets, as well as on thick long-haul routes. Elsewhere, estimates of the extent of economies of density vary wildly, being the smallest for thin long-haul and mid-size medium-haul routes and the largest for short- and medium-haul thick markets, as well as for thin medium-haul routes. It is also true, however, that our simulated equilibrium price elasticities of demand are closer to those estimated by Brueckner and Spiller for lower values of A, other things equal.

Among issues left outside of our analysis, the 'network' considerations appear the most important. Suppose airline 1 services another end-point (call it end-point D) with a non-stop service from its hub B. Assume airline 1 is a monopolist on BD market. Due to cost complementarities arising from economies of traffic density, events on the three markets within

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parameters.

our network will affect airline 1's cost of carrying AD, CD, and consequently BD passengers. When competition emerges on AC market, the monopoly BD market will be adversely affected. As Brueckner and Spiller (1991) noted, competition on one network segment usually causes reduction of traffic throughout the network. Yet, the effect on the BD market will clearly be less adverse with the semi-complementary partnership between carriers 1 and 2 (let us keep CD market outside of the agreement), as less competition is effectively created. Therefore, to assess 'full' effects of airline partnership in real-world applications, it will be necessary to address the issue of potential losses on parts of airlines' networks not directly covered by the proposed agreement. We will not address this issue in detail here; this example is merely used to show that in real-world cases it will be necessary for the regulator to think outside of the box of network segments directly covered by the proposed airline partnership.

To sum it up, the regulator should not be afraid of semi-complementary airline partnerships as described here. In fact, if economies of traffic density are substantial and the domestic carrier planning to feed traffic to international routes of another domestic airline is a low-cost one, it is very likely that such a partnership (if it excludes overlapping portions of the carriers' networks) will yield higher total welfare than if a low-cost carrier partners with an international carrier. A consumer-welfare conscious regulator, however, should remember that higher total welfare may not necessarily mean lower prices, as not all cost savings are passed on to lower fares.

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Appendix – Supplementary Derivations

Constant Returns to Traffic Density

With economies of traffic density choices across routes become interrelated, as number of connecting passengers enters the first-order conditions for direct markets, as vice versa. This is not the case with constant returns to traffic density, where choices across different markets within the network are made independently. Therefore, our analysis of differences in prices across the two suggested types of airline partnerships can be confined to the AC market. Indeed, both proposed scenarios suggest equal competition on AB and BC markets.

Let us consider our problem with constant returns to density, the per passenger cost being symmetric across carriers and network segments and equal to *c*. For the case of partnership between carriers 2 and 3, the following trivial first-order conditions apply to the AC market[10]:

$$\frac{\partial \pi_i}{\partial q_i^{AC}} = p(Q) + q_i^{AC}\frac{\partial p}{\partial Q} - 2c = 0, \qquad i = 1,2+3 \tag{A.1}$$

where $Q = q_i^{AC} + q_{-i}^{AC}$. Whereas for the case of the non-overlapping partnership between carriers 1 and 2, we obtain (see (6) and (7) for the corresponding revenue functions):

$$\frac{\partial \pi_1}{\partial q_1^{AC}} = p(Q) + \frac{\partial p}{\partial Q}\left(q_1^{AC} + \tfrac{1}{2}q_2^{AC}\right) - 2c = 0 \tag{A.2}$$

$$\frac{\partial \pi_2}{\partial q_2^{AC}} = p(Q) + q_2^{AC}\frac{\partial p}{\partial Q} - 2c = 0 \tag{A.3}$$

Note that (A.3) is effectively the same as (A.1), albeit applied to carrier 2. Comparing (A.1) for airline 1 to (A.2), we can see that in the second scenario airline 1's marginal revenue is higher with the same marginal costs, suggesting lower quantity and higher prices.

This simple analysis demonstrates that with constant returns to traffic density overlapping partnership between carriers 1 and 2 will consistently lead to higher fares on the AC market, as compared to the partnership between airlines 2 and 3. The reason this result obtains is clear from (A.2). Airline 1 makes its decision taking into account the number of interline passengers supplied by its partner airline. If airline 2 adds a passenger on the AC market, airline 1 will decrease the number of ticket it sells. Additional passengers (other things equal) mean more competition and lower fares; yet, carrier 1 can offset for this by decreasing the number of its 'own' connecting passengers. In fact, for the linear demand function as assumed in this paper, the non-overlapping partnership between carriers 1 and 2 will yield $q_1^{AC} = \frac{1}{2}q_2^{AC}$ in equilibrium, and this result is valid with economies of traffic density, given symmetric cost as here.

Joint versus Independent Decision Making on AC Market by Partner Airlines 2 and 3

We establish equivalence of separate and joint decision-making by partner airlines 2 and 3 on the AC market in the respective partnership scenario. To do this we show the equivalence of the first-order conditions in both cases.

We begin by observing that the first-order condition in case of joint decision making is (see (3) and (5) for corresponding revenue and cost functions):

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[10] Since AC passenger's itinerary includes two network segments, the total cost of transporting such a customer is equal to *2c*.

$$\frac{\partial \pi_{2+3}}{\partial q_{2+3}^{AC}} = p(Q) + \frac{\partial p}{\partial Q} q_{2+3}^{AC} - 2 + \theta\left(q_2^{BC} + q_3^{AB} + 2q_{2+3}^{AC}\right) = 0 \tag{A.4}$$

If two carriers make independent choices on the numbers of tickets to be sold to AC passengers, their revenue and cost functions will look as follows. We assume, like elsewhere in the paper, that an airline using its network to transport an interline AC passenger obtains half of the total ticket price paid by such customer.

$$R_2 = p\left(q_1^{BC} + q_2^{BC}\right)q_2^{BC} + \tfrac{1}{2} p\left(q_1^{AC} + q_2^{AC} + q_3^{AC}\right)q_2^{AC} \tag{A.5}$$

$$C_2(q_2^{BC}, q_2^{AC}, q_3^{AC}) = q_2^{BC} + q_2^{AC} + q_3^{AC} - \tfrac{1}{2}\theta\left(q_2^{BC} + q_2^{AC} + q_3^{AC}\right)^2 \tag{A.6}$$

$$R_3 = p\left(q_1^{AB} + q_3^{AB}\right)q_3^{AB} + \tfrac{1}{2} p\left(q_1^{AC} + q_2^{AC} + q_3^{AC}\right)q_3^{AC} \tag{A.7}$$

$$C_3(q_3^{AB}, q_2^{AC}, q_3^{AC}) = q_3^{AB} + q_2^{AC} + q_3^{AC} - \tfrac{1}{2}\theta\left(q_3^{AB} + q_2^{AC} + q_3^{AC}\right)^2 \tag{A.8}$$

which yield the following first-order conditions for profit maximization with respect to quantity choice on AC market:

$$\frac{\partial \pi_2}{\partial q_2^{AC}} = \frac{1}{2}\left(p(Q) + \frac{\partial p}{\partial Q} q_2^{AC} \right) - 1 + \theta\left(q_2^{BC} + q_2^{AC} + q_3^{AC}\right) = 0 \tag{A.9}$$

$$\frac{\partial \pi_3}{\partial q_3^{AC}} = \frac{1}{2}\left(p(Q) + \frac{\partial p}{\partial Q} q_3^{AC} \right) - 1 + \theta\left(q_3^{AB} + q_2^{AC} + q_3^{AC}\right) = 0 \tag{A.10}$$

Simple addition of (A.9) and (A.10) yields (A.4), with $q_{2+3}^{AC} = q_2^{AC} + q_3^{AC}$.