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Airline-alliance extensions: Spillovers within networks[☆]

Jan K. Brueckner[a], Ricardo Flores-Fillol[b,*]

[a] Department of Economics, University of California, Irvine, USA
[b] Departament d'Economia and ECO-SOS, Universitat Rovira i Virgili, Spain

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ABSTRACT

This paper explores beneficial network spillovers resulting from airline-alliance extensions like those that occur when a US carrier adds new foreign partners to its existing international alliance. In the model, a US carrier and an existing foreign alliance partner initially cooperate in providing service between an interior US domestic endpoint and a foreign destination via an international US gateway. Then, a second foreign carrier, which previously provided traditional interline service to a different foreign endpoint via the same gateway, also becomes an alliance partner of the US carrier. Since trips to the two foreign destinations from the interior US endpoint share the same domestic route to the gateway, cost complementarity between the two international markets exists under economies of density. As a result, the alliance extension, by reducing the fare and raising traffic to the new foreign endpoint (which flows on the domestic segment), leads to a lower cost for alliance service to the original foreign endpoint, further reducing the fare in this market, which was already low due to the presence of the initial alliance. The paper analyzes this beneficial spillover along with others using a simple model.

1. Introduction

Since deregulation in the US in the 1980s, the airline industry has experienced major structural shifts, including consolidation, the spread of hub-and-spoke networks, and the rise of strategic international alliances. Before alliances emerged, connecting itineraries involved limited coordination between carriers, with fares and schedules set non-cooperatively.

The formation of alliances in the early 1990s fundamentally changed this framework. With antitrust immunity, partner airlines could coordinate fares and operations on connecting routes, effectively internalizing pricing decisions and lowering fares for multi-carrier trips. By linking complementary networks, alliances also improved service integration through schedule coordination, smoother transfers, and unified frequent flyer programs.

Today, alliances dominate international air travel, grouping major US airlines with global partners into three large networks: Star Alliance (anchored by United and Lufthansa), SkyTeam (Delta and Air France/KLM), and Oneworld (American Airlines and British Airways). Through integrated pricing and operational coordination, these alliances offer more "seamless" international travel while delivering lower fares on connecting journeys than comparable trips involving nonaligned carriers.

After their initial founding by the anchor partners, the history of alliances is one of growth in the number of partner airlines, mostly through the addition of non-US carriers. The purpose of the present paper is to analyze the effects on fares and passenger volumes of this incremental growth, which we call an alliance "extension". Our main focus is on the beneficial spillovers created by a new partner *within the networks of previous alliance partners*, with spillovers in other directions also being considered.

These spillovers arise via economies of traffic density, under which cost per passenger on a nonstop route segment falls with traffic volume (reflecting increasing returns to scale). To see how such spillovers occur, we focus on a domestic route of a US carrier with one endpoint at an international gateway airport, where the US carrier feeds traffic to overseas non-US carriers for two-segment trips. Start with a situation where one of these non-US carriers (which flies to a particular foreign country) is already an alliance partner of the US carrier, and suppose that a second carrier (which flies to a different foreign country) becomes a new alliance partner. The result is elimination of double marginalization in the pricing of two-carrier trips to this second country, with a lower fare raising traffic on such trips. Since this traffic growth raises traffic on the *domestic* portion of the two-segment trip, it reduces cost per passenger on this route and thus

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* Corresponding author.
E-mail addresses: jkbrueck@uci.edu (J.K. Brueckner), ricardo.flores@urv.cat (R. Flores-Fillol).

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reduces cost for the two-carrier trips to the *first foreign country*. As a result, fares for the latter trips, which were already low given the initial alliance, *become even lower*. Therefore, the alliance extension amplifies the benefits created by the initial alliance.

Another beneficial spillover is created by the formation of the initial alliance itself. By eliminating double marginalization and thus reducing the fare, the alliance raises traffic on the US domestic route, and the resulting reduction in cost per passenger reduces costs and thus the interline fare in the other international market. Such positive spillovers related to airline-alliance formation and extensions have been overlooked in the previous literature. Thus, the paper identifies additional network transmission mechanisms beyond those typically associated with connectivity or congestion.

While positive alliance spillovers are analyzed in the model, Brueckner and Spiller (1991) analyze *negative* spillovers from introduction of competition within an incumbent carrier's hub-and-spoke network. This competition, which drains traffic from the network, raises cost per passenger and most fares.

We explore the alliance-extension spillover mechanism and its full implications in a simple, stylized model that builds on previous theoretical work in the international-alliance literature. This literature, which has become large, started with theoretical papers by Park (1997), Oum et al. (1996), Brueckner (2001), and Park et al. (2001). These initial theoretical papers were later followed by Hassin and Shy (2004), Heimer and Shy (2006), Zhang and Zhang (2006), Flores-Fillol and Moner-Colonques (2007), Chen and Gayle (2007), Bilotkach (2007a,b) and Fageda et al. (2019). Early empirical papers testing for lower fares on two-carrier alliance trips include Brueckner and Whalen (2000), Brueckner (2003), and Whalen (2007), and the more-recent retrospective studies of Brueckner et al. (2011), Calzaretta et al. (2017) and Brueckner and Singer (2019) test this hypothesis over a longer time period.[1] Other empirical papers on international alliances include Oum et al. (1996), Park and Zhang (1998, 2000), Bilotkach (2005), Wan et al. (2009), Bilotkach and Hüschelrath (2013), Gayle (2013), Alderighi and Gaggero (2014), Gayle and Brown (2014), and Gayle and Thomas (2015). Our paper contributes to the theoretical literature, highlighting a previously overlooked network-based spillover mechanism.

Taking a broader look at the Industrial Organization literature, the seminal paper by Salant et al. (1983) identifies positive effects of horizontal integration on outsider firms, which expand their outputs and market shares in response to a reduction in output of the merged entity from exploitation of its market power. Other influential studies qualify this result by incorporating cost efficiencies (Perry and Porter, 1985), introducing price competition with product differentiation (Deneckere and Davidson, 1985), differentiating between early- and late-stage acquisitions (Kamien and Zang, 1990) or looking at the evolution of stock returns (Clougherty and Duso, 2009).

Like the alliance literature, the literature on vertical integration has also focused on the effect of eliminating double marginalization (Spengler, 1950; Hastings and Gilbert, 2005; Rey and Tirole, 2007). It has also studied foreclosure backfire and rival expansion (Hart and Tirole, 1990; Choi and Stefanadis, 2001; Crawford et al., 2018). More related to our study, O'Brien and Shaffer (1997) find positive effects on outsiders when competition is softened downstream. In a more recent paper, Luco and Marshall (2020) refer to a potential anticompetitive effect associated with vertically integrated operations by a multi-product firm (named the *Edgeworth–Salinger effect*) that would counteract the efficiency effect of vertical integration and could lead to price increases. Instead, our findings identify beneficial spillovers to merger (or alliance) outsiders stemming from cost complementarities that are propagated through networks. To the best of our knowledge, this aspect remains absent from the current literature.

[1] These papers, along with Brueckner and Whalen (2000), test a second prediction of alliance models: an alliance-induced increase in fares on nonstop trips between international gateway airports, where alliance partners fly side-by-side (such as New York–London).

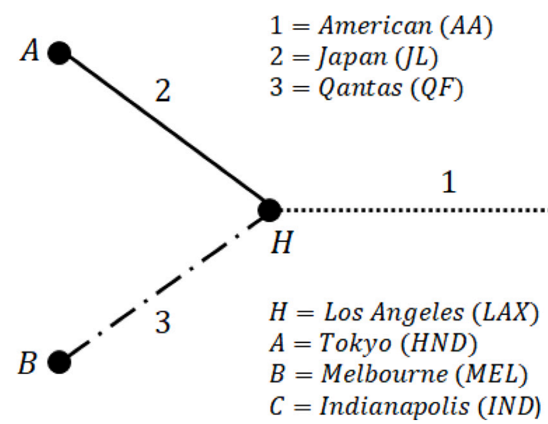

Fig. 1. The network.

Section 2 of the paper provides more detail on the network example from above while introducing features of the model. Section 3 analyzes the effects of alliances on fares, traffic volumes, and profits, with the derivation of the equilibrium values and proofs of the propositions presented in the appendix. Section 4 illustrates the results that can be derived without functional-form assumptions and Section 5 extends the analysis by adding greater realism to the model. Finally, Section 6 offers conclusions.

2. The analytical setup

The analysis is based on the network shown in Fig. 1. For concreteness, suppose that city H is Los Angeles, city C is some interior US endpoint such as Indianapolis, city A is Tokyo, and city B is Melbourne, Australia. Airline 1 (serving the CH route) is American Airlines; airline 2 (serving the AH route) is Japan Airlines; and airline 3 (serving the BH route) is Qantas. While in reality, American itself flies from Los Angeles to both Tokyo and Melbourne, suppose that this service does not exist, with the AH route served only by Japan Airlines and the BH route served only by Qantas. Then, travel between C and A requires a two-carrier trip on American and Japan Airlines, and travel between C and B requires a two-carrier trip on American and Qantas.[2]

An additional simplifying assumption is that travel demand in the nonstop markets CH, AH, and BH is absent, with demand only present in the international markets CA and CB (AB demand is also absent).

[2] The network considered in Fig. 1 allows us to identify spillovers arising from cost complementarities across two connecting markets that share a route segment. Analyses based on simpler networks with a single connecting market focus on the effects of eliminating the double-marginalization externality (e.g., Bilotkach, 2007a; Brueckner and Flores-Fillol, 2020), thereby neglecting these spillovers. Other papers analyze the effects of alliances on competition using either simple networks (e.g., Bilotkach, 2007b) or more complex network structures (e.g., Brueckner, 2001; Brueckner and Proost, 2010; Fageda et al., 2019), but they do not address alliance extensions, which are the focus of the present analysis. The latter incorporate network overlap between previously competing airlines to examine how partnerships affect competition across markets. Furthermore, Brueckner and Proost (2010) and Fageda et al. (2019) also study deeper forms of cooperation involving cost-sharing agreements (i.e., joint ventures) on overlapping routes. This aspect is not relevant to our analysis based on airline-alliance extensions. However, we consider a model variant in Section 5, where we discuss the implications of our results in the presence of network overlap between previously competing airlines. In another extension, we examine the potential collusive effects of alliance expansions, which may partially or fully offset the positive spillovers identified.

While this framework is thus highly stylized and lacking in full realism, the resulting simplicity makes the analysis manageable. Its lessons would also presumably emerge in a more-realistic setup, but at the cost of greater complexity and a likely need for numerical analysis.

In the pre-alliance era, travel in the CA and CB markets would have involved two-carrier trips on nonaligned carriers (American + Japan Airlines or American + Qantas), with the fare reflecting double marginalization. This situation is referred to in the analysis as the "double-interline" case, with pricing reflecting old-fashioned "interline" pricing between nonaligned carriers.

American, however, formed immunized alliances with Japan Airlines in 2010 and with Qantas in 2019, with both carriers joining the Oneworld alliance. Building on this example of an alliance extension, the analysis begins by first showing, relative to the double-interline case, the effect of the initial alliance between carriers 1 and 2 (which omits carrier 3) on fares and traffic, both in the CA market, which is directly affected by the alliance, and in the CB market, which is indirectly affected through the shared route segment CH.[3] In the analysis, this mixed case is referred to as the "alliance-interline" case.

Next, the analysis turns to the impact of the alliance extension, where carrier 3 becomes an alliance partner of carrier 1, creating a "double alliance". Note that, with no travel demand in the AB market, alliance partners 2 and 3 do not interact directly, as they would in a more-complete model, hence the name double alliance (1 + 2 and 1 + 3). The goal of the analysis is again to see how this alliance extension affects fares and traffic, both in the CB market, which is directly affected, and in the CA market, where effects are indirect. In practice, the comparison is made by deriving fares and traffic levels in the three cases: double-interline, double-alliance, and alliance-interline, and then making comparisons.

In the analysis, travel demand in the CA and CB markets is the same, given by a common (inverse) demand function $D(\cdot)$. The argument of this function depends on the case being considered.

2.1. Double interline

In the double-interline case (denoted ii), carriers behave noncooperatively, charging "subfares" for their portions of the two-carrier trip in uncoordinated fashion, with the subfares summed to get the overall fare. Given symmetry, carrier 1 charges the same subfare s_1^{ii} for its portion of both CA and CB trips, with carriers 2 and 3 charging subfares $s_2^{ii} = s_3^{ii} \equiv s_{2,3}^{ii}$ for their portions (AH and BH) of these respective trips, which end up equal by symmetry. This scenario is illustrated in Fig. 2. The cost function $C(Q)$, which pertains to an individual route segment with traffic equal to Q, satisfies $C'(Q) > 0$ and $C''(Q) < 0$, indicating economies of density. Costs for carriers 2 and 3 corresponding to segments AH and BH are given by $C(Q_{12}^{ii})$ and $C(Q_{13}^{ii})$, while cost for carrier 1 is given by $C(Q_{12}^{ii} + Q_{13}^{ii})$ because it carries traffic pertaining to the CA and CB markets on the CH segment. Therefore, profits for the carriers are

$$\pi_1^{ii} = s_1^{ii}\left(Q_{12}^{ii} + Q_{13}^{ii}\right) - C(Q_{12}^{ii} + Q_{13}^{ii}) \tag{1}$$

$$\pi_{2,3}^{ii} = \pi_2^{ii} = \pi_3^{ii} = s_{2,3}^{ii} Q_{12}^{ii} - C(Q_{12}^{ii}) = s_{2,3}^{ii} Q_{13}^{ii} - C(Q_{13}^{ii}), \tag{2}$$

where $Q_{12}^{ii} = Q_{13}^{ii} = D(s_1^{ii} + s_{2,3}^{ii}) \equiv Q^{ii}$. The carriers maximize their profits by their choosing subfares in non-cooperative fashion.

[3] In a similar transatlantic example involving American Airlines, city H would be New York, city B London, and city A Helsinki. After the initial alliance between American and British Airways (carrier 3), Finnair (carrier 2) joined the Oneworld alliance in an alliance extension.

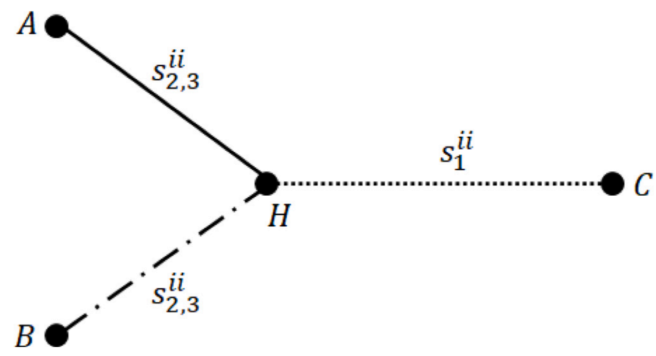

Fig. 2. Interline – interline (ii).

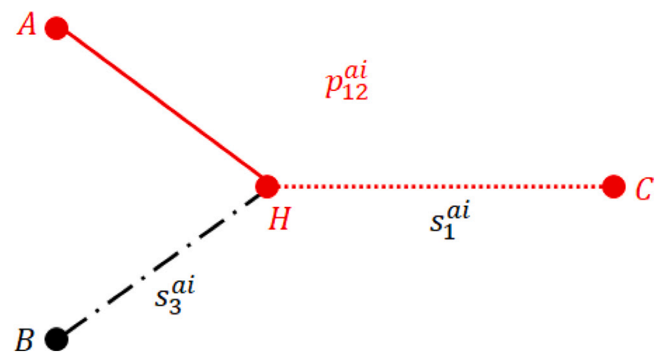

Fig. 3. Alliance – interline (ai).

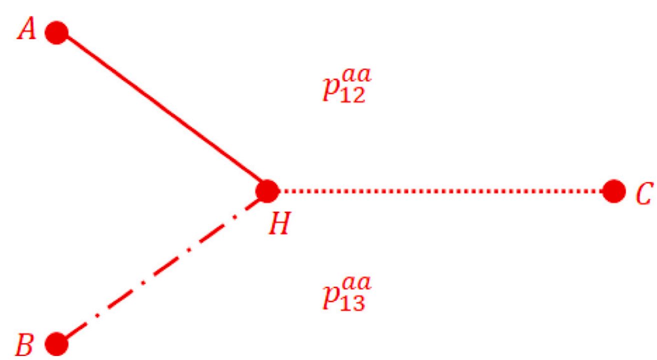

Fig. 4. Alliance – alliance (aa).

2.2. Alliance-interline

While the carriers maximize their profits individually in the double-interline case, in the alliance-interline case (denoted ai) the profit sum for carriers 1 and 2 is maximized, with carrier 3 separately maximizing its own profit. The alliance partners choose an overall fare p_{12}^{ai} for the relevant international trip CA (instead of choosing subfares) along with carrier 1's subfare for CB trips, denoted s_1^{ai}. Carrier 3 maximizes its own profit by choice of its subfare s_3^{ai}. This scenario is illustrated in Fig. 3. Therefore, profits are

$$\pi_{12}^{ai} = \pi_1^{ai} + \pi_2^{ai} = p_{12}^{ai} Q_{12}^{ai} + s_1^{ai} Q_{13}^{ai} - C(Q_{12}^{ai} + Q_{13}^{ai}) - C(Q_{12}^{ai}) \tag{3}$$

$$\pi_3^{ai} = s_3^{ai} Q_{13}^{ai} - C(Q_{13}^{ai}), \tag{4}$$

where $Q_{12}^{ai} = D(p_{12}^{ai})$ and $Q_{13}^{ai} = D(s_1^{ai} + s_3^{ai})$. The alliance-interline case is, of course, inherently asymmetric. As explained further below, the form of profit sharing with the alliance has no effect on our results.

2.3. Double alliance

In the double-alliance case (denoted aa), the sum of all three carriers' profits is maximized. The chosen fares are p_{12}^{aa} and p_{13}^{aa}, which give overall fares for the CA and CB trips, respectively (these fares end up equal by symmetry). This scenario is illustrated in Fig. 4. Therefore, the joint profit is given by

$$\pi_{123}^{aa} = \pi_1^{aa} + \pi_2^{aa} + \pi_3^{aa} = p_{12}^{aa} Q_{12}^{aa} + p_{13}^{aa} Q_{13}^{aa} - C(Q_{12}^{aa} + Q_{13}^{aa}) - C(Q_{12}^{aa}) - C(Q_{13}^{aa}), \tag{5}$$

where traffic levels are $Q_{12}^{aa} = D(p_{12}^{aa})$ and $Q_{13}^{aa} = D(p_{13}^{aa})$, which also end up equal, with the common values denoted Q^{aa} and p^{aa}.

3. Effects of alliances

The analysis now turns to examining the effects of alliances, with the aim of shedding light on the spillovers that emerge within airline networks as alliances expand. In order to facilitate the derivation of closed-form solutions for all the variables, the demand function $D(\cdot)$ is assumed to be linear and the cost function $C(\cdot)$ is assumed to be quadratic, yielding a linear marginal-cost function.

Demand function. In the double-interline case, demand in the two-carrier international markets CA and CB is given by

$$Q_{12}^{ii} = Q_{13}^{ii} = a - b\left(s_1^{ii} + s_{2,3}^{ii}\right), \tag{6}$$

with $a, b > 0$. As suggested above, the alliance-interline case is inherently asymmetric, as carriers 1 and 2 form an alliance and cooperate in setting the fare p_{12}^{ai} for the CA market while carrier 3 remains independent. Therefore, demand functions are given by

$$Q_{12}^{ai} = a - b p_{12}^{ai} \tag{7}$$

$$Q_{13}^{ai} = a - b\left(s_1^{ai} + s_3^{ai}\right). \tag{8}$$

Finally, in the double-alliance case, carriers 1 and 2 cooperate in setting the fare p_{12}^{aa} while 1 and 3 cooperate in setting the fare p_{13}^{aa}. Hence, demands become

$$Q_{12}^{aa} = a - b p_{12}^{aa} \tag{9}$$

$$Q_{13}^{aa} = a - b p_{13}^{aa}. \tag{10}$$

Cost function. As in previous airline papers (Brueckner and Spiller, 1991; Brueckner et al., 1992; Brueckner, 2001), the marginal cost on a route segment is given by

$$C'(Q) = 1 - \theta Q, \tag{11}$$

with Q denoting the total traffic on the segment. Marginal cost is decreasing with total traffic, with $\theta > 0$ capturing the intensity of economies of traffic density.[4]

Profits for carriers are given by (1)–(5). In the alliance-interline and the double-alliance cases, the exact nature of the profit-sharing arrangement among the carriers is irrelevant for our analysis.[5,6]

[4] The corresponding cost function is given by $C(Q) = Q - \theta Q^2/2$, so that $C''(Q) = -\theta < 0$.

[5] In the alliance-interline case, a 50-50 revenue-sharing rule implies the following profit allocations: $\pi_1^{ai} = \left(p_{12}^{ai} Q_{12}^{ai}\right)/2 + s_1^{ai} Q_{13}^{ai} - C(Q_{12}^{ai} + Q_{13}^{ai})$ and $\pi_2^{ai} = \left(p_{12}^{ai} Q_{12}^{ai}\right)/2 - C(Q_{12}^{ai})$. An alternative approach to modeling the sharing rule is to consider a Nash bargaining process over the total equilibrium profits, where airline 1 has greater bargaining power.

[6] In the double-alliance case, an egalitarian revenue-sharing rule implies the following profit allocations: $\pi_1^{aa} = \left(p_{12}^{aa} Q_{12}^{aa}\right)/2 + \left(p_{13}^{aa} Q_{13}^{aa}\right)/2 - C(Q_{12}^{aa} + Q_{13}^{aa})$, $\pi_2^{aa} = \left(p_{12}^{aa} Q_{12}^{aa}\right)/2 - C(Q_{12}^{aa})$, and $\pi_3^{aa} = \left(p_{13}^{aa} Q_{13}^{aa}\right)/2 - C(Q_{13}^{aa})$.

Assumption 1. The analysis assumes that the parametric conditions $a > 2b$ and $\theta < 1/(3b)$ hold throughout. The latter is a stricter form of the most stringent second-order condition across the three cases, which requires $\theta < 2/(3b)$. Together, these assumptions guarantee positive fares and quantities.

The proposition that follows summarizes the effect of the transition from double-interline to alliance-interline. The derivation of equilibrium subfares, fares, traffic levels, and profits is provided in Appendix A, while the proofs of the propositions are presented in Appendix B.

Proposition 1. *When forming an alliance, partner carriers 1 and 2 eliminate double marginalization, leading to lower fares ($p_{12}^{ai} < s_1^{ii} + s_{2,3}^{ii}$), higher traffic volumes ($Q_{12}^{ai} > Q^{ii}$), and higher profits ($\pi_{12}^{ai} > \pi_1^{ii} + \pi_{2,3}^{ii}$). The same effects are observed in the other market, even though carriers 1 and 3 remain nonaligned ($s_1^{ai} + s_3^{ai} < s_1^{ii} + s_{2,3}^{ii}$, $Q_{13}^{ai} > Q^{ii}$, and $\pi_3^{ai} > \pi_{2,3}^{ii}$).*

The shift from double-interline to alliance-interline eliminates double marginalization, leading to lower fares, increased traffic volumes, and higher profits for partner carriers in the city-pair market CA. This is a well-documented mechanism in the literature (e.g., see Brueckner, 2001). Notably, the same pattern emerges in city-pair market CB, even though carrier 3 is an alliance outsider. The reason is that beneficial spillovers stemming from cost complementarities on the route CH are propagated to market CB.

Next, the analysis examines the consequences of extending the alliance to the former outsider airline, and the results are formally stated in the following proposition.

Proposition 2. *When the alliance is extended to the former outsider airline, the new partner carriers 1 and 3 eliminate double marginalization, leading to lower fares ($p^{aa} < s_1^{ai} + s_3^{ai}$) in the CB market and increased traffic volumes ($Q^{aa} > Q_{13}^{ai}$) relative to the alliance-interline case. Overall profit ($\pi_{123}^{aa} > \pi_{12}^{ai} + \pi_3^{ai}$) also rises. The alliance extension also generates positive spillovers in the CA market, driven by cost complementarities transmitted through the network, which materialize as decreased fares and expanded traffic volumes relative to the alliance-interline case ($p^{aa} < p_{12}^{ai}$ and $Q^{aa} > Q_{12}^{ai}$).*

The fact that both city-pair markets share the route segment CH is the key network feature linking them through cost complementarity. It enables the propagation of efficiency gains, arising from economies of traffic density, from one market to the other when alliances are formed and extended.

4. Generalization

This section illustrates the results that can be derived without functional-form assumptions, with the purpose of illustrating the effects of eliminating double marginalization and of cost complementarity between markets in a more general setup.

Consider the double-interline case, where profits for the carriers are given by (1) and (2). Given that $s_2^{ii} = s_3^{ii} \equiv s_{2,3}^{ii}$ and that $Q_{12}^{ii} = Q_{13}^{ii} = D(s_1^{ii} + s_{2,3}^{ii}) \equiv D^{ii}$, the first-order conditions $\partial \pi_1^{ii}/\partial s_1^{ii} = 0$ and $\partial \pi_{2,3}^{ii}/\partial s_{2,3}^{ii} = 0$ yield

$$D^{ii} + s_1^{ii} D^{ii\prime} - C'\left(2D^{ii}\right) D^{ii\prime} = 0 \tag{12}$$

$$D^{ii} + s_{2,3}^{ii} D^{ii\prime} - C'\left(D^{ii}\right) D^{ii\prime} = 0, \tag{13}$$

where $D'(s_1^{ii} + s_{2,3}^{ii}) \equiv D^{ii\prime}$. If economies of density are absent, then $C' = \tau$ and $C'' = 0$. In this case, the conditions (12) and (13) are identical, so that $s_1^{ii} = s_{2,3}^{ii}$. The fare in each market is then $p^{ii} = s_1^{ii} + s_{2,3}^{ii}$. The double-interline case is revisited below when economies of density are reimposed.

Now consider the effect of an alliance between carriers 1 and 2 without economies of density. Substituting for Q_{12}^{ai}, the alliance's profit is then $\pi_{12}^{ai} = p_{12}^{ai} D(p_{12}^{ai}) + s_1^{ai} Q_{13}^{ai} - \tau\left[D(p_{12}^{ai}) + Q_{13}^{ai}\right] - \tau D(p_{12}^{ai})$. Since the CA

and CB markets are separable when $C'' = 0$, Q_{13}^{ai} can be ignored, with p_{12}^{ai} chosen independently of s_1^{ai}. The first-order condition $\partial\pi_{12}^{ai}/p_{12}^{ai} = 0$ reduces to

$$\frac{1}{2}D^{ai} + \frac{p_{12}^{ai}}{2}D^{ai\prime} - \tau D^{ai\prime} = 0, \tag{14}$$

where $D^{ai} \equiv D(p_{12}^{ai})$ and similarly for $D^{ai\prime}$. By contrast, the common conditions (12) and (13) for the double-interline case (which are identical when $C' = \tau$) can be written

$$D^{ii} + \frac{p^{ii}}{2}D^{ii\prime} - \tau D^{ii\prime} = 0. \tag{15}$$

Eq. (14) determines p_{12}^{ai} and (15) determines the total interline fare p^{ii}, and the equations have nearly identical forms, except for the $1/2$ multiplying the first term in (14).

To compare the p_{12}^{ai} and p^{ii} values that solve (14) and (15), note that both expressions must be decreasing functions of their respective variables for the second-order conditions to be satisfied. The function in (14), however, is lower than the function in (15) given the presence of the leading $1/2$ factor, which captures the elimination of double marginalization. As a result, the point where (14) crosses the horizontal axis (thus equaling zero) lies to the left of the point where (15) crosses the axis, so that $p_{12}^{ai} < p^{ii}$. Thus, the alliance partners 1 and 2 charge a lower CA fare than the carriers do when they are nonaligned. This conclusion, which was first demonstrated by Brueckner (2001), shows that alliances unambiguously reduce the fare for two-carrier trips in the absence of economies of traffic density.

This result cannot be established in general when economies of density are present, requiring instead the imposition of specific functional forms, as is done in the analysis above. However, one general effect of economies of density, which also emerges in that analysis, can be illustrated for the double-interline case, without reliance on functional forms. In particular, consider (12)–(13) from above when $C'' < 0$. Since $C'\left(2D^{ii}\right) < C'\left(D^{ii}\right)$ then holds, it follows that s_1^{ii} must be less than $s_{2,3}^{ii}$ for both equations to be satisfied given $D^{ii\prime} < 0$. Therefore, carrier 1 charges a lower subfare than the other carriers, a result of serving both the CA and CB markets when a cost complementarity exists between them. This complementarity is absent when economies of density are not present, making the subfares of all three carriers equal.

This cost-complementarity force generates a host of results when explicit functional forms are imposed, as seen in the above analysis.

5. Analysis extensions

The analysis could be extended by adding greater realism to the model. For example, a demand for trips in the AB market (currently absent) could be added, creating new types of spillovers.[7] Because the alliance extension raises traffic on the route segments from the international gateway to each foreign endpoint, reducing cost per passenger on both segments, the extension will put downward pressure on the fare in the AB market, which is served via these segments, in a different type of spillover. But further effects unfold: since the alliance extension also leads to cooperative pricing in the AB market and a resulting further increase in traffic and lower costs on the AB route segments, a reverse spillover leads to lower fares in the CA and CB markets.

Other extensions would increase the number of domestic US endpoints (increasing the number of international markets) or would add CH, AH, and BH nonstop travel markets. Neither of these changes, however, would fundamentally alter the spillover mechanism at work in the simple current model.

Another extension based on a different model would start with the more-traditional alliance structure shown in Fig. 5, where cities A and B (C and D) are now US (European) domestic endpoints and H_1 and H_2 are US and European international gateways (see Brueckner, 2001). As is well known, a transatlantic alliance between carriers 1 and 2 (US and European) reduces fares in the two-carrier markets AC, AD, BC, and BD, while possibly raising the fare in the interhub H_1H_2 market due to the elimination of competition between the two carriers in this market under the alliance.

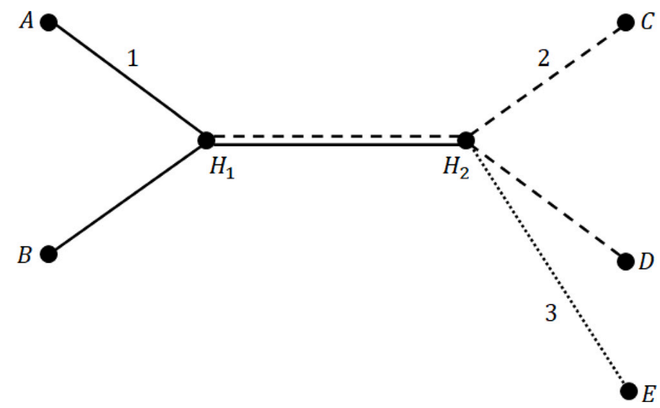

Fig. 5. The traditional alliance network (Brueckner, 2001).

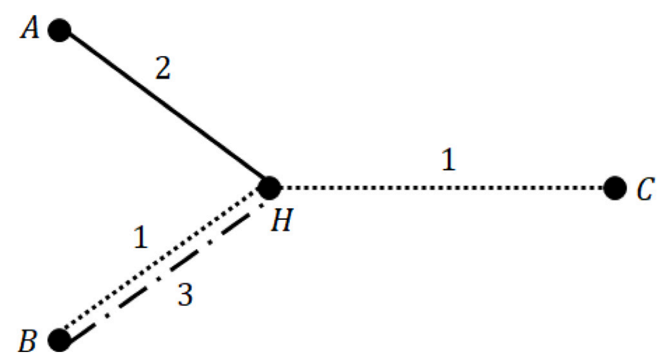

Fig. 6. Online connecting service in the CB market.

Now suppose that a third European carrier (#3) is added to the model, serving only the route between H_2 and endpoint E (also shown in Fig. 5). Assuming the absence of travel demand in the CE, DE, and H_2E markets, this airline would initially carry only interline traffic in the markets AE, BE, and H_1E. Now suppose that carrier 3 becomes the second alliance partner of carrier 1, resulting in elimination of double marginalization and lower fares in the AE, BE, and H_1E markets. The result would be higher traffic levels for carrier 1 on its domestic route segments AH_1 and BH_1 and on the H_1H_2 route segment as well. With traffic higher on these segments, the cost reduction from economies of traffic density would be expected to reduce fares in all of the previous two-carrier markets AC, AD, BC, and BD. In addition, lower costs for carrier 1 on the interhub H_1H_2 route would put downward pressure on the fare in the interhub market. Crucially, since these lower costs are generated with no change in competition on the route (which still involves only carriers 1 and 2), the result is downward pressure on the interhub fare, possibly offsetting any increase in the fare due to the alliance between 1 and 2. Therefore, this kind of alliance extension could reverse the possible downside of the 1-2 alliance (a higher interhub fare) by generating a beneficial cost spillover on the interhub route.[8]

[7] In the context of our example, this demand (between Tokyo and Melbourne) would be served, quite unrealistically, only by connecting service through Los Angeles. This case nevertheless gives further analytical insight.

[8] Brueckner (2001) theoretically identified the potential anticompetitive effect of airline alliances in interhub markets where airline networks overlap.

Another possible extension of the original model with less clear-cut implications is illustrated in Fig. 6, in which airline 1 serves the BH route, thus being able to provide online connecting service in the CB market (but no BH service since demand is absent). In this situation, airline 1 will refuse to book interline CB service with airline 3, thus keeping all that market's traffic for itself (with no other travel demand, airline 3 then does not operate). Relative to the double-interline case, the new absence of double marginalization means a lower CB fare (now online) and higher CH traffic, which also yields a lower CA fare relative to the double-interline case. As before, the alliance between carriers 1 and 2 will reduce the CA fare, raising traffic on the CH route and reducing airline 1's online CB fare. In this setting, an alliance extension will not occur, because lost economies of density means that airline 1 will still have no incentive to share CB traffic with airline 3. The outcome, however, could be different with travel demand in the BH market. Then, airline 1's loss from splitting CB traffic under an alliance with airline 3 could be made up by the gains from new collusion in the BH market, in which the carriers previously competed. However, the 1-3 alliance's effect on CH traffic in this situation is unclear, making the direction of the spillovers (positive or negative) in the CA market also unclear.

Finally, the network effects in our setup, arising from economies of density, generate additional effects in a more-complete model in which carriers choose both fares and flight frequencies, so that a carrier's full price includes the fare and schedule delay (see Brueckner and Flores-Fillol, 2020). Under standard assumptions, it can be shown that: (i) carrier 1 's flight frequency is higher than that of carriers 2 and 3 in the double-interline case, reflecting carrier 1's pooling of traffic on route CH; and (ii) alliances have a positive effect on frequency on route CH, benefiting both the partner airlines and any outsider airline.

6. Conclusion

This paper has explored beneficial network spillovers resulting from an airline-alliance extension like those that occur when a US carrier adds new foreign partners to its existing international alliance. In the model, a US carrier and an existing foreign alliance partner initially cooperate in providing service between an interior US domestic endpoint and a foreign destination via an international US gateway. Then, a second foreign carrier, which previously provided traditional interline service to a different foreign endpoint via the same gateway, also becomes an alliance partner of the US carrier. Since trips to the two foreign destinations from the interior US endpoint share the same domestic route to the gateway, cost complementarity between the two international markets exists under economies of density. As a result, the alliance extension, by reducing the fare and raising traffic to the new foreign endpoint (which flows on the domestic segment), leads to a lower cost of alliance service to the original foreign endpoint, further reducing the fare in this market, which was already low due to the presence of the initial alliance. The alliance extension thus amplifies the benefits of that alliance. The paper analyzes this beneficial spillover along with others using a simple model.

Overall, our simple framework allows us to identify beneficial spillovers of alliances (or mergers) on non-participating firms, arising from cost complementarities that propagate through the network. The extensions further show that, within a traditional alliance structure, these effects may offset potential anticompetitive outcomes in interhub markets. This latter finding underscores the importance for policymakers of adopting a balanced view of alliances, taking into account these spillovers alongside possible competitive concerns.

This effect is empirically supported by Gillespie and Richard (2012) and Brueckner and Singer (2019). However, several other studies find no evidence of such behavior, including Oum et al. (1996), Park and Zhang (1998), Brueckner and Whalen (2000), Bilotkach and Hüschelrath (2013), Calzaretta et al. (2017), and Fageda et al. (2019).

CRediT authorship contribution statement

Jan K. Brueckner: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Ricardo Flores-Fillol:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Derivation of equilibrium subfares, fares, traffic levels, and profits

This appendix details the computations used to derive the equilibrium outcomes across the three scenarios.

A.1. Double interline

Making use of (1)–(2), (6), and (11), the first-order conditions $\partial\pi_1^{ii}/\partial s_1^{ii} = 0$ and $\partial\pi_{2,3}^{ii}/\partial s_{2,3}^{ii} = 0$ yield

$$\frac{a}{b} - 2s_1^{ii} - s_{2,3}^{ii} + 1 - 2\theta\left[a - b\left(s_1^{ii} + s_{2,3}^{ii}\right)\right] = 0 \tag{A.1}$$

$$\frac{a}{b} - 2s_{2,3}^{ii} - s_1^{ii} + 1 - \theta\left[a - b\left(s_1^{ii} + s_{2,3}^{ii}\right)\right] = 0. \tag{A.2}$$

Condition (A.2) gives rise to standard reaction functions for two firms setting prices noncooperatively. Differently, (A.1) shows the interaction of carrier 1 with both of the other two carriers in terms of marginal cost, as the route it operates serves both connecting markets, thereby generating a cost complementarity.

The subfare equilibrium values are

$$s_1^{ii} = \frac{a(1-2b\theta) + b(1+b\theta)}{3b(1-b\theta)} \tag{A.3}$$

$$s_{2,3}^{ii} = \frac{a+b}{3b}, \tag{A.4}$$

and substituting (A.3)–(A.4) into (6) yields the uniform equilibrium traffic level:

$$Q^{ii} = Q_{12}^{ii} = Q_{13}^{ii} = \frac{a-2b}{3(1-b\theta)}, \tag{A.5}$$

where fares and quantities are positive and second-order conditions hold.[9] As noted above, because of carrier 1's pooling of traffic, cost complementarity on the CH route segment arises, making the carrier's equilibrium subfare lower than those of carriers 2 and 3 ($s_1^{ii} < s_{2,3}^{ii}$), with the gap increasing with the strength of economies of density ($\partial s_1^{ii}/\partial\theta < 0$). Finally, substituting the equilibrium subfares and quantities into the profit functions yields

$$\pi_1^{ii} = \frac{2(1-b\theta)}{b}\left(Q^{ii}\right)^2, \tag{A.6}$$

$$\pi_{2,3}^{ii} = \frac{2-b\theta}{2b}\left(Q^{ii}\right)^2, \tag{A.7}$$

where, naturally, $\pi_1^{ii} > \pi_{2,3}^{ii} > 0$.

[9] Note that $\partial^2\pi_1^{ii}/\partial\left(s_1^{ii}\right)^2 = -4b(1-b\theta) < 0$ and $\partial^2\pi_{2,3}^{ii}/\partial\left(s_{2,3}^{ii}\right)^2 = -b(2-b\theta) < 0$ under Assumption 1.

A.2. Alliance-interline

The first-order conditions $\partial\pi_{12}^{ai}/p_{12}^{ai}=0$, $\partial\pi_{12}^{ai}/s_1^{ai}=0$, and $\partial\pi_3^{ai}/\partial s_3^{ai}=0$ now yield

$$\frac{a}{b}-2p_{12}^{ai}+2-\theta\left[3a-b\left(2p_{12}^{ai}+s_1^{ai}+s_3^{ai}\right)\right]=0 \tag{A.8}$$

$$\frac{a}{b}-2s_1^{ai}-s_3^{ai}+1-\theta\left[2a-b\left(p_{12}^{ai}+s_1^{ai}+s_3^{ai}\right)\right]=0 \tag{A.9}$$

$$\frac{a}{b}-2s_3^{ai}-s_1^{ai}+1-\theta\left[a-b\left(s_1^{ai}+s_3^{ai}\right)\right]=0, \tag{A.10}$$

where (A.10) is the same as under the double-interline scenario (see (A.2)), given that carrier 3 is an outsider of the alliance and continues to set its subfare s_3^{ai} noncooperatively. By contrast, (A.8)–(A.9) show the joint determination of p_{12}^{ai} by partner carriers 1 and 2, where the coefficient 3 in condition (A.8) reflects the fact that serving the CA market requires operating two routes: (i) route CH, which is jointly used by CA and CB passengers, and (ii) route AH, specific to CA passengers. By contrast, the smaller coefficient 2 in condition (A.9) for s_1^{ai} arises because carrier 1 is not coordinating with carrier 3 in this market. It is easy to check that the second-order conditions hold.[10]

Solving (A.8)–(A.10), equilibrium values are now

$$p_{12}^{ai}=\frac{3a\left[1-b\theta(3-b\theta)\right]+2b(3-b\theta)}{bA}, \tag{A.11}$$

$$s_1^{ai}=\frac{2a\left[1-b\theta(3-b\theta)\right]+b\left[2+b\theta(2-b\theta)\right]}{bA}, \tag{A.12}$$

$$s_3^{ai}=\frac{a\left[2-b\theta(3-b\theta)\right]+b\left[2-b\theta(4-b\theta)\right]}{bA}, \tag{A.13}$$

with $A\equiv[6-b\theta(10-3b\theta)]$. Substituting (A.11)–(A.13) into (7)–(8) yields the equilibrium traffic

$$Q_{12}^{ai}=\frac{(a-2b)(3-b\theta)}{A}, \tag{A.14}$$

$$Q_{13}^{ai}=\frac{(a-2b)(2-b\theta)}{A}, \tag{A.15}$$

where fares and quantities are positive.[11] It is easy to observe that $p_{12}^{ai}<s_1^{ai}+s_3^{ai}$, meaning that the partner airlines eliminate double marginalization in market CA and set a lower overall fare than the nonaligned carriers in market CB. Consequently, traffic is higher in market CA: $Q_{12}^{ai}>Q_{13}^{ai}$. Finally, equilibrium profits are

$$\pi_{12}^{ai}=\frac{26-b\theta\left[54-5b\theta(6-b\theta)\right]}{2b(3-b\theta)^2}\left(Q_{12}^{ai}\right)^2, \tag{A.16}$$

$$\pi_3^{ai}=\frac{2-b\theta}{2b}\left(Q_{13}^{ai}\right)^2, \tag{A.17}$$

where it can be shown that $\pi_{12}^{ai}>\pi_3^{ai}>0$.[12]

[10] Under Assumption 1, $\partial^2\pi_{12}^{ai}/\partial\left(p_{12}^{ai}\right)^2=\partial^2\pi_{12}^{ai}/\partial\left(s_1^{ai}\right)^2=-2b(1-b\theta)<0$ and the remaining positivity condition on the Hessian determinant is $b^2(2-b\theta)(2-3b\theta)>0$. Note that the conditions $1-b\theta>0$ and $2-b\theta>0$ are already implied the second-order conditions for the double-interline case, and that the Hessian condition further requires $2-3b\theta>0$, or $\theta<2/(3b)$, which is thus the most stringent of all the second-order conditions, as noted in Assumption 1. This latter condition is also required in the double-alliance case, as seen below. Finally, $\partial^2\pi_3^{ai}/\partial\left(s_3^{ai}\right)^2=-b(2-b\theta)<0$ also holds.

[11] Sufficient conditions for $p_{12}^{ai}>0$ and $s_1^{ai}>0$ are $1-b\theta(3-b\theta)>0$ and $A\equiv[6-b\theta(10-3b\theta)]>0$, which hold for $\theta<\left(3-\sqrt{5}\right)/(2b)$ and $\theta<\left(5-\sqrt{7}\right)/(3b)$, respectively. These conditions are satisfied for $\theta<1/(3b)$, which is imposed in Assumption 1. Therefore, $s_3^{ai}>0$ is satisfied as well given that $2-b\theta(4-b\theta)>1-b\theta(3-b\theta)$. Finally $Q_{12}^{ai}>0$ and $Q_{13}^{ai}>0$, as $a>2b$, which is also imposed in Assumption 1.

[12] $\pi_{12}^{ai}-\pi_3^{ai}=\frac{(a-2b)^2(3-b\theta)[3-2b\theta(3-b\theta)]}{bA^2}>0$ for $3-2b\theta(3-b\theta)>0$, which holds for $\theta<\left(3-\sqrt{3}\right)/(2b)$. This condition is satisfied for $\theta<1/(3b)$, which is imposed in Assumption 1.

A.3. Double alliance

The first-order conditions $\partial\pi_{123}^{aa}/\partial p_{12}^{aa}=0$ and $\partial\pi_{123}^{aa}/\partial p_{13}^{aa}=0$ yield

$$\frac{a}{b}-2p_{12}^{aa}+2-\theta\left[3a-b\left(2p_{12}^{aa}+p_{13}^{aa}\right)\right]=0 \tag{A.18}$$

$$\frac{a}{b}-2p_{13}^{aa}+2-\theta\left[3a-b\left(2p_{13}^{aa}+p_{12}^{aa}\right)\right]=0, \tag{A.19}$$

where (A.18) and (A.19) are symmetric and naturally mirror the structure of the first-order conditions for p_{12}^{ai} under the alliance-interline scenario (see (A.8)). It is straightforward to verify that the second-order conditions hold,[13] which implies that the equilibrium values are now

$$p^{aa}=p_{12}^{aa}=p_{13}^{aa}=\frac{a(1-3b\theta)+2b}{b(2-3b\theta)} \tag{A.20}$$

and

$$Q^{aa}=Q_{12}^{aa}=Q_{13}^{aa}=\frac{a-2b}{2-3b\theta}, \tag{A.21}$$

where $p^{aa}>0$ and $Q^{aa}>0$. Finally, overall profit is

$$\pi_{123}^{aa}=\frac{(2-3b\theta)}{b}\left(Q^{aa}\right)^2. \tag{A.22}$$

Appendix B. Proofs

Proof of Proposition 1.

▶ Proof of $p_{12}^{ai}<s_1^{ii}+s_{2,3}^{ii}$ and $Q_{12}^{ai}>Q^{ii}$.

The inequalities $s_1^{ii}+s_{2,3}^{ii}-p_{12}^{ai}=\frac{(a-2b)(3-2b\theta)}{3(1-b\theta)bA}>0$ and $Q_{12}^{ai}-Q^{ii}=\frac{(a-2b)(3-2b\theta)}{3(1-b\theta)A}>0$ hold given the parametric conditions in Assumption 1.

▶ Proof of $\pi_{12}^{ai}>\pi_1^{ii}+\pi_{2,3}^{ii}$.

$\pi_{12}^{ai}-\pi_1^{ii}-\pi_{2,3}^{ii}=\frac{(a-2b)^2(18-b\theta\{54-b\theta[60-b\theta(31-6b\theta)]\})}{18b(1-b\theta)^2A^2}>0$ requires $18-b\theta\{54-b\theta[60-b\theta(31-6b\theta)]\}>0$. From Assumption 1, we know that $\theta<1/(3b)$, which can be rewritten as $b\theta<1/3$. Therefore, we can rename $b\theta\equiv x$, so that $P(x)\equiv18-x\{54-x[60-x(31-6x)]\}$, which is a quartic polynomial with positive leading coefficient that has two positive real roots. It is easy to check that $P(0)>0$, $P(1/3)>0$, and that $P(x)$ is decreasing smoothly in the interval $x\in(0,1/3)$. Therefore, $x<1/3$ guarantees that $P(x)>0$. This proves that $18-b\theta\{54-b\theta[60-b\theta(31-6b\theta)]\}>0$ for $b\theta<1/3$.

▶ Proof of $s_1^{ai}+s_3^{ai}<s_1^{ii}+s_{2,3}^{ii}$ and $Q_{13}^{ai}>Q^{ii}$.

$s_1^{ii}+s_{2,3}^{ii}-s_1^{ai}-s_3^{ai}=\frac{(a-2b)\theta}{3(1-b\theta)A}>0$ and $Q_{13}^{ai}-Q^{ii}=\frac{(a-2b)b\theta}{3(1-b\theta)A}>0$ given the parametric conditions imposed in Assumption 1.

▶ Proof of $\pi_3^{ai}>\pi_{2,3}^{ii}$.

The inequality $\pi_3^{ai}-\pi_{2,3}^{ii}=\frac{(a-2b)^2(2-b\theta)\theta[12-b\theta(19-6b\theta)]}{18(1-b\theta)^2A^2}>0$ requires $12-b\theta(19-6b\theta)>0$, which holds for $\theta<\left(19-\sqrt{73}\right)/(12b)$. This condition is satisfied for $\theta<1/(3b)$, which is imposed in Assumption 1. ■

Proof of Proposition 2.

▶ Proof of $p^{aa}<s_1^{ai}+s_3^{ai}$ and $Q^{aa}>Q_{13}^{ai}$.

$s_1^{ai}+s_3^{ai}-p^{aa}=\frac{2(a-2b)(1-b\theta)}{(2-3b\theta)bA}>0$ and $Q^{aa}-Q_{13}^{ai}=\frac{2(a-2b)(1-b\theta)}{(2-3b\theta)A}>0$ hold under Assumption 1.

▶ Proof of $\pi_{123}^{aa}>\pi_{12}^{ai}+\pi_3^{ai}$.

$\pi_{123}^{aa}-\pi_{12}^{ai}-\pi_3^{ai}=\frac{(a-2b)^2(54-b\theta\{189-b\theta[223-5b\theta(20-3b\theta)]\})}{(2-3b\theta)bA^2}>0$ requires $54-b\theta\{189-b\theta[223-5b\theta(20-3b\theta)]\}>0$. From Assumption 1, we know that $\theta<1/(3b)$, which can be rewritten as $b\theta<1/3$. Therefore, with $b\theta\equiv x$, $P(x)\equiv54-x\{189-x[223-5x(20-3x)]\}$, which is a quartic polynomial with positive leading coefficient that has two positive real roots that are, approximately, 2.4 and 2.8. Since $P(0)>0$

[13] Under Assumption 1, $\partial^2\pi_{123}^{aa}/\partial\left(p_{12}^{aa}\right)^2=\partial^2\pi_{123}^{aa}/\partial\left(p_{13}^{aa}\right)^2=-2b(1-b\theta)<0$ and the remaining positivity condition on the Hessian determinant is $b^2(2-b\theta)(2-3b\theta)>0$, which also holds.

and $P(1/3) > 0$, it follows that $P(x) > 0$ for $x \in (0, 1/3)$, proving that $54 - b\theta\{189 - b\theta[223 - 5b\theta(20 - 3b\theta)]\} > 0$ for $b\theta < 1/3$.

▶ Proof of $p^{aa} < p^{ai}_{12}$ and $Q^{aa} > Q^{ai}_{12}$.

$p^{ai}_{12} - p^{aa} = \frac{(a-2b)\theta}{(2-3b\theta)A} > 0$ and $Q^{aa} - Q^{ai}_{12} = \frac{(a-2b)b\theta}{(2-3b\theta)A} > 0$ hold under Assumption 1. ■

Data availability

No data was used for the research described in the article.

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