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The structural wings of Matthew effects: The contribution of three-level network data to the analysis of cumulative advantage

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Abstract

The article presents a three-level network approach to the Matthew effect as a multilevel complement to Burt's (2005) conception of the relationship between networks and performance. We first introduce a three-level dataset and the specificity of this data structure for explorations of cumulative advantage. Second, we present a population of scientists and provide a heuristic visualization—as “paragliders”—of their position in this multilevel structure. Third, we cluster these actors into groups of performance to better understand who is in a multilevel position to make progress with performance measurements over time. We use Ronald Burt's representation of the combined effect of brokerage beyond group and closure within group to show that several of these performance groups do not follow his own principles very closely. Fourth, we provide evidence, for one of these groups, of the usefulness of combining constraint in the personal network of its members with constraint in their “extended” network—that is, for looking at the relationship between performance and borrowing from “dual alters” in the extended network. This shows that, when it is present, network lift from three-level structural wings is provided by different levels for different actors. Hypotheses induced by the paraglider metaphor can thus be tested progressively to provide new understandings of the structural conditions under which the Matthew effect of cumulative advantage operates. Finally, we list limitations of this three-level approach to the Matthew effect as examined here and suggest further developments for this approach.

Keywords

Meso-level Matthew effect, cumulative advantage, multilevel networks, paraglider, productivity, performance, inequality, scientists, relational capital, borrowing

Introduction

The asymmetrical ways in which productivity is distributed in populations of all kinds are often examined in economics and economic sociology to account for individual performance inequalities, persistence, and reinforcement over time. This descriptive article contributes to the literature explaining and evaluating performance by emphasizing both individual and organizational contexts intertwined. It proposes a new three-level network approach to analyze cumulative advantage at the individual, intra-organizational, and inter-organizational levels. It uses a structural metaphor for this cumulative advantage, the superposed wings of a paraglider, and builds around this metaphor to explore the usefulness of extended networks for understanding performance data as measured at the individual level. It thus provides a new structural translation of the kind of cumulative advantage that Merton (1968), in his famous paper, called “Matthew effect.”

The complexity of conceptualizing and analyzing the Matthew effect has often been addressed by existing research.

Since Merton's seminal paper on how advantage begets further advantage in science, the Matthew effect has been studied in many social situations in which populations fall behind in terms of abilities (Rigney, 2010). A network analytical perspective was developed by Price (1976; see also Mullins et al., 1977) in his article on networks of scientific papers, showing a preferential attachment mechanism among aggregated journal–journal citation networks and expressing it as a negatively exponential function, an approach further developed by statistical physicists following Barabási and Albert (1999). Another example is Gould (2003) using transitivity to explain this effect as concentration of status on specific members: actors confer status on others when they perceive

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that their peers do the same. Snijders (2011) provides measurements for this transitivity as an endogenous effect in his analyses of relational turnover in longitudinal network data, but defines the Matthew effect as self-reinforcing popularity in such networks, thus using centrality for prominence that increases over time.

The social science literature on the link between networks and performance, however, is dominated by Burt's (1992, 2005, 2010) theory: performance increases when actors have dense ties within their workgroup and high brokerage beyond the group. Burt's work shows that members benefit from brokerage and structural holes unless they are in a highly dependent situation. In the latter case, they can try to borrow someone else's (a champion's, a mentor's) relational capital to reach the same levels of performance as their average competitors. Borrowing social capital can be an efficient strategy for members who suffer from a lack of legitimacy (e.g. women in a male-dominated organization): it consists of benefiting from a colleague's or a superior's support through a use of the latter's network. Setting aside the case of such actors, who are considered to be socially illegitimate ("not one of us") by the majority of mainstream members, neighbor networks are presented as relatively useless for performance (Burt, 2010).

In this article, our contribution is to propose an organization-based approach to Burt's "borrowing" for which one needs three levels of network data to measure an additional dimension of the Matthew effect, that is, an effect based on what Lazega et al. (2013) call an extended opportunity structure. Here we are inspired by Breiger's (1974) theory of duality, that is, of co-constitution of individuals and groups, to provide an extra determinant of Matthew effects that are inextricably individual and collective. We generalize Burt's theory by assuming that all members (not only dominated members considered socially illegitimate) of an organization can borrow relational capital from other members through indirect and affiliation ties in a multilevel context. In our view, this is equivalent to "augmenting" individual networks. Translated in Burt's terms, adding a third level of analysis suggests that performance increases when an actor has dense ties within group, high brokerage beyond the group, and the opportunity to access an organizationally augmented network.

Using this three-level approach to borrowing and performance, we therefore argue that borrowing can be much more widespread than previously assumed. By looking at the inter-organizational context as well, via "expanded" or "org-augmented" networks, we show that sharing relational capital within one's organization and borrowing relational capital from outside one's organization (via colleagues and bosses or by using the name of one's organization) add to members' performance. Because it brings into the picture "dual alters" (potential contact accessible by closing a multilevel four-cycle) and complementary resources, this three-level approach helps understand rather invisible dimensions of the Matthew effect. Indeed previous work has shown that when

focal actors' dual alters are rich in resources that are complementary to the resources of these focal actors, including these dual alters in the model improves explanations of the focal actors' performances and returns on organizational investments. In other words, this inclusion of dual alters reshapes members' opportunity structure.

Here, the analysis is carried out on a small population of elite scientists in public research, the French field of oncological research (1996–2005), whose production of knowledge is recognized as efficient. All individuals are "sublime" in terms of productivity, with four papers per semester published in internationally visible journals over five successive semesters. Cumulative advantage mechanisms can be seen as a mix of economic and social mechanisms, in the sense that scientists who participate in the production of a successful publication are rewarded by obtaining resources that help them carry on with research, such as funding, free time, stimulating laboratories, talented students (Allison et al., 1982) that, in turn, help them win "scientific tournaments" in which the winner (the first to publish a result) takes all. But these scientists are also, as identified by Merton (1968, 1973), recognized by colleagues in terms of citations and reputation that go to already well-known researchers who can thus build a dominant position in their specialty and impose their "scientific orthodoxies" (Mulkay, 1972)—whereas unnoticed researchers accumulate obstacles and often end up exiting the system.

This gives a chance to combined individual and organizational network dimensions of productivity to become visible. Since Lotka (1926), productivity of scientists is known to have a very asymmetrical distribution with a minority of very prolific scientists and a majority of scientists with a much smaller contribution to the publications in any single domain. This asymmetry reflects a hierarchy in terms of productivity and this hierarchy is known to be not only persistent over time but also self-reinforcing, with amplification of inequalities within a given generation of researchers. This is especially the case when these patterns are combined with individual skills and strategies, and with organizational dimensions of scientific activities. For example, Bellotti (2012) shows that being in a brokerage position is extremely important for getting funding. Lazega et al. (2008, 2013) show that the centrality of the researcher in their peer networks and the centrality and size of the laboratories in which these researchers are affiliated can be combined elements of a structural explanation of scientific performance over time.

The "paragliding" visualization of cumulative advantage that we propose for the superposed levels of collective agency is based on a complex combination of these three kinds of network measurements, which is how it captures some of the multilevel relational processes producing together a meso-level Matthew effect. With the data structure represented by this paragliding metaphor, we account for variance unexplained by Burt's model. The characteristics

that make the potential networks (i.e. top surface of the paraglider) ascending or crashing is the specific constraint that they exercise on the individual researcher and the high or strong complementarity of resources that researchers can access through them (Lazega et al., 2013).

This three-level dataset includes and combines inter-laboratory networks, inter-individual networks within a specific subpopulation of scientists in that field, egocentric networks, and performance variations (impact factor (IF) scores associated with these researchers' publications) as measured at the individual level. Thus, network paragliders allow sociologists to measure the extent to which individual scientists' performance depends on the characteristics of the administrative unit in which they belong, on their position in the system of collective action in which they both cooperate and compete, and on the structure and composition of their personalized ego-network of collaborators. This unexplored dimension of cumulative advantage is thus based on effects that are a combination of individual, organization and 'industry level effects.

The article is structured as follows. We first present our three-level dataset and the specificity of the data structure that we use to explore cumulative advantage. Second, we provide a heuristic visualization of the combination of levels as paragliders. Third, we cluster the scientists into groups of performance to better understand who is in a multilevel position to make progress with performance measurements over time. We use Burt's representation of the combined effect of brokerage beyond group and closure within group to show that several of these performance groups do not follow his own principles very closely. Fourth, we provide evidence, for one of these groups, of the usefulness of combining constraint in the personal network of individuals and in their extended network, that is, for looking at the relationship between borrowing from dual alters and performance. Finally, we list current limitations of this three-level approach to the Matthew effect as examined here.

A three-level network dataset

The following section briefly describes the manner in which we selected the population, collected the data, and studied this milieu.

Population and data

Members of this population were identified by the number of articles published in scientific journals between 1996 and 1998. The numbers are based on the Cancerlit database of the US National Library of Medicine. The criterion used was a threshold of 25 papers over the period of 2.5 years. The list of scientists selected based on this criterion includes different types of actors: those who publish heavily, those who co-publish heavily, and those who are present in the list of authors because they provide technical help, or because they

run the laboratory. Following "Lotka's law" (Lotka, 1926), the vast majority of researchers working on a specific problem only publish one article about the problem. A very small, but more prolific minority of scientists publish the majority of their articles in a specific domain. In this list, we selected precisely those who, while based in France, had published the most (including in international journals) in cancer research during this period.

Selecting these scientists who are already at the top of their field to study who becomes highly productive through cumulative advantage may seem paradoxical. A different sample including much less productive scientists would have provided more variation in productivity. However, we found that there was already enough variability in this population of "sublime" scientists to explore the issue of cumulative advantage. Even the scientists and laboratories with lower performance scores are still more elite than other French cancer researchers at the time. This should not matter for the development of the method and its potential uses because the selection criterion and the list of names used in the study do not eliminate differences between the most productive and successful cancer researchers.

The sample was reduced to the first 168 researchers because this number represents all of the scientists who met the 25+ publications criterion. The construction of the measure of actors' performance is based on the IF of the journals in which each researcher has published. IF scores are limited as measurements of performance and they have long been criticized by information scientists and sociologists (Fox, 1983; Gingras, 2014; Long, 1978; Mulkey, 1972; Reskin, 1977; Seglen, 1992, 1997). In particular, IFs change over time. We therefore used them based on the year when a scientist published in the journal. All IF scores were computed using the same database, that is, PubMed in which Cancerlit was merged. The correlation between the number of publications and the IF scores of the individual's publications is 0.37. The score was calculated for publications with multiple co-authors in the following way. If a researcher published four articles in a journal, the IF score of that journal was multiplied by 4. IF scores of all publications were summed for each individual. We did not take into account the fact that a researcher was publishing alone or in a team: each person mentioned as a co-author received the same score. We could have divided the score by the number of co-authors, but this procedure seemed even more problematic than our procedure since we did not have any information about who did what for each paper. The researchers in the population received the full IF even if they were co-author #10 on a team of 15, not a fraction based on their rank and the size of the team.

Among the 168 researchers, 128 persons (76%) accepted an interview. Few central names are missing from our network. Most of the researchers who declined to be interviewed were rarely, if ever, selected from the list of names that was presented to the participants who did agree to be interviewed.

Their indegree centralities were very low in the relational networks of their French colleagues. We determined that few important names were missing by showing the list of those missing to several researchers who were reinterviewed after fieldwork, as well as to the cancerologists on the board of the non-profit organization that funded this research. Despite meeting the formal criterion to be included in the population, most were at the periphery of this network.

Following the strategy of structural linked design, we tried to interview all the directors of the laboratories to which these researchers belonged. In total, we interviewed (face-to-face) 82 laboratory directors in the system of French cancer research. In 51 of the 128 cases, the selected researcher is also the director of his/her laboratory; these persons agreed to two interviews (one as a researcher, one as a laboratory director) and responded to the two questionnaires. Insofar as, for various reasons, some directors of laboratory were interviewed but not the researcher in their laboratory, or the researcher but not the director, we are left with 93 researcher/director "pairs." Thus, the number of researchers that we are able, thanks to the structural linked design, to position in the dual system of superposed interdependencies is finally 93. All further network results at either level refer to the networks formed by these 93 pairs.

Data structure for network measurement and visualization of cumulative advantage

Next, the multilevel networks of interdependencies in France in 1999 were reconstituted. First, the inter-organizational networks between the majority of laboratories involved in cancer research; second, the advice networks constructed by the members of the "elite." This was done in the following manner. At the individual level, each researcher is considered a "scientific entrepreneur" who needs resources that may be social or financial. From the individual researcher's point of view, research may be analytically broken down into five steps: selecting a line of research, finding institutional support, finding sources of financing, recruiting personnel, and publishing articles. The five steps were identified based on ethnographic work with the researchers and discussion of where they really thought they needed advice. At each step, the researchers depend upon their relational capital and seek advice from other members of the research community in order to handle these uncertainties. In this competitive environment, access to advisors is an important resource because carrying out these tasks is facilitated by access to advice offered by competent colleagues who agree to help.

Scientific work was thus reduced analytically to a sequence of five non-routine tasks, each one characterized by a strong degree of uncertainty. The assumption that researchers follow five sequential steps, beginning with selecting a line of research and ending with publication, seems very simplified. This process is often not linear or rational. For example, researchers often choose their research

questions on the basis of available funding. While this is a simplification, it provides quite a complex view of the process in terms of networks. A different advice network was collected at each step, which was hard work for the interviewees. In addition, these steps are used here purely analytically and we do not carry out any sequential analysis. Indeed, in the analyses below, we aggregate the five advice networks to derive our network variables.

In order to reconstitute the resulting system of interdependencies among actors at the inter-individual level (within the elite), we asked the actors to identify those from whom, in the list of the 168 cancer researchers presented to them, they sought advice to handle these challenges at each step. It was thus possible to reconstitute one advice network per step: one network dealing with choices about the direction of projects, one for helping to find institutional support, one for handling financial resources, one helping with recruitment, and finally one network of colleagues to whom researchers send their manuscripts for advice before submitting them to journals. Other data were also collected about the researchers themselves: their attributes, their performances, and their opinions in several domains. Finally, each individual researcher was asked about the composition of his/her immediate workgroup, that is, collaboration ego-network, and about ties among the members of this workgroup, as in Burt (1992).

At the inter-organizational level, we also collected systematic data about inter-laboratory networks and about laboratory characteristics. Whereas talent is everywhere, a longstanding challenge for smaller laboratories and their researchers has been poor access to various kinds of resources. All in this system, including researchers in small laboratories, must rely on informal access through personalized relationships, which does not help level the competitive field. Some are shut out from the circuits of tacit knowledge, the exchange of which is socially and strategically driven, which highly benefits the larger organizations.

The laboratory directors indicated with which other laboratories, among those practicing cancer research in France, their laboratory exchanged different types of resources. The list of reconstituted transfers and exchanges includes recruitment of post-docs and researchers, development of programs of joint research, joint responses to tender offers, sharing of technical equipment, sharing of experimental material, mobility of administrative personnel, and invitations to conferences and seminars. The complete inter-organizational network examined here is the aggregated and dichotomized network of all these flows. Dichotomization created a tie between two individuals or organizations if there was at least one tie between them in one of the aggregated matrices.

To summarize, at the inter-individual level, five advice networks are aggregated and dichotomized to reconstitute a complete network density of 0.06 with average degree of 8.8. In this network, the reciprocation rate is 0.36. Likewise, the inter-organizational network reaches a density of 0.04

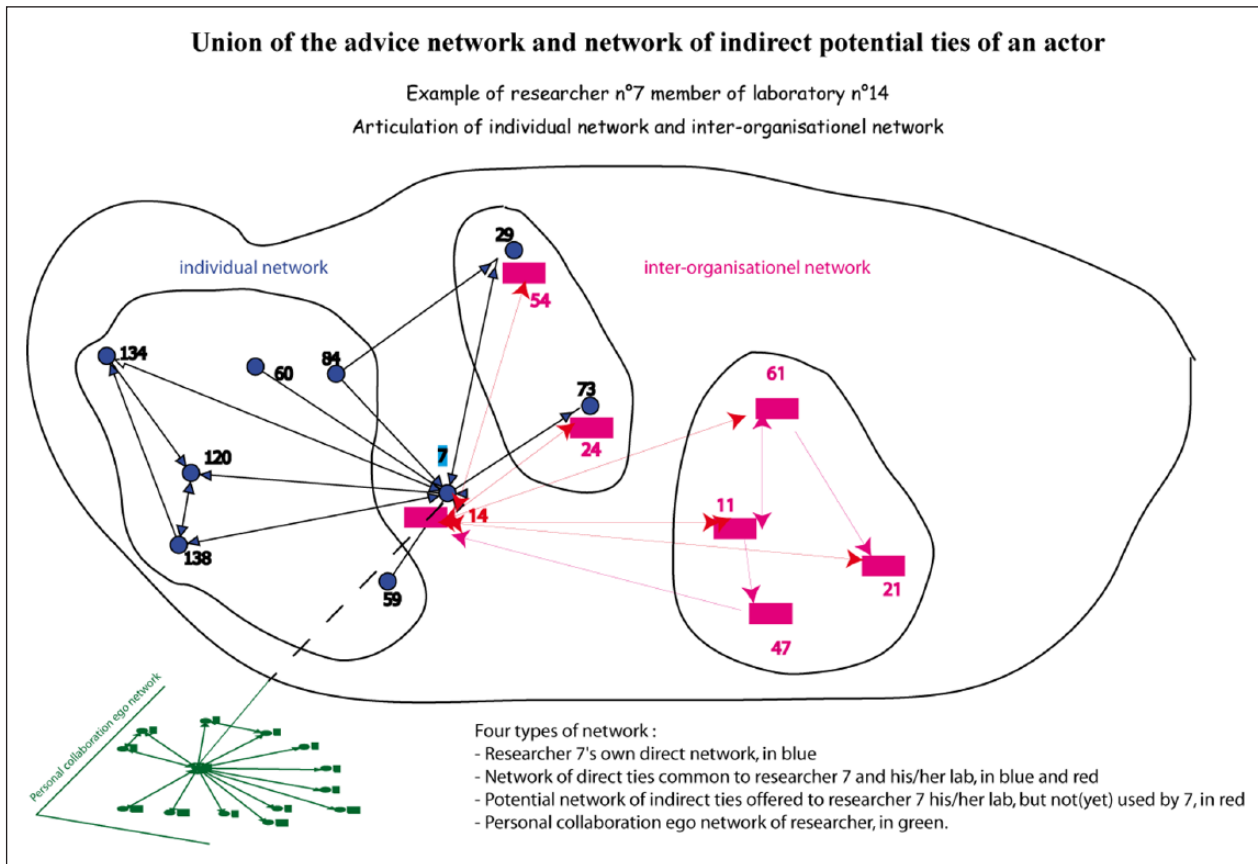


Figure 1. Multilevel network data structure for visualization of cumulative advantage.

Based on the data collected in this project, each researcher in the dataset has four types of networks. A first network of advisors composed of alters that are his/her own personal contacts among the other researchers in the observed population at the time of fieldwork. These contacts are represented as blue dots. A second network of alters that are both his/her contacts and that of his/her laboratory because they belong to laboratories with which his/her own laboratory has exchanges of several types of inter-organizational resources. These contacts, who are common to the researcher and his/her laboratory, are represented as blue dots above a pink rectangle. A third network of dual alters who can be reached by ego through inter-organizational ties between ego's laboratory and alter's laboratory. These dual alters are accessible through the inter-organizational network but who are not yet accessed by ego. They are represented as pink rectangles. Finally, each researcher has a team of close collaborators that is represented as an ego-network in green. There is no overlap in this dataset between this team and the direct contacts among the other members of this population of scientists.

with average degree of 6; the reciprocation rate is 0.39. This shows strong relational activity in this system, at both levels. Collaboration ego-networks, which can be considered to be intermediary-level relational infrastructures (Lazega, 2016), were used to compute 128 aggregate constraints measurements (Burt, 1992).¹ The reconstitution of this complex system of interdependencies at three levels of collective agency provides a realistic specification of multilevel sources of productivity. It also provides a basis for a structural explanation of cumulative advantage and performance measured at the individual level. Figure 1 represents the three levels of network data in the same space.

Performance measured at the individual level, but produced by the supporting organization in which the individual belongs, makes obvious sense in the life of scientific researchers. At each step of their work, laboratories provide their members with economic, social, and technical resources. For example, when a new researcher arrives in a laboratory,

he or she benefits from established cooperative relationships between the laboratory and other laboratories, and also from the reputation and sometimes the networks of its director. Regular institutional budgets and funds raised for specific scientific projects represent obvious causal factors for performance measured at the individual level and, in the end, for obtaining high IF scores. Therefore, performance may simultaneously depend on the characteristics of the laboratory, including its position in the network of exchanges between laboratories, and on the characteristics of individuals, including their positions in the network of exchanges between them. Likewise, performance may depend on the combined structural characteristics of the laboratory and the researcher because their interdependencies are based on the complementary nature of resources provided by each level. In addition, the composition and structure of teams working with these researchers also matter in explaining performance measured at the individual level.

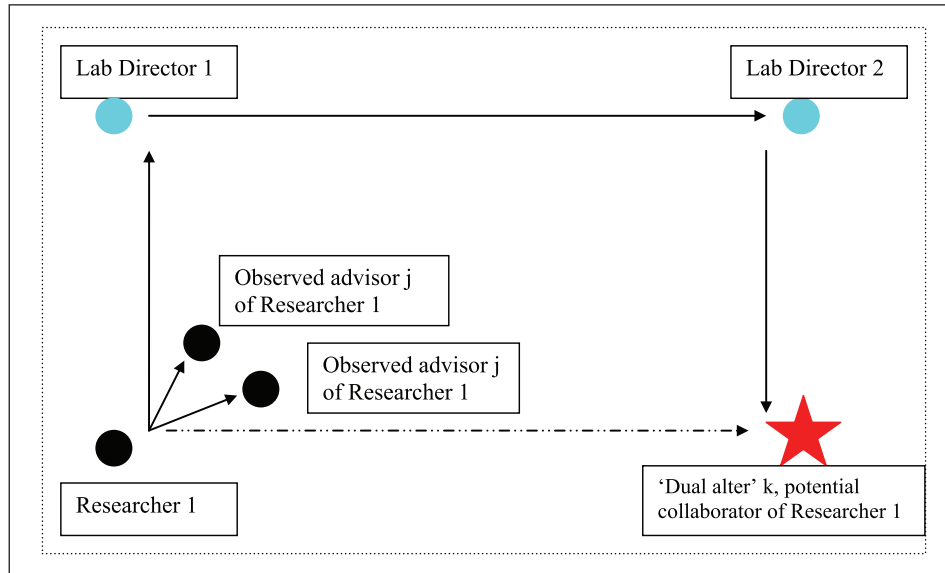


Figure 2. Tetrads substructure of organizational extension of social capital.

Red star is a potential contact, a dual alter who is part of Researcher 1's potential relational capital accessible through direct tie with Lab Director 1 and indirect tie with Lab Director 2. Dotted edge represents a potential collaboration tie for Researcher 1. Other black nodes represent direct contacts of Researcher 1 as observed in his/her declared advice network.

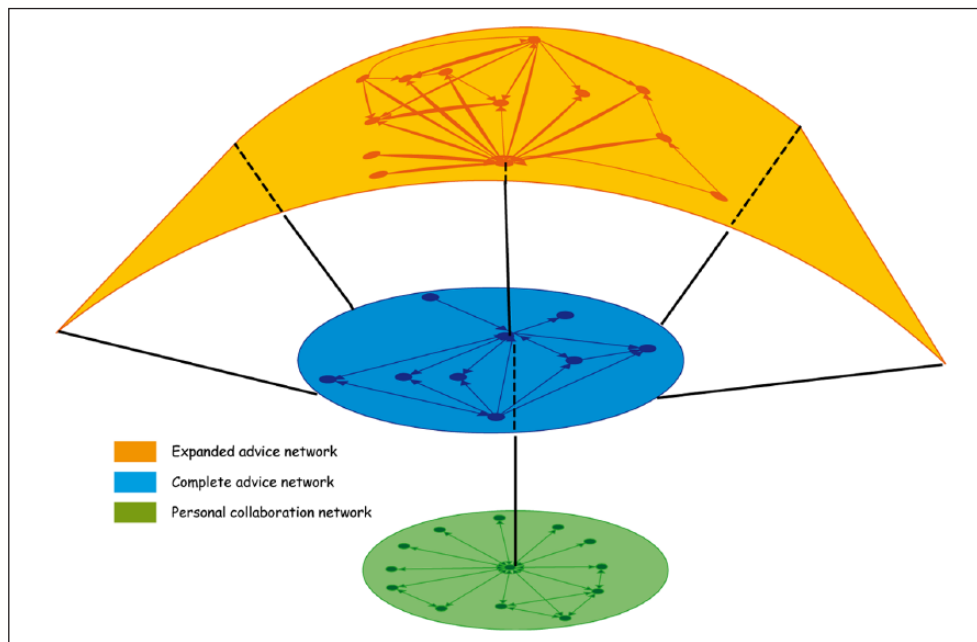


Figure 3. Ascending paraglider.

Finally, the combination of such levels can also have specific cross-level effects. For example, a latent and expanded network built on multiplex and multilevel ties can account for part of performance measured at the individual level. This is what we call organizational augmentation of individual performance based on his/her “extended” opportunity structure (Lazega et al., 2013). This adds a multiplex dimension to multilevel positioning through linked design,

suggesting the notion of a latent and expanded network in which both the nodes and the edges are nested within organizational units, but the ties can be among nodes of different organizational units. Actors have a complex inter-individual network at the personal level combined with an inter-organizational network at the collective level. The latter is based on affiliation ties or personal ties with colleagues or managers (hierarchical superiors) who themselves have ties in other

organizations. We simply add the two networks and treat the “augmented” network as a latent structure mixing “actual” and “potential” relational capital. As shown in Figure 2, this organizationally augmented network is constructed by adding to an observed network of actors i all the potential ties to actors k that i can access through their manager and through the manager’s ties to other managers at the inter-organizational level. We assume that this potential can be more easily realized by individual actors than creation of new ties, provided that members and managers get along reasonably well in terms of cooperation in their organization.

Of course, managers’ ties do not represent all the relational possibilities offered by the organization; peers can also broker ties to new contacts. All researchers do not benefit in the same way from potential ties. However, sharing relational capital is part of a manager’s job (at least in theory) and including this potential represents an additional dimension of network measurements of status. It is equivalent to a multilevel use of Burt’s concept of “borrowing” social capital. Lazega et al. (2013) provide a multilevel analysis where performance at time 1 interacts with network variables to generate even greater performance in time 2.

Scientists as network paragliders and network lift

This three-level structure based on the organizationally augmented latent network can be represented by a figure that looks like a multilevel paraglider. In this figure, actors are characterized by the three superposed networks: a personal network at the intra-organizational level is located at the bottom of the parachute; an observed inter-individual network at the inter-organizational level is located at the middle of the parachute; the augmented or expanded inter-individual network at the inter-organizational level is located at the top of the parachute. The paragliding metaphor points to variance unexplained by Burt’s model of structural advantage based exclusively on brokerage and closure in the network of direct ties.

We distinguish two kinds of paragliders: ascending and crashing. The characteristics that make the augmented networks (i.e. top surface of the paraglider) ascending or crashing is the specific constraint that they exercise on the individual researcher and the high or strong complementarity of resources that researchers can access through them (Lazega et al., 2013). In the first situation, as represented in Figure 3, the org-augmented network helps individual members increase their performance; in this situation, borrowing relational capital helps when centrality provides resources, neighbors provide complementary resources, and the ego-network is capable of collective action. In Figure 4, the org-augmented network has a negative effect on performance as measured at the individual level; borrowing relational capital detracts from performance when a peripheral position decreases access to resources, dual alters provide “more of the same” resources, and one’s ego-network is not capable of

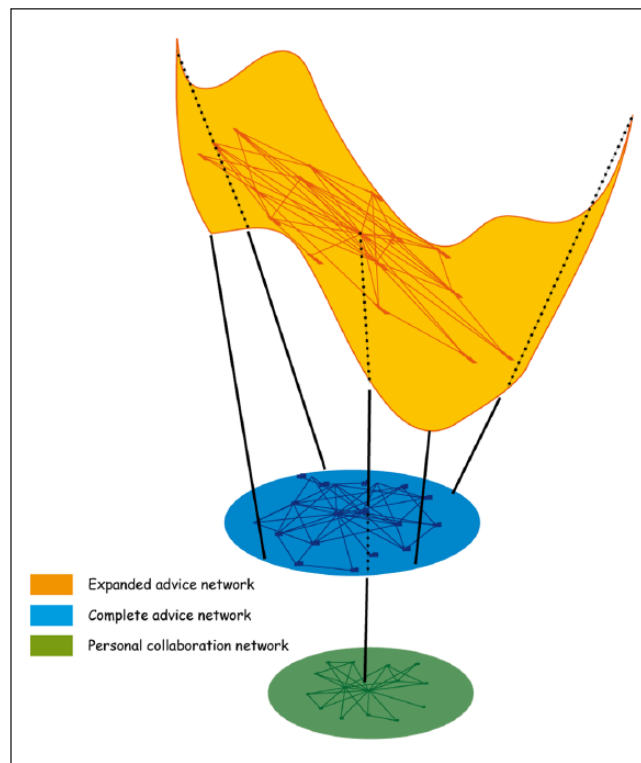


Figure 4. “Crashing” paraglider.

collective action. In this situation, borrowing represents a handicap in terms of performance and we therefore call this a crashing paraglider.

This multilevel network visualization is a representation of position and status as superposed structural wings. It is heuristic because it shows the contribution of multiple and superposed levels of collective agency to the very definition of status. Of course, hierarchy is one component of status in that respect, but not the only one, as outlined in the introduction. The superposition of forms of collective agency is also a matter of affiliation and membership, not only of hierarchy.

Exploring cumulative advantage in complex multilevel effects

A simplified measurement of performance (increasing or decreasing) provides insufficient responses to the question of what accounts for this performance when explanatory factors include dual positioning and strategy (Lazega et al., 2008). In order to enrich these explanations, we cluster researchers in terms of specialties and in terms of performance levels over time.

Clustering researchers into performance groups

Analyzing performances at the individual level for all researchers in the population provides six categories of such performances over 10 years. In order to better explain

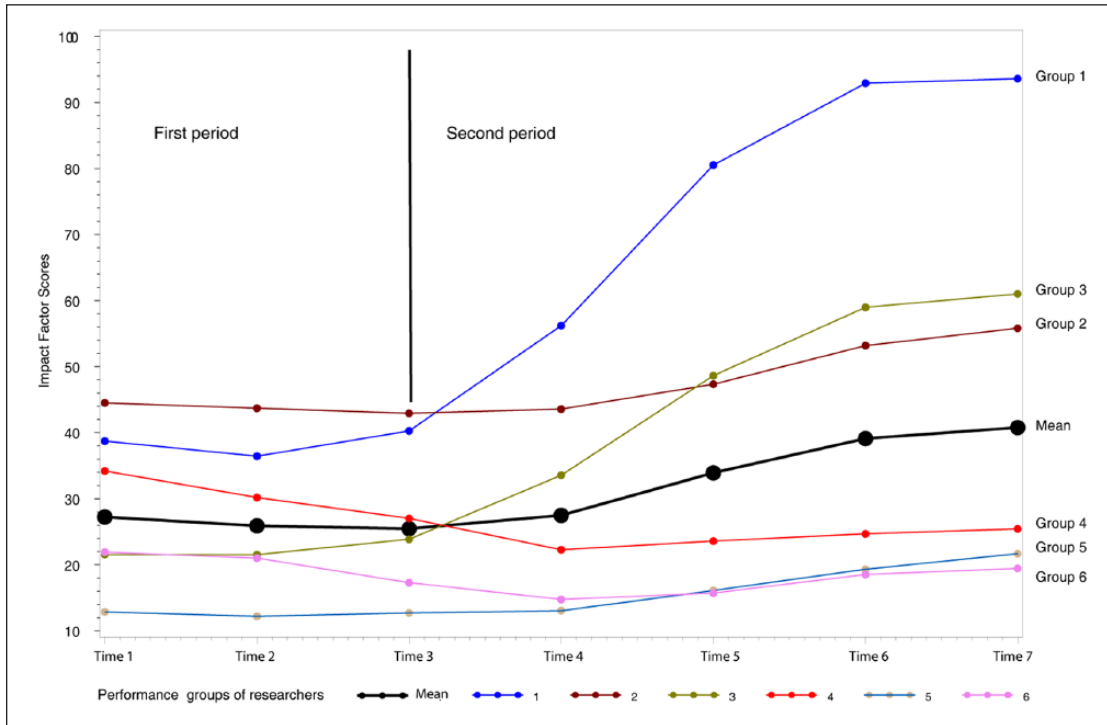


Figure 5. Moving means of Impact Factor scores (1996–2005): six groups of performance levels for 126 researchers in the population. Source: Lazega et al. (2013).

Network measurements were carried out at Time 3, at the end of the first period.

performances, we calculated for each researcher: (1) his/her yearly IF score between 1996 and 2005 and his/her yearly position compared to the average annual performance of all researchers, and (2) the evolution of this IF score compared to the evolution of this mean during the first (1996–2000) and the second (2001–2005) periods. Based on these indexes, researchers were clustered into one of the six “IF career” groups. Figure 5 visualizes the evolution of performances for each performance group. Clustering was performed by grouping the researchers with similar trajectories. We looked at whose performance was stable, increasing, or decreasing over time and compared to the overall mean at each point in time.

Clustering researchers in groups of performance helps in understanding who is in a multilevel position to make progress with IF scores over time. Figure 5 presents these evolutions for the six groups of performance identified by this analysis. Group 1, the “top of the top” in terms of performance, are always above average and progressing towards the top. Group 2 are also above average during the two periods, but they do not make much progress over time. Group 4’s performances decrease: they start above the mean in Period 1 and are below in Period 2. Group 3 start below the mean in Period 1 but are in the amazing position of trying to catch up with Group 1 in the second period. Group 5, although below the mean in both periods, make progress during the second period. Group 6 performances are below the mean in Period 1 and decrease even further during Period 2.

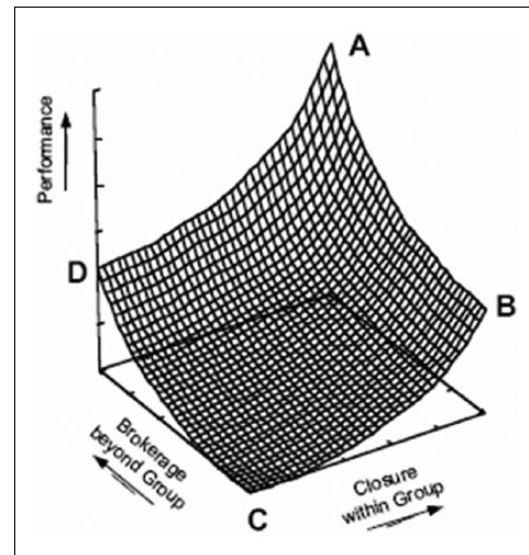


Figure 6. Burt’s (2005) representation of combined effect of brokerage beyond group and closure within group on performance.

As already mentioned, Burt’s (2005) theory argues that performance increases when actors have dense ties within their workgroup and high brokerage beyond the group. This is represented in Figure 6.

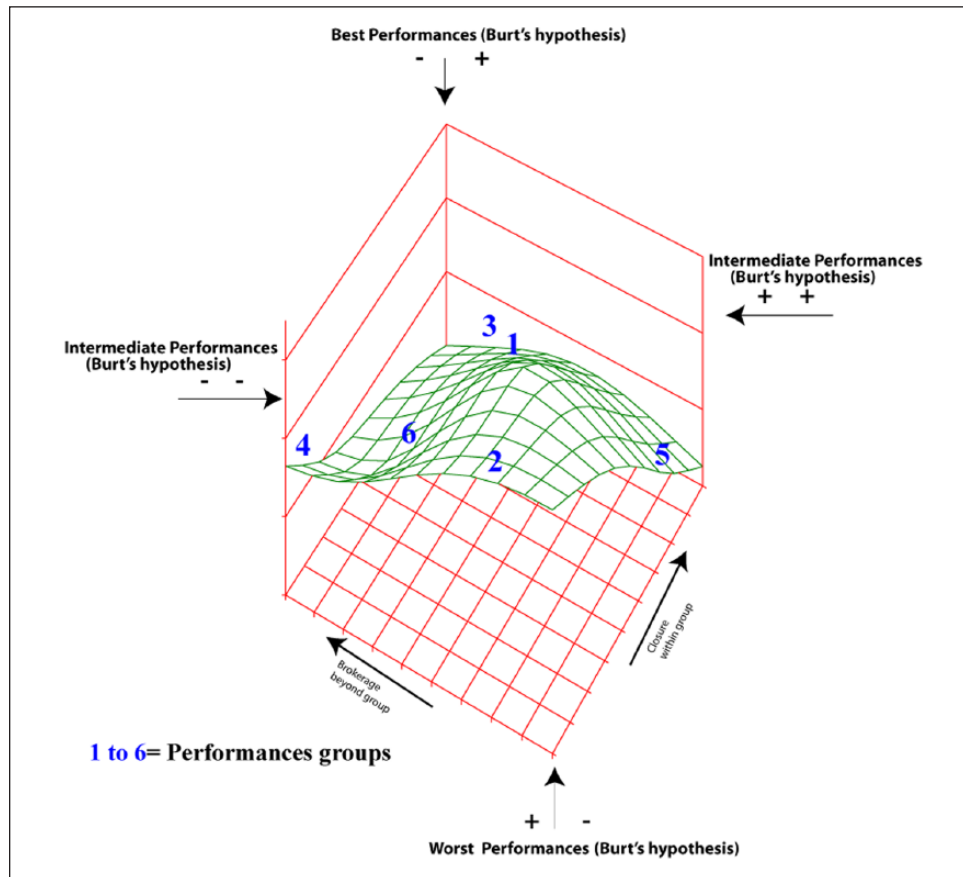


Figure 7. Mapping the average effect of brokerage beyond group and closure within group on average performance for each of the six groups at the end of Period 1.

This type of visualization focuses on the relation between constraints and the evolution of performance. Stagnating performances are located at the bottom; improving performances are located at the top, and in between evolutions in an intermediary position. Except for members who are often ostracized as not being “one of us” and who are in a highly dependent situation,² this picture suggests that performance should reach a maximal value represented by the A letter when brokerage beyond group and closure within group are at their highest levels. Following this argument, we map the two values for each of the six groups of performance observed in this population of scientists based on the average constraint in the ego-network of collaborators and the average number of structural holes in the observed network. As expected from Figures 5 and 6, cumulating the right values for the two sources of performance produces cumulative advantage akin to a meso-level Matthew effect only for two groups (performance groups 1 and 3).

In Figure 7, we make these outcomes comparable, thus showing how constraint along one dimension varies with constraint along the other dimension. Adding this information on the 3D visualization, we can check the position of each performance group compared to Burt’s A, B, C, and D

performance points in Figure 6. This shows that the two groups that increase their performance the most during the second period are performance groups 1 and 3. Both are well positioned on Burt’s graph, although far from the strongest performances predicted by his theoretical platform. Group 2 is closest to the lowest performances. Groups 4 (– –) and 5 (+ +) would have intermediary performances on average.

In short, when averaged within groups of performance, scientific outcomes do not follow Burt’s principles very closely at the beginning of Period 1 and based on the observed network (i.e. without borrowing). But this nevertheless supports the idea that the good position of Group 1 is caused by the configurations of both of these networks. The strong network constraint within group and weak constraint beyond group for both Groups 1 and 3 are stepping stones for future higher performance, that is, over time. The lowest position (intermediary in D) of researchers of Group 4 could be a cause for the strong decrease in their performance during the second period (they start above the overall mean during Period 1 and end up below the mean during Period 2). The same is true for Group 5 except that its modest increase remains below the mean. Groups 2 and 6 stagnate the most, whether above or below the overall mean, and are closest to Burt’s point C.

Based on averages computed for each performance group, Group 3 is the closest to the point representing high performance in this type of visualization and Group 2 is closest to the lowest, with Groups 4 and 5 displaying average performances. This visualization confirms the good position of the groups that increase their performances over time, including the catchers up, who are located close to the “right” places in Burt’s terms. It is more difficult to provide a straightforward explanation for the position of Group 4 in D and Group 5 in B. Is it an explanation for Group 4’s important slump in the second period? Of the modest catching up by Group 5 in the second period given its low performances in the first? Groups 2 and 6, being groups with stagnating performances, whether with high performances or with low ones, are both located close to point C.

Having identified members who both have constraining work groups and who are brokers beyond their group, we realize that, although Burt’s approach is confirmed for some performance groups, it is not confirmed for others. Constraint levels in both networks seem to play a clear role for some groups, facilitating cumulative advantage for Groups 1 and 3, but not for the others. This is where we propose to add, based on our paragliders’ heuristic, another possible measurement of cumulative advantage: a measurement of inter-organizational network lift. The purpose of introducing this measurement is to show that what was left unexplained by Burt’s approach can be explained by the same measurements but in the extended network constructed on borrowing. In effect, we argued above that the position of the individual’s organization in the inter-organizational context of this industry can provide additional and different resources for cumulative advantage and performance. The inter-organizational context of the organization in which actors operate has been recognized by the literature as an important context. Here, we combine both approaches. We do so in two complementary ways. We first show that brokerage beyond the group is improved for most performance groups by its measurement in the extended network, that is, the network including potential ties (dual alters) reached through tetradic substructures. Second, we then focus on the nature of the resources that can be reached through potential ties, in particular their relative utility and complementarity with respect to resources that actors already have in their observed network.

Rich-get-richer through borrowing from the organization and access to dual alters

This unexplored dimension of cumulative advantage is based on effects that are a combination of individual and organizational level effects. The interesting aspect of these results is that they confirm Breiger’s theory of duality, that is, of co-constitution of individuals and groups, thus providing an extra determinant of Matthew effects that are unextricably individual and collective.

Two groups of researchers are of particular interest for illustrating our point. Group 1 of top performers with an ascending paraglider, and Group 4 of lower level performers with a crashing paraglider. When comparing brokerage, constraints, and performances in the observed networks (as in Burt) with the same measurements in the expanded networks, we obtain the following results. As represented in Figure 8(a) and (b), Group 1 comparison shows that borrowing increases brokerage and helps with performance: this confirms the existence of a Matthew effect but only for the haves. The more the researchers who are already top performers borrow complementary resources from their neighbors, the higher their performance is likely to become. In contrast, as represented in Figure 9(a) and (b), for members of Group 4, the have-nots, whose performances decrease over time, borrowing does not increase performance. The extended network has a different effect here. Within this group, performances of researchers do not react positively to variations in constraint in both networks: the expanded advice network worsens their performance.

Using structural wings for measurement of cumulative advantage combining two levels of the paraglider (constraint in the personal network and in the observed network) seems to be a good method for understanding and explaining productivity and status of some categories of actors in the social setting. Combining two other levels (constraint in the personal network and in the extended network) provides a good method for understanding and explaining productivity and status of other categories of actors. This suggests that differentiating the input (complementary vs. redundant resources) in observed networks from potential resources coming from direct or dual neighbors provides a better understanding of variations in cumulative advantage. When it is present, network lift from three-level structural wings is provided by different levels for different actors. Hypotheses induced by the paraglider metaphor can thus be tested progressively to provide new understandings of the structural conditions under which the Matthew effect of cumulative advantage operates.

“More of the same” can be useful in this context. Burt was primarily concerned with information and knowledge from diverse ways of thinking and behaving. Brokerage provides a “vision advantage” that individuals can profit from. In Burt’s case, closure, and by extension having “more of the same thing,” is suboptimal because it insulates the focal actor from new ideas. Still, Burt argued that closure also has benefits, such as helping to build trust and get things done. There are some advantages to be gained from “more of the same” in the advice networks in our population. The main justification for constructing advice networks is that they help scientists and directors make decisions in conditions of uncertainty at multiple stages of the research process. Obviously there are benefits to having more information. But the benefits of closure include trust, capacity of mobilization, and homogeneous advice, which makes it easier to act decisively. Being in brokerage positions might maximize

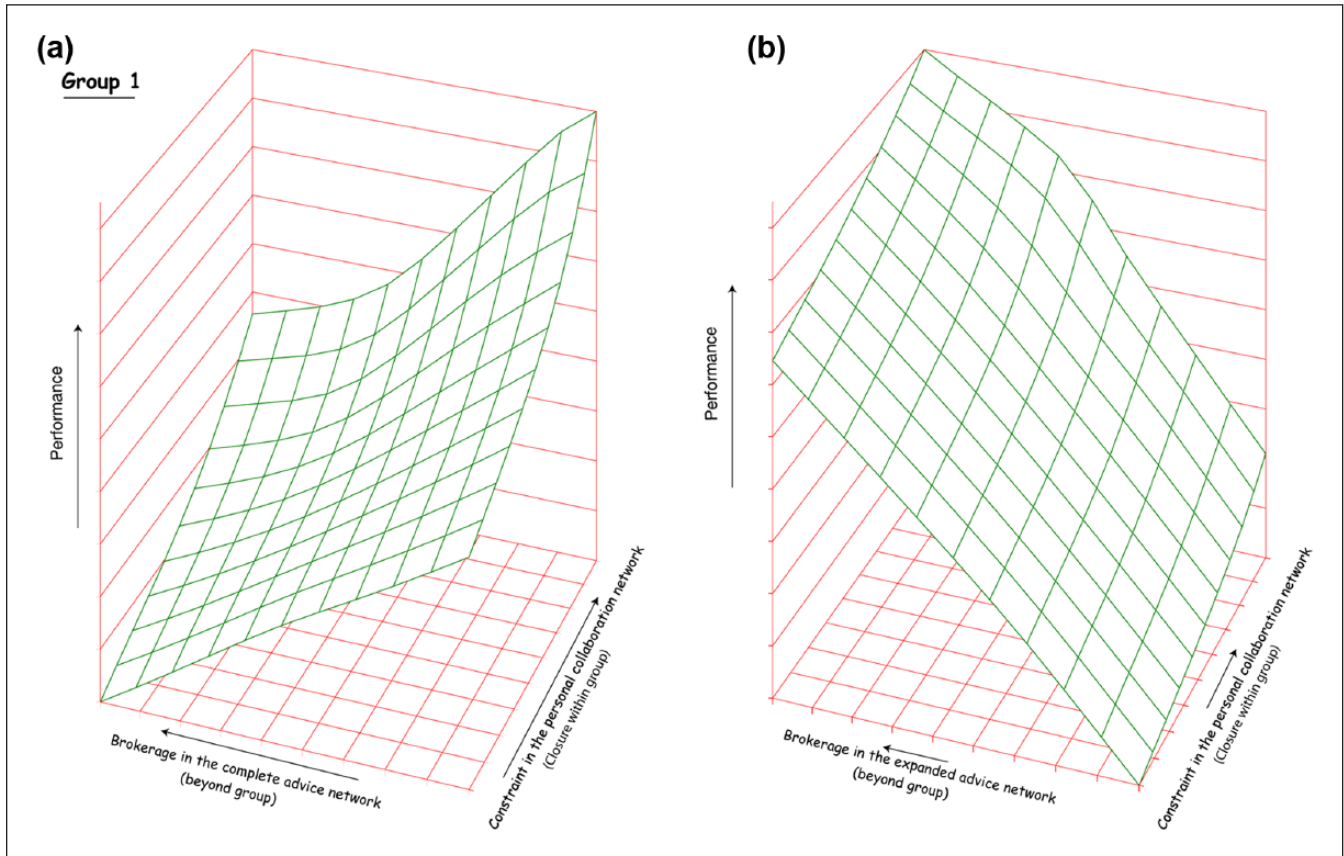


Figure 8. Borrowing through tetradic substructures for actors with an ascending paraglider: (a) constraint in observed network and (b) constraint in expanded network.

In Group 1, comparisons carried out at the end of Period 1 show that borrowing increases brokerage and will help with performance during Period 2.

new information, but it might also result in contradictory advice and low levels of trust. This could have negative influences on performance in conditions of uncertainty.

However, in our case, the specificity of our dataset tends to underscore the value of complementary resources. Empirical results show precisely that the value of closure varies with the kind of group, that is, with the level of performance. Thus, there is value in using three-level data and in looking at how dual alters are likely to increase focal actors' performance by modifying their opportunity structures.

Conclusion

This study examined the Matthew effect (the strong get stronger, the weak stay weak or become weaker) with a sample of highly productive cancer researchers from France among whom strong differences exist in terms of performance as measured at the individual level. We used multilevel network data through linked design to further explore the articulation of teams, inter-individual and inter-organizational networks of scientists. We proposed that a three-level “paragliding” visualization of cumulative advantage based on a complex combination of different network

measurements has heuristic value as the “structural wings” of cumulative advantage. Exploratory analyses of such data show that this visualization captures some of the complex relational processes producing together a meso-level Matthew effect.

We outlined this three-level network approach to the Matthew effect as a multilevel complement to Burt's approach of the relationship between position in networks and performance. The specificity of the data structure (combination of levels) that we use to explore cumulative advantage was visualized as paragliders. We then clustered the scientists whom we interviewed into groups of performance to better understand who was in a multilevel position to make progress with performance measurements over time. We used Burt's representation of the combined effect of brokerage beyond group and closure within group to show that several of these performance groups do not follow his principles very closely. We provided evidence, for one of these groups, of the usefulness of combining constraint in the personal network of individuals and in their extended network, that is, for looking at the relationship between borrowing relational capital from the organization (and reaching dual alters in the expanded network) and performance. This showed that,

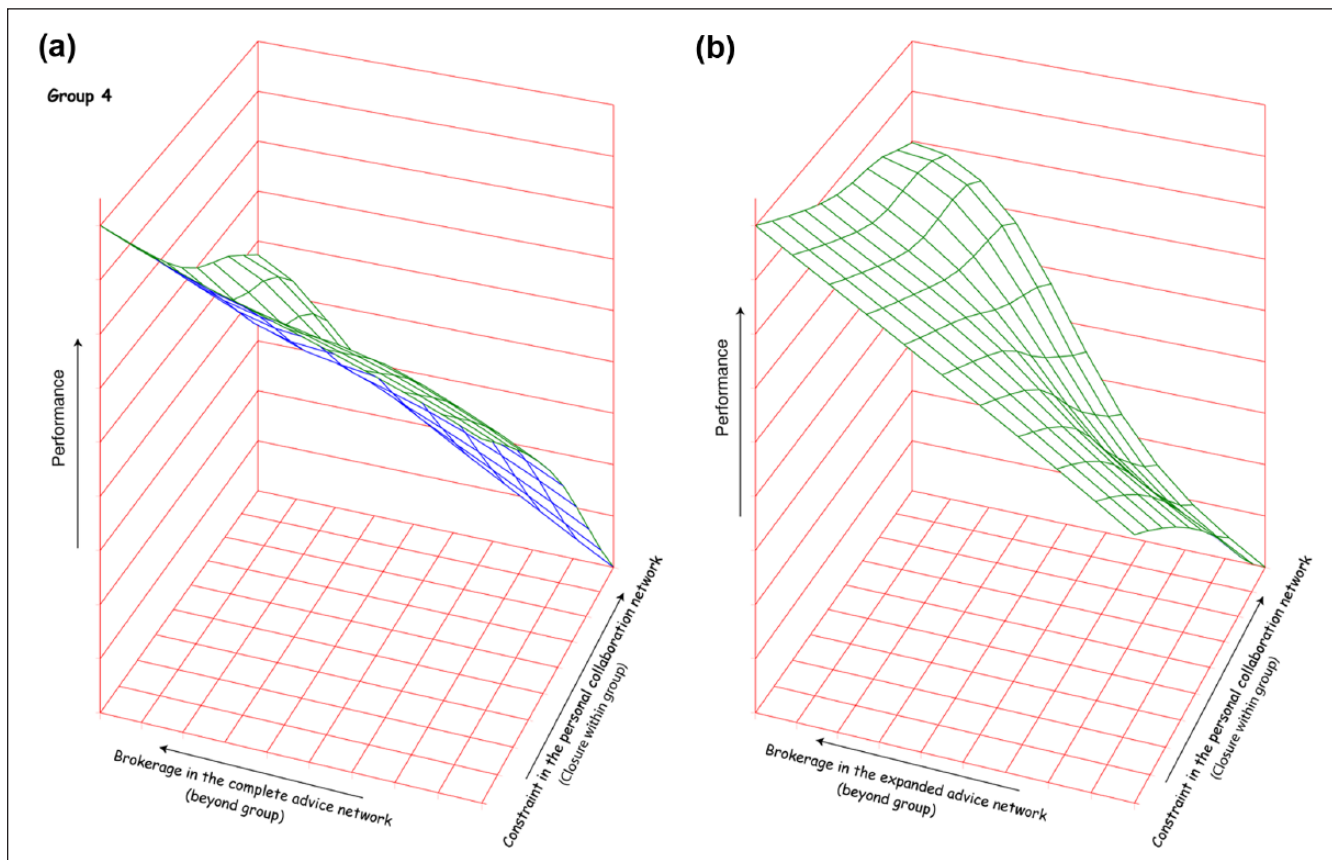


Figure 9. Borrowing through tetradic substructures during Period 1 for actors with a crashing paraglider: (a) constraint in observed network and (b) constraint in expanded network.

In Group 4 comparisons, carried out at the end of Period 1, borrowing decreases brokerage and will not help with performance during Period 2.

when it is present, network lift from three-level structural wings is provided by different levels for different actors. Hypotheses induced by the paraglider metaphor can thus be tested progressively to provide new understandings of the structural conditions under which the Matthew effect of cumulative advantage works.

As presented here, this three-level perspective on the Matthew effect has several limitations that should be dealt with in further explorations of this approach to cumulative advantage. Future studies will need a more inclusive and comparative selection criteria for the population to test this method for a larger sample of researchers including researchers with lower productivity as measured at the individual level. Adjustments need also to be made for cases where an actor was both a researcher and a laboratory director, and therefore belonged to two sets of actors. In addition, effects identified here should be more systematically tested using multilevel exponential random graph models (ERGMs) (Wang et al., 2013). In that respect, much remains to be done.

Productivity and performance are strong preoccupations in the organizational society and in economies dominated by the capacity of hierarchical superiors to expose subordinates

and people below them in social stratification to increasingly open competition. This multilevel approach to performance questions in many ways the capacity of hierarchical superiors to overcome vertical competition with their subordinates to improve these subordinates' performance by helping them in reaching the right dual alters. Our results suggest that more research is needed on managerial behavior, responsibility, and contribution to collective performance that is less focused on decision making (as it was during the past four generations), and more on relational abilities and strategies, for example on help for subordinates to borrow from the social capital of the organization, even if this capital is in part the managers' own relational capital.

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Notes

1. Burt's (1992: 54) measurement of constraint is an aggregate constraint based on this equation: $C = \sum_j (P_{IJ} + \sum_Q P_{IQ} P_{QJ})^2$, $Q \neq I, J$. In this equation, P_{QJ} is the proportional strength of Q's relationship with J and P_{IJ} is the proportional strength of I's relations with J. C is the sum of constraints exercised on I by each of I's direct contacts plus the latter's indirect constraints.
2. For example, women in a men's world, minorities in a majority's world, who need to borrow someone else's relational capital (a champion's, a mentor's) to reach the same levels of performance as members of the dominant category (Burt, 1992).

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