A New Order of Things: Network Change and Field Transformation Following an Exogenous Shock

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3 authors:

Leonardo Corbo
Universidade Católica Portuguesa

Raffaele Corrado
University of Bologna

Simone Ferriani
University of Bologna

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3 authors:


Leonardo Corbo
Universidade Católica Portuguesa


Raffaele Corrado
University of Bologna


Simone Ferriani
University of Bologna

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Network Mechanisms of Field Evolution in the Aftermath of an Exogenous Shock

Leonardo Corbo
School of Management and Economics
Catholic University of Porto
lcorbo@porto.ucp.pt

Raffaele Corrado
Management Department
University of Bologna
raffaele.corrado@unibo.it

Simone Ferriani
Management Department
University of Bologna
simone.ferriani@unibo.it
&
Cass Business School
City University London

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Organization Studies

Abstract

This study examines the role of a major environmental shock in triggering change in the social structure of an organizational field. Based on the longitudinal analysis of changing network configurations in the global airline industry, we explore how logics of attachment shift before, during and after an exogenous shock and how the rewiring of network ties in response to the shock may act as a countervailing force to the network dynamics that drive field stratification. Using the terrorist attacks of September 11 2001 as a natural experiment, our work reveals how shocks may affect key mechanisms of network evolution thus altering tie distribution and access among members of the field. Overall this article contributes to emergent literature on field dynamics by exposing the evolution of interorganizational dynamics when external events produce unsettled times that render extant logics brittle and open prospect for change.

Keywords

Network change, environmental jolt, field evolution, rules of attachment, core/periphery

INTRODUCTION

The agentic turn in institutional theory has marked a shift in attention from the normative forces that stabilize interorganizational fields toward consideration of the processes by which such fields transform (Fligstein, 2001). Opportunities for radical transformation of existing fields have often been suggested to arise primarily from large scale events that impose crises on the field and are experienced as severe ruptures in its social structure (Meyer, 1982; Sine and David, 2003). There are a number of studies that have highlighted the role of exogenous shocks in exposing rules that had been taken for granted, calling into question the perceived benefits of those rules, and undermining the calculations on which field relations had been based (McAdam and Scott, 2005). It is during these convulsive moments that, as pointed out by Fligstein and McAdam (2012: 4) "new logics of action and interaction come into existence" that may shuffle resources and thereby alter the relationships within the field. Powell et al. (2005: 1190) similarly note that "shocks to any system […] can destabilize it and result in a tip in the rules of affiliation and the resulting combinatorial possibilities". Scholars in the social movement theory too have advanced the idea that exogenous shocks may alter the underlying social fabric of fields by catalysing the mobilization of peripheral actors who can advance their position in the social structure (Thornton, 2002).

In our view, belying the abundant evidence that emphasizes the role of exogenous shocks in subverting the existing social order, is the comparative absence of theoretical and empirical work on the network mechanisms – those that are thought to regulate the likelihood that particular relationships materialize – that bring about such transformations. Prior work on change in interorganizational fields has emphasized the tendency of interorganizatinal networks to reproduce themselves over time (Gulati and Gargiulo, 1999), resulting in increasingly stratified social structures. According to this view, which is reminiscent of the Mertonian principle of the rich get richer, highly connected organizations in the pre-existing network structure are more likely to form subsequent ties with highly connected partners, while firms that are not as well connected remain in the periphery of the network. Yet, in contrast to the prevailing self-reproducing conception of the social structure, theorists have raised the possibility that networks change because of external crises that produce unsettled times, rendering existing logics of action and interaction brittle and opening prospects for transformation (Madhavan et al., 1998). Unfortunately such punctuated accounts of socio-economic change say little about what logics of attachment are poised for change consequent to exogenous shocks or how such logics cumulatively shape the evolutionary trajectory at the interorganizational field level. Addressing this knowledge gap is important for the advancement of current understanding in field dynamics, as the way fields change rests on the particular relationships of its actors and "change to these relationships are a powerful source of change to a field" (Sauder, 2008: 210). Accordingly the present article asks, How do field actors alter their interorganizational affiliations in response to transient shocks that disrupt fields temporarily? What logics of attachment prevail in the aftermath of large scale-events that have the effect of creating a sense of generalized uncertainty? These questions lie at the heart of field theory, as they draw our attention to the relational "structuration" of organizational fields (Phillips et al., 2000).

The theoretical orientation we follow to address these questions brings together ideas generated by field and network theorists. From field theorists we borrow the understanding of field as a “network or configuration of relations between positions” (Bourdieu and Wacquant, 1992: 17) and as social arenas where actors frame their actions vis-à-vis one another and struggle to secure and preserve social and material benefits (Fligstein and McAdam, 2011). This competition gives rise to social structure, understood here as social topology, which constitutes different profit opportunities (Fligstein, 2001). As noted by Beckert (2010: 612) “since profit stems from the relative position of a firm in the network actors have diverging interests with regard to the reproduction and change of existing network”. In its simplest expression this is a struggle between incumbent actors who embrace a frame of reference that encapsulates their self-serving view of the field and thus strive for the reproduction of network positions, and peripheral actors who seek avenues for improving their position.

From network theorists we borrow arguments concerning how the topology of a network and the mechanisms of tie formation/dissolution among its constituents orient the choice of partners and ultimately shape the structure of the field. Drawing on network evolution literature (Gulati and Gargiulo, 1999; Snijders, 2001; Powell et al., 2005; Rivera et al., 2010) we explore different sources of attachment bias and examine if and how these simple rules that guide the process of partner selection shift in the aftermath of an exogenous shock that destabilizes the entire field. In doing so, we move away from the depiction of social change as an invariant process affecting all actors equally, and emphasize instead its different ramifications depending on an actor’s location in the overall network, as that structure evolves over time (Powell et al., 2005; Powell and Owen-Smith, 2012). Our intuition is that patterns of interorganizational network ties provide a lens through which to view critical junctures that question extant logics and open prospect for change, enabling us to shed light on organizational responses to external events.

To explore these ideas empirically and inform our understanding of the interorganizational dynamics characterizing fields that undergo cataclysmic upheavals we focus on the global airline industry in the aftermath of the September 11 2001 terrorist attacks (henceforth 9/11), which caused one of the most severe crises ever experienced by civil aviation worldwide. Given the exploratory, theory-building nature of the study we employ a hybrid research design that combines qualitative data analysis with quantitative social network analysis, enabling us to capture "a more complete, holistic and contextual portrayal of the units under study" (Jick, 1979: 603). We first offer a comprehensive overview of the main factors that have shaped the evolution of the commercial field of global air transportation over the past fifteen years. We turn next to a closer examination of the dynamics of interorganizational attachment of field members. To assess the evolving topology of the field in relation to the occurrence of the shock we draw on 9 years (1998-2006) of alliance records that capture the formation and dissolution of collaborative relationships. From this data we extract and map several network properties in the periods pre-, during and post-shock which offer an appreciative understanding of how the logics of attachment switch, with divergent ramifications depending on whether the actors are central or peripheral players in the context of the field. We then turn to a statistical analysis of the micro-mechanisms that govern actors' interorganizational choices and link these mechanisms to the evolution of field-level network patterns. For this analysis we use stochastic actor-based models for network dynamics (Snijders, 2005; Snijders et al., 2010). This modelling approach is especially appropriate for our analysis for at least two reasons. In the first place, it focuses on the micro-level mechanisms that drive actors' choices as factors of change at the network level. Further, it overcomes the problems that network interdependence poses to estimation and testing, and is the only tried and tested approach that does so in a truly longitudinal fashion. Using actor-based stochastic network models (Snijders, 2005) we examine a few mechanisms that have been featured in previous work on network evolution: degree distribution, assortativity (or degree-based homophily), transitivity, and preferential attachment. Each of these statistics provides a different yet complementary insight into the interplay of network dynamics and field structuration in the aftermath of an environmental shock. We trace these bases of interaction in the pre-, during and post-shock period and in doing so we address recent calls to increase our understanding of whether "different [network] mechanisms play greater or lesser roles as networks evolve" (Rivera et al., 2010: 108).

Our findings suggest that the shock engenders a blended logic of partner selection. On the one hand, we find systematic differences in the pre- and post-shock eras in the pattern of connections that link the most prominent members of the field to one another and to more peripheral alters. More specifically, the shock appears to push the network towards disassortativity and "poor get richer" dynamics (or preferential avoidance) (Qiao et al., 2014) causing an inversion in the correlation patterns in the degree of connected nodes and making peripheral actors more attractive partners. On the other hand, we find that the shock accelerates the clustering tendency of the network as captured by different measures of network transitivity. After the upheaval, in other words, interactions with a common third party induce stronger triadic closure resulting in a more cohesive structure. Thus, in the wake of the exogenous shock triadic closure, disassortativity and preferential avoidance operate as simultaneous structuring forces, with the former enhancing cohesion and reliability of exchanges (Uzzi, 1997) and the latter two preventing insularity and pulling in peripheral players, more likely to aid in exploration and renewal. In the closing part of the manuscript we offer a discussion of the study's main implications, limitations and promising areas for future research.

THEORETICAL ORIENTATION

Fields, networks and shocks

Bourdieu (1984, 1992) has presented one of the most elaborate theoretical statements about the structure of fields. Bourdieu positions actors in social space, or topography, where they compete to secure and preserve social, material and symbolic benefits. This competition gives rise to social structure, understood here as social topology, which positions actors relative to each other according to the combination of symbolic and social resources available to them. The structural outcomes of this competition are usually conceptualized as dichotomies that classify actors into incumbents and challengers, insiders and outsiders, core and peripheral players (Anheier et al., 1995; Fligstein and McAdam, 2012). On the one hand core players serve as arbiters for the direction of the field. Being strongly embedded in the field and dependent upon the worldview subsumed by it they use their clout to reinforce the existing institutional arrangements, especially when their interests appear to be well served by the prevailing settlement. Peripheral players, on the other hand, strive to improve their position and change the balance of control over resources within the field but they are hindered by their low status and limited resources in convincing others to partake in their project. As a result, the social structure of fields proves typically highly resistant to peripheral players' challenges.

In rare instances, however, such stratification order may not be strong enough to forestall convulsive moments triggered by exogenous shocks or other dramatic events that suddenly alter the relations within the field, setting in motion "a period of prolonged and widespread crisis in which actors struggle to reconstitute all aspects of social life" (Fligstein and McAdam, 2011: 32). Events of such kind include the French Revolution, the Great Depression and the economic crisis of the 1970s. These events, also known as environmental jolts, represent significant milestones in the evolution of a field and play a key role in enabling transformative change (Fligstein, 1997, 2011; Meyer, 1982) by reshuffling control over resources and thereby providing avenues for action for some actors while hindering others. After such moments of possibility things eventually settle down and a more stable order returns. Unfortunately, such punctuated accounts of social change say little about what precise patterns of interaction emerge, take root and transform in response to sudden shifting environmental circumstances. Do core actors respond to exogenous shocks by turning their attention inward to connections with other core players, thus creating an increasingly stratified elite? Alternatively, do they prospect for more diverse peripheral partners who seek the legitimacy and resources that accrue from affiliation to core players?

The perspective we adopt to tackle these questions rests on the idea that organizational fields are structured by relationships that function both as pipes through which resources and practices are diffused and as prisms that provide signals of status and identity (Podolny, 2001). Because differently positioned organizations garner different status and control benefits, some organizations may be more responsive to suddenly shifting circumstances. As suggested by Fligstein and McAdam (2011: 10): "Different actors in different positions will vary in their interpretation of events and respond to them from their own point of view". Our intuition is that the patterns of interaction that link central members of the network with one another and with less well-positioned alters offer a lens through which to examine periods of ferment, enabling us to flesh out endogenous network mechanisms that operate in response to exogenous events. In particular, by examining the dynamics of interorganizational tie formation and dissolution of field members in the pre- and post-jolt eras, we can distil how rules of attachment vary over time. As we shall see the actors may well play by different rules of partner selection at different stages in the evolution of the network, depending on their position in the social structure and the characteristics of their current and/or prospective partners.

Dynamics of network change in interorganizational fields

We enter the discussion of interorganizational network dynamics with data from a field where political and market forces loom large in shaping patterns of attachment. Unlike other industries where collaborative ties are forged to last, the airline industry has been characterized over the past twenty years by strong pressure towards deregulation and liberalization that have resulted in a high rate of formation and dissolution of interorganizational linkages. Because of endogenous and exogenous discontinuities the industry has also witnessed a significant amount of entry and exit into the field, with a small elite of highly connected incumbents exerting considerable influence over the developmental pattern of the overall network, and newcomers seeking the relational imprimatur of these core players positioned at the centre of the stage. The challenge to understand the shifting topology of this complex highly stratified field is to link the overall structure with the affiliation choices of its constituting actors and examining how these choices shape the evolution of the field at critical points in time.

As a point of departure for examining such link we focus on assortativity (or degree-based homophily), a key attachment mechanism that network theorists (Watts, 2004) as well as interorganizational network scholars (Powell et al., 1996; Gulati and Gargiulo, 1999) have identified as being conducive to the kind of stratified social structures (Borgatti and Everett, 1999) that distinguish Bourdieusian fields. Assortativity reflects the degree to which nodes with similar degrees connect to each other (Watts 2004). It implies that nodes with numerous connections are more likely to be linked to other nodes with numerous connections while low degree nodes connect to other low degree nodes. Scholars in the network perspective on interfirm collaboration suggest that these dynamics – somehow reminiscent of Merton's cumulative dynamics (1968) – result from the tendency of highly embedded organizations in a network, that is organizations with many interorganizational ties that provide them with a central position in the network, to form additional ties with other highly embedded organizations to mitigate collaboration hazards (Gulati and Gargiulo, 1999). By contrast organizations with few connections located at the periphery of the network, lack informational and reputation benefits which constraints their ability to work their way towards the centre of the network. A topology dominated by assortative logic thus results in divide between an 'elite club' situated in the core and 'the mass', represented by peripheral players. Disassortativity occurs when nodes with many connections prefer to link to nodes with few connections and vice versa. Because exogenous shocks increase uncertainty and alter the configuration of the resource space, a change in the assortative logic of the field may follow it. As noted by Ahuja et al. (2012: 437): "Significant changes in assortativity might signal a shift in the resource requirements for success in the interorganizational field".

We supplement the idea of assortativity with other attachment mechanisms that sociologists have repeatedly found to be important in the evolution of social structures. The first mechanism, which nicely complements the assortative one, is preferential attachment or the tendency of an organization to attach to another organization that already has ties. Preferential attachment purportedly occurs because actors looking for new connections use an actor's degree as a proxy for their fitness (Rivera et al., 2010). The extreme case would result into a star network with one central node being connected to every other node, leading to an average path length under two. Significant evidence indicates that alliance networks are structured by preferential attachment because larger and more prestigious firms tend to attract and sustain a far greater number of alliances than smaller or less prestigious firms (Stuart, 1998). Underlying this logic of attachment in interorganizational networks is the understanding of organizations as status-seeking (Podolny, 1994). Because organizations' status rankings are a function of the status rankings of their partners, lower status organizations search for ties to higher status organizations who attempt to avoid ties with lower status players. The second mechanism we analyse is based on Simmel's triadic closure (Simmel, 1950) or the tendency of open triads to close. Triads, subsets of three actors and the possible ties among them, play a key role in relating micro-structural tendencies with macro-structural patterns being at the intersection between dyadic relationships and overall networks (or parts of it). Triads are central to the formation of relationships due to the transitivity principle (Granovetter, 1973). Transitivity is the tendency of forming mutual ties by two actors A and B that are connected to a third common party C, thus resulting in triadic closure. At the dyadic level this implies that prior indirect ties – at geodesic distance of two – turn into direct ties. Triadic closure is a very strong structural tendency and empirical evidence consistent with it has been found in a variety of interorganizational settings (see for instance Madhavan et al., 2004; Lazzarini et al., 2008; Ferriani et al., 2013). The third mechanism we examine is nodal degree or the simple tendency of actors to instantiate new relationships. Within our setting this mechanism captures the extent to which airlines respond to the changed environmental conditions by expanding or reducing their alliance network. On the one hand, to cope with the increased uncertainty that follows exogenous shocks firms may strengthen existing ties and refrain from establishing new ones (Krackhard,t 1992). An example of this pattern can be found in Podolny (1994), who posits that the proclivity of organizations to re-instantiate past relationships increases with uncertainty in market conditions. On the other hand, under increasing uncertainty firms might seek more flexibility and options (Owen-Smith and Powell 2004), which would suggest that large upheavals in a network or shocks that change the environmental or market conditions within which a network is embedded may lead to greater partnering activity and a consequent increase in the parameter capturing the actor's propensity to establish new ties. A similar conundrum is present in organizational theory (Staw et al., 1981), do firms respond to threat by becoming more active or by becoming more rigid?

By analysing how these mechanisms play out in the wake of an exogenous shock we seek to extend prior related research on interorganizational change and field dynamics that has attended to such key aspects as logics of attachment (Powell et al., 2005), network topology (Sytch et al., 2012), and more broadly the impact of industry events on the relational structuration of fields (Madhavan et al., 1998; Powell and Owen-Smith, 2012). While a more comprehensive view of interorganizational network change might include other network mechanisms, our main objective here is to make a first step towards more clarity and analytical tractability in studying the relational dynamics that shape fields at critical evolutionary junctures that open prospects for change.

EMPIRICAL SETTING: THE GLOBAL AIRLINE INTERORGANIZATIONAL FIELD

Our empirical focus is on the commercial field of air transportation, which has undergone deregulation and liberalization in the 1980s and 1990s, significant development of bilateral airline alliances as preferred mode of expansion in the 1990s, and the emergence of multilateral alliances and consolidation in the late 1990s and early 2000s. This field is known for being inherently global, characterized by a mixture of competition and collaboration. Globalization and deregulation have been identified as the two phenomena that have radically changed the air transport industry and its rules over the past thirty years (Iatrou and Oretti, 2007). Globalization forced airlines to cater for the needs of a global market by operating across national boundaries. Deregulation and liberalization increased competition dramatically and paved the way for the emergence of low cost carriers. Faced with these challenges, the commercial airline industry has been marked by a heavy reliance on interorganizational networks (Iatrou and Oretti, 2007). For example, in 2000 more than 80% of global airline carriers engaged in some form of alliance (Baker, 2001). In the early years of cooperation, alliances were confined to tie formation between two carriers mainly in the form of a code-sharing agreement where two airlines cross-sell each other's capacity on selected routes, or one carrier markets its code on another's flights. Cooperation at this level was generally limited to specific routes or regions, and the carriers involved are still marketed as independent companies. Starting from the mid-1990s, the pressures stemming from both deregulation and globalization increased sensitively influencing the nature of competition within the airline industry. Once again, airlines reaction was to forge alliances. In their quest to achieve global reach, based on the assumption that those that offer a global service (with a credible presence in each of the major air travel markets) will be in the strongest competitive position, airlines realized that multilateral alliances or constellations (Gomes-Casseres, 1994) would have been more adequate for that purpose[1]. By the end of the 1990s the field was divided into constellation members and non-aligned carriers which enjoyed relatively more freedom in their partnership choices. This is the period we focus on, with data from 1998 to 2006. Figure 1 illustrates the evolution of airline membership in alliance constellations.

[Figure 1 about here]

The main three multilateral airline alliances are Star Alliance, SkyTeam and oneworld which control the 69% of world revenue passenger kilometres. At the time of our study, there were two additional constellations, Qualiflyer and Wings. These constellations involve full marketing cooperation with respect to frequent flyer programs (FFPs) and promotion (including investments in common brand name), besides joint access to airport facilities controlled by individual members (Lazzarini, 2007: 347). They also offer comprehensive code-sharing agreements involving several routes instead of bilateral agreements comprising few routes (Oum and Yu, 1998). However, the interorganizational field we explore is not stable, it shifts markedly through the formation of new alliances and dissolution of existing ones, as agreements are ended, new players join the ranks and businesses fail. The evolving structure of these interorganizational linkages is the focus of our network study. We analyse patterns in the formation and dissolution of ties between airlines in the wake of the 9/11 terrorist attacks as a key trigger to field transformation.

DATA AND METHODS

We explored the evolutionary dynamics of the global airline industry using longitudinal data on alliances formed between 1998 and 2006. In line with prior work (Lazzarini, 2007) we identified an alliance as any code-sharing agreement between two airline companies. All airlines that had formed at least one alliance during the period of our study were included in the database. Data on airline alliances and their change over time were collected through company reports and several issues of the Airline Business magazine. These issues contain data on code-sharing agreements but exclude cooperation on frequent flyer programs as well as alliances among charter and cargo carriers which are not the focus of this study.

We used these data to build a series of sociomatrices. These are binary symmetric matrices whose entry on row i and column j (Xij, same as Xji) equals to 1 if a code-sharing agreement existed between companies i and j, and 0 otherwise. One sociomatrix was coded for each year of the interval 1998-2006, our period of observation, and this resulted in a panel network dataset of nine adjacency matrices. We used this panel network dataset for modelling the evolution of the network of code-sharing agreements between airlines across the period of observation using the SIENA actor-based models of network change (Snijders, 2005). These models reconcile the inquiry of the macro-level evolution of the network with a focus on the individual choices of the actors (Felin and Foss, 2005), thus making possible to strike a balance between the competing emphases on structure or agency in the study of networks. Within this framework the global evolution of the network is modelled as driven by the choices actors make about establishing new ties or interrupting old ones, based on their preferences about local configurations of ties. While the emergent result of these choices drives the evolution of the whole network, choices themselves are conditioned by broad network patterns that are outside the control of any individual actor. The statistical modelling of the evolution of the airline alliance network is preceded by a mapping of the evolution of the field in the pre-, the during and post-jolt periods, based on a variety of network diagnostics which allow us to delineate a rich contextual framework with which to better understand the changing dynamics of the network over time.

Information on airlines operations were collected from IATA and ICAO statistics. The database includes information on individual airlines observed over time. The final sample consists of an unbalanced panel of 261 airlines, including companies that have disappeared from the business arena and those that were founded during the analysis period. Among these a subsample was selected that consisted of the companies that met at least one of these requirements: 1) they were included in the Lazzarini (2007) sample, 2) they were identified by industry experts as important field players 3) they belonged to the main connected component of the network at least once across the nine observed years 1998-2006. This resulted in a subsample of 132 actors observed across the nine years period that decreased from the 128 actors observed in 1998 to the 107 in 2006. The information about code-sharing agreements was coded in nine binary and symmetric adjacency matrices 132x132.

In addition to the quantitative data, and in order to gain a more nuanced understanding of our quantitative findings, we collected qualitative evidence by performing eleven semi-structured interviews with experienced professionals and key informants in the airline industry (see Table 1). The questions asked were open-ended ones and aimed at uncovering the role and importance of the alliance network in the pre and post 9/11 eras. All informants are experts in alliance management and/or business development. These interviews had an approximate length of one hour each and were carried between February 2012 and May 2014. All interviews were digitally recorded and transcribed. Despite the information being mainly retrospective, these interviews provided valuable insight into the firms' alliance tactics and resilience strategies in the face of the 9/11 terrorist attacks that add richness to our quantitative findings. We draw on selective quotes from some of the managers we interviewed wherever relevant in the paper.

[Table 1 about here]

Network mechanisms

In our modelling approach actors are assumed to add or remove outgoing ties according to their preferences for alternative local network configurations, formalized as a hypothesized random utility function. The parameter estimates thus provide a model for the rules governing the dynamic change in the network (Snijders et al., 2010). The parameters we focus on are those that operationalize the attachment mechanisms in each of the four variants presented earlier: assortativity, preferential attachment, triadic closure and nodal degree (note that while we include the variable 'Degree' among our controls, as it is common practice to do so in SIENA models to account for the baseline relational tendency of network members, yet this variable assumes for us special theoretical interest when interacted with the time dummies). We now describe such structural effects along with the control variables.

Parameters of interest. The mechanism of triadic closure in our models is represented by the '*Transitive Triads*' parameter. This parameter measures the extent to which two airlines that share a network contact (i.e. maintain a code-sharing agreement with the same third company) tend to establish a code-sharing agreement among them. This micro-level mechanism, which may be represented graphically by a closed triangle and is often referred to either as triadic closure, transitive closure or simply transitivity, has important large scale consequences for the structure of the network. In fact, the higher is the transitivity in the network (i.e. the more frequent are closed triads or triangles), the more the network tends to be structured into internally cohesive subgroups. The '*Degree Assortativity*' parameter measures the propensity of network actors to establish ties with other actors that have similar degree to them. In our context this means that airlines with many code-sharing agreements tend to establish new agreements (or keep existing ones) with other companies that themselves have already many such agreements, and airlines with few agreements tend to ally with companies that similarly have few agreements. The '*Degree of Alter'* parameter operationalizes the preferential attachment mechanism through which popular actors (i.e. actors with high degree) become even more popular. This parameter measures the extent to which network actors (independently from their own degree) tend to choose as new contacts other actors who already have high degree; in our context this translates into airlines preference (independently from how many code-sharing agreements they have) to establish new agreements with partners that already have many code-sharing agreements.

Control variables. The *'Degree'* parameter measures the propensity of actors to maintain ties. The role of this parameter in SIENA models is that of controlling for the number of ties (i.e. density) of the network, in order to rule out the possibility that higher order structural patterns (like transitivity for example) are the mere by product of network density. The negative value that this parameter typically takes corresponds to the low density of the networks composed of more than a few actors, and indicates a negative propensity of actors to maintain ties for their own sake; a tie is initiated only when its cost is outweighed by other components of the utility function that receive positive parameter estimates. The 'Degree' effect may be referred to as endogenous in that it is a structural feature of the network that takes an explanatory role (such as the *x* of a regression) in modelling the network itself (which here takes the role of the *y*). The average propensity to maintain ties measured by the degree parameter may vary across the airlines depending on attributes like size or other. These are *exogenous* effects since they represent the impact on network structure of factors observed at the level of individual companies. We controlled for the following actor level attributes. We use country- and region-specific variables to control for time-varying effects related to carriers' domestic markets, which are likely to affect their likelihood to collaborate. *'North'* is a dummy variable valued 1 for the airlines that belong to countries in the northern hemisphere, precisely those that were coded as European, North American or from Asia-Pacific countries. This variable measures the differences in the propensity to establish ties for companies from the north hemisphere compared to the ones from the southern emisphere[2]. *'Gdp growth'* controls for the differences in the propensity to establish ties that may be possibly related to the speed of economic growth in the home country of each airline since the demand for air transport is directly linked to economic growth. The dummy '*Alliance*' equals to 1 if an airline is a member of one of the five constellations in existence during our study period (Star Alliance, SkyTeam, oneworld, Qualiflyer and Wings) and 0 if the airline is not a member of any constellation. The parameter associated to this variable measures the differences in the propensity to establish ties for members of one of the five constellations compared to non-constellation members. *'Experience'* is the age of the airline measured as the number of years since its foundation. A positive parameter estimate reflects a higher propensity of older airlines to build and retain ties compared to younger airlines. *'Fleet Size'* is the size of the airline measured as the number of aircrafts it operates. A positive parameter estimate indicates a higher propensity to maintain ties for larger airlines. *'Load Factor'* measures the operating efficiency of the airline as the amount of utilization of the total available capacity. This is measured as the Revenue Passenger Kilometres (RPK) divided by the Available Seat Kilometres (ASK). A positive parameter estimate indicates a higher propensity to maintain ties for the airlines with high load factor, those that exploit their capacity better. Finally, we control for another common indicator of performance in the airline industry which corresponds to the total scheduled passenger traffic ('*Passengers*'). A positive parameter estimate indicates a higher propensity to maintain ties for airlines with greater passenger traffic. In order to take into account alternative explanations of ties based on homophily of the airlines over these attributes, we include similarity effects defined over all these control variables. In all cases, a positive parameter implies that actors prefer to establish ties to others who are similar to them on that attribute. For example, a positive load factor similarity estimate would indicate that actors with similar load factors are more likely to collaborate. The variable 'Same Alliance' measures the extent to which airlines tend to establish code-sharing agreements preferably with members of their same constellation.

Interactions with time dummies. To discern variations in patterns of interaction over time we partitioned our period of observation in three sub-periods: 1) the pre-jolt era (1998-2001), 2) the jolt (2001-2003) era and 3) the post-jolt (2003-2006). We then estimated the interactions of our parameters of interest (i.e. *'Transitive Triads', 'Degree of Alter'* and *'Degree Assortativity'*) with *'Dummy 2001-2003'* and *'Dummy 2003-2006'* to assess the existence of time heterogeneity in the parameters. We take 1998-2001 as the reference period and assess whether differences existed with respect to such period in the network structural dynamics in 2001-2003 (*Dummy 2001-2003*) and in 2003-2006 (*Dummy 2003-2006*).

Estimation procedure

We model the evolution of the network of code-sharing agreements by using SIENA actor-based models of network change (Snijders, 2005). These models are actor-based since they analyse network evolution as resulting from the aggregation of the choices that individual actors make to create new ties or discontinue old ones. In our alliance network the creation of a tie is modelled as the common choice of two airlines where one takes the initiative and the other has to confirm; for the dissolution of an alliance the confirmation is not required (unilateral initiative and reciprocal confirmation; Ripley et al., 2013: 43). Individual network actors choose with whom to create a new tie or discontinue an old one based on their preferences about local configurations of relations. The dynamic tendencies of the network are then modelled as the components of the utility function that the airlines try to maximize by choosing other airlines with whom to initiate a new alliance or dissolve an existing one. The parameters associated to the components of the utility function are estimated by simulations of the evolution of the network between consecutive observations that are iterated until convergence on a set of parameter estimates is obtained. Based on these parameter estimates another series of simulations is performed which produces an estimate of the standard errors. Simulations allow an assessment of the probability distribution of the parameters estimates that is needed for testing, whose exact analytical form remains unknown. This is a general issue in analysing network dynamics, because of the departure from the standard assumption of independence of observations that is intrinsic to the task of assessing structural tendencies, equivalent to that of assessing forms of interdependence between ties. Structural zeros in the adjacency matrices are used for dealing with changing membership in the network during the observed period, as explained by Ripley et al. (2013).

RESULTS

Table 2 shows the descriptive statistics. We include the number of companies present each year as well as the average and the standard deviations of the control variables included in our models, namely the size of the companies, in our case computed using fleet size, their experience and load factor, the percentage of airlines belonging to one of the three regions of the northern part of the hemisphere, GDP percent growth and the passengers carried. Table 3 shows the correlations of the variables included in the estimations. We also computed the Jaccard index to gauge the similarity of two consecutive observations and hence the amount of change in the network. The Jaccard index measures the similarity of two networks by discarding the ties that do not exist in either network, in order to avoid inflating the similarity of sparse networks whose adjacency matrices are filled mainly with zeros. This index remains within an acceptable range during the observation period, with a maximum in 2004-2005 (Jaccard = .84; slow change) and a minimum in 1998-1999 (Jaccard = .63; fast change).

[Tables 2, 3 and 4 about here]

Table 4 shows the results of the SIENA models. The convergence of the estimation algorithm was very good for all models, with the *t* statistics for all parameters below 0.1, which is the typical convergence threshold in SIENA models. In SIENA models all the parameters are coefficients of the utility function that actors try to maximize by choosing to create new ties, to maintain existing ties, or to terminate them. If a parameter is positive, then there is a higher probability of moving toward a network configuration where that variable has a higher value or, in other words, that the variable associated with such parameter drives network evolution; the opposite is true if the parameter value is negative (Lazega et al., 2011).

In the control model (model 1), we included both endogenous and exogenous effects. The degree parameter is significant and negative suggesting that actors are generally reluctant to form ties. This finding is common in network evolution models as actors draw no benefit from forming random ties to other network members which are not part of specific local structures. With respect to firm characters we find that actors with significant experience are more likely to be involved in tie formation. For the similarity measures, we find that airlines that belong to Europe, Asia-Pacific and North America (north hemisphere), airlines that belong to the same multilateral alliance, and airlines originating from countries with similar GDP growth are more likely to cooperate with each other. On the other hand, we observe that experienced firms are more likely to choose partners with less experience, and vice versa.

In models 2a and 2b we include the parameters of interest which correspond to the rules of attachment described earlier (we have two variants of this model as we found "assortativity" and "degree of alter" highly correlated. Accordingly, the effects of these two variables were estimated separately). The positive and significant parameter 'transitive triads' indicates that open triads tend to close. As previously noted this result is quite recurrent in a variety of networks since actors generally tend to become "friends of their friends" (Granovetter, 1973). The parameter 'degree assortativity' is negative but not significant. Therefore, when one considers the whole 9-year period, the presence of assortative mixing based on degree is not confirmed. Similarly, there is no significant preferential attachment (or rich get richer) effect as the parameter 'degree of alter' is positive but not significant. With the exception of experience and experience similarity, controls that are significant in model 1 continue to be significant, and in the same direction, in both models 2 and 3.

The social dynamics of the network vary when one takes into account time heterogeneity. We do so in models 3a and 3b, where we interact the variables of theoretical interest with two time dummies capturing the jolt (2001-2003) and post jolt (2003-2006) periods. The parameter 'degree' remains negative and significant. However, the interaction between ‘degree’ and the two time dummies is positive and significant suggesting that in the aftermath of the shock the cost of establishing linkages decreases or, stated differently, actors are relatively more inclined towards creating new partnerships. We integrate this finding with a portrait of the trends in degree distributions for the years 1998-2006, illustrated in figure 2. Degree distributions are often used as a diagnostic indicator to assess if tie formation in a network is equiprobable for all pairs of nodes or biased proportional to existing ties of potential partners (Powell et al., 2005). Figure 2 shows the degree distribution in the airline field for three distinct periods, before, during, and after the jolt. The *x*-axis indicates the number of ties per company (i.e. degree) and the *y*-axis indicates the number of companies. We see in the picture that the number of companies having very few connections drops significantly over the three periods. This result suggests that the years after 2001 marked a long-term shift in relational logics leading to an increasingly less stratified field.

[Figure 2 about here]

When interacted with the time dummies, the parameter for degree assortativity changes significantly. We find that both in the immediate aftermath of the jolt and in the period that followed, disassortativity occurs as confirmed by the negative and significant interactions between ‘degree assortativity’ and both time dummies. Actors that occupy prominent positions in the field exhibit an increasing propensity towards forging alliances with more peripheral actors and vice versa. Since disassortativity is often driven by complementarity needs (Ahuja et al., 2012), a possible interpretation is that the jolt induces actors towards a stronger preference for diversity. Note that most high-degree airlines belonged to the Northern hemisphere (namely Asia, Europe and North America) and that 9/11 hit these regions more severely. Not only a reorientation of these carriers’ alliance strategy towards diversity allowed them to compensate for demand reduction in their Transatlantic and Transpacific routes, but it also enabled them to expand their presence in local markets which were less hit by the jolt. At the same time, peripheral players attaching to high degree players could take advantage of status and reputation transfer. One such example is provided by the code-sharing agreement established between Lufthansa and the much smaller regional carrier Aegean Airlines. The latter's CEO commented the cooperation between the two carriers as follows (Aegean, 2005):

> "Lufthansa, one of the world's leading airlines, has done us proud by recognising us as a strong regional partner. We are delighted at becoming Lufthansa's partner in Greece as we are with the opportunity of offering our passengers connections into Lufthansa's global route network"

The tendency towards transitive closure is stronger both in the jolt and post-jolt periods as indicated by the positive and statistically significant interaction terms between "transitive triads" and the two time dummies. The increase in clustering after the shock is significant especially in the immediacy of the shock, suggesting that the large upheaval in the network acts as a catalyst for retrenchment and cohesion. In other words, the jolt seems to trigger relationships that increase the organizations' embeddedness into the network rather than a motivation to alter the present structure with new bridging ties (Galaskiewicz and Shatin, 1981; Podolny, 1994). These findings suggest that the returns to cohesion, such as reliability and trust, provide especially appealing benefits when field actors have to cope with convulsive moments triggered by exogenous shocks that suddenly disturb field-level consensus causing indeterminacy (Clemens and Cook, 1999).

The interaction between degree of alter and the time dummies yields also interesting results. Both interactions are negative although the degree of alter parameter is significant only in the post-jolt period. These results support a 'poor get richer' argument indicating that actors with lower degrees become more attractive partners in the post-jolt period compared to the period before the jolt. Our perspective on this trend builds on the idea of "structure-loosening" event (Madhavan et al., 1998). A structure-loosening event is believed to occur when the poor get richer or when highly central actors forgo a central position while more peripheral actors become more central. To explore this argument, we turn to examine the core-periphery dynamics of the field over the study period. In an idealized core-periphery structure, the core is a group of nodes that are connected to all other nodes of both the core and the periphery. The periphery is a group of nodes that are not connected to each other but only to the nodes in the core. Although no real social network conforms to this ideal, an algorithm is used to maximize the density within the core and to minimize the density within the periphery. This can be accomplished with a genetic algorithm first proposed by Borgatti and Everett (1999) and implemented in UCINET VI package (Borgatti et al., 2002). The resulting partition of the network into core and peripheral members over the 9 year period of the study is depicted in figure 3 which shows trends for core and peripheral organizations annually. Note that starting from 2001 and throughout the post-jolt period the two curves have opposite trends with the periphery thinning and the core growing. The difference in size between these two partitions becomes increasingly less pronounced up to 2004, when the two trends change direction and the magnitude of the core-periphery divide picks some momentum once again. The number of peripheral organizations declines especially rapidly after 2001 while organizations in the core increase and subsequently almost stabilize.

[Figure 3 about here]

Robustness checks

An event focus tracks the evolution of an interorganizational field over time by examining structure through various 'windows of time' (Doreian, 1986). The window's length depends on specific events. A key advantage of this approach is that both managers and researchers are likely to agree that industry events provide more relevant ‘check points’ for network evolution than arbitrary time periods (Madhavan et al., 1998). Since the jolt we studied took place in September 11 2001, we chose 2001 as a starting year for the jolt period. This choice was driven both by previous contributions studying the effects of the 9/11 (Bradley et al., 2011) and by interviews with airline alliance managers. However, to test for the possibility that the duration of the post-jolt period may have a different length, we used alternative time windows. In particular, we re-ran our full model using the following windows for the jolt period: 1) 2001-2002, 2) 2002-2003, and 3) 2002-2004. Results from these analyses – available from the authors – do not differ substantially from the results obtained with the 2001-2003 time window for the jolt period.

In order to control for alternative measures of the dynamics in the local (triadic) structure, we run transitive ties effect which is similar to the transitive triads effect, but instead of considering for each other actor j how many two-paths i → h → j there are, it only considers whether there is at least one such indirect connection (Ripley et al., 2013). This analysis – available from the authors – did not yield different results from the model with the transitive triads thus providing additional robustness to our results. Additionally, to explore the changes in relational logics presaged in the figures and tables presented above, we offer in the appendix additional insights into the triadic combination of core and peripheral organizations in the pre-, during and post- jolt periods.

DISCUSSION

Accounting for social change is one of the enduring problems of social science. Many such accounts paint organizations as “plaint in response to exogenous shocks, whose effects appear to radiate outward like a tsunami toppling those in its path” (Powell and Owen-Smith, 2012: 466). Whether in the form of social upheavals, technological disruptions, regulatory change or environmental shocks (e.g., Davis et al., 1994; Kraatz and Moore, 2002; Meyer et al., 2005), jolts can disturb field-level consensus triggering alternative logics of action and interaction and thus rupturing the creation and re-creation of stable systems of relationships. Unfortunately, these punctuated accounts of organizational life do not tell us much about how organizations restructure their ties after such convulsive moments, and even less explored is the subsequent evolutionary trajectory of the network in which such organizations are embedded. We sought to address this gap through an analytical strategy rooted in the understanding of markets as fields (Bourdieu and Wacquant, 1992) structured by relationships that both channel the flow of information and resources and provide signals of status and identity. These networks mark past experiences but are also a roadmap of future prospects. Thus, by examining the dynamics of interorganizational tie formation and dissolution over time we set out to expose changes in the logics of attachment guiding actors' interorganizational affiliations in the aftermath of an exogenous shock.

Drawing on rich qualitative as well as quantitative evidence on the interorganizational structuration of the global field of commercial airlines in response to the terroristic attacks of September 11 2001, we illustrated a pattern of network transformation conducive to a gradually less stratified and more inclusive field. Through a combination of methods ranging from the analysis of interview material, to social network analysis to actor-based statistical modelling we documented the emergence of a blended logic of partner selection that combines both "conservatism" through triadic closure and outreach to peripheral members through disassortativity and preferential avoidance. Purely from the perspective of network dynamics, the picture suggested by the analysis of the mechanisms of network change is that the members of the network respond to the negative shock by pursuing a mix of consolidating and expansive ties (i.e. a hybrid network structure). They consolidate positions by closing open triads at a greater rate, thereby increasing their embeddedness into the network, but they simultaneously prospect for less connected members and newcomers, thus enabling the formation of a more permeable network core. This strikes us as particularly interesting, for two reasons. First, we surmise that this tension between cohesion and outreach to peripheral members is key to determine the overall poisedness of the field in the face of exogenous shocks. In the airline industry the mix of conserving and prospective ties has resulted in a porous core that neither calcified nor dramatically transformed despite the major turmoil that shook the system. Exploring the durability and resiliency of these at least partially diverging interorganizational arrangements that emerge in response to external shocks is a fascinating area for future inquiry. Second, research on the social structure of fields has had relatively little to say so far in respect to possible mechanisms that may curb the stratification order that conserves the privileges of the field's core members. One possibility suggested here is that the environmental jolt creates an 'occasion' for field restructuring by catalysing the emergence of a less skewed distribution of interorganizational ties and fostering greater integration between the core and the periphery of the network. And the fact that these affiliation dynamics persist both in the immediacy of the jolt and in the longer term suggests that the rewiring of the network is not a temporary response to a situation of sudden crisis but the expression of a new logic of interaction that comes into existence.

CONCLUSIONS

Research on the formation and dissolution of interorganizational ties has been flourishing in management and sociology (e.g., Gulati and Gargiulo, 1999; Madhavan et al., 1998; Powell et al., 2005). By progressively recognizing that actors in an interorganizational field are not only situated in space but also in time, these and other studies have contributed to a better understanding of how and why fields evolve to take the forms that they do. Much of this research has highlighted the role of the endogenous influence of the network structure in which an organization is embedded in affecting that organization's opportunities to select its partners and so position itself in the field. Existing structures have been found to provide social cues about the reliability of future partners and their competencies which in turn reduce the search costs and the risks associated with opportunism (Gulati, 1995). Yet, not all ties are predicted by network endogeneity and other factors other than network structure may motivate tie dynamics.

In this study we have focused on one such factor exogenous to the network and to the entire field, as an attempt to move away from accounts of how networks reproduce themselves and gain instead a better understanding of why and how logics of attachment change. Indeed, it is relatively unknown "whether different mechanisms play greater or lesser roles as networks evolve" (Rivera et al., 2010: 108). A central contribution of our study, therefore, is to expose such mechanisms and show how they change over time as a result of an exogenous shock that undermines the calculations on which field relations had been based.

From a methodological standpoint we wish to emphasize that the mechanisms of tie formation and dissolution we have examined rest on complex processes, operating both at the level of actors' attributes and at the endogenous level of their relationships. The interplay of these mechanisms makes the disambiguation of causal relationships in the dynamics of tie formation and dissolution particularly hard to pin down (Rivera et al., 2010). Achieving this goal is made more difficult by the methodological challenge of endogeneizing network change (Fligstein and Stone Sweet, 2002) due to the composite dependence structure of the tie variables. The statistical modelling approach we use in this paper offers a distinctive and powerful toolkit for addressing this issue. It is distinctive because it focuses on the evolution of the entire network, and not only on dyadic tie formation, which can account simultaneously for generative mechanisms across different levels without making unrealistic assumptions of dyadic independence, thus allowing us to model interdependencies and assess network evolution properly (Ferriani et al., 2013). It is also powerful because it is based on maximum-likelihood estimation, which has been shown to be superior in estimating network change compared to the pseudo-likelihood estimators traditionally used for inference from exponential random graph models (Van Duijn et al., 2009). The stochastic actor-based models for network dynamics implemented by SIENA rely on simulations for estimation and testing and can be compared to other simulation based methods: they embody a logic similar to agent-based models (ABMs; Gilbert, 2008) in that they focus on the micro-mechanisms of actors choices as drivers of macro-structural change. The difference with ABMs is that SIENA models are based on observed rather than simulated data. They can also be compared to other network modelling approaches, like exponential random graph models (ERGMs; Robins et al., 2007), which also overcome the estimation and testing problems posed by network interdependence. ERGMs, however, are cross-sectional and "can best be understood as a model of a process in equilibrium" (Snijders et al., 2010: 57), while SIENA models are longitudinal and more general than ERGMs, because they do not require the equilibrium assumption. By using SIENA to analyse the evolution of the interfirm collaboration network in the airline industry, our study aims to contribute to the small but growing research that uses stochastic actor-oriented model for network dynamics (Ebbers and Wijnberg, 2010; Balland et al., 2013; Ferriani et al., 2013).

This research is not without caveats. The single and negative event we chose may put some limits to the generalizability of our results. First, given the idiosyncratic nature of each event, it is necessary to take into account the properties of shocks when examining their impact on networks. Future studies may start discriminating between different types of shocks based on several dimensions such as: 1) the sign of the shock (positive versus negative), 2) the locus in which the shock takes place (within or outside the field), 3) the influence field actors can exert on the event (low versus moderate), 4) the magnitude of the shock (low versus high impact), and its 5) duration (short-term versus long-term). Moreover, field-specific factors may influence the relationship between the type of shock and the network rewiring that ensues. Examples of such factors include, among others, the stage of maturity of the industry and the distinction between service and manufacturing industries. The patterns found in our study may for instance not be the same in less bureaucratic and younger industries. Third, an issue worth noting is that the exogenous shock we focused on took place somewhat in between two other disruptive events: the Asian financial crisis, widely regarded as an environmental jolt that suddenly reduced global environmental munificence (Wan and Yiu, 2009), which reached its apex in the period 1998-1999; and the pandemic crisis caused by SARS in 2003. The sequencing of these events (Asian crisis, 9/11, SARS) over a relatively short span of time (6 years) means that some of their effects may have been intertwined. For instance, it is quite possible that some airlines may have first changed their dynamics of affiliation in response to the Asian crisis and then reinforced such transition in response to 9/11 first and the SARS next. This may explain the acceleration observed in triadic closure and, more generally, the persistence of all network effects in the post-jolt period. If this is indeed the case, the sample may have provided us with a conservative test of our central claim that jolts have the potential to subvert the field's prevailing logics of attachment. Finally, interesting results could emerge from the interactions between different levels of analysis. For instance, using the variables we identified in this paper future research could explore: 1) whether transitive triads between firms sharing a common attribute are more likely to occur before or after an environmental jolt, 2) whether homophilous ties are more likely when two firms share a common partner before and after an environmental jolt. We hope our initial findings provide new insights, encouraging scholars to undertake more research on situations far from equilibrium and explore their effects on the evolution of networks and fields.

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Notes

1. Constellation members are linked through dyadic collaborative agreements but not all of them are necessarily tied to one another (Gomes-Casseres, 1994). In other words, ties with non-constellation members and with members of other constellations are still possible.

2. We followed the division suggested in the Airline Business magazine which identifies six regions: Africa, Asia-Pacific, Central-South America, Europe, Middle East and North America. The patterns of the average degrees from the six geographical areas showed a similarity among the companies from the northern hemisphere (Asia-Pacific, Europe and North-America) on one hand, and those from the southern on the other, with the former characterized by similar and higher average degrees across the period of observation. Since exogenous covariates are included in SIENA models for controlling actors' degree heterogeneity, we aggregated the six geographical areas in the two hemispheres to reflect the heterogeneity of these two patterns, without burdening the estimation with redundant parameters.

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APPENDIX

Table 1. Details of key informants

Company	Position	Region of origin
Aeroflot	Deputy General Director for Strategy and Alliances	Europe
Aeromexico	Director Alliances	Latin America
Austrian	Senior Director Partner Management	Europe
CSA Czech Airlines	Head of Alliances & International Relations	Europe
Delta	Director Alliances	North America
JAL	Alliance Manager	Asia-Pacific
KLM	Senior VP Strategy & Corporate Development	Europe
Lufthansa	Senior Manager Alliances and Cooperations	Europe
n.a.	Former CEO oneworld	North America
SkyTeam	VP Sales	Europe
SWISS	Head of Emergency Response Process Management	Europe

Table 2. Descriptive statistics (means and standard deviations)

Descriptive Statistics:
Nr. of Companies, Region, Experience, Fleet Size, GDP Growth, Load Factor, Passengers

	1998	1999	2000	2001	2002	2003	2004	2005	2006
Nr. of Companies	127	127	125	125	118	115	112	109	107
Companies from North Hemisphere (%)*	89 (70.1%)	89 (70.1%)	87 (69.6%)	89 (71.2%)	85 (72.0%)	82 (71.3%)	81 (72.3%)	78 (71.6%)	77 (72.0%)
Average Experience (Std. Dev.)	42.03 (22.77)	43.03 (22.77)	44.62 (22.46)	45.27 (22.94)	45.58 (23.51)	46.69 (23.63)	48.23 (23.52)	49.43 (23.72)	50.35 (23.81)
Average Fleet Size (Std. Dev.)	95.83 (125.81)	80.38 (119.89)	81.03 (122.31)	80.76 (123.49)	81.97 (117.48)	82.95 (111.88)	92.35 (115.77)	88.97 (115.78)	98.67 (115.99)
Average GDP Growth (Std. Dev.)	0.025 (0.04)	0.035 (0.03)	0.046 (0.02)	0.025 (0.02)	0.030 (0.03)	0.039 (0.03)	0.053 (0.03)	0.047 (0.03)	0.054 (0.03)
Average Load Factor (Std. Dev.)	0.667 (0.06)	0.665 (0.07)	0.678 (0.07)	0.676 (0.06)	0.685 (0.07)	0.680 (0.06)	0.708 (0.06)	0.714 (0.06)	0.733 (0.06)
Average Passengers (Std. Dev.)	12.10 (17.99)	11.71 (17.88)	12.07 (18.01)	12.70 (18.00)	12.58 (17.97)	12.32 (17.86)	14.72 (19.74)	14.72 (20.58)	16.56 (20.85)

* North America, Europe and Asia-Pacific

Table 3. Correlation matrix (degree assortativity)

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1. Degree (Density)																						
2. North Hemisphere	0.368																					
3. Same Hemisphere	-0.551	-0.384																				
4. Alliance Member	0.207	-0.093	0.010																			
5. Same Alliance	-0.082	0.022	-0.089	-0.361																		
6. Experience	0.115	0.245	-0.020	-0.226	0.026																	
7. Experience Similarity	-0.029	0.041	0.057	0.057	-0.055	-0.282																
8. Fleet Size	0.014	-0.043	-0.027	0.073	-0.063	-0.136	0.052															
9. Fleet Size Similarity	0.029	-0.029	-0.038	0.074	-0.046	-0.061	0.020	0.802														
10. GDP Growth	-0.073	0.024	0.002	0.054	-0.011	0.055	0.026	0.021	0.029													
11. GDP Growth Similarity	-0.074	0.050	-0.024	-0.062	0.007	-0.102	0.032	-0.064	-0.036	-0.102												
12. Load Factor	-0.038	-0.195	0.040	-0.082	0.012	-0.062	0.046	0.040	0.074	-0.107	-0.128											
13. Load Factor Similarity	-0.016	0.147	-0.050	0.000	0.015	0.062	-0.119	-0.028	-0.065	-0.041	0.021	-0.246										
14. Passengers	0.076	0.029	-0.014	-0.112	0.040	0.163	-0.071	-0.851	-0.663	-0.019	0.033	-0.092	-0.016									
15. Passengers Similarity	0.041	0.045	-0.017	-0.106	0.026	0.118	-0.051	-0.630	-0.838	-0.035	0.010	-0.098	0.028	0.766								
16. Transitive Triads	0.201	-0.009	-0.045	0.034	-0.347	-0.015	-0.010	0.065	-0.001	-0.003	0.010	0.014	-0.048	-0.017	0.022							
17. Degree Assortativity	-0.657	-0.210	0.034	-0.253	0.259	-0.205	0.017	-0.078	-0.050	0.051	0.083	-0.029	-0.018	-0.045	-0.032	-0.644						
18. Degree (Density) x Dummy 2001-2003	0.092	-0.038	0.033	-0.012	-0.013	0.005	-0.014	0.049	0.016	0.012	-0.023	-0.062	-0.011	-0.040	-0.018	-0.001	-0.042					
19. Degree (Density) x Dummy 2003-2006	0.279	0.069	-0.020	0.036	0.005	-0.067	-0.001	0.034	0.021	-0.168	0.082	-0.174	0.060	-0.008	-0.025	0.002	-0.128	0.312				
20. Degree Assortativity x Dummy 2001-2003	0.009	0.113	-0.048	-0.050	0.025	0.053	0.018	0.042	0.054	0.016	-0.032	0.016	0.011	-0.006	-0.010	0.054	-0.064	-0.693	-0.237			
21. Degree Assortativity x Dummy 2003-2006	-0.073	0.063	-0.010	-0.021	-0.014	0.078	0.006	0.034	-0.021	0.028	-0.037	0.018	-0.016	-0.014	0.060	0.097	-0.065	-0.297	-0.682	0.486		
22. Transitive Triads x Dummy 2001-2003	-0.057	-0.098	0.056	0.008	-0.047	-0.043	0.018	-0.020	-0.028	0.027	-0.002	0.000	-0.013	0.001	0.001	-0.054	0.075	0.201	0.081	-0.730	-0.390	
23. Transitive Triads x Dummy 2003-2006	-0.051	-0.072	0.040	-0.037	-0.046	-0.036	0.060	0.008	0.015	0.057	-0.034	0.024	0.007	-0.032	-0.046	-0.099	0.100	0.101	0.155	-0.374	-0.704	0.523

Correlation matrix (degree of alter)

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1. Degree (Density)																						
2. North Hemisphere	0.408																					
3. Same Hemisphere	-0.480	-0.452																				
4. Alliance Member	0.241	-0.113	-0.015																			
5. Same Alliance	-0.185	0.012	0.055	-0.406																		
6. Experience	0.188	0.196	-0.030	-0.231	0.057																	
7. Experience Similarity	-0.062	0.007	0.029	0.040	-0.046	-0.277																
8. Fleet Size	0.061	-0.038	-0.058	0.020	-0.035	-0.145	0.021															
9. Fleet Size Similarity	0.054	-0.028	-0.071	0.037	-0.024	-0.087	0.010	0.824														
10. GDP Growth	-0.032	0.042	-0.006	0.030	0.018	0.135	-0.015	0.002	0.037													
11. GDP Growth Similarity	-0.015	0.064	-0.018	-0.039	-0.004	-0.056	0.007	-0.013	0.015	-0.097												
12. Load Factor	0.032	-0.148	0.013	-0.059	0.035	-0.057	0.039	0.020	0.059	-0.136	-0.116											
13. Load Factor Similarity	-0.074	0.086	-0.077	-0.042	0.027	0.008	-0.075	-0.085	-0.104	-0.055	0.074	-0.207										
14. Passengers	0.029	0.004	-0.008	-0.084	0.012	0.177	-0.054	-0.846	-0.671	0.002	0.010	-0.054	0.040									
15. Passengers Similarity	0.012	0.014	0.007	-0.099	-0.003	0.138	-0.053	-0.631	-0.830	-0.049	-0.004	-0.053	0.049	0.765								
16. Transitive Triads	0.280	0.040	-0.089	0.043	-0.317	-0.022	-0.010	0.021	-0.025	-0.002	0.056	-0.019	-0.047	0.009	0.035							
17. Degree of Alter	-0.833	-0.255	0.112	-0.255	0.232	-0.233	0.069	-0.063	-0.040	0.032	-0.008	-0.047	0.044	-0.044	-0.029	-0.544						
18. Degree (Density) x Dummy 2001-2003	0.046	-0.044	0.081	-0.061	0.032	0.014	0.034	0.026	-0.011	-0.010	-0.023	-0.034	-0.012	-0.031	0.020	-0.024	-0.040					
19. Degree (Density) x Dummy 2003-2006	0.129	-0.025	0.083	-0.009	0.000	-0.074	-0.006	0.004	0.022	-0.149	0.052	-0.111	-0.010	0.012	-0.005	-0.001	-0.078	0.307				
20. Degree of Alter x Dummy 2001-2003	-0.006	0.069	-0.094	0.015	0.005	0.004	-0.040	0.009	0.034	0.080	0.007	0.023	-0.017	0.009	-0.037	0.019	0.019	-0.851	-0.278			
21. Degree of Alter x Dummy 2003-2006	-0.043	0.069	-0.097	-0.022	0.036	0.017	0.003	0.051	-0.012	0.088	-0.006	0.022	0.027	-0.061	-0.008	0.031	0.021	-0.314	-0.843	0.394		
22. Transitive Triads x Dummy 2001-2003	-0.033	-0.015	0.087	-0.003	-0.024	-0.025	0.022	0.019	0.018	-0.070	-0.026	-0.041	0.039	-0.036	-0.020	0.002	-0.006	0.293	0.084	-0.636	-0.245	
23. Transitive Triads x Dummy 2003-2006	-0.026	-0.026	0.093	-0.005	-0.092	0.061	0.013	-0.007	0.018	-0.053	-0.054	-0.034	-0.013	0.013	0.002	-0.046	-0.002	0.120	0.232	-0.288	-0.585	0.461

Table 4. SIENA models for the evolution of interorganizational networks

	Model 1			**Model 2a**			**Model 2b**			**Model 3a**			**Model 3b**		
	Controls			Controls Main Effects			Controls Main Effects			Controls Main Effects Time Heterogeneity			Controls Main Effects Time Heterogeneity		
	Estim.	SE	p-value	Estim.	SE	p-value	Estim.	SE	p-value	Estim.	SE	p-value	Estim.	SE	p-value
Degree (Density)	-0.870	0.048	<0.001 ***	-1.124	0.060	<0.001 ***	-1.240	0.080	<0.001 ***	-1.075	0.065	<0.001 ***	-1.241	0.085	<0.001 ***
North Hemisphere	0.143	0.090	0.113	-0.094	0.087	0.282	-0.127	0.088	0.150	-0.068	0.089	0.445	-0.120	0.091	0.187
Same Hemisphere	0.202	0.061	<0.001 ***	0.163	0.055	0.003 **	0.162	0.054	0.003 **	0.171	0.056	0.002 **	0.182	0.057	0.001 **
Alliance Member	0.143	0.088	0.105	-0.049	0.087	0.570	-0.110	0.089	0.217	-0.082	0.092	0.370	-0.162	0.094	0.084 †
Same Alliance	1.336	0.127	<0.001 ***	0.600	0.137	<0.001 ***	0.696	0.140	<0.001 ***	0.580	0.141	<0.001 ***	0.714	0.141	<0.001 ***
Experience	0.007	0.002	<0.001 ***	0.002	0.002	0.243	0.001	0.002	0.518	0.002	0.002	0.222	0.001	0.002	0.617
Experience Similarity	-0.251	0.110	0.022 *	-0.198	0.110	0.072 †	-0.188	0.109	0.084 †	-0.195	0.115	0.090 †	-0.175	0.109	0.110
Fleet Size	0.000	0.001	0.716	0.000	0.001	0.934	0.000	0.001	0.758	0.000	0.001	1.000	0.000	0.001	0.817
Fleet Size Similarity	0.727	0.543	0.181	0.323	0.597	0.588	0.184	0.647	0.776	0.251	0.577	0.664	0.136	0.627	0.828
GDP Growth	1.465	1.090	0.179	1.844	1.093	0.092 †	1.914	1.069	0.073 †	1.442	1.107	0.192	1.490	1.171	0.203
GDP Growth Similarity	0.962	0.316	0.002 **	1.183	0.313	<0.001 ***	1.229	0.321	<0.001 ***	1.142	0.315	<0.001 ***	1.176	0.308	<0.001 ***
Load Factor	-0.095	0.635	0.881	-0.208	0.644	0.747	-0.349	0.638	0.584	-0.687	0.650	0.290	-0.811	0.649	0.211
Load Factor Similarity	0.317	0.239	0.185	0.132	0.235	0.576	0.108	0.241	0.653	0.119	0.236	0.614	0.109	0.241	0.651
Passengers	0.009	0.007	0.209	0.005	0.007	0.526	0.004	0.007	0.574	0.005	0.007	0.532	0.004	0.007	0.588
Passengers Similarity	-0.455	0.492	0.355	-0.311	0.525	0.553	-0.300	0.552	0.587	-0.231	0.506	0.649	-0.257	0.523	0.623
Transitive Triads				0.309	0.021	<0.001 ***	0.275	0.020	<0.001 ***	0.307	0.021	<0.001 ***	0.267	0.019	<0.001 ***
Degree Assortativity				0.000	0.000	0.182				-0.001	0.000	0.096 †			
Degree of Alter							0.008	0.008	0.305				0.010	0.008	0.202
Degree (Density) x Dummy 2001-2003										0.220	0.110	0.046 *	0.255	0.151	0.091 †
Degree (Density) x Dummy 2003-2006										0.358	0.113	0.002 **	0.424	0.148	0.004 **
Degree Assortativity x Dummy 2001-2003										-0.001	0.001	0.046 *			
Degree Assortativity x Dummy 2003-2006										-0.001	0.001	0.030 *			
Degree of Alter x Dummy 2001-2003													-0.025	0.016	0.134
Degree of Alter x Dummy 2003-2006													-0.033	0.015	0.023 *
Transitive Triads x Dummy 2001-2003										0.157	0.053	0.003 **	0.133	0.048	0.006 **
Transitive Triads x Dummy 2003-2006										0.095	0.047	0.042 *	0.083	0.041	0.04 *

† $p<0.1$, * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Figure 1. Constellation membership evolution

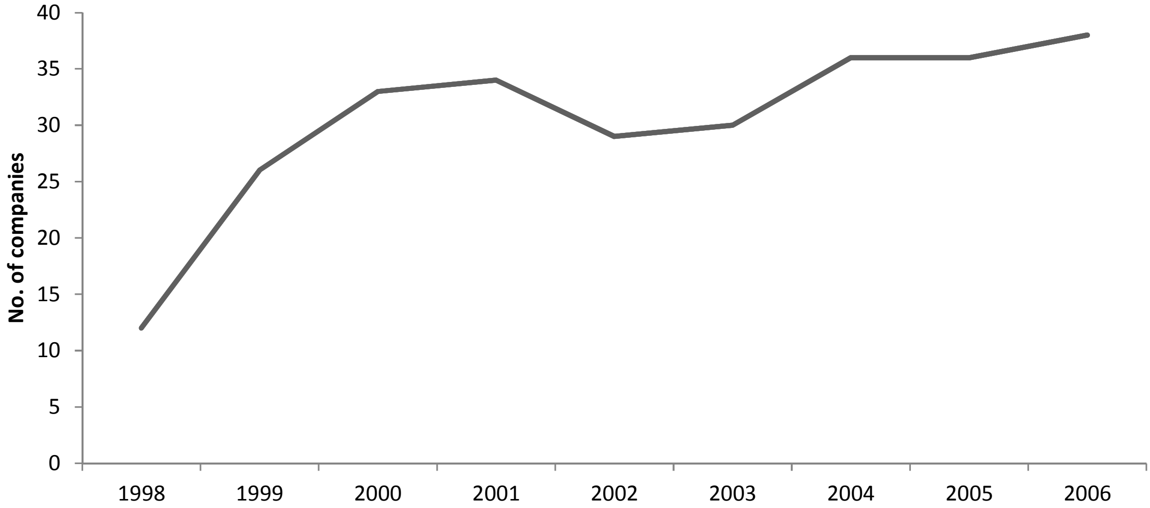
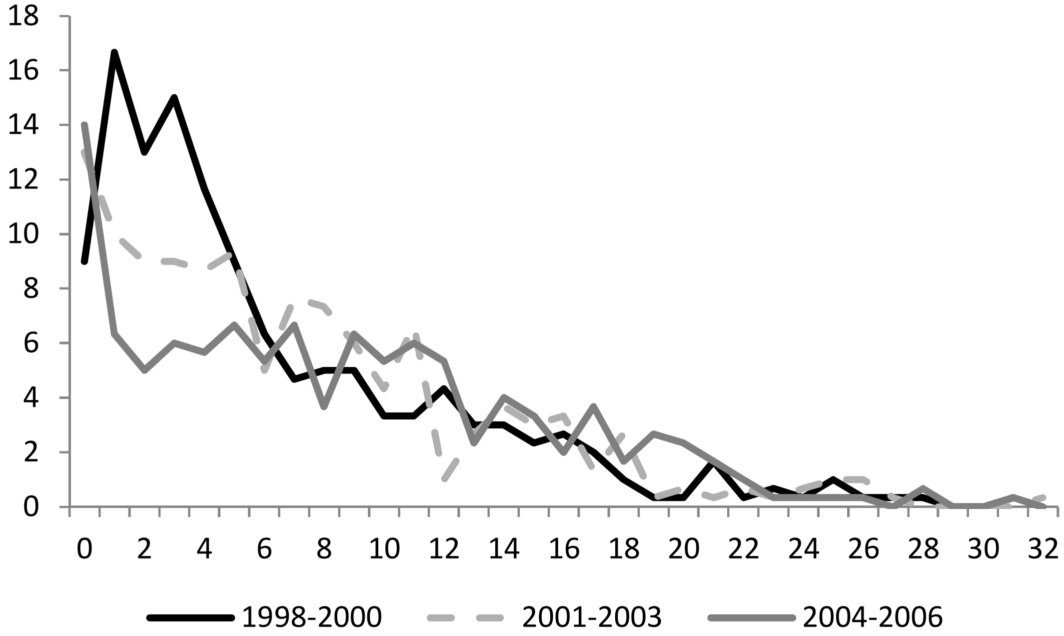
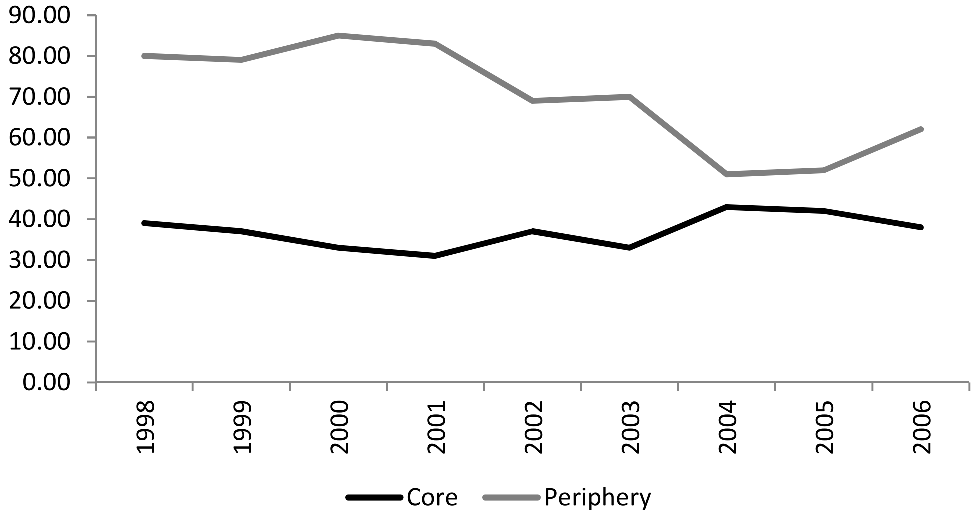


Figure 2. Degree distributions in the pre-, during, and post-jolt periods



Horizontal axis: number of ties per company by year; Vertical axis: number of companies

Figure 3. Annual count of core and peripheral organizations, 1998-2006, full sample



APPENDIX

Consider the table below where we partitioned the closed triads for the three representative time periods (1998, 2002, and 2006) and by type of triad. With respect to the type of closed triad, we distinguish among core triads that link three members of the core (C-C-C); periphery triads that link three members of the periphery (P-P-P); core-periphery triads that link two members of the core and one member of the periphery (C-C-P) and periphery-core triads that link two members of the periphery and one member of the core (P-P-C). The number of closed triads snowballs through the decade. In 1998 there were 310 closed triads and more than twice as much in 2006. As the overall field becomes less stratified in the post-jolt periods, it also increases its internal cohesiveness as more pathways between the core and the periphery are created.

Table 1. Closed triads by year and type

	1998	**2002**	**2006**
C-C-C	205	314	339
C-C-P	90	120	214
P-P-P	5	19	18
P-P-C	10	38	69
Total	***310***	***491***	***640***

In the turmoil and uncertainty that follows the tragic events of the early 2000s, all field members become increasingly embedded into the network. Yet, it is the dramatic upsurge in the amalgamation of core and peripheral players that stands out most vividly in these cohesive dynamics. Indeed, closed blended triads involving both core and peripheral members exhibit by far the strongest increases in the post jolt period, with C-C-P triads growing two and half times and P-

P-C triads showing the sharpest increase, with a sevenfold jump. Cohesion within the core remains dominant throughout the period, with C-C-C triads accounting for well over 50% of the total triangles in the in the network. But at the same time core members become more involved with peripheral players, using their gravitational pull to draw peripheral players closer and embed them into core interconnections. The core, in other words, grows more cohesive, but not at the expenses of the periphery. Instead, this growth appears to be the result of a well-connected yet increasingly permeable core. As more organizations are entwined in the core, the logic of attachment shifts.