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Title

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Abstract

Recent developments in innovation theory and policy have led policymakers to assign particular importance to supporting networks of cooperation among heterogeneous economic actors, especially in production systems composed of small and medium enterprises. Such innovative policies call for parallel innovations in policy analysis, monitoring and assessment. Our analysis of a policy experiment aimed at supporting innovation networks in the Italian region of Tuscany intends to address some issues connected with the design, monitoring and evaluation of such interventions. Combining tools from ethnographic research and social networks analysis, we explore the structural elements of the policy programme, its macroscopic impact on the regional innovation system, and the success of individual networks in attaining their specific objectives. This innovative approach allows us to derive some general methodological suggestions for the design and evaluation of similar programmes.

Classification-JEL: D78; O31; O32; O38; R58

Keywords

Innovation policy and cooperation networks, evaluation, regional development, SMEs production systems, complex systems

Titre de l'article

Réseaux de coopération et innovation. La perspective des systèmes complexes pour l'analyse et l'évaluation d'un programme européen de politique régionale de l'innovation.

Abstract (résumé)

Les développements récents dans la théorie et la politique de l'innovation ont poussé les responsables des politiques à donner une importance particulière à l'appui aux réseaux de coopération entre agents économiques hétérogènes, notamment dans les systèmes de production formés par des petites et moyennes entreprises. De telles politiques innovantes demandent des innovations parallèles dans les domaines de l'analyse des politiques, du suivi et de l'évaluation. Notre analyse d'une expérience de politique visée à favoriser des réseaux d'innovations dans la région italienne de Toscane a comme but d'aborder certains enjeux liés à l'élaboration, au suivi et à l'évaluation de telles interventions. En associant des instruments de la recherche ethnographique et de l'analyse des réseaux sociaux, on explore les éléments structurels du plan d'action, son impact macroscopique sur le système régional d'innovation, et le succès des réseaux individuels dans la réalisation de leurs objectifs spécifiques. Cette démarche innovante nous permet également d'en tirer des propositions pour les responsables des politiques qui pensent appliquer des programmes similaires.

Classification-JEL: D78; O31; O32; O38; R58

Mots clés

Politiques d'innovation et réseaux de coopération, évaluation, développement régional, PME, systèmes de production, systèmes complexes.

1. Introduction: Context and objectives of the analysis

In the last ten years, innovation has gained increasing importance in the context of European development policies. Starting from the Green Paper on Innovation (1995) and the First Action Plan for Innovation in Europe (1996), the European Commission has increasingly bet on innovation policies as a tool to improve Europe's economic growth, competitiveness and social cohesion (European Council, Lisbon, 2000; European Council, Brussels, 2005).

At the same time, the policymakers' theoretical understanding of innovation processes has evolved (Mytelka and Smith, 2002). The traditional view of innovation as a linear process has been challenged by theories that consider innovation as a complex process, involving many actors, their relationships and the social and economic context in which they are embedded[1]. This perspective has been adopted in the literature on national systems of innovation. Emerging at the beginning of the 1990s with the path-breaking contributions by Lundvall (1985; 1988; 1992), Freeman (1988) and Nelson (1988; 1993), this approach has highlighted the roles of national institutions in influencing how innovation processes unfold. Other contributions have applied the concept of 'innovation system' to the regional (Saxenian, 1994; Scott, 1994; Ehrenberg and Jacobsson, 1997; Malerba, 1997; Cooke, 2001) and even sector levels (Breschi and Malerba, 1997). Interest for social interactions as a locus for innovation has led policymakers to assign particular importance to supporting networks of cooperation among heterogeneous actors, especially in economic contexts composed of small and medium enterprises (Audretsch, 2002; European Commission, 2003a; European Council, 2000).

These changes in framing the understanding of innovation processes call for 'innovations in innovation policy'. While the European Commission has undertaken some

steps in this direction by introducing the Regional Programmes of Innovative Actions[2], little attention, so far, has been paid to the innovative character of such policy interventions, their effects, and the need for proper tools in order to analyze and monitor them. In this paper we focus on the methodological and theoretical issues that arise in connection with the implementation of a particular kind of innovative policies, which attempt to foster innovation through the creation of cooperation networks. Our aim is to contribute to the evaluation and modeling of such interventions in order to derive precise suggestions for their design and management.

We explored these issues through empirical research on a specific policy experiment funded within the ERDF Innovative Actions framework: the 'Innovazione Tecnologica in Toscana' programme (henceforth RPIA-ITT), implemented by Tuscany's regional administration in the period 2001-2004.

The RPIA-ITT intended to promote development in the regional economy, characterized by a prevalence of small and medium enterprises, through the creation of cooperation networks, with the purpose of integrating competences and testing new methodologies for stimulating technological innovation. Previous experience in the context of RITTS (*Regional Innovation and Technology Transfer Strategies*) and in the Advanced Technology Virtual Network programme had led the regional administration to issue a tender for innovative projects within four action lines. Two of them intended to promote technology transfer and diffusion of innovation in, respectively, the geographical area of Western Tuscany (action line 1) and a set of technological applications in the fashion industry (action line 2), both of which had recent histories of sluggish growth. The other two were targeted to high-tech applications, optoelectronic technologies (action line 3)

and biotechnologies (action line 4). A synthetic overview of the programme is presented in Table 1.

Table 1. A synthetic overview of the RPIA-ITT programme

	applications	**funded projects**
number of projects	36	14
number of partners	528	264
number of different organizations involved	409	203
number of SMEs featuring as partners	295	129
number of different SMEs involved	262	118
organizations involved in more than one project	58	22
budget (in euro)	15.504.764*	6.494.298**

* of these, 11.661.951 euro were to be financed by the Region

** of these, 4.703.029 euro were financed by the Region

Action lines	**% available resources**
1. Promoting technology transfer and diffusion of innovation in Western Tuscany	29%
2. Promoting technology transfer and diffusion of innovation in the fashion industry: textiles, clothing, shoes	27%
3. Promoting technological development and industrial applications of optoelectronic technologies	21%
4. Promoting technological development and industrial, agricultural, environmental appliications of biotechnologies	23%

Although the 36 submitted applications were roughly balanced between the four action lines, the final distribution of the resources assigned to individual lines was influenced by the very low scores obtained by the projects in action line 4, and by the comparatively higher scores obtained by the projects in action lines 1 and 2.

The programme required heterogeneous networks[3] and encouraged participation by SMEs[4]. Data show that small firms, both in the manufacturing and service industries, constituted a large share of the actors taking part in the programme. If we consider only funded projects, half the participants were SMEs, and almost one third were small manufacturing companies (with less than 30 employees, in line with the prevalent organizational structure of Tuscany's production system).

Many organizations that applied to the programme were involved in more than one application[5]. Although no correlation was found between the number of applications that an organization submitted and the number of funded projects in which it took part, if we consider the 58 organizations that were involved in more than one project, it is apparent that some of them were extremely active within the programme: 10 of these were to perform activities corresponding to one quarter of the financial resources of the entire programme.

This background information helps us in framing the main issues that are dealt with in the following sections, in particular the identification of the channels through which the RPIA-ITT impacted the regional economy, and of the roles played by different types of organizations both within each project and in the programme. An evaluation of the success of individual networks in attaining their specific objectives has been developed within the accompanying measures of the programme. Since, our aim is to outline an analytical framework in evaluating policy experiments, such as the RPIA-ITT, we are mainly interested in the analysis of the structural elements of the programme and its macroscopic impact on the regional innovation system, in order to assess some general features of the evaluation process. In particular, we try to assess whether the programme had succeeded in promoting the creation of well-functioning networks capable of integrating heterogeneous competences and to foster systemic effects in the regional economy; to understand to what extent the programme supported pre-existing networks of relationships or mobilized new ones; to point out which elements of this programme can be generalized to other innovation-supporting interventions; and to formulate suggestions that might help policymakers improve their management of similar programmes.

To analyze the structural characteristics of the networks of relationships underpinning the programme and to explore some of the emergent effects that resulted from it, our methodology relies on complementary tools from ethnographic research and social networks analysis.

The paper is organized as follows. In section 2 we outline the theoretical background and the methodological framework that we implemented in order to analyze the programme and assess its impact. Section 3 introduces the results of our empirical analysis. This exercise has allowed us to derive some recommendations specific to the programme, presented in section 4, and has also suggested some general methodological considerations that we present in section 5.

2. Exploring innovation networks: theory and methodology

2.1 Generative relationships and scaffolding structures

We adopt a view of innovation as a process comprising cognitive, social, technical, economic and political elements, unfolding at multiple levels of social organization and across multiple temporal scales (Lane and Maxfield, 2005; van der Leeuw, 1981). In particular, we consider innovation as driven by interactions happening within *generative relationships*, that is, relationships among heterogeneous agents that can induce changes in how agents interpret themselves, other agents and artifacts, bringing about innovations that are generally characterized as new entities (Lane and Maxfield, 1997). These changes are frequently cumulative and in turn create conditions for new generative relationships. This boot-strap dynamics is a major feature of the dynamics of innovation. Although the innovations that result from these relationships cannot be predicted on the basis of the knowledge of the characteristics of the agents involved[6], Lane and

Maxfield (1997) claim that it is possible to assess whether relationships have *generative potential,* on the basis of five conditions. The agents involved in a potentially generative relationship must share, in their interaction, a focus on the same artifact or agent (aligned directedness). Agents must differ in terms of expertise, attributions or access to particular agents or artifacts (heterogeneity). Agents must seek to develop a recurrent pattern of interactions from which a relationship can emerge (mutual directedness); their willingness to do so depends on the interpretation that each makes of the identity of the other. In this context, mutual trust helps but is not a precondition: actually, trust may result from the interactions themselves. The agents involved must be able to carry out discursive interactions, outside the conventional exchanges that are generally confined to requests, orders, declarations (right permissions). Interactions can prove more fruitful if the agents have the chance to work together on a common activity (opportunities for joint action).

As Lane and Maxfield (1997) stress, these conditions must be constantly monitored. Monitoring can suggest ways of nurturing and maintaining the relationships' generative potential, and therefore it plays an important role in the context of the programme that we analysed. Through ethnographic interviews, we explored to what extent agents interacting within each cooperation network were able to monitor these changes, and we found that monitoring proved important in order to allow them to foster the relationships that, in turn, were more likely to give rise to further changes. We consider monitoring generative potential as a crucial issue not only at the project level, but also when assessing the impact of an innovation policy programme. This requires proper indicators and the definition of a relevant time profile, as we discuss in section 3.2.

Generative relationships contribute to the dynamics of innovation processes; this dynamics is also affected by the presence of institutions and collective actors that build connections among agents and organizations with similar and complementary competencies, foster the reproduction of regulatory systems and the diffusion of shared communication codes, produce a wide range of public goods endowed with externalities that are important to the production system (Lane and Maxfield, 1997; Brusco, 1999; Russo, 2000, Bellandi and Di Tommaso, 2006). These institutions and collective actors can also support the creation and maintenance of cognitive and physical *scaffolding structures* in agent space — such as trade fairs, research networks, standard setting organizations, or the policy programmes themselves — that are fundamental in supporting processes of cooperation and exchange (Lane and Maxfield, 2005).

2.2 Identifying and assessing cooperation networks

In studying the structure and impact of this programme, we first distinguished between the cooperation networks set up in response to the RPIA-ITT and the presence of other networks of relationships among the organizations involved in the programme. According to the procedure described in the RPIA-ITT's call for tender, expected applicants had to formalize their cooperation by setting up Temporary Associations of Enterprises. However, the relationships that underpinned the innovative activities of each network could not be reduced to those unfolding within the individual cooperation networks. We decided to examine direct connections among the participants in the programme, crossing the various projects and action lines, as well as those that linked the participants through common involvement in other activities (for example, other regional research projects or other European programmes). We investigated both the indi-

vidual cooperation networks and the RPIA-ITT programme as a whole, which we looked at as a 'network of networks'.

This two-level analysis requires appropriate data, that can be partly drawn from the programme's administrative documents (the call for tender, the EU guidelines on which the tender was based, the application forms, the projects' administrative documents) but must also be supported by ad-hoc investigations. Through interviews with a subset of agents involved in the programme[7], we examined the process of creation of cooperation networks, their degree of formalization, the ties between the participants within and across projects (nature of these ties, history of how they emerged and changed in time, between which actors - individuals or organizations - and for which common activities) and the temporal dimension of network structure.

At one level of analysis, we reconstructed the networks of relationships within each funded project, using the participants' joint involvement in the various work modules of the project as proxy for the existence of a relationship between them. At another level, we explored the network of relationships underpinning the programme as a whole; here, we used the participation of the same organization in two project proposals as a proxy for the existence of a relationship between the projects.

Networks were analyzed through visualization (Freeman, 2000) and the computation of statistics relating to network cohesion and node centrality.

The centrality indexes[8] highlighted the actors most actively involved in the programme, and therefore helped us select the organizations to be interviewed. The study of the network's cohesion (Moody and White, 2003) allowed us to identify the presence of densely connected subgroups (cores) of actors. Operationally, this requires the identification of all the subgroups within the network whose nodes have at least *k* independent

links with each other[9]. This measure of structural cohesion defines a subgroup property and situates subgroups relative to each other. Network cohesion is then analyzed by examining both the k-cores' values (a low value of *k* implies weak cohesion among the nodes in the k-core) and the presence of hierarchical nesting of lower connectivity levels and of overlapping subgroups.

The study of the structure of relationships underpinning the entire programme allowed us to better understand which agents were able to facilitate the generative relationships that support innovation. This methodology also allowed us to explore the systemic nature of the effects produced by the RPIA-ITT programme, by highlighting to what extent some cooperation networks, connecting different projects, had become relevant as a system of innovation, which might trigger further innovation cascades.

3. Networks of relationships within and between RPIA projects

3.1 Two-level networks

In order to evaluate the effects of the various projects, the regional administration focused on each project individually, and on each action line separately. This approach is encouraged by the European Commission itself, which, in order to collect information about the programmes' results, requests the administrators to construct indicators referred to individual projects (e.g. number of patents filed, number of partners, number of workshops held, number of publications). Although these indicators are commonly accepted in cross-programme comparisons, they do not provide sufficient elements in order to properly address the issues that we introduced in section 1 concerning the structure and characteristics of project networks: Was the RPIA-ITT programme able to tap into an existing structure of interorganizational relationships, and in turn impact that

structure? Among the organizations that responded to the programme, which ones were most active in formulating proposals for innovative projects and obtaining funding? Which kinds of cooperation networks, in terms of participants' competences, were most successful in carrying out innovation processes?

To analyze the structure of each cooperation network we describe, in section 3.2, the interactions between the participants involved in the various activities performed within the projects; we then analyze, in section 3.3, the role of actors mediating heterogeneous competences. The overall emergent structure of the programme is investigated by focusing on the network of relationships among the set of 58 organizations that participated to more than one project proposal (section 3.4) and on the relationships among the 36 project proposals (section 3.5).

A relevant issue in the reconstruction of the networks of relationships underpinning the individual projects and the general programme was the choice of a unit of analysis. Certainly, innovation networks are always a matter of personal interactions: inter-individual relationships were explored in the course of the interviews, and the insights emerging from these interviews were taken into account when we interpreted the structure of the programme. However, supra-individual structures enable and mediate personal interactions, providing spaces and opportunities for encounter, exchange and discussion. Since our purpose was to understand how the RPIA-ITT programme relied upon an existing structure of interorganizational and interinstitutional relationships, we decided to build networks whose nodes were organizations, not individuals[10].

3.2. The structure of the funded projects

In order to retrace the process of construction of the cooperation networks and the different roles played by the participants, we retrieved — for the funded projects —

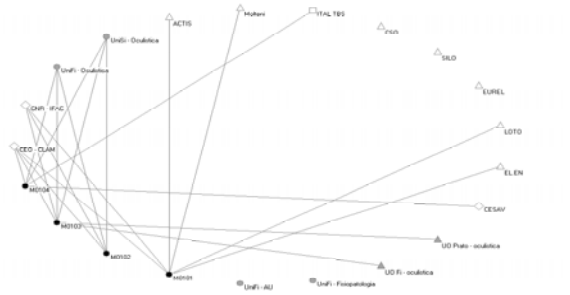
information about the activities performed and the person-months committed to the project by each partner organization. According to the application forms, the activity of each project had to be divided into work modules. Since the participants were involved in more than one activity in the same project, joint participation in each module provided us with an indicator of the interweave of collaborations within the project.

For each project we constructed the module-partner network at three different times: presentation of the request (application form), beginning of the work (executive plan), and report on the results achieved (final report). An example of the visualization of the three partner-module networks is given in Figure 1. In each graph, the nodes are arranged in a circle: the organizations participating in the project are represented in the upper part of the circle, while the work modules of the project are represented in the lower part. Different symbols are assigned to organizations belonging to different sectors of economic activity, while work modules are numbered progressively. The ties in the network are weighted with respect to the organization's engagement in terms of person-months. Within each project, the nodes are maintained in the same position in the three networks in order to easily compare the number and the quantitative importance of the partners over time (while the qualitative importance of the various partners can be gauged only through careful analysis of each project).

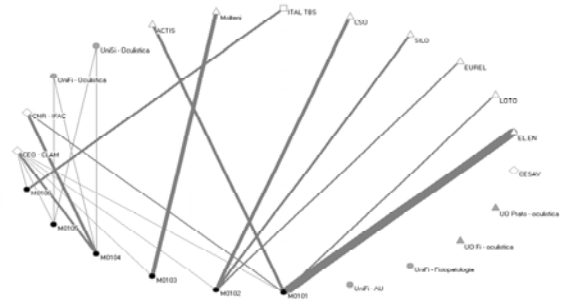
The number of cases is too small to identify a significant network typology. However, the 13 sets of the three representations (data were not available for one project) allowed us to better focus our qualitative interviews and to formulate some suggestions about the kind of information the policymaker should have collected in order to improve both the initial selection of proposals and the programme's final evaluation.

Figure 1. Networks of participant organizations and work modules.

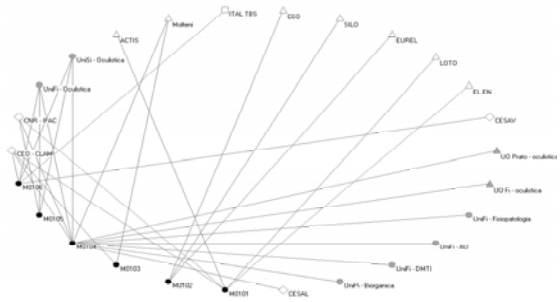
a. data from application form



b. data from executive plan



c. data from final report



Key

Sector of economic activity of the participant organizations:

- Manufacturing (Ateco 1991: 15-36)
- Computer and related activities (Ateco 1991: 72)
- Research and development (Ateco 1991: 73)
- Business services (Ateco 1991: 74)
- Public administrations
- Education (Ateco 1991: 80)
- Activities of membership organizations (Ateco 1991: 91)
- Other (excluding agriculture hunting and forestery)

In network b (produced on the basis of the information contained in the "executive report") lines are proportional to the person-months that each organization committed to the project

First, we were able to assess the different intensity with which different organizations were involved in each project. On the basis of the information available about the total and mean person-months committed to the 13 projects, some actors were found as being more active than others[11]. On the one hand, this seems reasonable because it is often necessary to implement a project with a central set of coordinating actors and a team of participants that collaborate on specific activities; on the other hand, this might suggest that the number of participants was inflated in order to achieve a higher score in the

assessment (the number of partners was one of the criteria used in the initial project selection process), without any corresponding engagement on their part. Besides the simple number of participants, the intensity of their engagement in the project should have been taken into account as a criterion for project selection.

Secondly, network visualization could provide an effective tool in order to better understand network features and project structure, thus complementing both the ex ante and the ex post qualitative evaluation and analysis of the proposals. It might also prove useful in order to highlight, at a later stage, changes in partners' roles and interactions. Network representations, in fact, could have helped the policymaker obtain more information about the characteristics and the roles performed by the participating organizations, both those that were involved in the formal "Temporary Association of Enterprises" constituted to bid for funding, and those that joined the network after the project's approval. The latter is a critical issue in managing a European funded programme such as the RPIA-ITT, where changes in network composition –which could signal emergent generative relationships – are generally not reported explicitly, because projects are evaluated on the basis of their ability to attain the expected results, rather than their ability to activate new relationships that might foster innovation processes. The formal inclusion of new partners in the network may even be considered counterproductive, due to the complication in accounting procedures that would ensue from it.

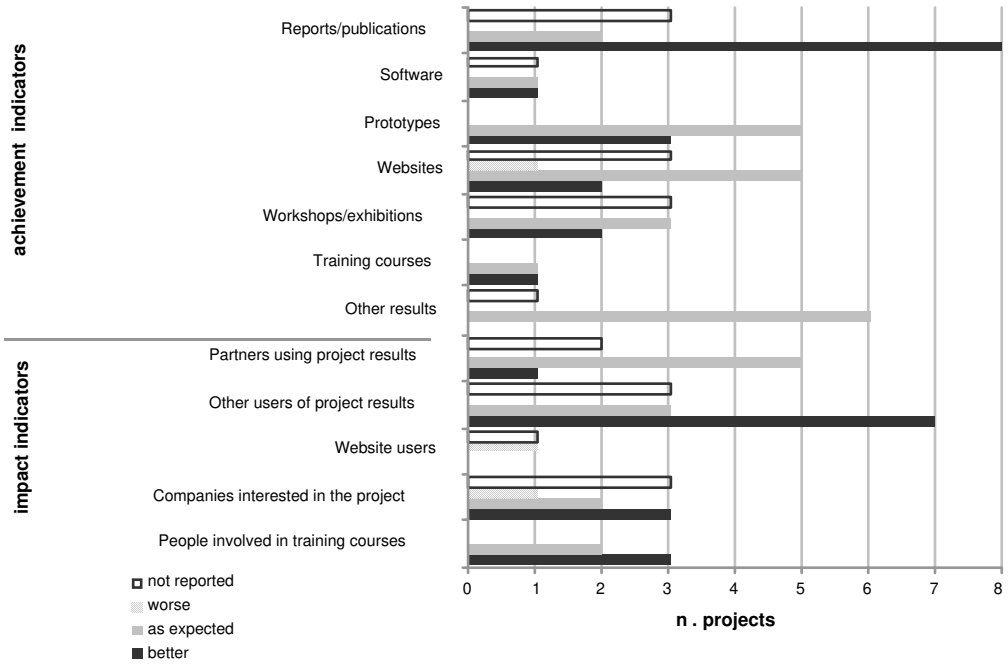
Third, although the projects were required to fulfil several conditions which in principle could increase the generative potential of cooperation networks, the policymaker did not set up any tools in order to assess whether the relationships activated had been generative, whether the agents' attitudes had changed, whether new scaffolding structures had been created or whether existing scaffolding structures had played an im-

portant role in the innovation processes[12]. In line with standard procedures, the indicators used by the regional administration referred only to the 'products' (reports, publications, software, prototypes, web pages, workshops, exhibitions, training courses) planned and actually realized within the duration of the programme. The projects' final reports provided some information about the networks' ability to attain the results that they intended to achieve: from Figure 2, we can see that most projects attained the expected results, they often performed better than expected and only in very few cases their performances did not meet the initial objectives.

The policymaker, in addition, should have gathered information about the activities of each network by focusing on the interaction processes that enabled these products to be obtained, and it should have updated these results some time after the conclusion of the project. In this way, it would have been possible to highlight, among other things: how changes in network composition, in terms of partners involved and their competences, affected a network's success, which organizations proved to be more successful in recruiting partners and obtaining funding, and which kinds of interactions were more conducive to successful innovation activities.

From the interviews, we could draw some insights in this sense. Although most of the non-funded projects that we interviewed had not yet been implemented, the experience of preparing the proposal was important, and many participants expressed an interest in pursuing the project as soon as another opportunity arose. In some cases, the participants had the opportunity to explore new directions for innovation, for example new applications of existing technologies; these applications were sometimes unknown at the beginning of the project, and were discovered thanks to interactions taking place within RPIA-ITT.

Figure 2. Projects' performance indicators



Another remark drawn from the interviews concerns the timing of the innovation process. Most of the projects that applied to the programme were based on ideas that had been circulating for a long time in the proponents' offices, who had been looking for suitable funding opportunities in order to implement them. The time scale of the innovation process was generally much longer than that of RPIA-ITT, which became one step in a broader process, sometimes hampered by lack of continuity in the possibility to access funds. Nonetheless, some of the participants remarked that the RPIA-ITT offered something more than the opportunity to continue a process that would have happened anyway: had the RPIA-ITT not specifically requested the setting up of a network of heterogeneous competences, they probably would not have chosen to involve such a wide range of partners, and therefore they would have missed out on interesting opportunities for interaction.

3.3. The creation of heterogeneous cooperation networks: 'multivocal' actors

One of the main difficulties reported by the interviewees concerned the involvement of small companies and university departments, since both, for different reasons, were unaccustomed to interact with other organizations, and often ill-equipped to deal with the bureaucratic procedures imposed by the administration of EU structural funds. The interviews showed that the RPIA-ITT programme marked an important opportunity for these actors. Participation in the programme enabled many of the university departments and research centres to interact with small and medium enterprises, with whom they might not have worked otherwise. Some firms were open to proposals that might improve the production process, and, in general, to the introduction of technological and management innovations in the firm. Interaction with these firms was generally quite easy, because they were able to appreciate the impact of innovation on their production process. From the manufacturing companies' point of view, the RPIA-ITT experience increased their willingness to participate in external collaborations.

Among the participants involved in the RPIA-ITT programme, some service providers were essential in order to recruit actors with specific competences. In many instances, these organizations also displayed the ability to develop good quality project proposals and to disseminate the project's results among a greater number of actors. In addition, the ability of service providers to monitor funding opportunities and to manage the relevant administrative and accounting procedures was crucial for the promotion and management of the projects.

The service providers involved in the programme have different structural characteristics, different behaviours and different objectives. However, they are all engaged in a set of activities, such as training, certification and technology transfer, that allow them

to weave a close fabric of relationships with both manufacturing firms and other local actors (trade associations, local administrations). This wide range of activities — from research to training to consultancy — brings them close to very different contexts, from which they learn several 'languages', while their diversified relationships give them the chance to identify local needs and promote interventions to foster local development. These actors can be defined as 'multivocal': with this term, we intend to convey their ability to engage with actors belonging to different cognitive domains − from academic research to specific production technologies − and consequently to interpret the needs of actors that might not even be able to express them. This ability allows them to facilitate connections among different organizations[13].

In general, interactions among actors with complementary competences enhance positive feedbacks (Richardson 1972; Powell, 1996; Von Hippel, 1988; Nooteboom, 2004). In this particular programme, the possibility to bridge the world of applied research with those firms that are less responsive to outside collaborations was facilitated by the service providers. Their action was effective especially with respect to those firms that were willing to follow the example of the more active firms, and to participate in the projects, once a set of participants had been confirmed. Involvement by the service providers was even indispensable for small manufacturing companies whose activity is entirely focused on production, and who are unlikely to establish, on their own initiative, relationships with academia and industrial research centres.

3.4 The emergent structure of the programme: inter-organizational links

The relationships that underpinned the innovative activities of each network cannot be reduced just to the relationships unfolding within the individual cooperation networks. This clearly emerged from the interviews, and from our observation that a sig-

nificant proportion of participants (58 of the 409 different organizations taking part in the RPIA-ITT) were in fact involved in more than one project. Because some of these 58 organizations were present in *numerous* projects, they actually featured 177 times as project partners, that is, they represented one third of the overall number of 528 project partners. From graph analysis it emerges that, except for two isolated projects whose participants were not present in other networks, most projects were connected, both in the same and in other action lines, through one or more organizations in common.

We focused on the 58 organizations that were present in more than one project since their relationships provided a backdrop to the whole programme. Among them, we observe the presence of organizations that had taken part in a set of talks set up by the regional administration when the programme was in its draft stage. On average, the number of partners participating to this 'negotiation' stage was larger for the approved projects and even larger for the funded projects; funding was granted to all the projects that included at least three partners involved in the talks. The informational activity conducted by the regional administration was, therefore, essential for the potential participants to be able to devise, in a very short time, higher-profile projects with the most appropriate partnerships.

The analysis of the centrality indexes[14] for this network highlights the presence of a set of organizations with very high degree and closeness centrality values, while the relatively modest values of the betweenness centrality index prove that these 58 organizations are connected through many different routes, a property confirmed by the analysis of k-cores. This network in fact contains a 9-core of tightly connected actors, but no *separate* k-cores of lower level, which indicates that the denser subnetwork of relation-

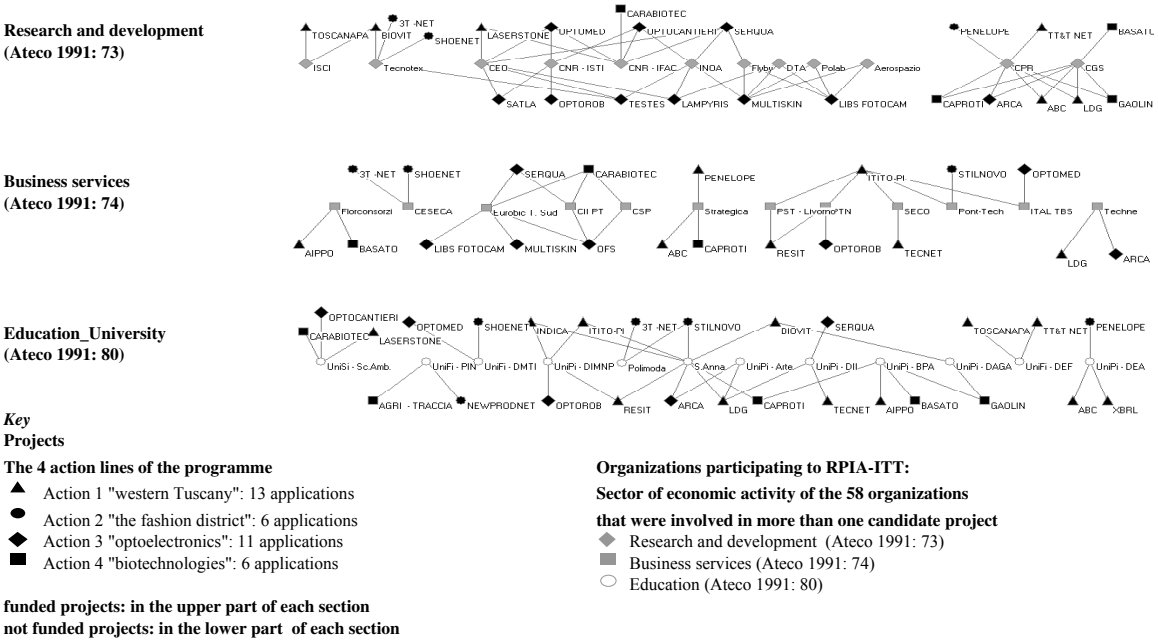
ships is nested into progressively less dense subnetworks, up to the larger network comprising all the 58 actors.

If we consider all the 409 RPIA-ITT's participants, we find that 98 RPIA-ITT actors had already collaborated[15], before and outside the RPIA-ITT programme, to 111 non-RPIA-ITT projects[16]. For these actors we computed the betweenness centrality index with respect to the non-RPIA-ITT projects' network: the ranking of the actors is generally the same as that observed for the 58 actors in the RPIA-ITT's network, i.e. the most active RPIA-ITT participants were also very active in other research and technology transfer programmes[17]. This analysis supports the claim that the RPIA-ITT's networks were activated by a relatively small set of organizations that were already accustomed to working together.

The role of these organizations in mobilizing different cooperation networks has further been disentangled through the analysis of subnetworks of actors engaged in the same economic activity and through cluster analysis.

We first partitioned the participants into eight categories, according to their sector of economic activity, and we extracted each category from the general network of 36 projects and 58 participants. While certain types of organizations present numerous links to each other (research and development organizations, service providers, university departments), other organizations have sparse connections (manufacturing firms, computer firms, public agencies, associations, 'other organizations', the latter mainly belonging to the telecommunication industry). Figure 3 below shows the relationships among the most densely connected types of organizations (funded projects are shown in the upper part of each network and non-funded projects in the lower part).

Figure 3. Connections between subsets of participants.



Apart from the optoelectronics case, discussed below, many links among the same type of organization do not necessarily imply greater success in obtaining funds. The university subnetwork confirms the central presence of S. Anna, often involved also in non-funded projects, and its links with other research groups of the University of Pisa. These subnetworks also provide some clues in order to interpret the structure of the 36 project proposals network discussed in section 3.5.

The analysis was further qualified by applying a simple clustering algorithm to the set of all participants, operating on the total number of projects in which the organization was present and the number of projects presented in each of the 4 action lines. With this analysis we identified six highly significant clusters: four of these (A-D) comprise 361 organizations involved in only one project and 34 organizations involved in two to four projects, mostly under the same action line; one cluster (E) includes 16 organizations involved in two or three projects mainly under RPIA-ITT action line 3 (optoelectronics); the last cluster (F) includes the most active participants in the RPIA-ITT:

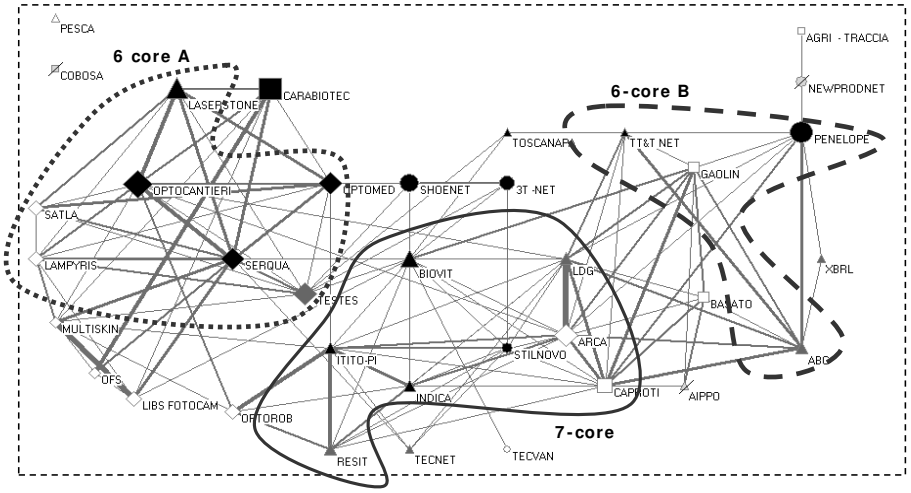
8 organizations involved in more than five projects. Four of the eight participants to cluster F (CEO, CNR-IFAC, El.En., INOA) are leading actors in the field of optoelectronics. Overall, 19 of the 24 organizations in clusters E and F were involved in funded projects — that is, 9.4% of all the participants to funded projects — performing activities in the RPIA for nearly 3.2 million euros, around 50% of the entire financial resources of the programme[18].

Interviews with a number of project coordinators and with the regional managers confirmed the presence, in the region, of an established network of specific, high-level competences in the optoelectronics field, comprising internationally renowned public research institutions (CEO, INOA, CNR-IFAC) and a company, El.En, worldwide leader in the production of laser technology. This is complemented by a tight fabric of SMEs involved in the production of high-technology instruments for optic technology and of related software applications. In order to set up a large number of RPIA-ITT projects, these organizations were able to rely on their previous experience of successfully bidding for regional and other public funds.

3.5 The emergent structure of the programme: cross-project links

From the analysis of organizations participating the RPIA-ITT it emerges that funded and not funded projects are embedded in the same network. This can be easily observed in Figure 4, where a link between two projects indicates that they have at least one partner in common, and the line's width is proportional to the number of partners in common. By examining centrality indexes (degree, betweenness and closeness centrality indexes) we note that they are lower for non-approved projects, but also that some of the funded projects have very low centrality indexes.

Figure 4. Connections between the 36 project proposals and k-cores representation.



Vertex size is proportional to the number of partner organizations that had been involved in the negotiation stage [min 0, max 4]

Key

The four action lines of the programme:

Action 1 "western Tuscany" Action 2 "the fashion district" Action 3 "optoelectronics" Action 4 "biotechnologies"

Evaluation score obtained by the 36 projects:

Funded proposals: 14 Approved, but not funded, proposals: 6 Non-approved proposals: 13 Incomplete applications (not scored): 3

Links between vertices: number of joint participants

1 2 3 4

Network cohesion can be better interpreted through the k-core analysis, where we find three k-cores of order greater than 5. There is a 7-core composed of eight vertices (grouped within the bold line). There are also two separate 6-cores: one (6-core A) composed of six vertices (within the dotted line) and one (6-core B) composed of four vertices (within the dashed line).

To interpret these results we must keep in mind that this is a network of networks and that organizations connecting projects play a crucial role in defining the structure of the network. Let us then summarize the results so far presented with respect to both organizations and projects. Figure 5 shows the graph of the relationships between the 36 projects through the 58 connecting organizations: projects are represented with different symbols according to their action line, actors are represented with different symbols according to their sector of economic activity. The 361 organizations participating in only

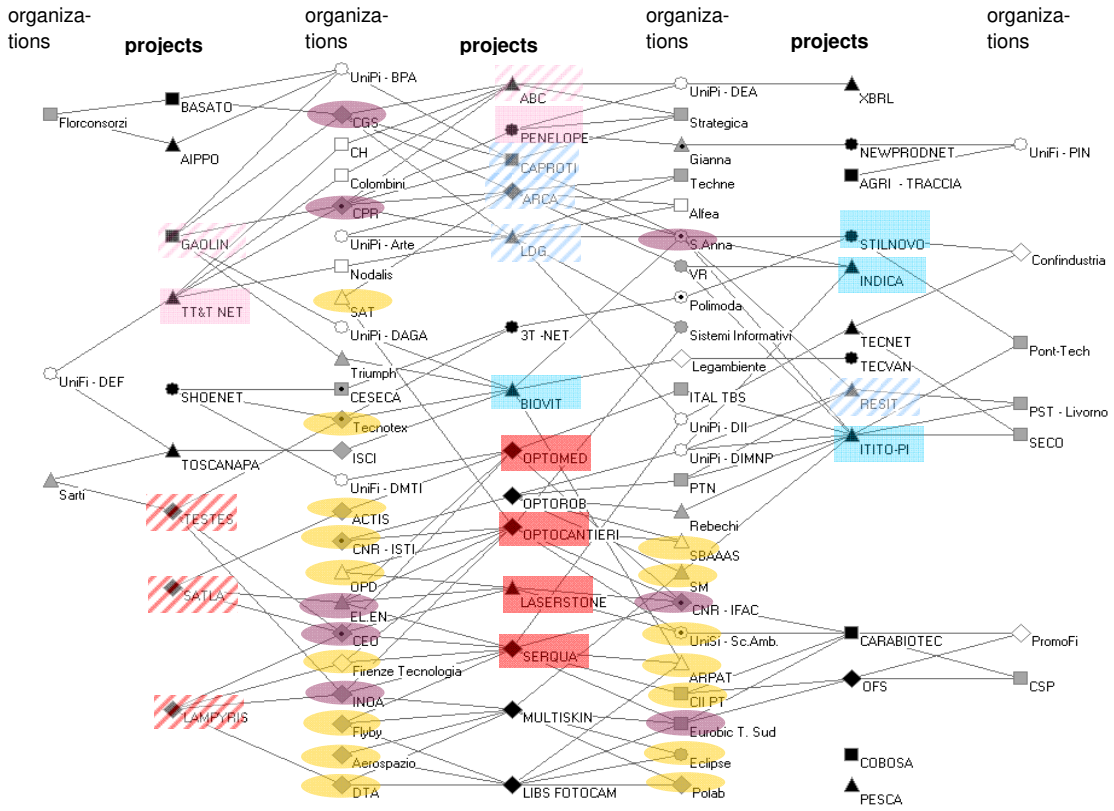
one project have been omitted in order to make cross-project links more visible. We have highlighted both the projects belonging to the higher k-cores in the projects' network (7-core, 6-core A and 6-core B) and the organizations belonging to clusters E and F. From Figure 5 it clearly emerges that different organizations had different opportunities and strategies of involvement in the RPIA-ITT. We can read the graph as essentially composed of two parts.

In the upper part, we see the 7-core and the related 6-core B. The organizations connecting these subgroups of projects are essentially the most central, both located in Pisa: Scuola Superiore S.Anna (one of the most influential university research centres in Italy, with many departments) and CPR (a consortium active in research and technology transfer which includes among its partners several local administrations and the main provincial academic institutions, including S.Anna and University of Pisa). The projects in these two k-cores were submitted mainly to action lines 1 and 2. Overall, the funded projects included in these two k-cores were assigned 45% of the RPIA-ITT's total budget (30% to the projects in the 7-core and 15% to those in the 6-core B).

In the lower part of the graph we find the 6-core A, comprising projects that are mostly related to optoelectronic technologies and appear to have been mediated by a network of research centres, belonging to clusters E and F, specialized in optoelectronics technologies, a field characterized by technological convergence in a vast range of applications. These organizations were able to diversify their proposals, thus ensuring the success of a number of them: 13 project proposals relating to optoelectronics were submitted to three of the four action lines; six of them were approved and five were funded. The funded projects in the 6-core A refer to optoelectronic technologies and were assigned 30% of the RPIA-ITT's budget. Optoelectronics was already a focus of

regional policy during the 1990s, when applications were made in the field of artwork restoration; through the RPIA-ITT the optoelectronics competence network was pushed to explore a further range of applications.

Figure 5. An overview of the 36 RPIA-ITT project proposals and 58 key organizations.



Key

Projects submitted to RPIA-ITT

The 4 action lines of the programme

- ▲ Action 1 "western Tuscany": 13 applications
- ● Action 2 "the fashion district": 6 applications
- ◆ Action 3 "optoelectronics": 11 applications
- ■ Action 4 "biotechnologies": 6 applications

k-core of projects

funded / *not funded*	6-core A
funded / *not funded*	6-core B
funded / *not funded*	7-core (also a 6-core B)

Participants

Sector of economic activity of the 58 organizations that were involved in more than one candidate project

- ▲ Manufacturing (Ateco 1991: 15-36)
- ● Computer and related activities (Ateco 1991: 72)
- ◆ Research and development (Ateco 1991: 73)
- ■ Business services (Ateco 1991: 74)
- △ Public administrations
- ○ Education (Ateco 1991: 80)
- ◇ Activities of membership organizations (Ateco 1991: 91)
- □ Other (excluding agriculture hunting and forestery)

• the organization was involved in the negotiation stage connecting organizations in the highlighted k-cores

cluster E

cluster F

Overall, the RPIA-ITT mobilized already existing connections and new ones to an extent that cannot be fully appreciated when considering only the funded projects within each action line. The social network analysis of the programme highlights some

important structural features both of the regional innovation system and of the channels through which these actors can be mobilized.

An important structural feature of the 'network of projects' networks' is the presence of a small number of organizations, mostly research institutions, that played a key role in the programme: on the one hand, S.Anna and CPR; on the other, a group of research centres operating in optoelectronic technologies. Most of the project networks that applied to the programme were in fact connected *to each other* through the common participation of these organizations. It is well known that networks of research centres as well as large firms are generally better able to monitor opportunities for funding; and in the context of RPIA-ITT they too played an important role in the coordination of project applications, and accessed a large share of RPIA-ITT funding. This was also facilitated by the involvement of many of these institutions in the 'negotiation stage' carried out by the regional administration, which was probably instrumental in allowing them to prepare good quality proposals in a short time.

In the RPIA-ITT, cooperation among heterogeneous competences was achieved through the involvement of these very active organizations, that could rely on existing networks of relationships (consolidated thanks to previous participation to other programmes) and on the intermediation of service providers, whose role we have previously highlighted. The outcome was an enlargement of cooperation networks targeting those actors that might find it difficult to perform innovation without external support[19].

4. Lessons for policy design and policy evaluation

Analysing the RPIA-ITT programme in a complex system perspective has allowed us to formulate some insights that may be useful when designing innovation policies that support cooperation networks among different kinds of organizations.

First, network setup is different from the creation of a prototype, or from the launch of a new product or service. In framing a policy supporting innovating networks, attention must be paid to the processes of network construction and management: monitoring and evaluating such processes requires the definition of appropriate units of analysis - in terms of relevant nodes, relationships and outcomes – and of their appropriate time scales. If we accept that innovation processes are stimulated by exploiting existing relationships and by supporting and consolidating generative relationships among organizations that are not accustomed to working together (small firms and universities, for example), then attention must be focused on how these relationships are initiated and sustained over time. The interviews showed that, in assembling the project partnerships, the promoters referred to relational networks that were already established and to proposals that, to some extent, had already taken shape in previous research and commercial activities — although the programme provided them the opportunity to activate new relationships. Moreover, one of the outcomes of the projects is that new actors might enter the networks, creating new opportunities for the networks as a whole or for some participants. Both cases (new networks, new actors) might potentially lead to cascades of innovations that should be part of the programme's evaluation.

Secondly, in order to construct and maintain generative relationships capable of sparking innovation processes, the participant must have enough time and opportunities to work together, since this will facilitate their understanding of the respective competences and identities. It is widely recognized that the timing of innovation processes cannot be foreseen, even in cases where innovations have already been acknowledged as commercially viable (Rosenberg, 1996; Lane and Maxfield, 2005). Exploitation is itself a process that cannot always be implemented (and is often not even clearly identi-

fied) in the limited time available for policy intervention. For many funded projects, the time allowed by the RPIA-ITT programme, which was a scant 13 months, was not sufficient to ensure appropriate exploitation and dissemination of results; however, many of our interviewees were actively seeking funds in order to continue the innovation activities started with RPIA-ITT, and some of them had already found some resources for this purpose. To assess the generative potential of the relationships activated in the course of the projects, the final project reports should be updated several times after the conclusion of the programme. Only in this way it is possible to understand to what extent the funded projects have led to other projects (carried out by individual actors in the network or by the network as a whole) or have benefited from the simultaneous implementation of other projects.

Third, an effort should be made to identify, ex ante, the actors that are better able to construct networks of relationships that can support innovation processes. Our analysis has produced some useful results in this sense. From the analysis of the programme it emerged that some actors were central in presenting projects and implementing funded proposals: ten per cent of the participants controlled almost half of the financial resources of the entire programme, but were also able, through multiple direct and indirect links, to mobilize some four hundred other actors, many of whom had no previous contact with research centres or universities. At the same time, the RPIA-ITT experiment showed how certain actors characterized by 'multivocality' - many of which were service providers - were essential in creating and shaping the networks, thanks to their ability to build bridges between different experiences, needs and competences. For a policymaker that needs to act on a local production system characterized by small firms concentrating on the production activity alone, strengthening interactions with the ser-

vice providers may be a successful strategy in order to involve small firms in 'unusual' networks of relationships (with universities and research centres, but also with firms in other sectors), which may give them direct or indirect access to a wider range of competences. The careful monitoring of these interactions, in order to promptly identify the needs for public intervention and the generative potential of specific relationships, should become common practice for the policymaker.

Finally, the RPIA-ITT example shows how the implementation of an innovative policy instrument – in this case, the funding of cooperation networks – often calls for complementary innovations in administrative procedures, evaluation criteria, and monitoring tools; a complex process of innovation in policymaking which can benefit from further empirical investigation.

5. Concluding remarks: implications of a complexity perspective

Evaluating a specific policy programme through the theoretical lenses of a complexity-based approach to innovation has not only allowed us to derive some recommendations specific to that kind of programme, but has also suggested some methodological considerations that we present as concluding remarks.

We consider generative relationships as the privileged locus where shifts in attributions of identity and functionality take place. In order to promote innovation, policymakers should attempt to foster relationships with high generative potential (Lane, Malerba, Maxfield and Orsenigo, 1996; Lane and Maxfield, 1997). To do so, they first of all need to explore which kinds of interactions - among which kinds of organizations and concerning which kinds of activities - support innovation processes; what are the most likely settings that promote the emergence of generative relationships; and how can interactions with high generative potential be identified, monitored and supported.

At a higher level than bilateral relationships, innovation processes are sustained by specific cognitive and physical scaffolding structures and require the creation of competence networks (Lane and Maxfield, 2005). In order to sustain these networks, policymakers should understand their structure and scope: they should identify whether local actors belong to local, regional, national, international competence networks, and which structures, if any, coordinate the competences required at the local or industry level with the training needs of individuals and organizations. They should explore how such structures can be monitored and supported, whether coordination with other policy fields (education, social, industrial policies) is required in order to design appropriate interventions, and, finally, whether it is possible to design policies that foster the emergence of new competence networks, in this way encouraging the development of new applications.

In order to implement effective interventions it is also crucial to involve the key agents and scaffolding structures that support local innovation processes. In the RPIA-ITT case, we observed that the business service providers' multivocality is a key competence in network formation and management, and that scaffolding structures such as networks of research centres are crucial in formulating the project proposals and in ensuring access to regional funds. Policymakers should understand how such scaffolds can be identified and monitored, and, if necessary, how can they be involved in the delivery of policy interventions.

In a complexity-based approach, innovation policies should be evaluated with respect to the systemic effects that they produce. Policies change the space of interactions, whereby new actors are involved in innovation processes, recurrent patterns of interactions consolidate, and new organizational structures are created. To assess these im-

pacts, new indicators and new evaluation procedures should be devised. Apart from traditional firm-level indicators (number of patents, of new products, expenditure in R&D, expansion in the number of users or potential users of a technology, etc.), policy effects should be measured in terms of new 'potentially generative' relationships activated, of changes in the structure of competence networks, of new scaffolds created, of changes in the patterns of use of products and services. Our empirical analysis has shown that the complementary use of network analysis and ethnographic interviews can provide effective tools in order to analyze these processes.

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NOTES

[1] The transition from a linear to a systemic view of innovation is explicitly captured by COM(2003)112 'Innovation policy: updating the Union's approach in the context of the Lisbon strategy', page 4.

[2] Since 1994, the European Commission has envisaged that, in the overall allotment of Structural Funds, up to 1% of the budget should be destined to Innovative Actions for experimenting new ways of community structural intervention.

[3] The call for tender requested each cooperation network to comprise at least four firms, one research institution (university or public research centre) and one public, private or mixed company having among its statutory aims the provision of services to firms.

[4] The programme's guidelines specified that higher scores would be given to applications that included a larger number of SMEs (this criterion counted for up to 15% of the final evaluation score).

[5] On average, each of the 36 submitted projects proposals had one partner in common with 7 other projects, with a peak in one project having one partner in common with 15 others. Within the set of funded projects the average figure was relatively higher, while the projects submitted under action line 3 (opto-electronics) had connections with the greatest number of projects (8.6 on average).

[6] Such changes are in fact the result of a process in which the technical, economic, social and institutional dimensions do not operate independently of one another (this point is discussed by Lane et al., 1996). The interpretation of the result of this process thus requires knowledge of the structure and dynamics of the interactions. As proposed by Agar (1996, 2004), the ethnographic method proves to be the most suitable in-

strument in order to reconstruct such dynamics.

[7] We interviewed representatives of seven cooperation networks, four of which had received funding (one for each action line envisaged by the programme) and three of which had not (and had obtained different scores in the initial selection), as well as three Regional managers in charge, at different times, of the management of the programme. Afterwards, the study was extended to two small firms involved in funded projects and twelve organizations that had been identified as the most central nodes in the RPIA-ITT general network: these were service providers, universities and a few particularly active service centres. The interviews were structured around a set of open questions dealing with some general topics - questions of descriptive, structural and contrast nature, aiming to outline the context in which the interviewees operate (Spradley, 1979) − and a very detailed set of research topics specific for each type of informant.

[8] Centrality measures are a wide category of indexes trying to measure the relational properties of the nodes in a network (Degenne and Forsé, 1999; Wasserman and Faust, 1994; Freeman, 1979). Degree centrality measures the number of links of each node with all the others. In the measurement of closeness centrality the central nodes of the network are those having minimum (geodetic) distance from all the other nodes; the normalized index of Sabidussi assigns maximum centrality equal to 1 when the distance is minimum. The betweenness centrality index, with values ranging from zero to one, measures to what extent each node provides a connection between other pairs of nodes: in fact, the betweenness centrality value for a node is the proportion of paths between all pairs of nodes in the network which contain that node.

[9] In computing k-cores, individual nodes can belong to multiple subgroups. K-connectivity, expressed as a group-level property, makes no reference to the group size.

[10] An attempt was made to highlight the role of interpersonal relationships by using the presence of the same people in different projects as a proxy for cross-project links: however, the resulting network displayed exactly the same structure as the network obtained by considering organizations as nodes.

[11] On average, the most important actor in each project was involved for 32.58% of the total person-time. In two projects, most of the activity was performed by two partners, engaged for more than 60% of the total person-time.

[12] For example, through our interviews we found out that a set of projects that applied to RPIA-ITT, dealing with different application of optoelectronic technology, were all promoted by a very cohesive network of research centres and other organizations, which however was not mentioned in any of the RPIA-ITT's documents. These links clearly emerged from the cluster analysis and the network analysis presented in section 3.4.

[13] We can find similarities with the kind of actors we are discussing here in Brusco's view of "real services" for small enterprises (Brusco, 2007).

[14] The values of all the centrality indexes mentioned in sections 3.4 and 3.5 are available from the authors upon request.

[15] Data on the joint participation to non-RPIA projects on the part of RPIA participants were collected starting from the information provided on the RPIA application forms, concerning each participant's previous research activity. This information was cross-checked and integrated using information available from the EU CORDIS project website (for EU projects), from other institutional websites, and from the websites of individual organizations. Although accurate, this manually assembled database is by no means exhaustive.

[16] These were mainly European projects (67) and projects sponsored by the Tuscany Region (21). The remaining projects were mainly funded by the Italian Government (by the Ministries of Research, of Industry, of Agriculture, and by the National Research Council).

[17] Only in one case is the index much higher, signalling the case of an organization generally very active in other programmes of technology transfer, but relatively less active in the RPIA-ITT.

[18] The centrality indexes show that organizations in cluster E and F have higher values of closeness centrality and betwenness centrality. Cluster analysis was in fact operating on a partially overlapping set of variables.

[19] For a discussion of similar targets in a context of development policy, see Natali (2006: 22-25).