Catching up with big fish in the big pond? Multi-level network analysis through linked design

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Summary

This article contributes to the study of "duality" (Breiger, 1974) in social life. Our study explores multi-level networks of superposed and partially connected interdependencies, the first being inter-organizational, the second inter-individual. We propose a method of structural linked design as an articulation for these levels. First, we examine separately the complete networks at each level. Second, we combine the two networks in relation to one another using systematic information about the membership of each individual in the first network (inter-individual) to one of the organizations in the second network (inter-organizational), as in bipartite networks. This dual-positioning, or the linked design approach, is carried out in an empirical study examining performance variations within the "elite" of French cancer researchers in 1999. By looking at measures of centrality, we identify the actors that these top researchers consider as central or peripheral at the inter-individual level (the big and the little fish among the elite), and the laboratories that the research directors consider as central or peripheral at the inter-organizational level (the big and the little ponds among all the laboratories conducting cancer research in France at that time). In addition to the rather trivial report of the competitive advantage of big fish in big ponds (particularly because of the advantage of size for laboratories in this field), we use measurements of scientific performance to identify "catching up" strategies that the smallest fish use in this system. We suggest that this method offers new insights into the duality and multi-level dimension of complex systems of interdependencies, and also into the ways in which actors manage these interdependencies. We believe that it adds a new dimension to the sociological exploration of the determinants of performance, of meso-level phenomena such as opportunity structures and institutional change, or of macro-level phenomena such as social inequalities.

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1. Meso-social order and the articulation of systems of superposed interdependencies.

The fundamental question of the influence of social structure on the behavior and performance of actors has been reexamined in recent decades thanks to the development of structural sociology and the analysis of social networks. Structural approaches, which examine elements of social structure in order to contextualize human action, help with detailed reading of systems of interdependencies between actors. Structural models, inspired by those proposed by White et al. (1976), remain close to actors, to their interdependent relationships, to their positions, and to the interdependent relationships between these positions. This provides a basis for systematic meso-sociological analysis.

In a parallel manner, statistical models that combine both individual and contextual effects in order to calculate the probability of an individual to achieve a given level of performance have also experienced, with multi-level analysis, a strong development (Bryk and Raudenbush, 1992; Snijders and Bosker, 1999). These models provide a statistical approach in which –once the effects of the most obvious determining factors are recognized– light is shed on the remaining factors that reveal less obvious properties of behavior and performance at the individual level, thanks in particular to interactions effects between pre-defined levels. However, these models have shown their limits, particularly when sociologists find it necessary to identify contextual effects that require some knowledge of the manner in which actors themselves perceive or construct their memberships or endogenous social differences (Duru-Bellat et al., 2004).

In order to further explore the meso-social order and the multi-level dimension of social phenomena, this article will follow a structural approach. This approach is different from, but complementary to, the now classic statistical approach. It is based on the study of the "duality" of social life (Breiger, 1974), in particular of multi-level networks observing two systems of superposed and partially interlocked interdependencies, one inter-organizational, the other inter-individual. We use the method known, in other areas, as "linked design" (Parcel et al., 1991) as a mode of articulation for these two levels. The idea of linked design, when applied to network analysis, consists of separately examining each complete network, and then combining them thanks to information about the membership of each individual in

the first network (inter-individual) to one of the organizations in the second network (inter-organizational).

Explorations of the vertical, multi-level dimension of social phenomena following a linked-design approach (Lazega et al., 2008) improves knowledge of multi-level conflicts and interdependencies, and additionally of the manner in which actors manage these interdependencies. Superimposed systems of interdependencies are in fact superimposed levels of collective agency, inter-individual and inter-organizational, that must not be conflated. Knowledge of multi-level interdependencies, and additionally of the manner in which actors manage theses interdependencies, adds an original dimension to multi-level reasoning and to meso-level exploration in sociology. Using information on superimposed interdependencies, particularly when this positioning is articulated with strategies of actors, it is possible to formulate specific hypotheses concerning the relationship between performance (measured at the individual level) and dual positioning in a complex structure. The term "strategy" refers to the fact that actors manage their interdependencies at different levels by appropriating, accumulating, exchanging and sharing resources, both with peers and with hierarchical superiors or subordinates. We will observe these strategies by looking at the choices of inter-individual and inter-organizational social exchange partners.

We carry out this approach using empirical data in the sociology of sciences. Our illustration is the study of the "elite" of French cancer researchers in 1999, examined at both the inter-individual and the inter-organizational levels. In itself, the study of "elites" is not new in the sociology of science or in network analysis (see for example Zuckerman, 1977 or Hargens et al., 1980). In particular, several studies about complete networks of scientists or laboratories have been presented before, beginning with the pioneering work of Mullins et al. (1977). Shrum and Mullins (1988), Callon (1989), Cambrosio et al. (2004), Cassier (1998) and Jansen (2004) provide literature reviews. Determinants of performance are also widely examined in the social network literature (Burt, 2005; Flap et al., 1998, and Sparrowe et al. 2001, for example). Our contribution is to seek an understanding of these systems of superimposed interdependencies, of the strategies of the actors who manage these interdependencies, and of their performance measured at the individual level. No deterministic order is pre-supposed between position, strategy, and performance, only an analytic one. This approach is particularly sensitive to the existence of inequalities between competing actors because these inequalities can render a given strategy more or less "profitable", depending on dual positioning as measurement of opportunity structure.

2. Dual positioning in the structural contextualization by linked design

Although the multi-level dimension is intrinsic to the analysis of social networks (Snijders and Baerveldt, 2003), the analysis of relationships between structures of different levels remains under-developed in structural sociology. As each level constitutes a system of exchange between different resources that has its own logic, it is important to examine them separately; this is what the main part of the literature does. However, it is also important to study the two levels jointly, because joint study allows us to identify opportunity structures and the actors that benefit from relatively easy access to the resources that circulate in each level, and also to measure their relative performance.

This way of presenting the problem of contextualizing action and actors' performances echoes the preoccupations of organizational sociologists who reason in terms of individual and collective social capital (Leenders and Gabbay, 1999). The most frequently cited studies are those that measure or conceptualize the effect of social capital at the individual level (Burt, 1992; Coleman, 1990), the organizational level (Leenders and Gabbay, 1999), the communitarian level (Putnam, 1993), the industrial level (Walker et al., 1997), or the national level (Fukuyama, 1995). But these studies almost never address the more difficult question of the integration of different levels of analysis in which they situate social capital.

Attempts at solving this problem of joint examination include Breiger's "dual" approach (1974) of bipartite or two-mode networks. When a fixed set of actors belongs to a fixed set of organizations, it is possible to derive multiple memberships from inter-individual networks (assuming that a connection exists between two individuals because they belong to the same organization), and from inter-organizational networks (assuming that a connection exists between two organizations because they share common members). The typical example is that of "interlock" connections, i.e. connections created between two enterprises when one or multiple individuals simultaneously belong to the boards of both enterprises. The networks, derived at two different levels, can be reconstituted likewise in a multi-level structure. However, this structure provides relatively poor insights into social phenomena because relationships are presupposed and symmetrical by construction.

A second important contribution in multilevel network analysis is that of Fararo and Doreian (1984). They generalize Breiger's and Wilson's (1982) formalisms in order to craft a "formal theory of interpenetration" of distinct entities such as individuals and groups. Seen from the perspective of their tripartite structural analysis our approach uses a network (call it P) of relations among persons, a network (call it G) of relation among groups, and a network (call it A) of affiliations of persons to groups. Unlike in Breiger's (1974) approach, only A is

an affiliation network; P and G are networks of social relations and interdependencies (such as getting advice from a colleague, or agreements among laboratories to share equipment, respectively). Fararo and Doreian's article points out many kinds of relations among levels (consider, for example, AGAT, the network of ties between people whose laboratories have agreements to share equipment). We use a similar idea below, in particular to reconstitute "overlaps" between the two kinds of networks (P and G via A) and reconstitute individual strategies of management of resources originating from both levels.

Finally, a third contribution is that of Hedström et al. (2000). They identify what they call meso-level networks by reconstituting the paths of "spatial diffusion" of a growing organization, for example a political party's path to the conquest of an entire country. In the case that they study, these meso-level networks are made up of routes borrowed by political agitators. These routes accelerate the diffusion of the party's ideas, and also create local representatives by constructing shortcuts for long distances. However, although these routes are studied as a system of specific interdependencies and are shown to be critical to the growth of this organization, they do not provide precise information about resources that are exchanged or transformed at different levels of analysis (jointly at the inter-individual and inter-organizational levels).

Figure 1 here

Figure 1 represents the principle of structural linked design. The upper map represents the ties among laboratories carrying out cancer research in France in 1999, in which we interviewed the director. Arcs indicate the direction in which the resource flows, in this example the direction in which recruitment was operated. For example a laboratory in Lille and a laboratory in Dijon recruited a researcher in cancerology coming from a Paris laboratory. Another example: a laboratory in Nice recruited a researcher coming from a Toulouse laboratory. The lower map represents the ties among researchers whom we interviewed. Arcs indicate the direction in which recruitment-related advice was sought among researchers in these laboratories. For example, a researcher in Nice sought advice from a researcher in Montpellier and from another in Toulouse regarding recruitment for his/her research project. Likewise, a researcher in Dijon and a researcher in Lille sought advice from a researcher in Paris regarding recruitment. Finally, vertical lines linking nodes in the upper map with nodes in the lower map indicate that the individual researcher represented in the lower map belongs to the laboratory represented in the upper map (linked design principle).

This Figure visualizes, as in Hedström et al. (2000), the value added by the linked design approach. One difference between our approach and Hedström et al.'s (2000) approach, for example, is that at the top of Hedström et al.'s figure (i.e., the "mesolevel network" in their vocabulary) are a series of long-distance linkages (tracing the hypothetical travel route of a labor union agitator); in contrast to the long-distance linkages in their meso-network, their micro-level network is composed entirely of short-distance links (ties of sociability) within villages. One could argue that, in our substantive context, the long-distance ties (which are conceived by Hedström et al. as necessary to spread diffusion) can be supplied either by the laboratories (meso-level) or by individual scientists, especially those of high prestige, who have contacts across the (geographical and social) spectrum of research. However, as will be shown below, our approach specifies the nature of interactions and relationships among individuals and among organizations, which complexifies the nature of interdependencies beyond the long-distance/short distance distinction (Lazega and Mounier, 2002). In contrast with Hedström et al. (2000), structural linked design allows us to specify the nature of multiple resource exchanges between different organizations; these are vital exchanges for production. From that moment on, individuals are considered as embedded in the multi-level relational and organizational opportunity structures that constitute the inter-organizational context of their actions.

Thus, the approach proposed here builds upon the above mentioned, but distinguishes itself by separately reconstituting systems of interdependencies at least at two different and partially interlocked levels of analysis: inter-individual and inter-organizational interdependencies. The flow of resources and the specific social exchanges at each level can be examined separately at first, and then jointly. This principle of dual-positioning individual actors (in the network of their inter-individual relationships and in the network of relationships between the organizations to which they belong) has two advantages.

Firstly, dual positioning allows us to construct a typology of the positions in the system, i.e. to characterize individuals and the organizations in which they work in the same "dual entity". Dual positioning corresponds to a form of relative status, or double structural characteristic of the individual. It is constructed by measuring both the centrality of the individual and the centrality of the organization (in inter-organizational networks) to which he or she belongs. In metaphorical terms, the actors are identified, thanks to centrality scores, as big or little "fish"; organizations are identified likewise as big or little "ponds." Belonging to one of the four categories that result (big fish in a big pond, big fish in a little pond, etc) locates actors in a meso-social space of opportunity structures, simultaneously inter-individual and inter-organizational.

Secondly, this localization allows us to identify the strategies that individuals use to appropriate, to accumulate, and to manage both their own resources and the resources of their organizations. Actors vary in their capacity to use organizations and their resources. Certain actors use a great deal of the resources of their organization, others much less. In particular, systems of interdependencies at different levels are controlled by actors of different hierarchical levels. Likewise, we can measure the overlap of relationships between individuals by those of their organizations. It then becomes possible to articulate these relational strategies to the performance of actors. It is in this respect that the contribution of structural linked design is most original. In effect, this design allows us to describe, using the same data evoked previously in the discussion of dual positioning, strategies of mobilization and of articulation of heterogeneous resources at different levels. As information about the relative status of individuals and information about the relational strategies of these individuals are used concurrently, we can eventually examine the performance of individuals with explanatory variables different from those used in classic ecological analysis –which, to our knowledge, rarely measures the position of an actor in systems of interdependencies.

In order to use the principle of linked design, we constructed an empirical study by simultaneously collecting data about the inter-personal networks of actors dominating a specific field, and data about the inter-organizational structure of the same field. The approach was carried out in a minimal fashion (and we discuss this limitation in the conclusion) because we identified a single member in each organization. Our goal is to identify effects of context – and the strategies of actors in these contexts – often overlooked by both classic ecological analyses (see for example Firebaugh, 1980), by the analysis of "single-level" networks, and even by the analysis of bipartite networks. These effects are due to differences in the access to resources and also to the different ways in which actors strategically use available resources at both levels.

3. Hypothesis

The articulation of a position in inter-individual networks within a position in inter-organizational networks allows us to formulate two expectations concerning relationships between duality and the performance of actors. Our hypothesis is that the highest individual performances are those of actors who benefit from a central position in both systems of interdependencies at the same time, i.e. those who can appropriate, accumulate, and combine social resources circulating jointly at the two levels. Metaphorically, the big fish in the big ponds should attain the highest levels of performance.

Our second expectation is derived from the idea that dual positioning in itself does not mechanically determine performance. There is no absolute determinism regarding the relationship between position in the opportunity structure and performance. Performance depends on the combined structural characteristics of the organization and the individual, because their interdependencies are based on the complementary nature of resources provided by each level in order to resolve the problems of individual or collective action. Still, individuals have to perform this combination. Strategies used by actors in their management of resource interdependencies (localized at different levels) matter as well. We therefore expect that strategies used by actors who do not belong to the big fish in the big pond category, allow them to catch up to the performance of the big fish in big ponds. Concretely, the use of specific strategies for the management of resources –"catching up" strategies– should enable those in handicapped positions (relative to the privileged positions of big fish in big ponds) to reach the highest levels of performance. At this stage of our exploratory work, this expectation remains descriptive and exploratory.

It is evident that long-term ascendant (in terms of performance) trajectories cannot be explained solely by individual "catching up" strategies. Other variables, such as scientists' phase in the individual career should ideally be included in the discussion. However, our exploratory focus in this paper is limited to strategies as explanatory variables, regardless of the other reasons for which actors in relatively weak positions can access resources that allow them to catch up.

4. All sublime: the case of the small world at the top of French cancer research (1996-1998)

These questions make obvious sense in the life of scientific researchers. At each step of their work, laboratories provide their members with economic, social, and technical resources (Law, 1989; Latour, 2001). For example, when a new researcher arrives at a laboratory, he or she benefits from established cooperative relationships between the laboratory and other laboratories, and also from the reputation and the networks of its director. Regular institutional budgets and funds raised for specific scientific projects represent obvious causal factors for individual performance, and, in the end, for obtaining high impact factor 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.

These ideas are tested through empirical research on a population, which we call an "elite," of French cancer researchers at the end of the 1990s. The following section briefly describes the manner in which we selected the population, collected the data, and studied this milieu.

Population and data

This elite was 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 two and a half years. The list of scientists that we constructed and used 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. Careers and scientific production are not uniform (Latour and Woolgar, 1979; Knorr-Cetina et al., 1980; Barber, 1990). To take these variations into account, we have enlarged the examined population by lowering, as much as our resources permitted, the threshold of the number of publications –our selection criterion– so that both researchers at the beginning of their careers and those at the end remain on the list. This approach produced a list of 168 researchers who constituted, at a given period, what we consider the elite of cancer researchers in France. The data from Cancerlit show that French researchers published 9149 articles between 1996 and the first six months of 1998. These articles were signed by 24285 different researchers. Following "Lotka's law" (Lotka, 1926; Price, 1963), the vast majority of researchers working on a specific problem only publish one article about the problem. A very small minority of scientists, more prolific, publish the majority of their articles in a specific domain. In this list, we have selected precisely those who have published the most in this domain, in France during this period.

Among the 168 researchers, 128 persons (76%) accepted an interview. Few important (internationally recognized) names are missing from our work. The majority of people missing are not very central in the relational networks of their French colleagues. The information in Cancerlit shows that during the 1990s French cancer researchers published about 3800 articles directly related to cancer each year, over a total of 80000 worldwide. The 128 persons interviewed obviously did not publish 3800 articles alone each year for two and a half years. These articles were published with several, even many coauthors. However, these 128 persons signed more than 3200. This is therefore a population of researchers that each has

sufficient status to put cooperative projects into place, to run them, and eventually to sign the work of others, including post-docs.

After identifying in Cancerlit the individuals who publish the most, we constructed a measure of actor performance. The construction of this measure is based on the impact factor of the journals in which each researcher has published. Technically, we proceeded in the following manner: if a researcher published four articles in a journal, the impact factor score of this journal was multiplied by four. The impact factor scores of all the publications of each individual were calculated likewise and summed for each individual. We did not take into account whether the researcher publishes alone or with a group: each person mentioned as a co-author in an article receives the same score. We could have divided the impact factor score between co-authors, but in our opinion this procedure seemed more problematic because we do not have information concerning who did what for each article. Given this choice for the calculation of individual impact factor scores, each individual beneficiates from the impact factor of the journals in which he/she publishes. This approach is appropriate in a milieu in which status competition is one of the strong motivations of actors. It could be vulnerable to strategies in which actors would voluntarily and systematically co-sign the same articles, thus "inflating" together and artificially their respective score. In our context, however, given the existence of a sophisticated division of work and status competition in each specialty, members of this elite published very little together. The density of the copublication matrix in this elite is 0.04. If this "inflation" strategy is quite easily carried out for mutual citations, it is much less easy to carry out for copublications.

The correlation between the two measures (the number of publications and the impact factor scores of the individual's publications) is 0.37. These results depend on the hierarchy of journals and disciplines such as it is defined by the system that evaluates articles in American institutions. The journals that have the highest impact factor scores (*Nature*, *Science*, etc.) are those that receive the most media attention. Technical and specialized publications can be more widely read by scientists even if they do not have comparably high impact factor scores. These bibliometric choices have certainly been criticized (Fox, 1983; Long, 1978; Mulkay, 1972; Reskin, 1977, Seglen, 1992, 1997), but one can suppose that they apply uniformly to the specialties examined here. In addition, if there exists a bias –in this system of evaluation– against publications in non-Anglo-Saxon journals, we assume that all French researchers are affected by this bias in a uniform manner, allowing at least comparisons between French researchers. This technique identified the most productive and the most "visible" authors during the course of the two and a half years considered in this study. A third of the publications of the members on this list are co-publications with non-French researchers.

Following the strategy of structural linked design, we tried to interview all the directors of the laboratories to which these researchers belong. 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 our 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 nodes.

Next, the networks of interdependencies in France in 1999 were reconstituted. First, the inter-organizational networks between the majority of laboratories engaged in cancer research; second, the advice networks constructed by 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 monetary. From the individual researcher’s point of view, research may be analytically broken down into five steps, beginning with the definition of a line of research and ending with the publication of scientific articles. Scientific work has thus been reduced analytically to a sequence of five steps, each one characterized by a strong degree of uncertainty: selecting a line of research, finding institutional support, finding sources of financing, recruiting personnel, and publishing articles. At each step, one must suppose that the researchers depend upon their relational capital and that they seek advice from other members of the research community in order to handle these uncertainties. In this competitive and uncertain 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.

In order to reconstitute, at least partially, 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 cancer researchers presented to them, they sought advice to handle these challenges at each step of the way. 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.

The image of the scientific research process reflected in this sequence is obviously over-simplified, but qualitative interviews showed that researchers considered these social resources essential, at least in the French institutional context. Scientific research organizations more generally do not ignore relational life when evaluating the work of researchers. In the decision to attribute research funds in the United States, for example, institutions such as the National Science Foundation are increasingly and systematically taking social criteria into account. Laboratories' capacity to produce post-docs who subsequently build teams is increasingly measured by a special module attached to application forms. Other data were also collected about the researchers themselves, their attributes, their performances, and their opinions in several domains.

At the inter-organizational level, we also collected systematic data about inter-laboratory networks and about laboratories characteristics. The laboratory directors indicated with which other laboratories, among those in France practicing cancer research, their laboratory exchanged different types of resources. The list of reconstituted transfers and exchanges includes the recruitment of post-docs and researchers, the 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 actors 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 of density 0.06 with average degree 8.8. In this network, reciprocation rate is 0.36, and the number of transitive triads (n=69) is lower than expected by chance (n=181). Likewise, the inter-organisational network reaches a density of 0.04 with average degree of 6; reciprocation rate is 0.39 and the number of transitive triads (n=102) is higher than expected by chance (n=32).

The reconstitution of this dual system of interdependencies at two levels allows us to test our hypothesis and more exploratory expectations. The position of each individual actor in this dual system of interdependencies is provided by describing, in each observed network, centrality scores for both the individual researchers (in the advice networks of the elite to which they belong), and the laboratories in which they work (based on the inter-organizational networks reconstituted in interviews with the laboratory directors). This meso-social positioning measures access to numerous resources, and therefore to performance

capacity measured at the individual level, i.e. the impact factor score associated with articles published by each member of this population.

Hierarchy and Compartmentalization of Specialties

This short section provides some information about the context of French cancer research in 1999 to recognize the importance of the variables that will be used to establish patterns of individual performance. This discipline brings together a great number of sub-specialties; each sub-specialty focuses on a different organ of the human body and represents a specific scientific sub-culture. French oncology is a young discipline (Lemaine et al., 1976) in which research is dominated, during this period, by studies in hematology-immunology. The latter sub-specialty is well-organized, prestigious, and recognized by the general public. For several generations, it has benefited from considerable institutional investments. It has been the first in French cancer research to use collectively the methods of molecular biology (Lazega et al., 2004). In addition, as explained by one of the laboratory directors of our population at the time, "(…) the problems that leukemia poses are relatively simple: the tumors are clonal, you find pure molecular events there. Hematologists consequently recruited sharp molecular biologists very quickly. Solid tumors are infinitely more complex; right now they are starting to become accessible to intellectual work and to fundamental research".

At the end of the 1990s, research was principally financed by public funds – in national research institutes (called CNRS, INSERM) or in generalist or specialized research hospitals – and by private foundations. Research is strongly concentrated in the Paris region, in terms of resources, number of researchers, and also in terms of publications. A separation between clinical research and fundamental research adds to a division into sub-specialties and to a certain weakness of "mixed" or "transfer" research in a domain nevertheless dominated by the medical profession and social practices of hospitals. Of the 128 researchers interviewed, 20 state involvement in purely fundamental research (15%), 47 in clinical research (36%), and 58 in both fundamental and clinical research (45%). Table 1 presents an overview of the variables used in the models below.

- Table 1 about here -

Median size of laboratories was close to 26 researchers. Half of these laboratories were located in the Paris region. The largest part of their financial resources (in 1999) came from their institutional budget, followed by support from non profit organizations (*Association pour la recherche sur le cancer*, *Ligue contre le cancer*, etc.) and private (pharmaceutical)

companies. Average age in this population was 48. 44% declared doing fundamental research, 45% "laboratory research", 28% haematology/immunology, 45% research on solid tumors (compared with 8% doing research in surgery and 15% in epidemiology and public health). The great majority are MDs (70%), professors (81%), and members of scientific (73%) or editorial (51%) boards. Almost half are PhDs in science (44%) and work in University hospitals (54%). The average score of impact factor for their publications was 85.3 (in 1999).

Not surprisingly (Hargens et al., 1980), as will be shown below, the “small world” at the top of French cancer research is stratified (Lazega et al., 2006). An oligarchy consisting of roughly thirty people (most of who belong to the category that will be labeled below the “Big Fish in the Big Pond”) controls the circulation of resources in inter-individual and inter-organizational networks. These “oligarchs” are often directors of a unit, and between 40 and 56 years of age. As in other areas of scientific research, middle-aged actors are key actors of the system (Zuckerman and Merton, 1972; Cole, 1979). They also work more frequently in institutions situated in Ile-de-France (i.e. in and around Paris) than the other researchers interviewed. They are usually professors of medicine, and, with the exception of three among them (who identify themselves with pure fundamental research), they are involved in clinical research or in both clinical and fundamental research. As expected from the literature (Crane, 1972; Hagstrom, 1965), different kinds of homophilous social preferences, as well as formal or informal markers of compartmentalization, characterize the interactions between the members of this population. Clinicians and professors of medicine, for example, have a tendency to cite amongst themselves (as sources of advice) more often than they cite fundamental researchers (Lazega et al., 2006).

Research laboratories are connected by the proximity of their research topics and by mutual surveillance resulting from competition among them. But they are also connected by scientific exchanges, and by the sharing of materials in complex configurations that combine disciplines, localization, and institutional membership. The units that exchange the most include the researchers who obtain the highest *impact factor* scores. We also find, at the level of laboratories, effects of preferences: laboratories specializing in fundamental research exchange more with laboratories of the same specialty and the same institutional affiliation. By contrast, they do not exchange more with laboratories in the same geographic location (notably because of the existence of research programs designed, in part, to bring together Parisians and residents of the provinces).

5. Positioning of actors in systems of superposed interdependencies

To carry out this multi-level approach, we measured the status of actors and organizations in the following manner. The status of an actor is measured by his/her indegree centrality in the advice network of the research elite. Centralities used in this article are indegrees and outdegrees. We use these measurements of centrality because we use incoming and outgoing ties further below in our measurement of overlap between the relationships of the researcher and that of laboratories. This provides a uniform basis for the interpretation of our results in the reconstitution of strategies of mobilization and articulation of heterogeneous resources at different levels. We do not think of this choice as an intrinsic limitation of our approach, although further research should be devoted to the possibility of using other kinds of measurement of centralities or of combining several different kinds at different levels. The central values used as reference values for the classification of individuals and laboratories are in Table 1. The distribution of some variables being skewed, we used the median value for comparisons.

The status of the organization is measured by three criteria: its indegree centrality in inter-organizational networks, its outdegree centrality (indicating the potential resources to which its director declares having access), and its size (measured by the number of researchers). We looked at whether each laboratory was above or below the median value in each of these three criteria. We considered a laboratory to be a “big pond” if its values were above the median for at least two of these criteria.

This produces an endogenous partition of the population into four classes. This partition allows for an initial use of the structural linked design to characterize and differentiate the researchers and laboratories that belong to each class. The four classes obtained are baptized metaphorically for a more intuitive understanding of this dual positioning. The construction of the four classes positioning actors at the meso level used the following thresholds : in order to be considered a Big Fish in a Big Pond, the researcher’s indegree centrality must be higher than 5.2, that of the laboratory higher than 2.75 ; the laboratory’s outdegree must be higher than 2 and its size higher than 26 researchers. The same thresholds are used for the three other categories (Big Fish in a Little Pond, etc.). As our population is elite, even the researchers that we call “Little Fish in Little Pond” are researchers at an exceptional level.

a. Big Fish in Big Ponds **(BFBP)**: In this first class, the researchers’ prestige, social resources, number of publications and impact factor scores are higher than the median. The size, indegree and outdegree of their laboratory are higher than the median. The majority of

these researchers are directors of laboratories, aging on average 48 years, and conducting fundamental research in solid tumors and hematology-immunology. The majority are simultaneously doctors (MDs) and scientists (PhDs), tenured research directors in national research institutions, usually heads of hospital services, and almost all University professors. In addition, most are members of scientific and editorial committees. The laboratories to which these big fish belong are large in size, more central than others in inter-laboratory exchanges, and most often located in Ile-de-France. Most carry out fundamental research and have European-level funding. The specialties of the researchers and the specialties of the laboratory are always the same. Nevertheless, this class is not entirely homogenous.

b. *Big Fish in Little Ponds* (BFLP): In this second class, the researchers' prestige and their social resources are also higher than the median. However the size, indegree and outdegree of their laboratory are lower than the median. This class is smaller in terms of the number of researchers (16) and laboratories. Its researchers, like those in class 1, are prestigious by definition. Like the members of class 1, the BFLP also benefit from resources superior to the median. On the other hand, they differ from the BFBP because their impact factor score is weak, despite the fact that they publish a large number of articles. They are both MDs, *agrégés* (a special kind of French elite), directors of research units in hospitals, and generally younger than the BFBP. They tend to specialize in laboratory research and in hematology. In general, there is little correspondence or alignment between the specialties of their laboratories and their own individual research; this constitutes a clear contrast with the class of BFBP. Very few belong to editorial boards (unlike the BFBP) and they teach less than the others. Their laboratories are small and located in Ile-de-France. In the domain of cancer research, they have less prestige and fewer inter-organizational resources than those in class 1. Their financial resources are largely limited to their institutional budgets. This class is more heterogeneous than the BFBP class.

c. *Little Fish in Big Ponds* (LFBP): In this third class, the researchers' prestige is lower than the median. Size, indegree and outdegree of their laboratory are higher than the median. This class is composed of 22 researchers among whom almost no one is a laboratory director. The average age in this group is lower than the median. The LFBP are engaged in both fundamental and laboratory research that is strongly aligned with the specialties of the laboratories in which they work. Without much prestige or access to resources, they have nevertheless relatively high impact factor scores. It is in this class that we find the most PhDs, the fewest MDs, and the fewest University professors. With respect to formal status, an equal number are research directors and simple researchers, and few belong to scientific or editorial committees. Their laboratories are generally located in the provinces. They have very diverse

financial resources, including European-level funding. In comparison with other classes, we find here a greater number of laboratories working on solid tumors (a domain that had just become more accessible to fundamental research at the time) and using European financing.

d. *Little Fish in Little Ponds* (LFLP): In this forth class, the researchers' prestige and social resources are lower than the median. The size, indegree and outdegree of their laboratory are also lower than the median. The majority of this class is composed of laboratory directors whose average age is higher than the median. They work in more heterogeneous specialties, but are nevertheless aligned with the specialties of their laboratories (which they have probably founded and defined). They are often MDs, *agrégés*, heads of service at their hospitals and University professors. Few belong to scientific or editorial committees. An equal number work in laboratories in Ile-de-France as in the provinces. These laboratories are heterogeneous in terms of size, specialty, access to European funding, and number of publications.

This dual positioning and the stratification that is derived from it raise the question of relationships between classes. Is the advantage of size combined, in this scientific milieu, with closure, or a picket fence around the BFBP category? Linked design offers a way to answer this question. A graphic inspection of inter-individual networks in each class, presented in Figures 2 and 3, as well as the measurement of intra and inter-class densities presented in Table 2, show that the density of inter-class relations drops with the centrality of laboratories and also with the centrality of researchers, with very marked thresholds separating the big fish from the smallest fish in this elite population. Intra-class density is higher among BFBP than among LFLP. In Figure 3, intra class ties represented in Figure 2 are not included and members of each focal class are in black. The density of inter-class ties is higher between BFBPs and all others than between LFLP and all others. Thus these figures show a strong difference between big fishes and little fishes for outgoing and incoming ties, a difference that will become important further below when we show that, in spite of the fact that differences between contexts are smaller than differences between individuals, access to resources (and upward mobility chances for researchers in terms of impact factor scores) is more shaped by the contexts (big ponds versus small ponds) and by the strategies of individuals than by their characteristics.

– Figures 2 and 3, and Table 2 here –

This visualization of the individual actors' networks is interesting because it confirms our results above by showing the importance of laboratory size and centrality. Relationships

between classes come from the fact that the researchers in other categories seek advice from the BFBP, and also because laboratories in the other categories actively exchange with the laboratories of the BFBP. Nevertheless, a relatively large proportion of this centrality comes from internal (i.e. endogamous) choices. We see clearly that the BFBP have more relationships than the others, both with each other and with those in other categories. The network of the top of the small world of elites in this discipline is not closed, but it is considerably more open to the LFBP than to colleagues in the little ponds. Inter-individual advice flows are dominated more strongly by fish category than by pond category.

As our approach is not deterministic, we ask now, following our expectations, the following question: what are the strategies and performances characterizing each category?

6. Can the Little Fish compete? The complex connection between multi-level position and performance measured at the individual level

All the researchers in this elite population are high performers in terms of the number of published articles. However, as shown by Figure 4, the BFBP have the highest impact factor scores. Figure 4 presents boxplots showing the level and dispersion of impact factors of the researchers of each class. 50% of researchers of each class are included in the rectangle. The threshold in the box indicates the median value of impact factors for the class.

– Figure 4 about here –

Fundamental research journals are the most interesting in terms of their contribution in impact factor scores. In order to do fundamental research, laboratories must be large in size. Working in large laboratories enables researchers to quickly find a given plasmid or a given cell that would take weeks to bring in from elsewhere. As formulated by a laboratory director in our population, “if you don’t have a critical mass and everything in hand, you aren’t in the fast lane. Unplugging the freezers is a very efficient way to bring a laboratory doing fundamental research to its knees. Sometimes, it takes years to reconstitute the stocks necessary for that kind of research”. Fundamental researchers have less administrative responsibilities and probably sign their own research. Located primarily in Ile-de-France, they work in specialties generating high impact factor scores (hematology in particular). Our first hypothesis is thus confirmed.

Due to the advantage of sheer size in these domains, there are twice as many big fish in big ponds than in little ponds. However, each of the four classes, even that of the BFBP, is

heterogeneous in terms of performance. The relationship between position and performance is neither linear nor simple. One finds very high performances in other classes, for example in the class of the LFBP. The BFLP often have a weak impact factor score, despite the fact that they publish a large number of articles. This class probably consists, in part, of laboratory directors who sign articles based on the work of younger researchers. In addition, few in the LFLP class, who are often also the oldest members of the population, have an impact factor score superior to the median at the time of this study. Many of them are directors of small, personal laboratories with relatively little prestige and weak social resources. Note, however, that in this classification we also need to make a special place for individuals with atypical profiles. Some leading experts with high reputations appear as LFBP because our analysis is based on the median and because they have not published exclusively in cancer research. In other disciplines, they would appear as BFBPs.

These results suggest that an organizational explanation may be highly relevant with regard to performance. For example, in big laboratories (those in which fundamental research is conducted with European-level funding), there are less disparities between the specialties of researchers and those of the organization as a whole. As already mentioned, the BFBP, in contrast with other members of the elite, have specialties perfectly aligned with those of their laboratories. The complementary relationship between the resources of the laboratory and those of researchers seems more rationalized.

This organizational explanation leads to our second expectation. There should be strategies for the management of resource interdependencies at two different levels, followed by actors in categories other than the BFBP (the BFLP and the Little Fish) that would allow them to catch up (in terms of impact factor scores) to the BFBP. At this stage, a question remains: in what terms should we examine these strategies? Here, the richness of the data on multi-level networks through linked design allows us go beyond an analysis based mainly on centralities. In order to examine the more or less cumulative character of the resources of actors and organizations, our structural linked design allows us to use the choices of inter-individual and inter-organizational exchange partners as indicators of these strategies. In order to identify and to classify these strategies, it is necessary to combine the data of interpersonal networks and those of inter-organizational networks.

7. Beyond the advantage of sheer size: Strategies of actors in the management of individual and collective resources

Actors who must manage interdependencies at different levels choose ways to appropriate, accumulate, exchange or share resources with their hierarchical superiors, their peers and their subordinates. These ways are reflected in strategies of articulation of the two levels (individual and collective), through the addition and the adjustment of different resources (economic and functional as well as social and cognitive) flowing at these levels. In this section we discuss these issues in two parts. First, we examine the typology of these strategies, and second, the link between multi-level position and strategies.

The connection existing between membership to a class and strategies for the management of interdependencies can be read in the overlap between the researcher's relationships and those of his/her laboratory, for outgoing as well as incoming ties. Figure 5 illustrates these overlaps.

-Figure 5 about here-

A researcher may be cited (in these advice networks) by colleagues belonging to a laboratory that may or may not have inter-organizational ties with his/her laboratory. The comparison of differences between these two types of relationships provides indications about the level of overlap between the two kinds of networks and about the behavior of these actors in their organization, thus offering indicators for their strategies. We interpret choices received as indicators, for the laboratories, of their importance from a functional point of view, and, for researchers, as indicators of prestige in terms of professional authority. We interpret outgoing ties as indicators of access. In the case of the laboratories, outgoing ties can be read as measures of access to exterior resources; for the researchers, they measure access to sources of learning and of personal support.

Figure 5 shows ten types of overlap between ties of researchers and ties of their respective laboratories. A researcher may have a set of contacts contributing to his/her indegree (we call it prestige), and another set of contacts constituting his/her outdegree (we call it access to resources). In Figure 5, codes 1, 4, 7 refer to a weak overlap between the relationships of a researcher and those of his/her laboratory. Code 10 refers to a situation in which there is no overlap at all: choices received by the actor come from colleagues who do not belong to the laboratories collaborating with the laboratory of this actor. For incoming choices, this is a situation in which the individual researcher enjoys a personal prestige

relatively independent from the prestige of his/her laboratory. For outgoing ties, this is a situation in which the individual researcher has access to resources relatively independently from his/her laboratory. Codes 2, 5 and 8 refer to an important overlap and codes 3, 6 and 9 to a maximum overlap: the actor has access to advice related resources (learning) from sources offered by the collaborations established at the level of his/her laboratory.

Using this typology, we can establish a correspondence between class (identified above: BFBP, etc.) and level of overlap. As shown in Figure 6, one may differentiate the strategies that result from these combinations into four categories.

-Figure 6 about here-

Firstly, there are combinations that articulate little (or no) common prestige and little (or no) joint access to the same organizational resources: combinations 1 and 5 and combinations 4 and 8. One could call these combinations "independent" strategies. It is not difficult to imagine concrete examples of behavior that reflect independent strategies. For example, a researcher representing an entire discipline in a scientific council might negotiate, in the name of the collective interest that he/she represents, to obtain resources for his/her own individual projects. Second, there are combinations that articulate little (or no) shared prestige but many or all of the common resources: combinations 2 and 6 and combinations 3 and 7. One could call these combinations "individualist" strategies (benefiting from common resources but not sharing their prestige). Third, there are combinations that articulate a great deal of shared prestige but little (or no) common organizational resources: combinations 9 and 13 and combinations 12 and 16. One could call these combinations "collectivist" strategies (constructing common prestige by using different resources than one's colleagues'). Fourth, there are combinations that articulate a great deal of shared prestige and common organizational resources: combinations 10 and 14, and also combinations 11 and 15. On could call these combinations "fusional" strategies. The reconstitution of these strategies allows us to examine the behaviors of big or little fish, in big or little ponds. In addition, it allows us to test our second hypothesis about the relationship between position, strategy, and performance.

In sum, a researcher may have a set of contacts contributing to his/her indegree (we call it prestige), and another set of contacts constituting his/her outdegree (we call it resources). Comparing the differences between the two sets of contacts suggests the existence of specific relational behaviour and provides indications about the researcher's strategy (independent, individualist, collectivist or fusional) of management of resources flowing in the observed networks. As each researcher and each laboratory belongs to a class, it is

possible to examine the correspondence between class and strategy. Table 3 shows the distribution of strategies in each class. Figure 7 presents a correspondence analysis based on Table 3.

- Table 3 and Figure 7 about here –

Figure 7 and Table 3 show that all classes are characterized by mixed strategies. Only the LFLP use a narrower range of strategies (0% fusional strategies). Nevertheless, certain strategies may be dominant, and may help to explain in part the performances of actors in relation to their position in the multi-level system. In effect, the uses of the organization and its resources vary from one class to another. In the BFBP class, overlaps of relationships between researchers with relationships between their laboratories are the greatest; it is also in this class where independent strategies are among the least frequent (24% in Table 3). In addition, the largest percentage of fusional strategies are found among the BFLP (36%); complete independence of individuals and institutions, especially with regard to prestige but also with regard to more functional resources, is relatively rare in this category. In Figure 7, the ellipses represent only the most important trends. For example even if dimension 1 explains much more than dimension 2, and even if the LFBP are very close to the individualist strategy in that projection, they are even closer to the independent strategy.

More generally, collectivist strategies characterize big fish more often than their small counterparts. In other words, the bigger the fish, the greater the overlap between the relationships of researchers and the relationships of their respective laboratories. Big fish know how, and are able, to use the resources of their laboratory. Among the LFBP, the majority have strongly independent strategies. On the other hand, for the LFLP, one finds a nearly complete separation between the relationships of researchers and those of laboratories, whether for outgoing or incoming ties. Among the 93 individuals, 41 have a personal network (including other members of the research elite) in which there is no overlap with the laboratory network (such as reconstituted by its director). Their laboratories may also offer resources to which they do not have direct access or that they do not use. The LFLP have no fusional strategies.

Big fish do not seem more prone to use individualist strategies than little fish. The only marked difference is the more frequent use of collectivist strategies, but also of fusion strategies (although in very small numbers). The difference in the use of independent strategies is not so much between the little fish and/or little pond as the column percentages show, but between the little and the big fish. Little fish –perhaps for the reason of less access

to laboratory resources– much more often follow an independent strategy (66% compared to 34% of big fishes). Also it is not the BFBP that most often use collectivist and fusional strategies, but the BFLP; they are more often the directors and can easily use the resources of the laboratory for their own interest.

Given these results, it is now time to determine under what conditions these independent or individualist strategies are rewarding in terms of impact factor scores for the researchers who are not BFBP.

8. Catching up strategies for the Little Fish?

We measure the way in which actors' strategies are associated with performance levels for researchers who are not BFBP, i.e. who are endowed with less social resources. In effect, we cannot exclude that strategies of appropriation of resources –stemming from different levels (individual and collective) – constitute a form of rationalization that allows for catching up in these opportunity structures. The examination of the evolution of the impact factor scores of all the researchers, and more specifically of those catching up, over five consecutive years following the study, allows us to identify "long-term catching up". In effect, until now, we have considered impact factor scores from three years: 1996, 1997, and 1998. In order to measure the evolution of all the researchers' scores, we also gathered information for the five following years: 2000 to 2004. In order to compare these two periods (as the number of years is different), the mean for scores in the first period is 28.4; the mean for scores in the second period is 38.4. Thus, the general mean of impact factor scores rose by about 10 points, an evolution rate of 36%. Impact factor at time 1 and impact factor at time 2 are both normally distributed.

Can membership in a class and the use of a strategy be associated with and, at least in part, "explain" the evolution of impact factors? Neither class membership nor strategy are necessarily equivalent with weak or strong impact factors. Because the number of cases observed in order to analyze these catching up strategies is low, it is best to ensure the robustness of these propositions by verifying that the users of these strategies are (or are not) on an ascendant trajectory –in terms of the accumulation of impact factor point scores– over the five years following the field study (2000 to 2004). Tables 4a, 4b and 4c present respectively the standardized means of impact factor scores at each period for the whole population, for the sub-population whose scores increased between the two periods, and for the subpopulation whose scores decreased between the two periods.

-Tables 4a, 4b and 4c about here-

Comparing the two distributions (t1 and t2) of Table 4a shows that members of seven categories of researchers increased their scores. All classes in table 4a show some strategies that yielded an improvement in relative scores: BFBP with an independent and a fusional strategy; BFLP with a collectivist and fusional one; LFBP with an individualist and collectivist strategy; and LFLP with an individualist one.

For the interpretation of the relationship between Table 4a and the tables on the sub-population that increased its scores (Table 4b) and the sub-population that suffered from decreasing scores (Table 4c), it should be stressed that the data in Table 4b and 4c are standardized using different means and standard deviations than in Table 4a. Each sub-population has its own mean and standard deviation. This is the reason for which there are minus cases in a sub-population that is defined by upward mobility and vice versa for the downward mobile sub-population.

Tables 4b and 4c are simple descriptions of what the strategies per classes for the upward / downward mobile sub-populations were. Table 4b shows that 46 researchers saw their scores increase between the two periods. This is especially the case for LFBP (but also for the LFLP). Notice that the mean, for the first period for researchers whose scores increased, is lower than the general mean of the whole population for that same period, whereas the opposite is true for the second period. This difference means that the researchers who progressed the most between the two periods are not, in general, the researchers who had the best scores during the first period. The degree of relative upward change in this sub-population is much higher for the little fish than for the big fish. Only the LFBP can improve their relative positions. On average, researchers who saw their scores increase the most profit from individualist strategies.

Among the 47 researchers whose impact factor scores decreased (Table 4c), one can identify the classes and strategies with the “lowest” performances in this elite. Among those whose scores decreased the most, we find the BF with an individualist and an independent strategy. The strategies that harm the most the LFBP of the downward group are the independent and collectivist strategies. In addition, collectivist / fusional strategies, on average, mitigate the decrease of their scores.

Figure 8 provides a correspondence analysis that summarizes the main results of Table 4a.

-Figure 8 about here-

Figure 8 shows the existence of strategies that help catching up, especially for some sub-populations (among those who are not BFBP) whose strategies contribute, over time, to the increase in impact factor scores. We consider three categories of performance: researchers with increasing, decreasing or stable impact factors between the first and the second period. We considered that, in order to be in the decreasing category, the difference between their standardized IF scores must be inferior to -0.1; in order to be in the increasing category, the difference between their standardized IF scores must be superior to 0.1; and in order to be in the stable category, the difference between their standardized IF scores must be between -0.1 and 0.1. The correspondence analysis is realized on these three categories and the eleven groups of researchers (from the independent BFLP to the collectivist LFLP). It uses the number of researchers in each group. In Figure 8, the two hexagons give meaning to the first dimension, the two ellipses to second dimension. One can also identify two additional sets (in rectangles): the first is close to the increasing category, the second to the decreasing category.

Among researchers with increasing IF scores, the individualist strategy seems efficient for the LFLP. It is not always necessary for these elite researchers to be in a big pond in order to have a chance to catch up. To say that the individualist strategy was the only strategy that gave the little fish the ability to catch up in the system of cancer research as it existed in 1999 remains nevertheless an oversimplification. The same individualist strategy seems to be counterproductive for the BFLP. BFLP do not deny themselves the advantages that their status in the laboratory offers, even if the resources they can appropriate in their non-central laboratories are insufficient to catch up to the BFBP. One might also easily imagine that a BFLP can attain very high levels of performance (measured at the individual level) if he/she is the only one in the little pond to be able to appropriate the necessary resources and enter competition with the BFBP.

The collectivist strategy seems also efficient for the BFLP, who also benefit from a fusional strategy. Following an independent strategy does not seem to benefit anyone in the figure. Among researchers with decreasing IF scores, the independent strategy seems to characterize the three groups: the LFLP, LFBP and BFLP. The latter with an individualist strategy have decreasing scores. Among researchers with stable IF scores, we find the LFLP with more sharing strategies. The other strategies do not appear to contribute to the increase or decrease, over time, of the researchers' scores, and are therefore not shown. It should be reminded that, in each class, several individuals see their scores increase between the two periods; but these increases are often not sufficient to reach, in the second period, a score that

is high enough above the new standardized mean of their class. In addition, given the limitations in our data, actors often access resources that are invisible to us.

One may explain this catching up by the fact that some LF, whether in big or little ponds, have learned, over time, to use the resources of their organization more efficiently. By speculating beyond our data, one can hypothesize that measurements of the same networks in 2004 would have shown inter-individual and inter-organizational interdependencies that would have become less disjointed for the LF in these elite. In other words, the LF would have learned to use to their own advantage the resources of their laboratory or the resources to which their laboratory gives access. In addition, one could interpret the results on upward mobility in table 4b from the point of view of status inconsistency and its potential motivating and resource giving effects. The odds of upward mobility are stronger for BFLP (resource giving effect) and LFBP (motivation). These groups are also slightly overrepresented in the upward mobility subgroup.

Finally, strategy alone cannot account for the variations observed in the impact factor scores during the second period. Other factors have allowed certain little fish to catch up to the performance level of the BFBP. The reasons that their strategies are efficient have to do with the fact that they give access to resources, but they may also have to do with more general contextual causes, for example institutional ones. But our study does not have sufficient data to reliably control for the effect of these strategies relative to the effect of the evolution of the characteristics of the context in which the researchers worked. More systematic research would be necessary to meet our second expectation entirely and to confirm that the choice of one strategy for the management of interdependencies can influence, in a general and causal manner, catching up strategies in this multilevel and highly competitive environment. As acknowledged in the Hypothesis section, long-term ascendant trajectories cannot be explained solely by the individual catching up strategies. Career data, for example, should ideally be included in the discussion. There are reasons for which some individuals end up in the laboratory or context in which they end up, and these reasons are likely to be related to their performance.

9. Meso-social explorations with multi-level analysis based on linked designs: limits and perspectives

In summary, this article presents an exploration of the meso-social order using a multi-level structural approach observing two systems of superposed interdependencies, one inter-organizational and the other inter-individual. This approach extends the principle of linked

design (Parcel at al., 1991) to structural analysis, which allows for this dual positioning. In effect, individual actors are positioned both according to their centrality in the network of inter-individual relationships and on the basis of the centrality of their organizations in the network of inter-organizational relationships. This dual positioning can add a causal factor in the explanation of action and performance measured at the individual level. It helps with the study of "duality" in social life (Breiger, 1974; Fararo and Doreian, 1984).

The knowledge of systems of multiple-resource and multi-level interdependencies, as well as the manner in which actors manage these interdependencies, adds, it seems to us, an underestimated dimension to multi-level reasoning in sociology. Using this knowledge for dual positioning in systems of superposed interdependencies allows us, especially when this positioning is articulated to actors' strategies, to form new hypotheses about the relationship between position in structure, individual and collective action, and performance (measured at the individual level). In the case examined here, the knowledge of interpersonal relationships in the elite of this system, of relationships between the organizations of this system, and of the multi-level articulation of the two patterns, clarifies the social processes leading to high performances in an elite in scientific research.

Specifically we showed that, in this opportunity structure, non-central researchers (little fish) in our population used individualist strategies to catch up with the BFBP. The quasi-totality of those catching up, who make up the LFBP and the LFLP categories, or more generally the non-central researchers of this elite, can benefit from this strategy to improve their score in this system. In particular, the LFLP, who have the least access to the rare resources of their laboratories, greatly improve their chances with this individualist strategy, i.e. when they can afford not to align themselves entirely on the relational discipline imposed by their laboratory (or by the director of their laboratory). Therefore, it is not necessary, a priori, to be in a big pond (a large laboratory designated by elites as a central laboratory) in order to have a chance at catching up. Those whose impact factor scores have risen are generally researchers who are younger than the majority of the population. In our case study, the majority among them are hematologists, laboratory directors, and in Ile-de-France. Note, however, that some actors possessing resources are invisible to us because of their multiple memberships and because of the limits of our data in this regard. We have identified several LFLP who have a strong reputation in domains other than cancer research (they would certainly be BFBP in another specialty), which may also help explain their capacity to catch up.

Empirically, our illustration of this approach is obviously limited. First of all, our study only uses multi-level structural analysis in a minimal fashion, identifying most often a

single member in each organization (not including the representative of this organization, its director). This is an obvious difference with more classical multilevel analysis: by observing only one researcher per laboratory, we are not able to show and analyze variance existing at the level of the higher level units (the laboratories). The systematic identification of several members in each organization would have allowed for combined analyses with these more classic multi-level approaches, ones that do not attempt to bring to light systems of heterogeneous interdependencies and resource management strategies by actors in different opportunity structures. Therefore, the relationships between the two methods remain to be examined in a more systematic manner.

Secondly, we no not have the data needed for a more systematic comprehension of the complementary nature of individual and organizational resources that contributes to the triggering of multi-level processes. Without longitudinal data, it is difficult to understand the extent to which the centrality of an organization in an inter-organizational network and the centrality of an individual actor in an inter-individual network mutually construct themselves. The articulation of both multi-level and dynamic structural analyses remains therefore to be explored, as in the direction pioneered by Snijders and Baerveldt (2003). Thirdly, our multilevel approach through linked design creates units of analyses at two levels (BFBP, etc.); much remains to be done to generalize and systematize this approach, as in the direction shown by Robins et al. (2005) or in the spirit of Fararo and Doreian (1984) for more numerous superpositions.

Finally, our results suggest that the position of an organization in the inter-organizational network is still more important in terms of attaining high levels of performance than the position of individual members in the network of the elite in the examined field or system. However, this result raises the question of how actors made it, in the first place, into the central organizations dominating these systems of interdependencies, upstream of the processes observed here. The only response to this question lies in the articulation of data of multi-level networks with other types of data – on the trajectories and careers of actors in the "small worlds" examined, and more generally at the meso-social level. This means, again, that other influences (than strategies) on impact factors should not, ideally, be left out of the discussion and the analysis. Beyond the big fish – big pond categorizations, empirical analyses testing their importance for performance need to be combined with additional data in order to provide strong evidence for causal effects.

In spite of all these limitations, this analysis of multi-level networks seems therefore adapted to certain types of questions that sociologists ask when they try to combine both individual and contextual factors in order to estimate the likelihood of an individual or a

group to adopt a given behavior or to reach a given level of performance. More generally, this approach explores a complex meso-social level of accumulation, of appropriation and of the sharing of multiple resources. This level, still poorly known, is difficult to observe without a structural approach. If it is true that contemporary society is an "organizational society" (Presthus, 1962; Coleman, 1982; Perrow, 1991) –in the sense that action and performance measured at the individual level strongly depend of the capacity of the actor to construct and to use organizations as instruments, and thus to manage his/her interdependencies at different levels in a strategic manner–,then the study of interdependencies jointly at the inter-individual and the inter-organizational level is important for numerous sets of problems. We should not overlook the domains of application for this approach in sociology, in particular for the study of relationships between organizations, careers, social stratification and inequalities.

In particular, this approach will reach its full potential when longitudinal observations at both levels of analyses will be available. In effect, in this paper we insisted on the effects of dual positioning on performance measured at the individual level, as well as on the contribution of specific strategies for relative catching up in a specific milieu and underlying opportunity structure. However, this approach also opens up research on institutional change and the evolution and/or redesign of inter-organizational systems and opportunity structures. Structural linked design and dual positioning will allow to evaluate the importance of inter-individual and inter-organisational networks of an elite when the latter attempts to redesign an institutional setting that it controls or represents, for example when organizational mergers are considered. Elites are often involved in power struggles that generate great uncertainties about such changes. The dynamic examination of multiple positionnings provided by structural linked designs should thus allow to anticipate or evaluate the respective capacities and strategies of different segments of an elite to compete for control of institutional change and redesign.

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Table 1

Medians and percentages for the variables characterising the population of 93 researchers and laboratories which participated in the study

Researchers

Variables	Median	%
Indegree centrality	5,2	
Environment		
Outdegree centrality	4,1	
Impact factor	84	
Number of papers	23,5	
Age	48	
Laboratory directors		52
Specialties		
Fundamental recherche		44
Laboratory research		45
Hematology		28
Solid tumors		45
Surgery		8
Public health		15
Diplomas		
MD		70
Pharmacy		4
PhD in sciences		44
Agregation		27
Current status		
Research director		29
Researcher		7
Technical engineer		3
Head of hospital department		45
Head of clinique		1
Instructor		81
Works in hospital		17
Works in hospital and univ. Professor		54
University professor		7
Scientific committee		73
Editorial board		51

Laboratories

Variables	Median	%
Indegree centrality	2,75	
Outdegree centrality	2	
Size	26	
Environment		
Sources of funding		
French research funds	12,5	
French non research funds	32	
Public or private foreign institutions	0	
European funds	3	
Institutional budget	26	
Geographical site:		
Île de France		52
Specialties		
Fundamental research		58
Laboratory research		43
Hematology		20
Solid tumors		33
Surgery		3
Public health		12

Table 2 : Density table for intra- and inter-class relationships in the advice networks among researchers.

Densities	Big Fish in Big Pond	Big Fish in Little Pond	Little Fish in Big Pond	Little Fish in Little Pond
Big Fish in Big Pond	0,16	0,15	0,04	0,03
Big Fish in Little Pond	0,11	0,13	0,03	0,04
Little Fish in Big Pond	0,07	0,05	0,03	0,01
Little Fish in Little Pond	0,05	0,05	0,02	0,03

Intra-class densities are indicated in grey. They decrease with the centrality of the laboratory and with the centrality of the researchers.

Table 3 : Distribution of the 93 researchers/laboratories per class and strategy

Strategies	*Classes*				
Frequency					
Percentage					
Row percentage	Class 1 –Big Fish –Big Pond	Class 2 –Big Fish-Little Pond	Class 3 –Little Fish-Big Pond	Class 4 – Little Fish-Little Pond	Total
Column percentage					
Strategy A - Independent	10	4	11	16	41
	11	4	12	17	44
	24	10	27	39	
	31	25	50	70	
Strategy B - Individualist	9	2	5	5	21
	10	2	5,5	5,5	23
	43	9	24	24	
	28	12	23	22	
Strategy C -Collectivist	9	6	3	2	20
	10	6	3	2	21
	45	30	15	10	
	28	38	13,5	8	
Strategy D - Fusional	4	4	3	0	11
	4	4	3	0	12
	36	36	27	0	
	13	25	13,5	0	
Total	32	16	22	23	93
	34	17	24	25	100

Table 4a : Means of standardized impact factor scores for all researchers at time t1 and t2 according to class and strategy

	Class 1 BFBP				Class 2 BFLP				Class 3 LFBP				Class 4 LFLP				Means of strategies			
	t1	t2	N	R	t1	t2	N	R	t1	t2	N	R	t1	t2	N	R	t1	t2	N	R
Strategy 1 "Independent"	0,5	0,66	10	+	-0,35	-0,45	4	-	0,05	-0,22	11	-	-0,43	-0,44	16	-	-0,06	-0,11	41	-
Strategy 2 "Individualist"	0,55	0,45	9	-	-0,01	-0,77	2	-	0,05	0,48	5	+	-0,30	0,10	5	+	0,17	0,25	21	+
Strategy 3 "Collectivist"	0,26	0,06	9	-	-0,34	-0,05	6	+	-0,40	-0,29	3	+	0,47	-0,13	2	-	0,002	-0,04	20	-
Strategy 4 "Fusional"	0	0,03	4	+	-0,07	0,28	4	+	-0,24	-0,38	3	-			0	0	-0,09	0,01	11	+
Means of classes	0,38	0,35	32	-	-0,23	-0,15	16	+	-0,05	-0,09	22	-	-0,32	-0,29	23	+	0		93	

t1=first period, t2=second period, N=number of researchers in that category, R=result. Distributions of scores of impact factors are standardized for easier comparisons.

Table 4b: Standardized means of impact factor scores for the sub-population of researchers whose scores increased between periods 1 and 2, according to class and strategy

	Class 1 BFBP				Class 2 BFLP				Class 3 LFBP				Class 4 LFLP				Means of strategies			
	t1	t2	N	R	t1	t2	N	R	t1	t2	N	R	t1	t2	N	R	t1	t2	N	R
Strategy 1 "Independent"	0,94	1	5	+	-0,47	-0,42	2	+	-0,52	-0,41	6	+	-0,53	-0,55	6	-	-0,13	-0,08	19	+
Strategy 2 "Individualist"	0,57	0,54	4	-			0		-0,04	0,26	3	+	0,11	0,13	4	+	0,23	0,31	11	+
Strategy 3 "Collectivist"	0,35	0,23	3	-	0,02	0,06	3	+	-0,51	-0,27	2	+	-0,32	-0,76	1	-	-0,02	-0,04	9	-
Strategy ' "Fusional"	-0,56	-0,44	2	+	0,48	0,09	4	-	-0,59	-0,95	1	-			0		0,03	-0,21	7	-
Means of classes	0,49	0,5	14	+	0,11	-0,03	9	-	-0,40	-0,27	12	+	-0,280	-0,324	11	-	0		46	

t1=first period, t2=second period, N=number of researchers in that category, R=result. All researchers in this table have on average higher scores during period 2 than during period 1. Scores higher than 0 correspond to scores of researchers who have the best scores among all those who saw their scores increase over the two periods.

Table 4c : Standardized means of impact factor scores for the sub-population of researchers whose scores decreased between periods 1 et 2, according to class and strategy

	Class 1 BFBP				Class 2 BFLP				Class 3 LFBP				Class 4 LFLP				Means of strategies			
	t1	t2	N	R	t1	t2	N	R	t1	t2	N	R	t1	t2	N	R	t1	t2	N	R
Strategy 1 "Independent"	0,2	0,11	5	-	-0,33	-0,6	2	-	0,94	0,15	5	-	-0,71	-0,36	10	+	-0,09	-0,15	22	-
Strategy 2 "Individualist"	0,6	0,45	5	-	-0,61	-0,94	2	-	0,53	0,96	2	+	-0,48	-0,97	1	-	0,23	0,13	10	-
Strategy 3 "Collectivist"	0	0,05	6	+	-0,84	-0,29	3	+	0,26	-0,58	1	-	1,50	1,03	1	-	-0,06	0	11	+
Strategy 4 "Fusional"	0,62	0,96	2	+			0		-0,41	0,16	2	+			0		0,1	0,56	4	+
Means of classes	0,2916	0,2828	18	-	-0,631	-0,568	7	+	0,526	0,245	10	0	-0,508	-0,297	12	+	0		47	

t1=first period, t2=second period, N=number of researchers in that category, R=result.

Figure 1: Example of visualization of multilevel networks in French cancer research (1999).

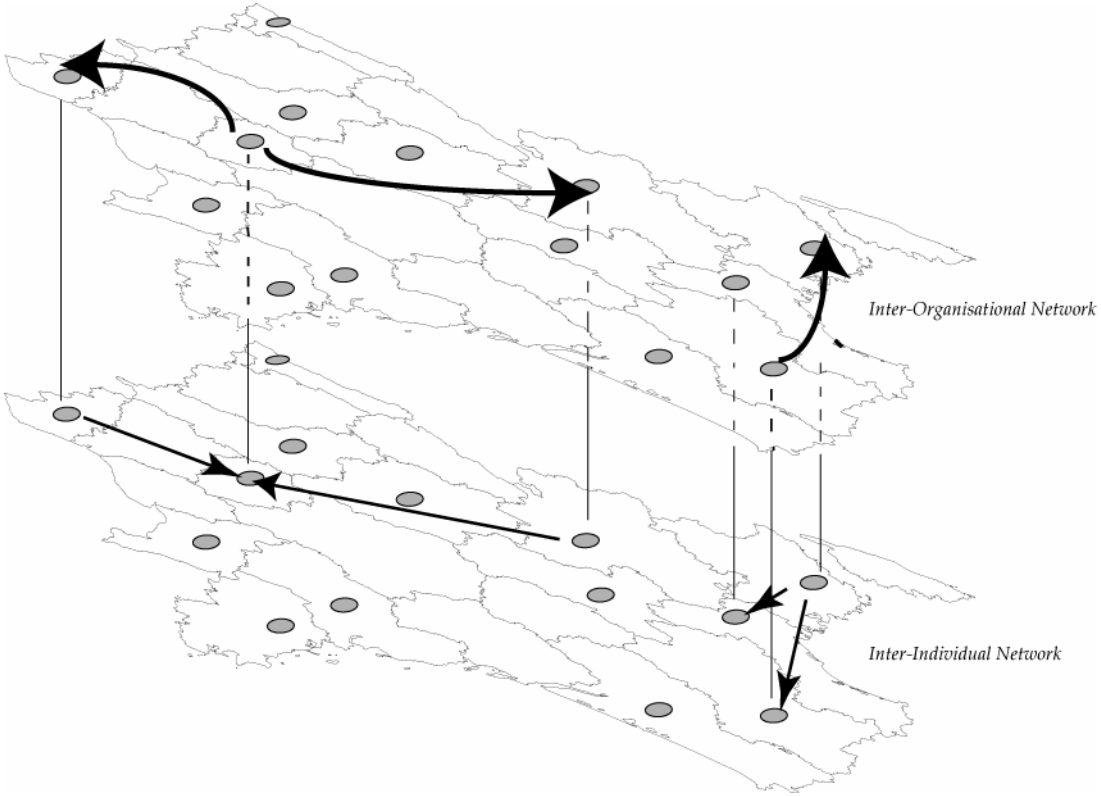


Figure 2: Graphs of intra-class advice ties (i.e. among members of each class).

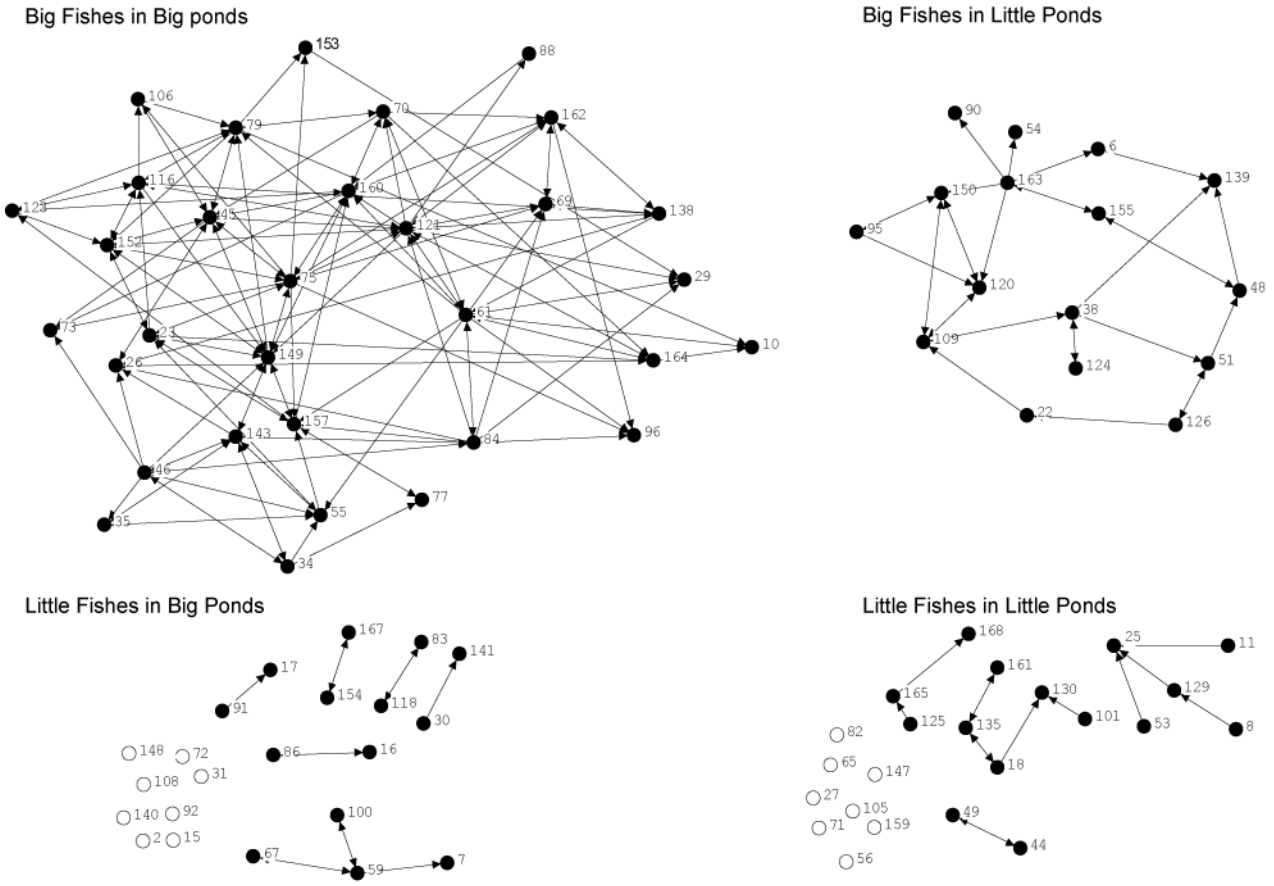
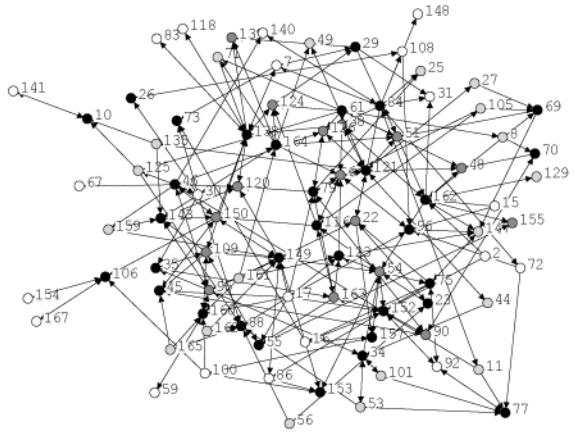
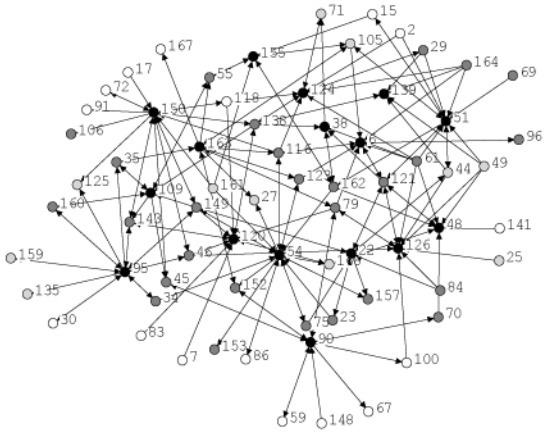


Figure 3: Graphs of inter-class advice ties

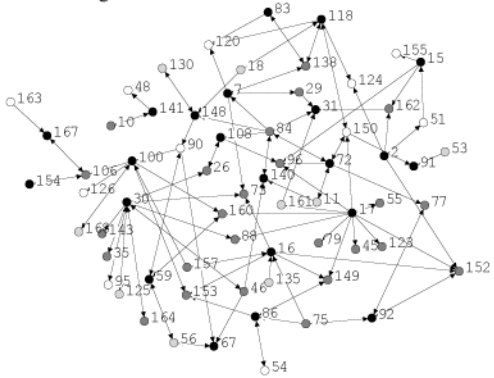
Big Fishes in Big Ponds and other classes



Big Fishes in Little Ponds and other classes



Little Fishes in Big Ponds and other classes



Little Fishes in Little Ponds and other classes

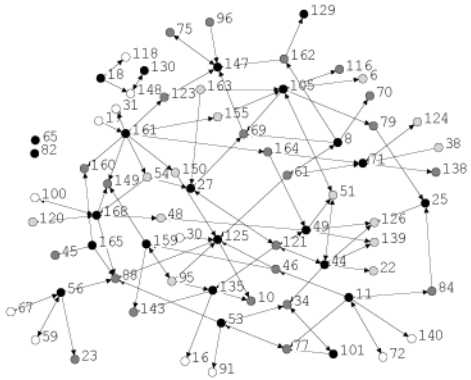


Figure 4: Boxplots of impact factors by class for the first period

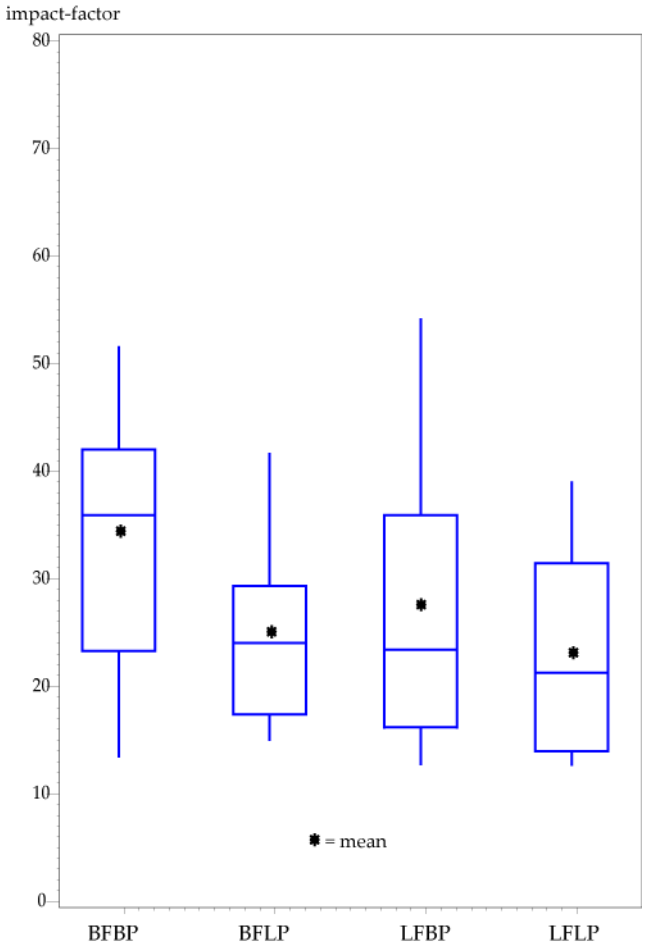


Figure 5: Types of overlap between the relationships among researchers and the relationships among laboratories (based on linked design)

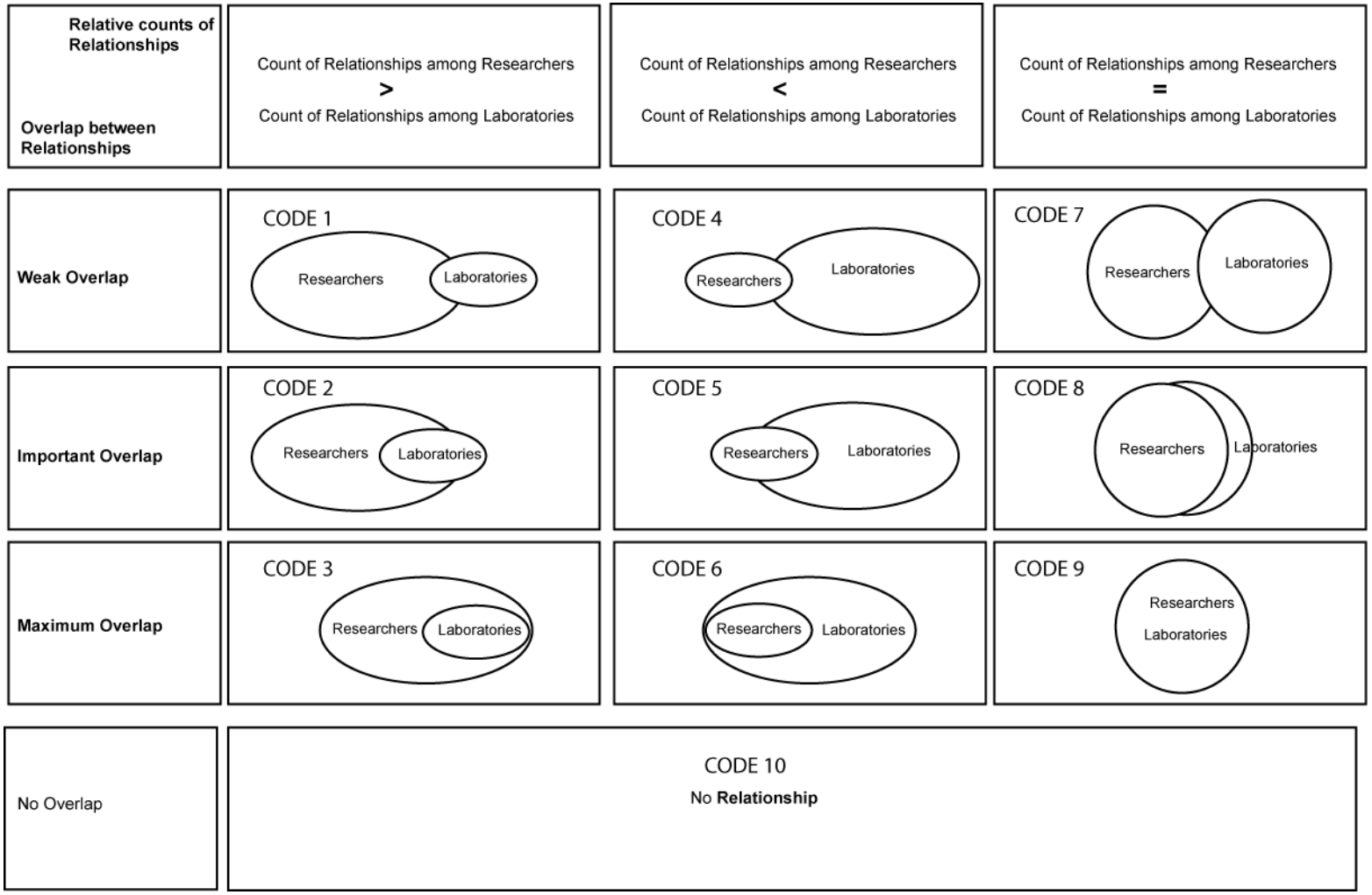


Figure 6 : Reconstitution of strategies of actors

A : Independent, **B :**Individualist, **C :**Collectivist, **D :**Fusional

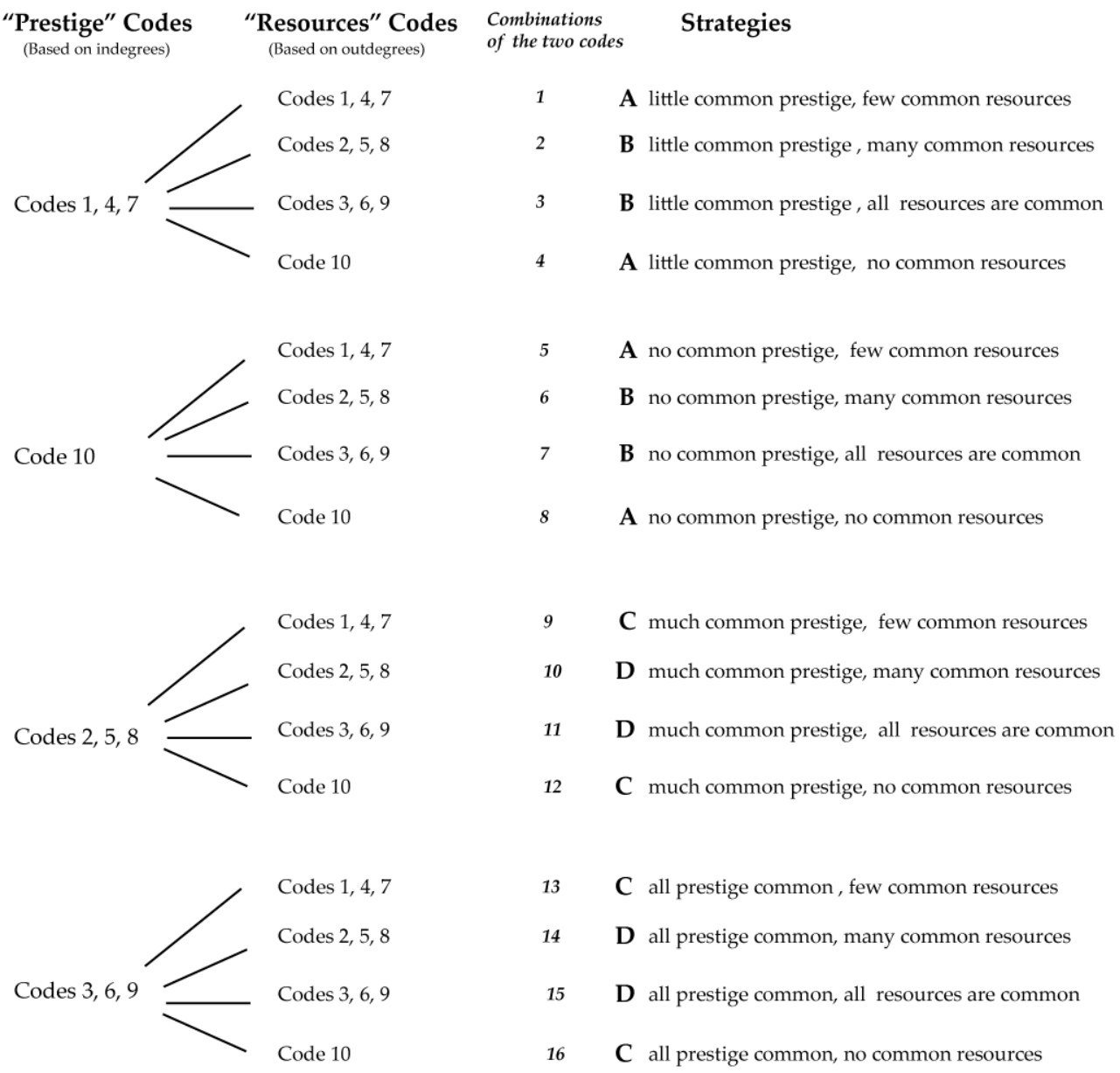


Figure 7: Proximities of classes and strategies
Correspondance Analysis of Table 3 (weighted counts)

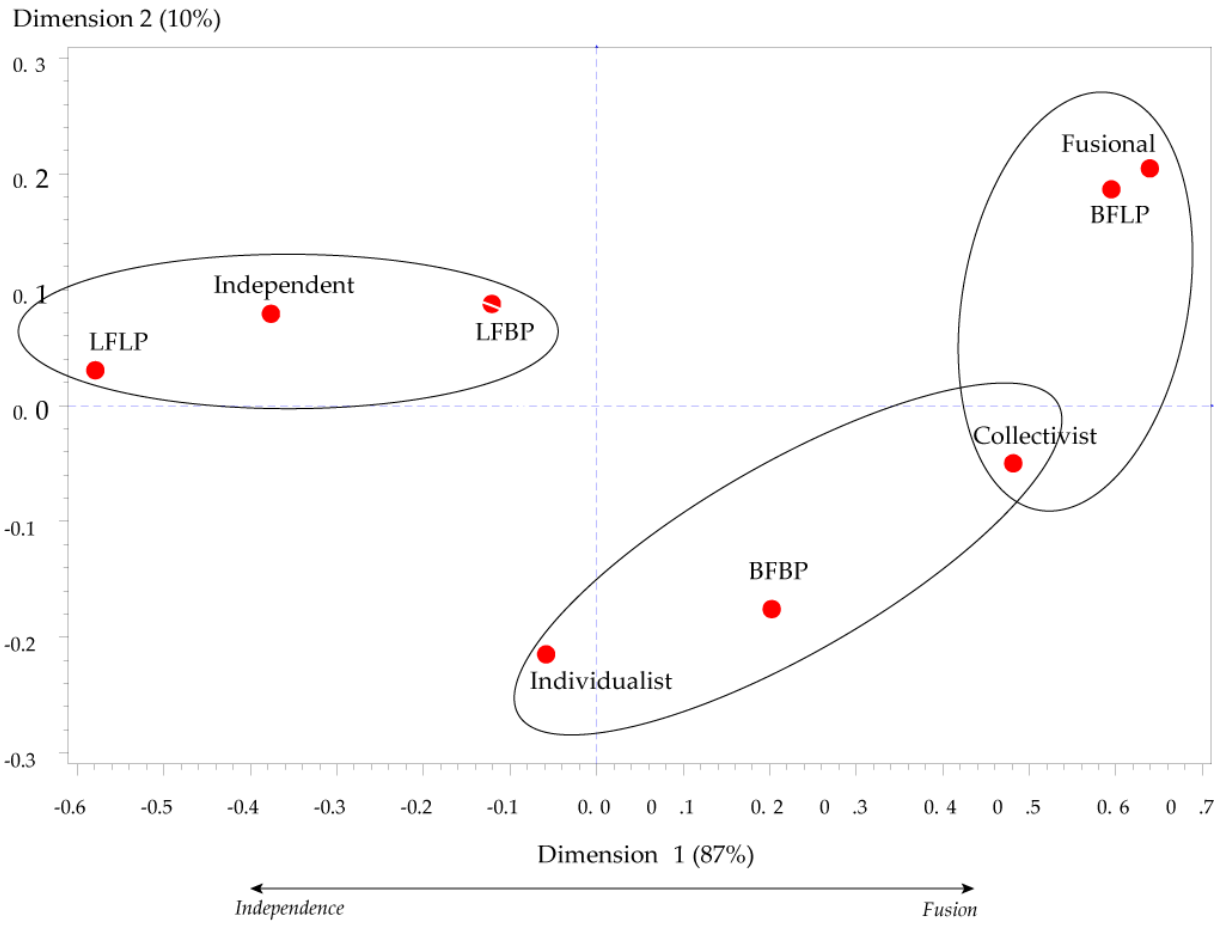


Figure 8: Which catching up strategies for actors who are not BFBP? Correspondence Analysis of Table 4a (weighted counts)