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What networks to support innovation

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Abstract

In the last decade, numerous regions, particularly in Europe, have implemented policies promoting innovation networks. The analysis and evaluation of these policies, however, is lagging behind. While several studies have assessed the gains for individual network participants, very few have attempted to detect the overall ?behavioural additionality? of these interventions, and in particular to assess to what extent they have been able to foster networks with high potential to generate innovations and to stimulate learning processes on the part of network participants. The present study intends to advance this line of research by investigating how the analysis of several aspects of network structure can support the evaluation of the behavioural impact of a set of regional policies promoting innovation networks among heterogeneous agents. Jelcodes:O32,L14

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What networks to support innovation? Evidence from a regional policy framework

Abstract

In the last decade, numerous regions, particularly in Europe, have implemented policies promoting innovation networks. The analysis and evaluation of these policies, however, is lagging behind. While several studies have assessed the gains for individual network participants, very few have attempted to detect the overall "behavioural additionality" of these interventions, and in particular to assess to what extent they have been able to foster networks with high potential to generate innovations and to stimulate learning processes on the part of network participants. The present study intends to advance this line of research by investigating how the analysis of several aspects of network structure can support the evaluation of the behavioural impact of a set of regional policies promoting innovation networks among heterogeneous agents.

Key words: evaluation, innovation networks, social network analysis, behavioural additionality, innovation policy.

JEL classification: D85, H43, L14, L52, O32

1. Introduction

The view that networks of heterogeneous organizations foster the development of innovations is increasingly shared within the scientific community. In the 1980s, contributions by Spence (1984) and Katz (1986) suggested that networks foster innovation through the production and the internalisation of spillovers within a group of heterogeneous participants. More recently, with a different perspective, Nooteboom (2000) and Powell and Grodal (2004) stressed that the creative recombination of competences and knowledge promoted by the interaction among diverse agents are important drivers of innovation processes, while Lane and Maxfield (1997; 2009) focused on the emergence of innovation processes fostered by generative relationships characterized by heterogenous competences, mutual and aligned directedness in contexts of joint action. In line with this growing consensus, policymakers are increasingly promoting interventions in support of networks among either small and large firms, or firms and universities, explicitly aimed at fostering innovation along the main dimensions that are targeted by policy - R&D, knowledge transfer, innovation diffusion.

The emergence of such policy instruments calls for the development of appropriate tools for their evaluation. Although this field of investigation has attracted some interest, most of the the existing studies have focused on capturing output additionality effects at the level of the individual participants[1]. As a result, the interactions among agents within such networks are rarely analyzed explicitly. We

[1] For large-scale analyses of policies promoting R&D collaborations, see, for instance, Branstetter and Sakakibara (2002) and Sakakibara and Branstetter (2003) and Odagiri et al (1997) on Japanese policies promoting research consortia; Benfratello and Sembenelli (2002) on the European-funded projects Eureka and the 3rd and 4th Framework Programs for Science and Technology (FPST); Barber et al (2005) on the research collaboration networks that have emerged in the European Union's first four successive four-year Framework Programs (FPs) on Research and Technological Development.

argue, instead, that the evaluation of policies in support of innovation networks should include an assessment of the extent to which the organizations involved have activated learning processes that have enabled them to become more effective innovators, particularly by improving their ability to form "promising" networks. We then provide some methodological tools that can support this assessment. The concept of "behavioural additionality" (Buisseret et al, 1995; Georghiou, 2002)[2] may help us to capture this point. In fact, this concept refers to the possible learning effects of a policy on a firm's (or on another agent's) behaviour during and/or after the project's implementation (Clarysse et al, 2009).

The present article contributes to the methodological debate on the assessment of the behavioural effects of policies by proposing a range of indicators, capturing aspects of network structure and characteristics, that can support these goals. While the application of Social Network Analysis (SNA) to the evaluation of innovation policies is a recent field of research, there is by now a wide literature on innovation networks which, mostly outside the innovation policy context, has tried to detect the basic features of the most performing network architectures (see e.g. Pyka and Saviotti, 2002; Powell et al., 2005 Fritsch and Kauffeld-Monz, 2010; Brenner et al., 2011). Drawing upon this literature, our study identifies a set of features that can boost the innovative capacity of a network and develops a set of tools to assess the extent to which policy interventions stimulate the participants' ability to become more effective innovators.

Specifically, we analyze the "learning effects" stemming from the participation to a network-based policy on the basis of the following features, which are recognised as important ingredients characterizing promising networks: i) the participants' ability to

[2] Or "second order additionality" (Autio et al, 2008)

form heterogeneous partnerships; ii) the participants' ability to involve intermediaries ("bridging organisations") that facilitate the creation of linkages between different partners (e.g. university departments, small firms, private research laboratories, knowledge-intensive business service providers, etc.); iii) the participants' ability to develop non transitory relations with external partners.

Indicators to assess these features are developed and applied to a set of policies implemented by the Italian region of Tuscany between 2002 and 2008, in the context of the regional Single Programming Document 2000-2006 (hereafter: SPD). Tuscany's regional government has been one of the most active promoters of innovation network policies in Italy, having engaged in the promotion of innovation networks since the early 2000s, with a succession of tenders supported by European regional development funds (ERDF). These policies were adressed to a regional economic context characterized by the prevalence of SMEs with no R&D activities, often operating in low or medium technology sectors affected by harsh international competition. There, the policymaker supported the development of collaborative relationships among SMEs, large firms, universities, and a wider set of agents acting as facilitators in order to establish inter-firm cooperation or to support the adoption and marketing of the main outputs of the innovative projects within the regional context.

The paper is structured as follows. Section 2 frames the issue of evaluating policies in support of innovation networks in the context of an "interactionist" perspective to innovation. Section 3 describes the set of interventions implemented by Tuscany's regional government between 2002 and 2008, presenting the main features of the programmes that were funded and their objectives in the broader context of the region's innovation policies. Section 4 discusses how some of the behavioural effects

of these interventions can be assessed using a set of original indicators aimed at describing several structural features of the networks. Section 5 concludes by drawing some general implications for policy evaluation.

2. From theory to policy: what networks to support innovation?

In recent years, several empirical contributions have explored the impact of publicly-funded R&D collaborations (consortia, JVs, innovation networks). Most of them have focused on the individual benefits deriving from the participation in a network (Branstetter and Sakakibara, 2002; Benfratello and Sembenelli, 2002), more or less explicitly trying to detect the output additionality of the public intervention. Few studies have tried to capture the interactions among agents within such networks in order to assess the effects of policies on both the individual participants (changes in their competences, in their social and relational capital, in their ability to engage in further innovation processes) and on the overall networks of relationships thus activated (Russo and Rossi, 2009, and Bellandi and Caloffi, 2010). These analyses are consistent with a behavioural additionality approach to policy analysis and evaluation (Buisseret et al, 1995), which focuses on the learning effects of a policy on the participants' behaviour during and/or after the project's implementation (Clarysse et al, 2009). This approach considers a policy as successful when it increases the participants' cognitive capacities, competencies and networking abilities in a non-transitory way (Georghiou, 2002).

Empirical applications of the concept of behavioural additionality to network-based policies needs to deal with multiple units of analysis: the individual participants; the funded networks; and even the network of relationships among funded networks. Moreover, they need to clarify what specific learning effects must be considered. In

this study we analyze empirically the extent to which the organizations involved in a set of successive policy interventions have learned how to set up networks with greater potential to generate innovations.

In order to identify what elements of the agents' and networks' behaviour should be included in this evaluation process, we refer to several theoretical arguments that support the view that the success of collaborative innovation is related to network structure. On the one hand, complexity-based approaches to innovation have emphasized the role of interactions among heterogeneous agents as key sources of innovation (Lane and Maxfield, 1997) highlighting what elements of such interactions are associated with greater likelihood to generate innovations ("generative potential", in these authors' terminology) and to foster long-lasting relationships giving rise to innovation cascades. On the other hand, network theory has addressed various problems of combinatorial optimization, suggesting that the effective management of flows of information, material assets and resources is linked to network structure. Applications to social sciences, and to innovation studies in particular, have focused on the analysis of the main properties characterising different network typologies, trying to identify the best performing relational architectures for innovation and diffusion processes (Pyka and Saviotti, 2002; Powell et al., 2005 Fritsch and Kauffeld-Monz, 2010; Graf and Kruger, 2011). Typical patterns of association are discussed, together with the strengths of the connections among the different agents involved, in order to shed light on network formation and network substructures.

These approaches show that the innovative potential of interactions among organizations in a network may be strongly influenced by the following elements.

(i) *The interactions, within the same network, of heterogeneous agents*. Networks among agents that differ in nature, knowledge and competencies lead to various

benefits in terms of information diffusion, resource sharing, access to specialized assets and inter-organizational learning (Arora and Gambardella, 1990; Dyer and Singh, 1998; Powell and Grodal, 2006; Becker and Dietz, 2004). This is particularly important in highly innovative and technology intensive industries, where agents need to complement their internal resources and competencies with specialized knowledge, technologies and know-how (Ahuja, 2000). In a different perspective, some authors highlight that a low degree of heterogeneity may lead to the emergence of competition among possible innovators instead of a collaborative effort, thereby reducing the incentives to invest in R&D (Katz, 1986; for an empirical application see Branstetter and Sakakibara, 2002).

(ii) *The involvement of bridging organisations linking different parts of the network*. This is needed in order to ensure interaction and communication among heterogeneous participants (and groups of participants), which differ in language, systems of incentives and objectives, etc. (Howells, 2006). Intermediaries may play a crucial role both in facilitating the expansion of the network and in creating/filling structural holes between the different areas of a network (Burt, 1992); in particular, through their bridging activity, such agents may modify the structure of the collaborations and create communities of innovators.

(iii) *The balance between stable and episodic networks*. In order to acquire and manipulate existing knowledge, as well as to produce new knowledge, the networked organisations should develop specific standards, skills and competencies, whose creation, in turn, requires non-episodic collaborations among the agents involved (Powell et al., 1996; Dyer and Singh, 1998; Nooteboom, 2000). At the same time, such collaborations should not become too stable, in order to avoid the risk of lock-ins (Lane and Maxfield, 1997). For this reason, some authors have stressed that

temporary networks, such as those emerging from the realization of a collaborative research project, are important in order to bring in new knowledge (Asheim, 2002; Grabher 2004). In the policy practice, it can be very difficult to find a balance between fostering efficient and effective teamwork (time to create mutual understanding and routines) and favouring the creation of ruptures and novelty. However, the particular tension between temporary and stable network relations could be solved by considering the specific objectives of a policy. That is, policies that explicitly prioritize innovation diffusion processes or the absorption of spillover effects may be more oriented towards the promotion of relatively stable communities of innovators that include either small and large firms or enterprises and universities; while policies aimed at supporting the production of radical innovations may give a prominent role to novelty-related aspects.

All these elements may provide a guide both in order to evaluate ex ante the innovative potential of individual networks and to assess ex post the behavioural additionality effects of a whole policy programme. In the following sections, we will apply them to the analysis of a set of policy programmes implemented by Tuscany's regional government. The policymaker who designed these programmes included in the tenders several mandatory requirements that were implicitly consistent with the above recommendations derived from innovation theory: (i) some degree of heterogeneity (several programmes explicitly required the network composition to include a range of different organizations); (ii) some degree of involvement of bridging organizations (the first programmes explicitly required the inclusion of certain types of organizations whose mission is to facilitate interactions among other participants); (iii) the implementation of a set of policies over time which may allow organizations to engage in long-lasting collaborations. These elements were not,

however, used in order to assess the impact of these policies, whose evaluation was instead only focused on the output additionality effects of individual project networks. Our analysis aims to fill, at least in part, the gap between the theoretical understanding of network performance and the evaluation of the behavioural additionality effects of actual network policies, by investigating to what extent the policy programmes have promoted learning processes on the part of the participants, leading them to form more "promising" networks in the context of successive policy interventions. Although our dataset does not allow us to extend the analysis of such behavioural additionality effects beyond the period of implementation of the policy interventions themselves nor to have a counterfactual analysis, we can draw some conclusions for innovation network policies.

3. Tuscany's regional policy in support of innovation networks: general features of policy programmes

The empirical analysis focuses on a set of recent policies supporting networks of innovators implemented by the regional government of Tuscany. We examined a set of nine programmes – co-funded by the ERDF and implemented in the programming period 2000-2006 – aimed at supporting innovative projects carried out by networks of heterogeneous economic agents. By funding network projects, the regional government intended to promote non-transitory forms of collaboration among firms, universities, research centres, service providers and other kinds of organisations localised in the region[3]. The interventions were ultimately intended to support the upgrading of the innovation skills of micro enterprises and SMEs, which constitute the large majority of enterprises of the region.

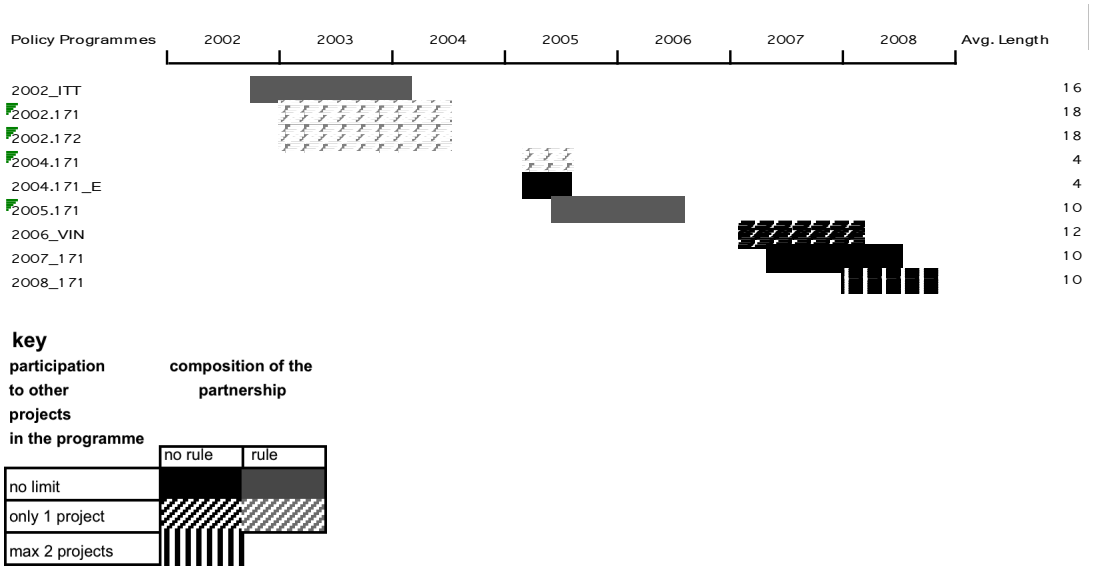
[3] As documented by the studies of Eickelpasch and Fritsch (2005), similar initiatives eliciting the growth of self-organised innovation networks have been promoted in several European regions.

These policies were initially developed through two lines (1.7.1 and 1.7.2) focusing, respectively, on the research and development of new technologies and on the dissemination/diffusion of existing technologies in the regional economy. Another strand of policies, funded by the EU Regional Programme of Innovative Actions (RPIA), was experimental in nature. Overall, programmes supporting innovation networks were assigned almost 37 million euros, representing around 40% of the total funds spent on innovation policies[4]. Half of these funds were assigned to programmes funded at 100%, while the rest was administered in co-funding (with shares ranging from 75% to 85% of admittable costs). Through the nine programmes, Tuscany's regional government funded 168 projects, which were carried out in the years 2002-2008.

Both the size and the composition of individual networks were partly influenced by the rules set by the regional government, and specified within each tender: some programmes required the candidate networks to fulfil certain criteria in terms of minimum number of participants and/or minimum composition of the partnership (number of SMEs and research centres, and sometimes also local governments) as well as maximum number of different projects in which each organization could enter. The rules underpinning each programme are schematized in figure 1.

Figure 1. The time profile and rules of the different programmes

[4] The remaining part has consisted of incentives to individual firms. The innovation policy measures we have considered are included in the SPD 2000-2006, and they refer to measures 1.1 and 1.8, funded in 2002, 2003, 2004, 2006. For an evaluation of these policies, see (Mealli et al., 2010).



Note to figure 1: The first column displays the nine policy programmes considered. The Regional Programmes of Innovative Action are identified with the following labels: RPIA_ITT 2002 (Regional Programme of Innovative Action issued in 2002, whose acronym was ITT – Tuscany Technological Innovation) and RRPIA_VINCI 2006 (acronym: Virtual INnovation and Cooperative Integration, issued in 2006). The different calls of the two lines 1.7.1 and 1.7.2 included in the Single Programming Document are identified with the name of the line and of the reference year, as identified by the administrative documents we have analysed.

In what follows we shall consider only the funded projects. The total amount of agents involved in the nine programmes was 1,127[5], a subset of which (348) had taken part in more than one project. By "agent" we refer to each individual organization participating in the different policy programmes (and projects). By "participant" we refer to the single participation instance of an agent in a project. Since many programmes allowed multiple participation (each agent could participate in more than one project), the number of participants amounted to 2,006[6]. Table 1 shows the numbers and shares of participants and agents involved in the programmes, classified in nine categories according to their nature: firms, business service providers (generally private companies); private research companies; local (business) associations; universities (and other public research providers); service centres

[5] The data refer to definitive projects, drafted in the format scheduled in the funding specifications. Our analysis includes all the subcontractors that have been explicitely identified in the application forms.

[6] On average, the funds and the number of participants per project range from slighty less than 27 thousand euros and 5 participants in programme 1.7.1E_2004, to almost 1.5 million euros for 35 participants in the only project in programme 171_2002.

(generally publicly funded or funded via public-private partnerships); chambers of commerce; local governments; and other public bodies. Firms[7] and other public organizations represented 48.7% of overall participants, and a larger share of agents, but they had the smallest ratios of participations per project (number of participants divided by the number of agents).

Table 1. Participants, agents and funding by type of organization

Type of organization	Participants		Agents		Total funding		Avg funding
	n.	%	n.	%	€	%	€ per agent
Firm	914	45.6	680	60.3	13,348,181	36.3	19,630
University	261	13.0	93	8.3	73,55,106	20.0	79,087
Private research company	32	1.6	22	2.0	537,613	1.5	24,437
Service centre	150	7.5	34	3.0	6,208,052	16.9	182,590
Business service provider	153	7.6	86	7.6	4,015,642	10.9	46,694
Local government	176	8.8	77	6.8	691,654	1.9	8,983
Local association	209	10.4	85	7.5	3,016,694	8.2	35,491
Chamber of commerce	49	2.4	11	1.0	802,151	2.2	72,923
Other public body	62	3.1	39	3.5	815,448	2.2	20,909
Total	2006	100.0	1127	100.0	36,790,543	100.0	32,645

The last column of table 1 shows average funding per type of funded organization, taking into account the fact that not all the agents were permitted to receive funding (large companies and organizations localized outside the region could enter the networks only with their own resources). Service centres on average received more funds than all other types of participants, followed by universities and chamber of commerce.

In terms of economic activity (based on Nace Rev. 1.1 codes) and size[8], the largest share of participating enterprises were manufacturing companies (68%): of these, 21.8% were micro and small firms in the traditional industries of the region (marble production and carving, textiles, mechanics, jewellery), while the remaining share

[7] Overall, 680 enterprises were involved in one or more of the policy programmes, that is, about 1% of the enterprises active in the region in 2001.

[8] Enterprises are grouped by size into four classes: micro-sized firms (less than 10 employees); small firms (10-40 employees); medium-sized firms (50-249 employees); large firms (more than 249 employees).

were micro firms in the service sector (Nace Rev. 1.1:72), the latter were an active group, with 1.8 projects per agent on average. The share of participanting enterprises varied in the different programmes, ranging from a minimum of 37.1% in programme 172_2002 to a maximum of 100% in the smallest programme (1.7.1_2004).

The various programmes addressed a set of technology/industry targets. A large share of funds was devoted to ICT and multimedia (48.2%), with the objective to widen their adoption in traditional industries and SMEs. Projects in opto-electronics, an important competence network in the region, received 16.4% of funds. The third targeted area, projects in mechanics, received 7.5% of funds. The remaining technological fields included organic chemistry (5%), biotech (4%), and others (new materials, nanotechnologies and a combination of the previously mentioned technologies).

4. Analysis of networks to assess policy impact

In our network-based perspective to the regional innovation policy framework, we consider two different levels of interaction. At the micro level of analysis we consider individual projects, that is, the network of relationships within each funded project, in each policy programme. In SNA terms, these are simple two-mode networks where each participant is linked to the project in which it is involved. At the meso level of analysis we consider individual programmes, that is, the network of relationships between different projects generated by the participation of the same organization(s) to more than one of them (these relationships are absent in the case of programmes where organizations were not allowed to take part in more than one project). In SNA terms, we obtain a network of meso-level networks, which we transform into a one-mode network. Here, two agents are linked when they participate to the same

project(s) within the same programme. At the macro level, it would be possible to consider the set of all programme networks and the relationships among them, but this is an aspect that is not explored in the present paper.

To assess the learning effects generated by the policies, we perform a dynamic analysis, by comparing different network architectures across the nine programmes over the period 2002-2008. The empirical analysis focuses on the main aspects of network structure that were highlighted in section 2 as important determinants of the innovative potential of collaborative networks: i) the participants' ability to form heterogeneous partnerships; ii) the participants' ability to involve bridging organisations and iii) the participants' ability to develop non transitory relationships. They will be presented in the following paragraphs.

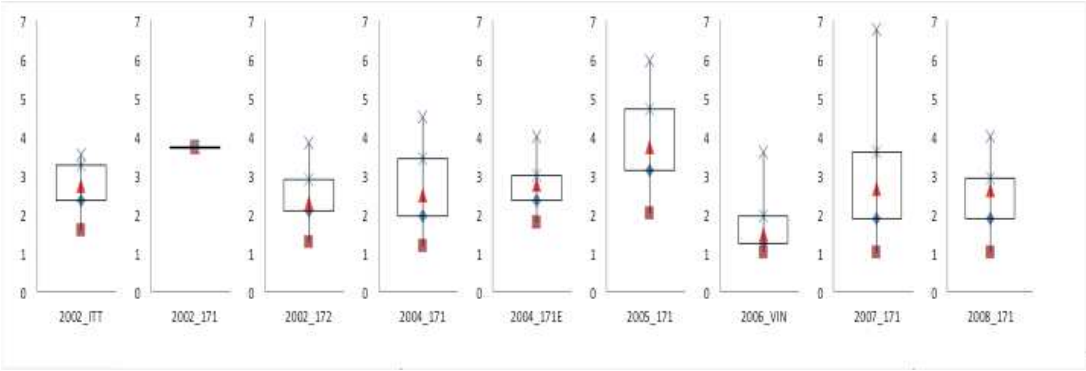
4.1. Heterogeneity

To assess the heterogeneity of each network in terms of composition, we adopt a heterogeneity index that measures the diversity of the types of participants[9]. The index is the reciprocal of the Herfindahl index computed on the shares of participants belonging to each of nine categories (as listed in table 1). First, we have computed this index for each network within each programme. The distribution of the heterogeneity index within each programme is shown in the box-plot diagrams illustrated in figure 2. The average heterogeneity index is not too dissimilar across programmes, ranging between 2 and 4. The only exception is the RPIA programme issued in 2006, which has lower average heterogeneity and low dispersion of these values around the average. Most of the variance (50%) is concentrated between values

[9] If a minimum degree of heterogeneity was required by the tender, we investigate whether such heterogeneity was in line with tender requirements, or greater; if no such rule was implemented, we investigate whether some degree of heterogeneity was present nonetheless.

of the heterogeneity index comprised between 2 and 5 – again, indicating that dispersion is not very large. It is also remarkable that there is not a large difference in average and dispersion of the heterogeneity index between programmes that imposed a minimum heterogeneity constraint (ITT_2002, 171_2002, 172_2002, 171E_2004, 171_2005) and those that did not. The policymaker's decision to drop minimum heterogeneity constraints in later programmes does not appear to have significantly influenced the actual heterogeneity of the networks' composition. This could be due either to a positive learning effect – i.e., participants learned that a certain degree of heterogeneity was associated with successful innovation performance – or simply to self-seeking behaviour – i.e., participants learned that greater heterogeneity in candidate networks' composition increased their probability to be selected for funding.

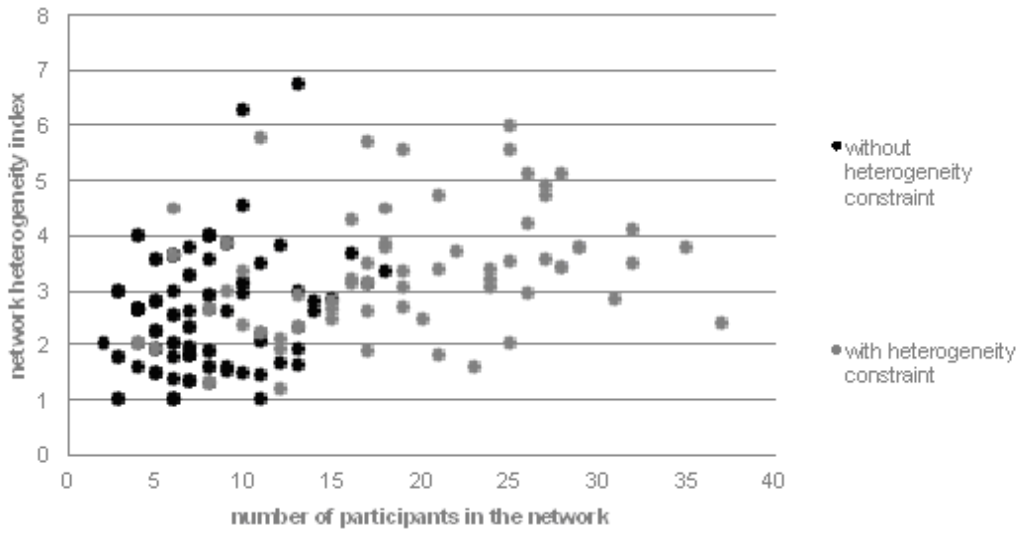
Figure 2. Distribution of heterogeneity index within each programme



To shed more light on these issues, we analyse the relationship between heterogeneity and size of project networks across all programmes (figure 3). We find that greater network size is associated with greater heterogeneity, although the relationship is only weakly positive and there is a large variety of possible heterogeneity index values for each network of a given size. What is interesting to observe is that networks funded within programmes where a minimum heterogeneity constraint was present were

generally much larger than networks funded within programmes without such constraint – and very often much larger than the minimum size required to fulfil the heterogeneity constraint.

Figure 3. Relationship between heterogeneity and network size

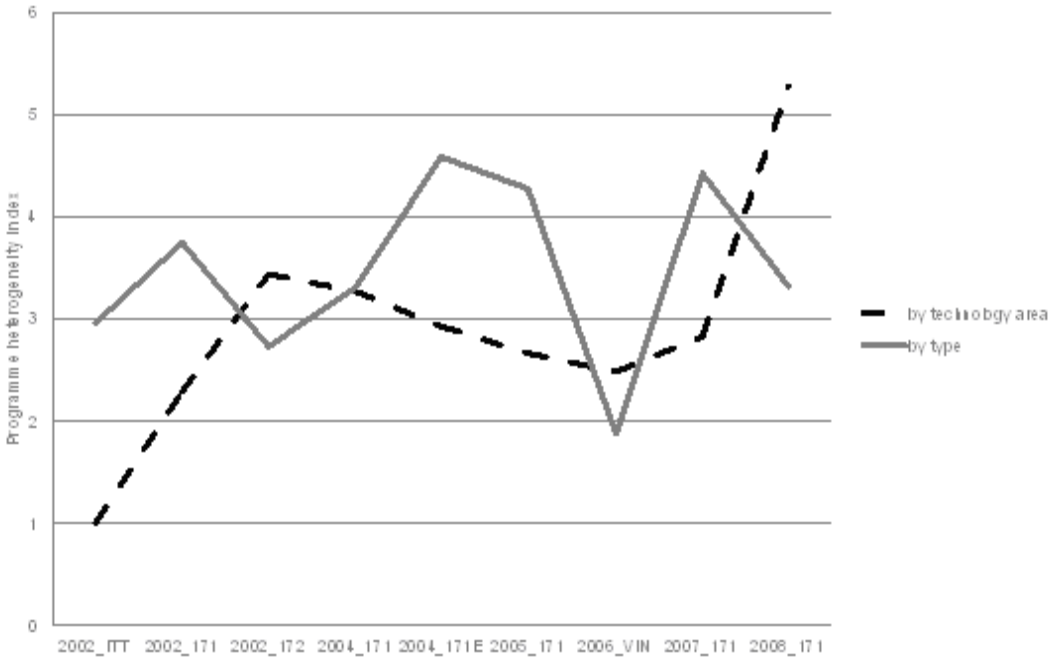


This may suggest that the imposition of a mandatory heterogeneity constraint forced networks to include organizations that were not strictly necessary to the project's success and required them to increase the network size to include all the desired participants; while the elimination of such constraints allowed the partnership to be designed according to the effective project requirements and to economise on the number of partners without necessarily reducing heterogeneity. This can therefore recommend caution in imposing arbitrary heterogeneity constraints without taking into account the actual partnership needs of the different projects.

Computing the heterogeneity index at the level of the entire programme, rather than at the level of individual project networks, provides a different outlook. Figure 4 shows the heterogeneity index of the various programmes measured in terms of the share of

participants of each type and in each technology area. The heterogeneity index in terms of participants' types follows a similar trend to the average heterogeneity index measured on the individual networks: except for a couple of outliers, it fluctuates around a stable trend and programmes with a minimum heterogeneity constraint are no more heterogeneous than the others. Instead, the heterogeneity index in terms of participants' technology areas is increasing over time, indicating that the programmes have progressively involved a wider range of technologically diverse organizations. Similar results (not shown here) are found if the heterogeneity indexes are computed in terms of the share of funding received by each type of participants and each technology area.

Figure 4. Programme heterogeneity index by participants' type and technology area



4.2. Bridging organisations

As mentioned previously, the policy programmes often explicitly required the involvement of organizations, such as service centres and other private organizations

providing services to businesses, whose mission is to facilitate the creation of relationships between other organizations. The rationale for their involvement is that such "bridging" organizations can act as catalysts for the creation of new networks, stimulate the participation of SMEs and provide an interface between the manufacturing SMEs (particularly those operating in low-tech sectors) and public and private research organizations.

In the following analysis we try to understand what types of organizations in the networks, if any, actually performed bridging roles, and whether any bridging organisations emerged in programmes where there were no specific requirements in terms of network composition. We also investigate whether such bridging organisations, over time, supported the creation of new relationships among policy participants, or whether instead they facilitated recurrent relationships among the same participants.

To identify bridging organizations, we analyze the presence of brokers. In SNA terms, a broker is a "go-between" for pairs of other agents that are not connected directly to one another. If A, B, C are three agents and A and C are not linked without the intermediation of B, B is a broker. In other terms, brokers cover a brokerage position[10]. For each programme network, we identify as brokers all agents whose brokering index is greater than zero, where the brokering index of a node is the proportion of all possible couples of nodes in its neighbourhood which are not directly connected to each other (Burt, 1992). Then, through the analysis of brokers, we scan the connections between all the pairs of nodes, and hence the types of agents connected through them.

[10] There may be several kinds of brokerage positions. For example, Fernandez and Gould (1994) identify four different positions (coordinator, consultant, liaison, gatekeeper, representative) on the basis of the specific group to which the broker and the agents it connects belong.

Because of their characteristics, brokers are computed only for the five programmes where each organization was allowed to participate in more than one project – that is, programmes ITT_2002, 171E_2004, 171_2005, 171_2007 and 2008_171. Only in two of these (ITT_2002 and 171_2005) there were specific constraints on the composition of the network by type of participants (see figure 1).

The following table 2 shows the number and share of brokers in each programme network; the programmes indicated with an asterisk imposed requirements in terms of network composition. The share of brokers in the network appears to be unrelated to the presence of such requirements. Instead, there seems to be a positive relationship between the overall size of the programme in terms of number of agents involved and the share of brokers. This is due to the fact that the larger the size of the programme, the larger the share of agents that were involved in more than one project, which created more opportunities for them to act as bridges between different organizations.

The table also show the incidence of "recurrent brokers", i.e. the share of brokers in each programme who also appeared as brokers in at least one other programme. The incidence of such agents is high in almost all programmes, indicating that there is a relatively small number of agents that facilitate the development of network relationships over time.

Table 2. Number of agents, brokers and recurrent brokers by programme

	RPIA ITT_2002*	SPD 171E_2004	SPD 171_2005*	SPD 171_2007	SPD 171_2008
N. of agents	223	70	565	278	247
N. of brokers	21	6	130	36	31
% of brokers on total agents	9.4	8.6	23.0	12.9	12.6
% of recurrent brokers	47.7	49.8	28.5	78.1	57.8

Note to table 2: Only programmes admitting multiple participation are considered. The programmes indicated with an asterisk imposed requirements in terms of network composition. The term "recurrent brokers", refers to the agents who appear as brokers in more than one programme.

However, as shown by the following table 3, only a very small percentage of the total number of relationships in which the brokers were involved was repeated over time: the same agents acted as intermediaries between different relationships..

Table 3. Number of brokers' relations by programme

	RPIA ITT_2002*	SPD 171E_2004	SPD 171_2005*	SPD 171_2007	SPD 171_2008
Relationships involving brokers (N)	2307	500	10564	3928	2722
of which: repeated over time (N)	91	14	609	265	173
of which: repeated over time (%)	3.9	2.8	5.8	6.7	6.4

Note to table 3: "Relationships involving brokers" refers to the total number of linkages (co-participation in the same projects) connecting each broker to the other nodes of the network.

The following table 4 shows that different types of organizations performed bridging roles in the programme networks. For each category of participants, the table shows the ratio between their presence as brokers and their overall presence in each of the five programmes that admitted multiple participation. When the index is greater than one, that category was over-represented as brokers, and vice versa[11].

Bridging roles were played mainly by (publicly funded or partly-publicly funded) organizations whose mission is to provide services and/or an interface between different organizations, as well as by public bodies with a knowledge transfer mission. In particular, service centres and universities (this category includes both university departments and public research centres) acted as bridges between different organizations in all or most programmes, regardless of the constraints imposed by the policy maker. On the contrary, local governments were present only in SPD 171_2005, clearly as a response to policy requirements. As soon as such requirements were removed, they disappeared from the group of bridging organizations, leaving the role to more specialised agents.

[11] The index is calculated as the ratio of participants of that kind that are brokers on the total number of brokers, divided by the ratio of participants of that type on the total number of participants.

Table 4. Relative incidence of each category of participants as brokers in the observed programmes

Participant categories	RPIA ITT_2002*	SPD 171E_2004	SPD 171_2005*	SPD 171_2007	SPD 171_2008
Firm	0.2	0.4	0.4	1.0	0.9
University	**3.1**	**1.9**	**1.9**	0.4	**1.4**
Private research company	0.0	0.0	0.0	0.0	0.0
Service centre	0.6	**2.0**	0.8	0.9	**1.4**
Business service provider	**3.5**	**2.6**	**2.2**	**2.9**	**2.1**
Local government	0.0	0.0	**1.7**	0.0	0.0
Local association	0.0	**1.8**	**2.1**	0.8	0.7
Chamber of commerce	-	0.0	**3.5**	**2.1**	**2.0**
Other public body	1.3	0.0	0.7	0.0	0.0

Note to table 4: The index is calculated, for each category, as the ratio between the share of brokers in that category and the share of participants in that category. The index is zero when no brokers belong to that particular category. Cells are empty when agents in that category did not participate in the programme. The numbers in bold highlight cases in which the category is over-represented among brokers. The programmes indicated with an asterisk (ITT_2002 and 171_2005) imposed requirements in terms of network composition.

If we consider jointly the last three programmes, we observe that the variety of bridging organizations slightly broadens through time, with the inclusion of chambers of commerce and private service providers. Given the (spontaneous) emergence of this variety, it does not seem particularly useful for the policy makers to impose ex ante restrictions on the types of agents who should play the roles of brokers.

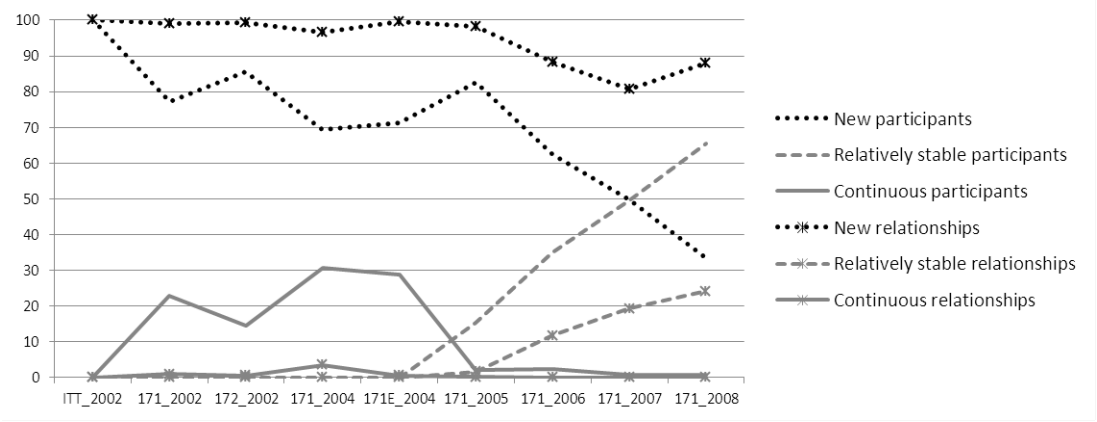
4.3. Stability vs. novelty

Considering the programme networks through time, we identify a set of participants and relationships that remained relatively stable. For each programme, figure 5 highlights new, relatively stable and continuous participants and relationships in the programme networks.

By definition, the first programme includes participants and relationships that were new to the programme. Then, as time goes by, we observe a progressive increase in the number of agents that have already benefited from these policies. Nonetheless,

relatively stable or continuous participation is associated to new relations among new and old participants.

Figure 5. Incidence of new/stable/continuous participants and relationships



Note to Figure 5: By continuous participants/relationships we refer to the agents/relationships that were continuously active in all the previous programmes, while relatively stable participants/relationships are agents/relationships that were present in at least one of the previous programmes.

Apart from the first, the programmes that attract the largest share of new participants are 172_2002 and 171_2005. Interestingly, these two programmes provided funds only to projects that had a minimum number of participants. Therefore, one of the effects of the presence of a high minimum number of participants was the involvement of a large number of agents that are new to the policy. On the contrary, broadening the range of target sectors/technology areas – as implemented in the programmes after 2004 – did not seem to have the same effect.

While relatively stable participations are observed in several programmes, only two agents (out of 1127) participated in all the policy programmes. These agents – the local agency of a national research centre localized in the region's administrative capital and a local service centre – are not among the most central agents of the network[12], but they support two key industries in the region, namely optronics-

[12] If we calculate a centrality index (either a degree centrality index or a closeness centrality index) on the whole set of projects and programmes, we can observe that the two previously mentioned agents are not among the most central. They participate to several projects but with the same – relatively small – group of partners.

optoelectronics and textiles. We do not observe any continuous relationships developing across the whole set of policy programmes.

Since one of the general objectives of the regional policies was to foster the development of non episodic relations between the local SMEs and the world of research, we are interested in verifying if and to what extent this goal has been achieved[13]. Our results show that around 86% of the total number of relationships was repeated over at least two years. Very often, such relationships developed between firms, between firms and universities, or between firms and service providers (service centres or private business service providers) indicating that, while bridging organizations are important in order to activate a diverse range of relationships, repeated relationships develop among organizations that have a common research or technological focus.

The following table 5 investigates this issue more in detail, by displaying the types of relationships that were most often stable or continuous. Similarly to the previous table 4, table 5 shows, for each of the observed programmes, an index of relative incidence of each type of relationship: when the index is greater than one, that type of relationship is over-represented in the group of stable/continuous relationships.

As shown in the table, university-industry relationships are over-represented among the group of most stable relationships. Such kind of relationships peak in the RPIA VIN_2006 – a small scale experimental programme – to which many firms participated with their proven university partners. However, they were over-represented from the programme SPD 171_2004E onwards. Besides stable university-industry relationships, the observed programmes also fostered the formation of stable

[13] Our interest for non-episodic relations is also justified by the fact that the observed programmes have a relatively short duration (cfr. figure 1).

relationships among local associations, Chamber of Commerce, local governments and other public organisations.

Table 5. Relative incidence of each type of stable/continuous relationships

Relative incidence of relationships between:	SPD 171_2002	SPD 172_2002	SPD 171_2004	SPD 171E_2004	SPD 171_2005	RPIA VIN_2006	SPD 171_2007	SPD 171_2008
Uni-Ent	0.0	0.0	0.0	**1.61**	**1.36**	**2.22**	1.00	**1.01**
Ent-Ent	0.0	0.0	0.0	**2.50**	**1.11**	0.62	0.43	0.66
Ent-KIBS	0.0	**1.66**	0.0	**1.20**	**2.12**	0.82	0.70	0.82
Ent-others	0.0	0.0	0.0	**1.61**	0.04	0.0	**1.04**	**1.07**
Uni-others	**8.75**	0.0	0.0	0.68	**1.89**	0.0	**1.68**	**1.47**
Other types	**2.22**	**28.25**	**3.14**	0.0	0.71	**4.51**	**1.35**	**2.06**

Note to table 5: The index is calculated as the ratio between the share of stable/continuous relationships of a certain type and the share of overall relationships of that type. The index is zero when no stable/continuous relationships of that type were present in the programme. The programme RPIA ITT_2002 is not displayed since, by definition, it includes only relationships that are new to the policy.

Summarizing, we can observe that although a non-negligible share of the agents exhibit a repeated participation to the policies, only a small share is involved in stable partnerships: agents participate several times to the funded networks, but in almost all the cases they change partners as they do so. This kind of behaviour – the same agents participate to more than one programme (and to more than one innovation project), but with different partners – can be considered as an individual participation strategy with a positive systemic effect, as it facilitates the recombination of knowledge and competencies and can prevent lock-in effects. As we have seen in the previous section, this behaviour is supported by the brokers, who participate in several programmes but in each programme they tend to activate new relationships, thus creating bridges among different partners.

If we focus on enterprises' behaviour, we see that the ability to change partners combines with a tendency to repeat some of the previous linkages with universities. This kind of relative stability can be judged as positive too. Given the relative short length of the observed programmes, a repeated partnership with the university can be necessary in order to complete a joint research programme.

5. Conclusions

The set of policies we have observed have been implemented in conditions of uncertainty about the amount and the flows of funds actually available to support the next programmes. This less than ideal situation had implications for the design of the set of policy interventions, in terms of fragmented goals, resources, and beneficiaries. Nonetheless, we find that the structural characteristics of the policy interventions allowed several positive outcomes in terms of behavioural effects.

Three main findings emerge from the empirical analysis of Tuscany's innovation network programmes in the period 2002-2008.

First, the earlier programmes imposed constraints on the composition of the innovation networks, mandating some degree of heterogeneity: although these constraints were progressively abandoned, the average degree of network heterogeneity did not change. Policy programmes also became more diverse in terms of projects' technological composition. So, while the calls issued by the region progressively reduced the mandatory requirements in terms of network composition, the involvement of heterogeneous sets of agents increased: this could suggest a process of learning on the part of programme participants. In those cases where the presence of heterogeneity constraints forced networks to include specific types of organizations, this led to the formation of larger networks. If the addition of participants was not necessary for the project's success, this result can be interpreted as suggesting caution in imposing arbitrary heterogeneity constraints without taking into account the actual partnership needs of the different projects. However, the increased size of the project networks might still have had positive effects in terms of recruiting new organizations and increasing the dissemination, sharing and cross fertilization of knowledge within each project and the overall programme network.

Second, we found that service centres, local associations, chambers of commerce, local governments and universities played important bridging roles throughout the programmes, being instrumental in activating many relationships. The involvement of bridging organizations was unrelated to the presence of constraints on network composition: this also suggests that policymakers should exercise caution when imposing constraints, as these may turn out to be unnecessary in order to achieve the desired results.

Third, the continuity of the policy interventions, despite some gaps, allowed many relationships to continue over time, contributing to the stability of the policy networks. The experience of joint participation in an innovation network fostered further joint participations to subsequent networks: in fact, the share of relationships which were already active in previous networks increased over time. Repeated relationships tended to develop among organizations that have a common technological or research focus. Organizations that acted as brokers, instead, tended to be involved in new relationships rather than in stable ones, despite their recurrent presence in in more than one programme. This result suggests that they did not behave just as a lobby, supporting the involvement of the same subset of participants, but that they facilitated the enlargement of the policy-supported networks to new participants. A peculiar role in the creation of a regional innovation network has been played by universities, which have been very active both as brokers and as partners in long-term relationships with firms. This is however not surprising. In fact, it is very likely that an innovation policy of regional scale ends up assigning a leading role to the main producers of knowledge in the area.

These findings suggest that, thanks to the regional policy framework implemented in 2002-2006, many organizations involved in the project networks improved their

ability to organize and engage in collaborative interactions. In order to further assess these results, it would be valuable to investigate whether this programme has produced long lasting results by tracking the collaborative behaviour of these organizations after the end of the policy programme. This is a related field of empirical research we intend to explore.

Lastly, beyond the assessment of the behavioural effects of a regional innovation policy framework, our exercise provides a methodological contribution to the issue of evaluating innovation networks, by identifying and empirically testing a set of indices, some of which borrowed from the SNA literature, that can be used both in order to evaluate ex ante the innovative potential of individual networks and to assess ex post the behavioural effects of a whole regional policy framework.

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