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Abstract

Firms not only create formal groupings in a multilateral fashion (explicit alliance constellations) but also engage in informal networks comprised of firms that have more bilateral ties to one another than to firms outside their group (implicit constellations). Using data from global airlines, we find that explicit constellations tend to grow by luring firms holding diverse resources and that are associated with key members through an implicit group. Explicit associations also tend to exhibit more inertia than implicit ones.

Keywords

Constellations, strategic alliances, networks, cooperative strategy, airline industry

Constellations are alliances among multiple autonomous firms, such that these groups compete against each other in the same or similar industries for both clients and members (Gomes-Casseres, 1994). Evidence on the formation of such groups pervades the literature, including industries as diverse as computer and microprocessors (Axelrod, Mitchell, Thomas, Bennett, & Bruderer, 1995; Hwang & Burgers, 1997; Vanhaverbeke & Noorderhaven, 2001), telecommunications (Joshi, Kashlak, & Sherman, 1998), financial services (Domowitz, 1995), automobiles (Burgers, Hill, & Kim, 1993; Garcia-Point & Nohria, 2002; Nohria & Garcia-Pont, 1991) and global airlines, the focus of this study (Hanlon, 1999; ter Kuile, 1997). Constellations differ from simple bilateral, dyadic alliances because they are a "collection of several alliances" among players in a certain industry (Das & Teng, 2002: 446). In contrast, bilateral alliances tend to involve agreements that are narrowed to a particular domain (such as a codesharing agreement between two airlines). Being more comprehensive, constellations generally define patterns of competition where rivalry shifts, to some degree, from firms to groups of firms (Gomes-Casseres, 1994). Thus, decisions to form constellations are likely to have profound strategic implications, as a firm's performance may crucially depend on which group it chooses to join (Gomes-Casseres, 1996; Gulati, 1998).

Despite the pervasiveness of constellations in several industries, we know relatively little about how these groups emerge because past research has focused on the formation of dyadic ties among firms (e.g. Chung & Singh, 2000; Gulati, 1995b; Gulati & Gargiulo, 1999; Li & Rowley, 2002; Martin & Park, 2002; Stuart, 1998). Although some studies do analyze constellations (Burgers et al., 1993; Nohria & Garcia-Pont, 1991; Vanhaverbeke & Noorderhaven, 2001; Walker, 1988), they do not examine in detail the determinants of group formation and the dynamics of the process. In this study, we make an initial attempt to examine these issues, using data from 75 global airlines and their alliances. The airline industry has witnessed a surge in alliances between carriers, in part because regulatory barriers prevent access to global resources and markets through the outright acquisition of domestic airport facilities or carriers (e.g. Hanlon, 1999; Oum & Yu, 1998). Thus, alliances become a crucial mechanism for carriers to internalize interfirm externalities in the form of international traffic flows (Oum & Yu, 1998; Park & Zhang, 2000; Park & Martin, 2001). Besides simple bilateral ties (such as codesharing and marketing agreements), in the mid 1990s carriers began to form groupings of firms competing for traffic, some of them associated with brand names (Star Alliance, Oneworld, SkyTeam, etc.). Estimates indicate that these groupings contributed to almost 60% of the global air traffic in 2001, representing 203.3 billion dollars in revenues (Baker, 2001). Thus, although focusing on the airline industry may prevent the generalization of our results to other contexts, it nonetheless provides a rich setting to test initial hypotheses related to the formation and evolution of constellations.

CONSTELLATIONS: EXPLICIT AND IMPLICIT

We are particularly interested in studying the co-evolution of two types of constellations: explicit and implicit (Lazzarini, 2002). *Explicit* constellations involve formal, publicly known agreements with a multilateral fashion in that such agreements tend to be broad and general (i.e., applied to all members). These formal constellations are also publicly known; in most cases, they are even associated with brand names, and their members constitute separate entities and committees to manage the affairs of the group. In the airline industry, explicit constellations have emerged especially in the mid 1990s, including the Star Alliance (with United Airlines, Lufthansa, SAS, etc.), Oneworld (with American Airlines, British Airways, Quantas, etc.), Sky Team (with Delta Airlines, Air France, etc.), among others. Coalitions of international financial exchanges (Domowitz, 1995) and formal R&D consortia (Axelrod et al., 1995; Hwang & Burgers, 1997; Vanhaverbeke & Noorderhaven, 2001) are also examples of explicit constellations.

Implicit constellations, by contrast, are informal groupings "implied" from the structure of bilateral agreements between firms, in such a way that members have relatively more bilateral ties to one another than to firms outside the constellation (Nohria & Garcia-Pont, 1991). In some cases, implicit constellations may also be "expanded" versions of explicit constellations in that they may include firms directly or indirectly tied to key (not necessarily all) members of the latter. Supposing that interfirm linkages are conduits of knowledge and exchange opportunities, the configuration of ties describing an implicit constellation implies that a firm will more likely benefit from the externalities emanating from the members of the constellation—for instance, access to certain consumer markets or technologies—than from other actors. Using clustering algorithms, researchers have revealed such informal groupings of firms in industries such as automobiles (Burgers et al., 1993; Nohria & Garcia-Pont, 1991) and microprocessors (Vanhaverbeke & Noorderhaven, 2001).

In the airline industry, there is evidence that implicit airline constellations have existed before the emergence of explicit groups and in most cases appear to be expanded coalitions with explicit constellations as their core group. Consider Figure 1 as an example. The figure depicts a subset of firms in our sample, directly or indirectly associated with the Star Alliance (explicit) constellation in early 2000. The thin lines represent bilateral ties—either alliances or equity stakes between two carriers. The thick, dashed circle includes members of the Star Alliance in that period. We see that some carriers that were not formal members of the explicit group were, to some extent, connected with some formal members. For instance, British Midland Airways (bmi) had bilateral ties with Air Canada, Air New Zealand, Austrian Airlines, Lufthansa, SAS, and United Airlines but was not a member of the Star Alliance until July 2000, when the carrier joined the explicit constellation. Other carriers, such as Emirates, Malaysia Airlines, South African Airways and Virgin Atlantic, were non-members but held bilateral ties with members of the group. This expanded group including both members of the explicit constellation and non-members suggests the existence of an implicit constellation.

<Figure 1 around here>

Several questions emerge in this context. What determines the formation of explicit and implicit constellations and their co-evolution? Does the bmi case discussed before generalize to other cases, i.e., is the expansion of explicit constellations based on the inclusion of firms that were previously associated with members through an implicit constellation? In other words, do implicit associations between firms tend to become more "formalized" over time? Or, alternatively, does the formation of explicit constellations set the stage for a reorganization of bilateral ties among firms such that the configuration of implicit constellations will change? These are some of the research questions that we attempt to tackle in this study.

HYPOTHESES

A common finding of the literature on alliances is that firms have to select in the future partners with whom they have transacted in the past (e.g. Gulati, 1995b; Gulati & Gargiulo, 1999; Li & Rowley, 2002; Martin & Park, 2002; Stuart, 1998). Through repeated interaction, firms develop shared norms and trust, thereby prompting the continuity of the relationship (e.g. Gulati, 1995a; Macneil, 1980; Ring & Van de Ven, 1994). Firms may also have a tendency to persist in a certain course of action, and hence maintain their association, due to the development of joint routines and common investments in non-redeployable assets (Blau, 1964; Levinthal & Fichman, 1988; Levinthal & March, 1993). Therefore, alliances tend to exhibit *inertia*: in a network of agents, similar sets of partners are expected to keep their relationship in the future.

We are particularly interested in how this effect may differ between explicit and implicit constellations. Recall that explicit constellations involve multilateral agreements that jointly formalize the association of the whole network of firms, and in some cases are even associated with joint non-redeployable investments in brand name, common administrative structures, and information technology. In contrast, implicit constellations are informal groupings whose composition is basically defined by the configuration of bilateral ties. Differently from explicit constellations, no formalization or specific investment for the group *as a whole* is involved in implicit constellations. Thus, although implicit constellations may exhibit inertia due to the costs to reorganize bilateral ties, inertia will tend to be even stronger in explicit groups because of overarching contractual commitments and joint non-redeployable investments, which substantially increase exit costs. In other words:

Hypothesis 1. The tendency of firms to stay in the same constellation over time will be stronger for explicit constellations than implicit ones.

We are also interested in analyzing the *co-evolution* of explicit and implicit constellations. On the one hand, membership in the same implicit constellation may turn into membership in the same explicit constellation. We noted earlier that implicit constellations in some cases simply represent expanded versions of explicit constellations. Thus, expanding the explicit group by attracting a member of its corresponding implicit constellation—as the bmi case discussed before—will tend to economize on search costs and allow partners to build upon existing bilateral arrangements. Furthermore, implicit constellations may be precursors of explicit groups, i.e., they may become increasingly formalized over time. This formalization has several advantages. First, the creation of standardized exchange procedures in explicit groups tends to increase compatibility across members' production and marketing systems, thereby enhancing their ability to capture market or technological externalities (Schilling & Steensma, 2001; Thompson, 1967). Second, the existence of formal boards and committees in explicit constellations facilitates control and improves collective decision-making (Farrell & Saloner, 1988). Finally, the formalization of interfirm associations and the creation of brand names bring legitimization and visibility to the group, which helps to attract not only new customers but also supporting actors such as suppliers and investors (Human & Provan, 2000; Katz & Shapiro, 1994). Therefore:

Hypothesis 2a. Firms belonging to the same implicit constellation in the past will likely belong to the same explicit constellation in the future.

On the other hand, common membership in an explicit constellation may turn into common membership in an implicit constellation. Some explicit groups may create exclusivity agreements aimed at reducing the externalities that a member may generate, via bilateral ties, to firms that do not belong to the group. Also, pursuing joint action with constellation members while maintaining extensive outside ties will likely reduce a firm's commitment to the constellation and destabilize the group (Jones, Hesterly, Fladmoe-Lindquist, & Borgatti, 1998).

Moreover, because explicit constellations increase firms' joint action through committees and other governance mechanisms, interfirm contact is likely to increase (McPherson, 1982) and lead to mutual agreements, via bilateral ties, that extend the activities of the explicit group. As a result, the nexus of bilateral agreements between a set of firms describing an implicit constellation may complement general agreements established by those firms in their explicit constellation. This suggests that, over time, firms will likely reorganize their bilateral association in a pattern that follows their collective linkage through the explicit group. Thus:

> Hypothesis 2b. Firms belonging to the same explicit constellation in the past will likely belong to the same implicit constellation in the future.

Our last hypothesis attempts to predict how the *resource profile* of firms will influence the emergence of explicit and implicit constellations. The possibility of capturing interfirm externalities increases when members hold complementary resources, i.e., when the use of a resource increases when it is jointly used with other resources supplied by partners. This tends to occur when firms have specialized roles and hence contribute to the constellation with *diverse* resources that can be combined with one another (Grandori & Soda, 1995; Richardson, 1972; Teece, 1992). For instance, an airline carrier can capture traffic from other carriers servicing alternative routes. Since international regulations prevent a carrier from owning foreign infrastructure, that carrier can complement its route network by partnering with firms controlling alternative hubs (and their associated routes), thereby pooling traffic emanating from different regions. This suggests that constellations will tend to be formed by firms holding diverse, complementary resources (Gomes-Casseres, 1994). But it is also possible to propose otherwise. Proximity and similarity of resource endowments facilitate interfirm monitoring, sharing of experiences, and the pursuit of common goals (Caves & Porter, 1977; Darr & Kurtzberg, 2000; Gnyawali & Madhavan, 2001; Kraatz, 1998). For example, a group of airline carriers will more easily coordinate their activities if their hubs are geographically close to one another and if they have experience with similar routes. Thus, although resource diversity increases the extent of interfirm externalities available to members, it also makes the internalization of these spillovers more difficult.

We propose that the net effect of resource diversity will depend on whether the constellation is explicit or implicit. As noted before, explicit constellations often involve formal agreements and decision-making entities such as boards and committees, which improve control and integration of activities. In contrast, joint action in implicit constellations is to a large extent tacit and even unconscious, as a firm may benefit from the externalities generated by other actors to which it is not directly linked through a bilateral agreement. Thus, increasing resource diversity in explicit constellations will not substantially tax the ability of the group to coordinate its activities because existing formal coordination mechanisms will ameliorate the difficulty in articulating dissimilar resource endowments. Since implicit constellations lack these formal mechanisms, resource diversity will undermine interfirm coordination to a larger extent than in explicit groups. Consequently, other things being equal, explicit constellations should support a higher level of resource diversity than implicit constellations. In other words:

> Hypothesis 3. Resource diversity will influence to a larger degree the formation of an explicit constellation involving a group of firms than the formation of an implicit constellation with the same firms.

DATA AND METHODS

Data

Our sample includes 75 global airlines representing about 81% of the total world passenger traffic in 2000 and 54 distinct countries (Table 1), observed from 1995 to 2000. The data come mostly from the *World Air Transport Statistics* compiled by the International Air Transport Association (IATA), which provides information on airlines' operations, and the *Airline Business* magazine, which presents annual surveys of bilateral alliances and equity stakes between carriers, as well as the composition of explicit constellations in the industry.[1]

<Table 1 around here>

Although the composition of explicit constellations is easily obtained through public sources, the composition of implicit groups is more difficult to retrieve and requires specific methods. Following previous work (Nohria & Garcia-Pont, 1991; Vanhaverbeke & Noorderhaven, 2001; Walker, 1988), we adopt a clustering approach to demarcating the boundaries of implicit constellations, based on the matrix of bilateral ties among carriers in the sample. We employ a clustering algorithm based on *tabu search* optimization (Glover, 1989), available in the software *UCINET 5.0* (Borgatti, Everett, & Freeman, 1999), which maximizes a "fit" function based on the average "proximity" of group members defined in terms of the existence of bilateral ties to one another, given a pre-specified number of groups or partitions. Thus, the algorithm has a clear rule for optimizing the composition of groups, which is somewhat obscure in other clustering methods (Lawless & Anderson, 1996). Another advantage of this algorithm is that it finds groups given a certain pre-specified number of partitions, independent of the clustering configurations found with fewer partitions.[2] To create a matrix of interfirm linkages, we simply consider that there is a linkage between two firms (coded 1) when they have either a bilateral alliance or an ownership relation (i.e., when at least one of the carriers has an equity stake in the other carrier). Otherwise, we consider that there is no linkage (coded 0). Such a matrix is constructed for every year in the sample.[3]

A critical decision in clustering algorithms is to define an "ideal" number of partitions, which in our case corresponds to the number of implicit constellations to be found. We choose 5 partitions mainly because, in the last year of the sample (2000), there were 5 explicit constellations in place. Since we suggested before that implicit constellations may be either precursors of explicit groups or "expanded" versions of such groups, it is natural to find a clustering pattern that has some correspondence to the configuration of explicit constellations. Another reason is that transatlantic routes between Europe and the United States are considered a key target for the formation of global airline alliances. In this sense, we can assume that the major U.S. carriers will be central players in each group. In our sample, 4 U.S. carriers can be considered key international players: American Airlines, Delta, Northwest Airlines, and United

Airlines, thus suggesting at least 4 constellations. Adding an apparent cluster of European carriers formerly led by Swissair results in 5 groupings.

The composition of implicit and explicit groups analyzed in this study is shown in Tables 2 and 3 respectively. Table 4, in particular, presents results from the cluster analysis. A way to judge the results is through an analysis of density tables for each year: diagonal entries represent the density of bilateral ties among firms within each group (i.e., the total number of observed ties divided by the total number of ties that could be possibly formed), whereas off-diagonal entries represent the density of bilateral ties among firms belonging to different groups. Since diagonal values are always higher than off-diagonal values, there is an indication that the algorithm employed here is capturing the operational definition of an implicit constellation as a cluster of firms that have more extensive ties to one another than to firms outside the group.

<Tables 2 and 3 around here>

Dependent variable

A natural way to model firms' decision to join a particular constellation would be to use a multiple-choice model (such as the multinomial logit) to describe which group a certain firm chooses. In this case, we could create a set of dependent variables coding the participation of firms in each group. This approach is problematic, however, because the set of choices available to firms is not fixed, and hence violates the assumption of multiple-choice models that the categories of choice are exogenous (Maddala, 1983). Instead, constellations are continuously formed every year, and firms may endogenously choose to ally and form new groups.

Thus, instead of describing which group firms choose, we must model which firms decide to associate with one another in the same constellation. But this approach can become cumbersome if we consider all possible coalitions that firms can create. Thus, N firms can create associations involving two, three, four or more actors, including the grand coalition with N members. To simplify the analysis, we evaluate instead constellation membership in a pair-wise way. Namely, we describe whether *two* carriers from the sample were observed in the same implicit or explicit constellation in a given year. Notice, therefore, that carriers can be associated in three different ways: they can belong to the same implicit constellation, they can belong to the same explicit constellation, or they can be bilaterally tied to one another. These alternatives are not mutually exclusive. Please refer again to Figure 1. Although bmi was not a member of any explicit group in early 2000, that carrier was part of the same implicit constellation involving several members of the Star Alliance (as retrieved by the clustering algorithm discussed above). Also, Virgin and South African Airways were members of the same implicit constellation but were not bilaterally tied; instead, they were indirectly associated through bmi. Finally, although Varig and Mexicana were members of the same explicit group (Star Alliance), no bilateral tie involving these two carriers was observed.

We therefore create two dependent variables to track a carrier's membership in implicit and explicit constellations: IC_{ijt}, coded 1 if carriers i and j belong to the same implicit constellation at year t and 0 otherwise; and EC_{ijt}, coded 1 if carriers i and j belong to the same explicit constellation at year t and 0 otherwise.

Explanatory variables

Past membership in constellations. We use variables IC_{ijt-1} and EC_{ijt-1} to track a firm's past membership in implicit and explicit constellations. These variables are simply the values of IC_{ijt} and EC_{ijt} respectively, lagged one year for the observation period, and are employed to test Hypotheses 1, 2a and 2b.

Resource diversity. To test Hypothesis 3, we create two variables measuring the resource diversity of carries associated in a constellation. We first define the international positioning of a carrier as the ratio of the traffic (RPK) emanating from international passenger flows to the total traffic of that carrier. We then create the variable $DIVINT_{ijt}$, which is the ratio of the largest to the smallest international positioning score of firms i and j at year t. The idea behind the use of this variable is that resource diversity in airline constellations depends on whether some members specialize in small, domestic markets, while other members specialize in large markets with a broad range of international routes. Thus, Clougherty (2002) shows that a large domestic network can improve a carrier's competitive position in international markets.

We also use the variable $DIST_{ij}$, which is simply the distance in kilometers between the main hubs of firms i and j. The main hub of a carrier is defined as the city that, for that particular carrier, shows the largest number of departing connections as evidenced by the *Traffic by Flight Stage* database, compiled by the International Civil Aviation Organization (ICAO). We justify the use of this variable because diversity regarding alternative routes offered to consumers will tend to be greatest when members are positioned in distant cities, which expands the possibilities for connections. By contrast, similar or proximate hubs will more likely be substitutes than complements.

To accommodate possible non-linear effects, we use the logarithm of these resource diversity variables in our regressions.

Control variables

Past bilateral ties. Existing bilateral associations between carriers can probably influence the dynamics of the formation of implicit and explicit constellations. For instance, existing members of an explicit group may attempt to lure new firms to which they have bilateral ties (Gomes-Casseres, 1996: 66). We therefore create the variable $DIRT_{ijt-1,}$ coded 1 if companies i and j were associated through a bilateral alliance or ownership relation at year t-1, and 0 otherwise. But *indirect* bilateral associations may also matter (Gulati, 1995b; Gulati & Gargiulo, 1999). Thus, two carriers not connected with one another but bilaterally associated with the same partner may become members of the same implicit or explicit constellation. In this sense, we also create the variable $INDIRT_{ijt-1}$, coded 1 if companies i and j were bilaterally associated with at least one common partner at year t-1, and 0 otherwise.

Number of explicit constellations. As explicit constellations are formed, they may become progressively institutionalized as new, legitimate organizational forms in the industry (Garcia-Point & Nohria, 2002; Gulati & Gargiulo, 1999; Hannan & Freeman, 1989). Customers, suppliers and carriers themselves may become progressively aware of the benefits derived from explicit groups—common frequently flyer programs, joint services, shared operations, and so on. Thus, the formation of explicit constellations will tend to be reinforced by the number of constellations already in place. To control for this effect, we add the variable $ECTOT_{t-1}$, which corresponds to the number of explicit alliances observed in the previous year of analysis. In the regressions we use the logarithm of this variable to capture possible non-linear effects.

Size. To control for differences in size or capacity between firms, we create the variable CAP_{ijt}, which is the ratio of the passenger available seat capacity (ASK) of both companies (greater to lesser value) at year t (e.g. Gulati & Gargiulo, 1999). We again use the logarithm of this variable in the regressions.

Year-specific controls. Finally, we create a set of dummy variables representing each year in the observation window, denoted as YEAR(t), in order to control for temporal effects such as variations in economic and regulatory conditions over time, as well as trends in the pattern of interfirm alliances.

Table 4 presents the description of all variables used in this study. An inspection of the correlation coefficients of the variables (Table 5) shows no possible problem of collinearity.

<Tables 4 and 5 around here>

Method

Since we have two dichotomous dependent variables coding joint membership in explicit and implicit constellations, we could run two separate binary choice models (e.g., probit or logit) to test our hypotheses. The problem of running these regressions separately, however, is that choices are likely influenced by unobserved factors that jointly affect membership decisions in explicit and implicit groups. For instance, two carriers may create particular agreements, which we do not observe, that simultaneously induce them to join the same explicit constellation and promote a reorganization of existing bilateral ties, in such a way that they will also become members of the same implicit group. We thus employ the *bivarate probit* model (Greene, 2000), which simultaneously estimates two regressions with related dichotomous variables and hence accounts for a possible correlation between stochastic factors affecting both choices. More formally, the model is specified as follows:

$y_{ijt}^{E} = x_{ijt}\beta^{E} + \varepsilon_{ijt}^{E}$

$y_{ijt}^{I} = x_{ijt}\beta^{I} + \varepsilon_{ijt}^{I}$

where $EC_{ijt} = 1$ (i.e., carriers i and j belong to the same explicit group at year t) if $y_{ijt}^{E} > 0$ and 0 otherwise; $IC_{ijt} = 1$ (i.e., carriers i and j belong to the same implicit group) if $y_{ijt}^{I} > 0$ and 0 otherwise; x_{ijt} is a vector of covariates; β^{E} and β^{I} are parameter vectors to be estimated; ε_{ijt}^{E} and ε_{ijt}^{I} are stochastic terms jointly distributed according to a bivariate normal with correlation ρ. Since partnering choices are observed through several years, we compute robust standard errors clustered on each carrier-pair.[4]

RESULTS AND DISCUSSION

Table 6 presents estimates from bivariate probit regressions. Model (1) reports results with control variables only, and model (2) adds the set explanatory variables to test our hypotheses. A Wald test indicates that explanatory variables significantly improve the fit of the regression ($\chi^2 = 1279.99$, $p < 0.01$). In all cases, the estimate of ρ is significantly different from zero, thus suggesting that the bivariate probit model is warranted: unobserved factors involved in carriers' choice of explicit and implicit groups induce a correlation of the error terms in the regressions ($p < .01$). Another way to assess this is to compare the bivariate probit results with the results obtained by running two independent probit models. Again, a Wald test comparing the relative fit of these alternative specifications favors the bivariate probit model ($\chi^2 = 19.06$ and 27.82 for models (1) and (2) respectively, both with $p < .01$).

<Table 6 around here>

Before turning to the test of our hypotheses, we provide some brief comments on the control variables, which provide themselves an interesting set of results. The significantly positive coefficients of $DIRT_{ijt-1}$ and $INDIRT_{ijt-1}$ indicate that, in our sample, carries holding past bilateral ties to one another or indirect associations through a common partner are more likely to become members of the same explicit or implicit group ($p < .01$). This supports the idea that firms tend to form multiple party associations based on actors to which they are already tied in a bilateral way.

The variable Ln($ECTOT_{t-1}$), in turn, shows different signs depending on whether the constellation is implicit or explicit. Consistent with the institutionalization view of the adoption of new organizational forms, an increase in the number of explicit constellations formed in the previous year significantly increases the likelihood that two carriers will become members of the same explicit group ($p < .01$). The proliferation of explicit groups, however, reduces the likelihood that two carriers will become members of the same implicit group in the future ($p < .01$). This result is difficult to explain. Perhaps Ln($ECTOT_{t-1}$) is simply capturing some time trend in the evolution of implicit constellations. It appears from Table 2 that in the last periods there is a lower concentration of carriers into a single implicit group, thus reducing the likelihood that *any* two carriers will be observed in the same partition. For instance, while in 1995 there was a single major group with 17 carriers (group 2), in 2000 we observe two major groups with 17 carriers each (groups 2 and 4).

The coefficient of the final control variable, Ln(CAP_{ijt}), reveals that carries with larger differences in size (capacity) are significantly more likely to ally through an explicit or implicit constellation. Possibly, carriers with equally large capacities may view themselves more as competitors than possible partners, and carriers with equally small capacities may not have sufficient scale to warrant membership in constellations whose operations have a global reach.

We now discuss the results for explanatory variables, introduced in model (2). Hypothesis 1 can be tested in our model by comparing the coefficients of EC_{ijt-1} and IC_{ijt-1}, which code past membership in explicit and implicit constellations respectively. Since the coefficient of EC_{ijt-1} is positively significant in the regression for explicit constellations and the coefficient of IC_{ijt-1} is positively significant in the regression for implicit constellations ($p < .01$), there is evidence of inertia: carriers tend to stay in the same constellation over time. Moreover, the coefficient of EC_{ijt-1} in the regression for explicit constellations is significantly larger in magnitude than the coefficient of IC_{ijt-1} in the regression for implicit constellations ($\chi^2 = 131.02$, $p < .01$). This supports Hypothesis 1: inertia tends to be stronger in explicit constellations than in implicit ones, probably because explicit constellations involve mutual investments in non-redeployable assets and overarching contractual commitments.

Hypotheses 2a and 2b deliver predictions about the co-evolution of implicit and explicit constellations. Support for Hypothesis 2a requires that the coefficient of IC_{ijt-1} should be positive in the regression for explicit constellations. This what we observe in the data: past membership in the same implicit constellation significantly leads to future membership in the same explicit constellation ($p < .01$). Hypothesis 2b, in turn, predicts that the coefficient of EC_{ijt-1} should be positive in the regression for implicit constellations. This hypothesis is rejected: past membership in the same explicit constellation does not significantly lead to future membership in the same implicit constellation.

These results confirm that implicit constellations may be "precursors" of explicit groups, but reject the idea that membership in the same explicit constellation will tend to promote a reorganization of firms' bilateral ties such as they will tend to become members of the same implicit group. A possible explanation is that members of an explicit group tend to focus on areas of overlapping strategic interest—for instance, transatlantic routes and their continental legs—and leave other activities to bilateral ties that are independently managed by firms according to their local conditions and strategies. In other words, forming an explicit group does not preclude carriers from partnering with a different set of firms via an implicit constellation. However, members of an implicit constellation will in the future likely become members of the explicit constellation to which their major partners belong. Note, in particular, that we observe this result even after controlling for past direct and indirect bilateral ties between carriers. Thus, carriers most likely to be members of the same explicit constellation are not only those with direct or indirect bilateral ties, but also those associated with the same group of firms that have more ties to one another than to other firms in the industry—i.e., carriers that belong to the same implicit constellation.

Finally, Hypothesis 3 predicts that the formation of explicit constellations should be more strongly influenced by the resource diversity of partners than the formation of implicit constellations. We can test this hypothesis by assessing the coefficient of our two proxies for resource diversity, the difference in international positioning of partners ($Ln(DIVINT_{ijt})$) and the distance between their main hubs ($Ln(DIST_{ijt})$). The coefficient of $Ln(DIVINT_{ijt})$ is significantly positive in the regression of explicit constellations ($p < .05$), but is significantly negative in the regression for implicit constellations ($p < .01$). This supports Hypothesis 3 in a stronger way than what we predicted: resource diversity not only influences to a larger degree the formation of explicit constellations, but is also *negatively* associated with the formation of implicit constellations. As for $Ln(DIVINT_{ijt})$, the coefficient of this variable is insignificant in the regression for explicit constellations but is negatively significant in the regression for implicit groups ($p < .01$). Thus, Hypothesis 3 is rejected when we take the distance between partners' main hubs as a measure of resource diversity. However, this result confirms that resource similarity plays a role in the formation of implicit constellations. Apparently, this reflects the tradeoffs involved in exploiting resource diversity. While diversity increases the externalities that constellation members can potentially internalize, this internalization is particularly difficult if the alliance does not have formal agreements and coordinating entities—which are available in explicit constellations but absent in implicit ones.

Thus, while partners with diverse resources are more likely to become members of the same explicit group, partners with similar resources are more likely to become members of the same implicit group. This suggests an interesting dynamics for the co-evolution of implicit and explicit groups. Explicit constellations may expand by incorporating firms holding diverse resources and that are more bilaterally associated with key members of the explicit group than to other firms in the industry. At the same time, members of an explicit group may create implicit associations with partners holding resources that are similar to their own resources, thereby creating a cluster of firms adjacent to the explicit constellation. Once formed, the explicit group will exhibit inertia: members will tend to stay together for some time, at least longer than implicit interfirm associations.

CONCLUDING REMARKS

This study contributes to the literature on the formation of interfirm alliances by moving beyond the focus on bilateral ties and assessing how alliances between multiple partners, commonly referred to as constellations, emerge over time. Using data from the global airline industry, we make an initial attempt to illuminate this issue. Airline carriers not only create formal groupings in a multilateral fashion—which we call explicit constellations—but also engage in a web of bilateral ties configuring alternative groups of firms that have more bilateral ties to one another than to firms outside their group—which we call implicit constellations.

We find that explicit and implicit constellations co-evolve in an interesting way. Explicit constellations tend to grow by luring firms that are associated with key members through an implicit group. Thus, apparently implicit constellations are precursors of explicit groups: they tend to be progressively formalized over time. However, explicit constellations more likely expand by attracting firms holding resources that are dissimilar to the resources of other members. And once explicit associations are formed, they tend to persist more over time than implicit groups, possibly due to the larger non-redeployable investments and contractual commitments required for their formation.

We note, however, that this is an exploratory study with important limitations. The airline industry presents many particularities that prevent a generalization of our results to other contexts. For instance, the international traffic in the industry is heavily regulated, which certainly influences alliance decisions. Also, the industry has witnessed an expansion in bilateral ties and constellations that may be unparalleled in other contexts. Nonetheless, we believe that our study can potentially guide future research in other industries. Consider, for instance, the microprocessor industry. Firms have not only established clusters of bilateral alliances (involving, for instance, technology licensing and marketing), but also formal consortiums for R&D and production (Axelrod et al., 1995; Hwang & Burgers, 1997; Vanhaverbeke & Noorderhaven, 2001). Similarly to the present study, one could track how these informal and formal interfirm associations change over time and try to find proxies for resource diversity to test the hypotheses suggested here.

We should also point out that although the composition of explicit groups is easily observable through public sources, the analysis of implicit constellations crucially depends on the quantitative method employed to split firms into groups. Although the tabu search optimization algorithm employed here is an improvement over usual methods such as hierarchical clustering, it still requires restrictive assumptions about interfirm linkages—for instance, what is the “ideal” number of partitions to be found. Further research on alternative methods to retrieve implicit constellations based on the network of bilateral ties between firms is crucial to improve our understanding on how formal and informal networks change and co-evolve.

[1] We assume that a carrier is a member of an explicit constellation in a given year if it announced its association to the group in the first half of that year, i.e., between January and June. If an explicit constellation is dissolved in a given year, we assume that the group is in place in that year if the termination occurs in the second half of that year.

[2] Conventional hierarchical clustering algorithms, in contrast, present the undesirable property that a partition "made at one of the early stages of the analysis cannot be undone at a later stage" (Wasserman & Faust, 1994: 385). The hierarchical clustering algorithm *CONCOR* has still another major drawback: it promotes successive splits of existing sets in exactly two new subsets. These criteria may not be an actual feature of the data in hand (Wasserman & Faust, 1994: 380).

[3] In some cases, the clustering algorithm groups together some carriers that do not have direct ties, or that show only pair-wise, isolated ties. These carriers probably have a pattern of bilateral ties that do not allow for their classification in any group. Thus, we consider that they do not belong to any implicit group. For more detailed information on the clustering procedure adopted here, see Lazzarini (2002).

[4] Since the data have a panel structure, the bivariate probit model may yield biased results since it does not account for within-pair correlation of the error terms. Random-effects regressions for explicit and implicit constellations, however, yield identical results (not reported here).

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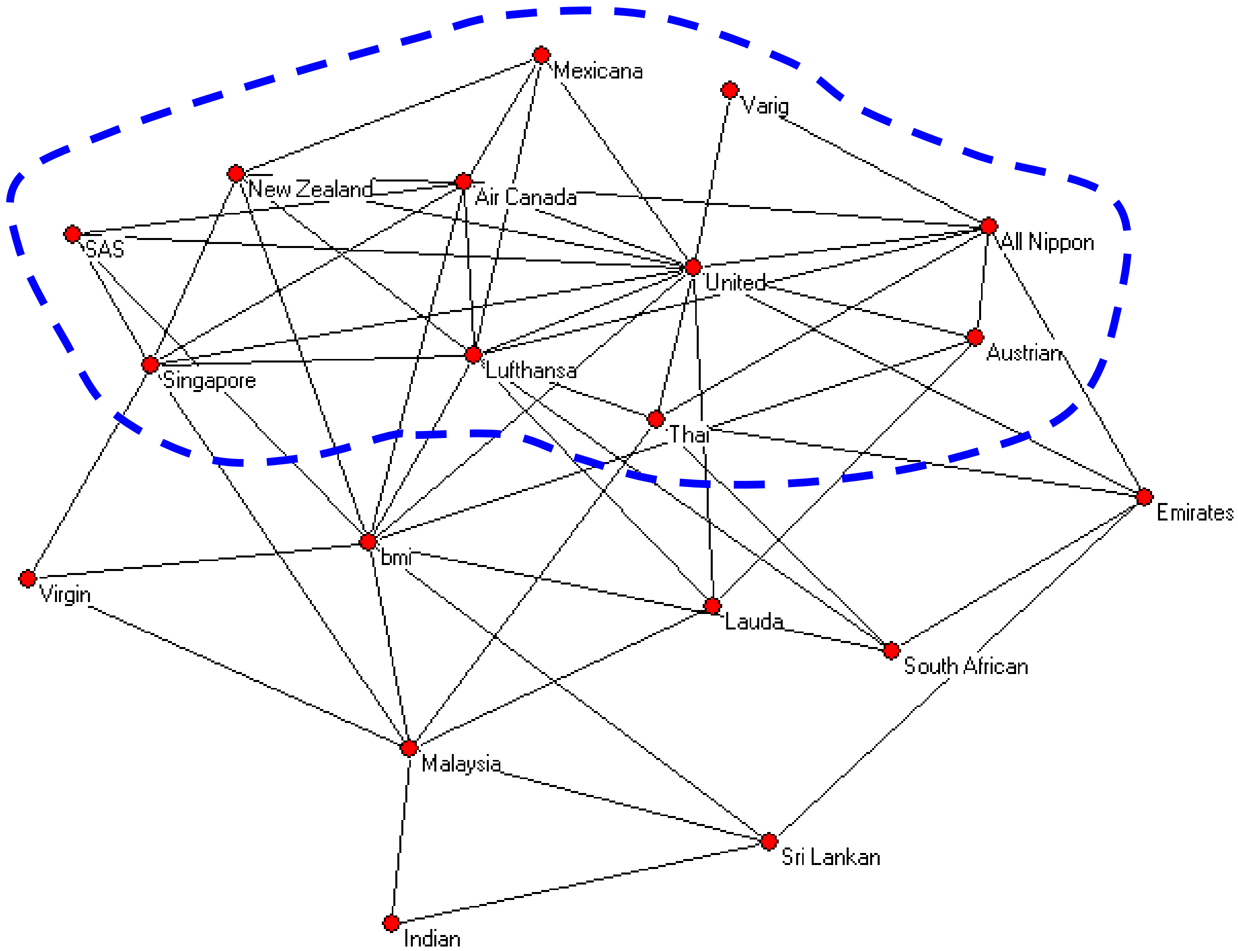

FIGURE 1
Network of airline carriers comprising the "Star Alliance" constellation in early 2000 (the dashed circle) and carriers that are associated through bilateral ties (the thin lines, representing either bilateral alliances or equity stakes)

TABLE 1
Airline carriers included in the sample

Carrier name (abbreviation)	Traffic*	Country	Carrier name (abbreviation)	Traffic*	Country
Aer Lingus (LIN)	8.889	Ireland	Japan Air System (JAS)	15.472	Japan
Aeroflot (AFL)	16.557	Russia	Japan Airlines (JA)	88.999	Japan
Aerolineas Argentinas (ARG)	11.111	Argentina	KLM Royal Dutch Airl. (KLM)	60.331	Netherlands
Aeromexico (AMX)	14.390	Mexico	Korean Air (KOR)	40.467	South Korea
Air Algerie (ALG)	3.051	Algeria	LanChile (LCH)	9.931	Chile
Air Canada (AC)	44.806	Canada	Lauda Air (LAU)	4.562	Austria
Air China (CHI)	18.116	China	Lloyd Aero Boliviano (LAB)	1.701	Bolivia
Air France (AFR)	91.801	France	LOT Polish Airlines (LOT)	4.757	Poland
Air-India (IND)	12.006	India	Lufthansa (LFH)	94.170	Germany
Air Liberte (LIB)	4.707	France	Malaysia Airlines (MA)	37.947	Malaysia
Air New Zealand (ANZ)	22.232	New Zealand	Malev Hungarian Airlines (MAL)	3.168	Hungary
Alaska Airlines (ALA)	19.273	United States	Mexicana de Aviacion (MEX)	13.498	Mexico
Alitalia (ALI)	40.618	Italy	Northwest Airlines (NW)	127.324	United States
All Nippon Airways (ANA)	58.042	Japan	Olympic Airways (OLY)	8.860	Greece
America West Airlines (AW)	30.742	United States	Qantas Airways (QUA)	63.495	Australia
American Airlines (AA)	187.542	United States	Royal Air Maroc (RAM)	7.185	Morocco
Ansett Australia (ANS)	17.110	Australia	Royal Jordanian Airlines (RAJ)	4.207	Jordan
AOM French Airlines (AOM)	9.248	France	Sabena (SAB)	19.379	Belgium
Austrian Airlines (AUS)	8.799	Austria	Scandinavian Airlines (SAS)	22.647	Sweden
Balkan Bulgarian (BAL)	0.808	Bulgaria	Saudi Arabian Airlines (SAU)	20.229	Saudi Arabia
British Airways (BA)	118.890	United Kingdom	Singapore Airlines (SIN)	70.795	Singapore
British Midland (BMI)	3.837	United Kingdom	South African Airways (SAA)	19.321	South Africa
Canadian Airlines Intern. (CAI)	23.395	Canada	Sri Lankan Airlines (SLA)	6.860	Sri Lanka
Cathay Pacific (CP)	47.097	Hong Kong	Swissair (SWR)	34.246	Switzerland
Continental Airlines (CO)	96.949	United States	Syrian Arab Airlines (SYR)	1.422	Syria
Croatia Airlines (CRO)	0.644	Croatia	TAP Air Portugal (TAP)	10.385	Portugal
Crossair (CRS)	2.073	Switzerland	TAROM (TAR)	2.075	Romania
CSA Czech Airlines (CSA)	3.294	Czech Republic	Thai Airways International (TAI)	42.236	Thailand
Cyprus Airways (CYP)	2.785	Cyprus	Trans World Airlines (TWA)	43.798	United States
Delta Air Lines (DL)	173.411	United States	Tunisair (TUN)	2.694	Tunisia
Egyptair (EGY)	9.086	Egypt	Turkish Airlines THY (THY)	16.492	Turkey
El Al (EL)	14.125	Israel	Ukraine Intern. Airlines (UKR)	0.401	Ukraine
Emirates (EMI)	19.413	Un. Arab Emirates	United Airlines (UA)	204.187	United States
Finnair (FIN)	7.460	Finland	US Airways (USAir) (USA)	75.380	United States
GB Airways (GB)	1.971	United Kingdom	Varig (VRG)	26.286	Brazil
Gulf Air (GUL)	12.739	Bahrain	VASP Brazilian Airlines (VSP)	4.918	Brazil
Iberia Airlines (IBR)	40.015	Spain	Virgin Atlantic Airways (VIR)	29.471	United Kingdom
Iran Air (IRA)	6.229	Iran			

* Passenger traffic in 2000, billion RPK (revenue passenger kilometers), from IATA's *World Air Transport Statistics*.

TABLE 2
Description of implicit constellations

Year/	Code	Members[a]	Density table[b]				
			1	2	3	4	5
1995	1	LIN, AMX, ALA, AW, BA, CO, GB, KLM, MEX, NW, USA.	*.22*				
	2	AFL, AC, CHI, AFR, ANA, AUS, BAL, CSA, DL, FIN, IBR, LOT, LFH, MLV, SAB, SWR, TAR, THY.	.04	*.36*			
	3	ARG, IND, ANS, BMI, EMI, MA, RAJ, SLA, TAP, TWA, UA, VIR.	.00	.06	*.24*		
	4	ALG, ALI, CYP, EGY, GUL, IRA, KOR, OLY, RAM, SAU, SYR, TUN.	.03	.06	.04	*.23*	
	5	ANZ, AA, CAI, CP, JAS, JA, LAB, QUA, SAS, SIN, SAA, TAI, VRG, VSP.	.04	.06	.04	.02	*.23*
1996	1	LIN, LIB, ANZ, AW, BA, CAI, GB, LCH, NW, QUA, SAS, USA, VRG.	*.22*				
	2	AFL, AMX, ALG, AFR, BAL, CRO, EGY, MEX, RAM, TUN, THY.	.00	*.24*			
	3	ARG, AA, ANS, BMI, CP, JAS, JA, MA, RAJ, SIN, SAA, SLA, TAP, TAI, VIR.	.05	.01	*.25*		
	4	AC, CHI, ALI, ANA, AUS, CO, CSA, DL, FIN, IBR, KOR, LAU, LOT, LFH, MLV, SAB, SWR, TAR.	.05	.06	.08	*.35*	
	5	IND, CYP, EMI, GUL, IRA, KLM, LAB, OLY, SAU, SYR, TWA, UA, VSP.	.03	.03	.04	.04	*.22*
1997	1	LIN, CHI, ALA, AW, DL, EL, FIN, KLM, KOR, NW, SAB, SIN, TAP.	*.26*				
	2	AFL, AMX, AFR, ALI, AUS, BAL, CO, CRO, CSA, IBR, LOT, MLV, SWR, TAR, THY, UKR.	.08	*.39*			
	3	ARG, AC, IND, ANZ, ANS, BMI, CP, EMI, LAU, LFH, MA, SAS, SAA, SLA, TAI, UA, VIR.	.04	.05	*.29*		
	4	ALG, CYP, EGY, GUL, IRA, LAB, OLY, RAM, SAU, SYR, TUN, VSP.	.01	.06	.03	*.20*	
	5	LIB, ANA, AA, BA, CAI, GB, JAS, JA, MEX, QUA, VRG.	.04	.04	.07	.01	*.25*
1998	1	LIN, AOM, CRO, EGY, LAU, MA, OLY, RAJ, SAB, SLA, TAP, THY.	*.20*				
	2	AFL, AMX, CHI, AFR, IND, ALI, AUS, BAL, CSA, DL, FIN, IBR, KOR, LOT, MLV, SWR, TAR, UKR.	.10	*.39*			
	3	ARG, AW, AA, BA, CAI, CO, JAS, JA, LCH, LAB, QUA, VSP.	.01	.07	*.26*		
	4	ALG, ALA, CYP, GUL, IRA, KLM, NW, RAM, SAU, SYR, TWA, TUN.	.03	.06	.03	*.23*	
	5	AC, ANZ, ANA, ANS, BMI, EMI, LFH, MEX, SAS, SIN, SAA, TAI, UA, VIR.	.06	.06	.05	.02	*.38*
1999	1	LIN, ALG, AOM, CYP, EL, FIN, OLY, RAM, SAB, TAP, TUN.	*.24*				
	2	AFL, AMX, CHI, AFR, IND, AUS, BAL, CSA, DL, IBR, KOR, LOT, MLV, SWR, TAR, UKR.	.09	*.41*			
	3	AC, ANZ, ANA, ANS, BMI, EMI, LFH, MEX, SAS, SIN, SAA, TAI, UA, VRG, VIR.	.01	.05	*.42*		
	4	ALA, ALI, AW, AA, BA, CAI, CO, JAS, JA, KLM, LCH, NW, QUA.	.05	.10	.05	*.38*	
	5	CRO, EGY, GUL, IRA, MA, RAJ, SLA, SYR, TWA, THY.	.03	.11	.07	.04	*.31*
2000	1	LIN, ARG, AA, BA, CAI, CP, EL, FIN, LCH, QUA, SAB, TAP.	*.41*				
	2	AFL, AFR, ALI, AUS, BAL, CRO, CSA, IBR, IRA, JA, LOT, MLV, RAJ, SWR, SYR, TAR, THY.	.13	*.43*			
	3	AMX, ALG, CYP, DL, EGY, GUL, OLY, RAM, TUN.	.05	.09	*.22*		
	4	AC, IND, ANZ, ANA, BMI, EMI, LAU, LFH, MA, MEX, SAS, SIN, SAA, SLA, TAI, UA, VIR.	.03	.09	.03	*.38*	
	5	CHI, ALA, AW, ANS, CO, JAS, KLM, KOR, NW, TWA, UKR.	.07	.06	.01	.05	*.29*

[a] Abbreviations of names as listed in Table 1. Composition of groups as revealed by clustering algorithm based on the matrix of bilateral ties among firms.

[b] Diagonal entries indicate density of constellation. Off-diagonal entries indicate density of ties between constellation members and members of other groups.

Sources: IATA's *World Air Transport Statistics*; *Airline Business*, several issues; analyses reported in Lazzarini (2002).

TABLE 3

Description of explicit constellations

Year	Name	Date founded	Members[a]
1995	Global Excellence	1990	DL, SIN, SWR.
1996	Global Excellence	1990	DL, SIN, SWR.
1997	Atlantic Excellence	Feb 1997	AUS, DL, SAB, SWR.
	Global Excellence[b]	1990	DL, SIN, SWR.
	Star Alliance	May 1997	AC, LFH, SAS, TAI, UA.[c]
1998	Atlantic Excellence	Feb 1997	AUS, DL, SAB, SWR.
	Qualiflyer	May 1998	AOM, AUS, CRS, LAU, SAB, SWR, TAP, THY.
	Star Alliance	May 1997	AC, LFH, SAS, TAI, UA, VRG.
1999	Atlantic Excellence[d]	Feb 1997	AUS, DL, SAB, SWR.
	Oneworld	Sep 1998	AA, BA, CAI, CP, QUA.[e]
	Qualiflyer	May 1998	AOM, AUS, CRS, SAB, SWR, TAP, THY.[f]
	Star Alliance	May 1997	AC, ANZ, ANS, LFH, SAS, TAI, UA, VRG.
	"Wings"[g]	1999	KLM, NW.
2000	Oneworld	Sep 1998	LIN, AA, BA, CP, FIN, IBR, LCH, QUA.
	Qualiflyer	May 1998	LIB, AOM, CRS, LOT, SAB, SWR, TAP, THY.[h]
	SkyTeam	Sep 1999	AMX, AFR, DL.[i]
	Star Alliance	May 1997	AC, ANZ, ANA, ANS, AUS, LFH, MEX, SAS, SIN, TAI, UA, VRG.[j]
	"Wings"	1999	KLM, NW.

[a] Abbreviations of names as listed in Table 1.
[b] Dissolved in November 1997.
[c] Varig joined the group in October 1997.
[d] Dissolved in November 1999.
[e] Finnair and Iberia joined the group in September 1999.
[f] Air Europe is also a member, but was not included in the analysis due to missing data. However, estimates indicate that it contributes to only about 6.2% of the constellation's total traffic.
[g] "Wings" is an unofficial name of the group. The alliance between KLM and Northwest exists since 1989, but we consider that the group was only officially institutionalized with the announcement that Continental and Alitalia would join the group in early 1999, which was later called off.
[h] Air Littoral, Portugalia and Volare are also members, but were not included in the analysis due to missing data. However, estimates indicate that they, together, contribute to only about 2.4% of the constellation's total traffic.
[i] Korean Airlines joined the group in July 2000.
[j] British Midland (bmi) joined the group in July 2000.
Sources: IATA's *World Air Transport Statistics*; *Airline Business*, several issues; analyses reported in Lazzarini (2002).

TABLE 4
Description of variables

Variables	Description	Expected sign[c]	
		Explicit constellation	Implicit constellation
Dependent			
EC_{ijt}	Dummy variable coded 1 if carriers i and j are in the same explicit constellation at year t, and 0 otherwise.		
IC_{ijt}	Dummy variable coded 1 if carriers i and j are in the same explicit constellation at year t, and 0 otherwise.		
Explanatory			
EC_{ijt-1}	The lagged value of dependent variable EC_{ijt}.	++	+
IC_{ijt-1}	The lagged value of dependent variable IC_{ijt}.	+	+
$DIVINT_{ijt}$	Ratio of carriers' international positioning (traffic coming from international passenger flows to the total traffic of the carrier, in RPK[a]), greater to lesser value, at year t.	+	+/0
$DIST_{ij}$	Distance in kilometers between the main hubs of companies i and j.	+	+/0
Control			
$DIRT_{ijt-1}$	Dummy variable coded 1 if carriers i and j had a bilateral tie at year t-1, and 0 otherwise.	NP	NP
$INDIRT_{ijt-1}$	Dummy variable coded 1 if carriers i and j had an indirect bilateral association (i.e., they were bilaterally connected to the same partner) at year t-1, and 0 otherwise.	NP	NP
$ECTOT_{t-1}$	Number of explicit constellations at year t.	NP	NP
CAP_{ijt}	Ratio of carriers' passenger available seat capacity (ASK[b]), greater to lesser value, at year t.	NP	NP
YEAR(t)	Set of dummy variables coded 1 if the observation is from year t and 0 otherwise.	NP	NP

[a] RPK = revenue passenger kilometers.
[b] ASK = available seat kilometers.
[c] NP = not predicted.

TABLE 5

Descriptive statistics (N = 16650)

				Correlations									
		Mean	Sd.Dev.	1	2	3	4	5	6	7	8	9	10
1	EC_{ijt}	0.016	0.124	1									
2	IC_{ijt}	0.141	0.348	0.126	1								
3	EC_{ijt-1}	0.008	0.091	0.597	0.080	1							
4	IC_{ijt-1}	0.138	0.345	0.119	0.418	0.101	1						
5	$Ln(DIVINT_{ijt})$	0.675	0.843	-0.010	-0.090	-0.012	-0.075	1					
6	$Ln(DIST_{ij})$	8.512	1.165	-0.028	-0.085	-0.034	-0.084	0.168	1				
7	$DIRT_{ijt-1}$	0.080	0.271	0.183	0.307	0.170	0.346	-0.071	-0.148	1			
8	$INDIRT_{ijt-1}$	0.383	0.486	0.125	0.260	0.107	0.288	-0.179	-0.063	0.177	1		
9	$Ln(ECTOT_{t-1})$	0.944	0.697	0.095	-0.009	0.073	-0.007	0.000	0.000	0.024	0.081	1	
10	$Ln(CAP_{ijt})$	1.500	1.090	-0.047	-0.052	-0.037	-0.059	-0.004	0.024	-0.015	-0.065	-0.003	1

TABLE 6

Bivariate probit estimates:[a] factors influencing the likelihood that carriers i and j will be observed in the same explicit (EC_{ijt} = 1) or implicit constellation (IC_{ijt} = 1) ay year t

	(1)		(2)	
	EC_{ijt}	IC_{ijt}	EC_{ijt}	IC_{ijt}
EC_{ijt-1}			2.707 **	0.073
			(0.141)	(0.130)
IC_{ijt-1}			0.201 **	1.028 **
			(0.076)	(0.036)
Ln($DIVINT_{ijt}$)			0.095 *	-0.090 **
			(0.042)	(0.020)
Ln($DIST_{ij}$)			-0.026	-0.034 **
			(0.029)	(0.013)
$DIRT_{ijt-1}$	0.988 **	1.093 **	0.661 **	0.719 **
	(0.089)	(0.051)	(0.086)	(0.043)
$INDIRT_{ijt-1}$	0.688 **	0.746 **	0.504 **	0.523 **
	(0.085)	(0.033)	(0.076)	(0.029)
Ln($ECTOT_{t-1}$)	0.478 **	-0.097 **	0.355 **	-0.067 **
	(0.051)	(0.020)	(0.060)	(0.023)
Ln(CAP_{ijt})	-0.209 **	-0.060 **	-0.166 **	-0.044 **
	(0.042)	(0.017)	(0.032)	(0.014)
Intercept	-2.938 **	-1.432 **	-2.679 **	-1.185 **
	(0.091)	(0.044)	(0.260)	(0.117)
ρ	0.228 **		0.265 **	
	(0.052)		(0.050)	
Log likelihood	-6717.89		-5972.99	
χ^2 (Wald test of regression)	1683.22 **		3284.69 **	
χ^2 (Wald test of ρ = 0)	19.06 **		27.82 **	

[a] N = 16429. Robust standard errors in parenthesis, clustering on each carrier-pair ij. All models include year-specific dummy variables (not reported here).

** p < .01

* p < .05