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Does participation in innovation networks improve firms' relational abilities? Evidence from a regional policy framework

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Abstract:
We contribute to the debate on the assessment of the behavioural effects of policies by investigating which features of policy interventions in support of innovation networks, if any, improve the firms' ability to form subsequent relationships. In order to do so, we analyse the evolution of dyadic relationships within a set of policy interventions implemented by the Italian region of Tuscany between 2002 and 2008, aimed at supporting innovation projects performed by networks of heterogeneous agents. Our analysis shows that the observed policies have changed the relational pattern of the firms, pushing them to collaborate – often in a stable way – with a number of agents. We find that a large sectoral heterogeneity among agents is generally associated with a lower probability of networking; and that the presence of specialized intermediaries increases the firms' ability to network with universities.

Keywords: Evaluation; innovation networks; dyadic relationships; behavioural effects; innovation policy

Jel codes: D85; H43; L14; L52; O32

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1. Introduction

The last twenty years have witnessed the diffusion of innovation policies in support of collaborations among heterogeneous agents (e.g.: firms and universities; small and large firms). Such policies have been implemented at different levels, including the regional one, and have been aimed at promoting R&D, knowledge transfer, and innovation diffusion.

How to assess and evaluate such policies is a timely issue (Vonortas, 2012). Most of the the existing studies have focused on capturing input or output additionality, while the interactions among agents within the policy-elicited networks (consortia, JVs, …) have been rarely analyzed explicitly (for some exceptions see: Breschi and Cusmano, 2004; Barber et al., 2006; Fier, Aschhoff and Löhlein, 2006; Chávez, 2011). We argue, instead, that the policy's effect on the agents' ability to activate relationships should be given special attention. In fact, it is not simply a means to achieve other policy goals (innovation, in this case), but it is also a specific objective of network- based policies. Therefore, the evaluation of policies in support of innovation networks should include an assessment of the extent to which the organizations involved have learned to form new relationships and consolidate existing ones. The concept of behavioural additionality (Buisseret, Cameron and Georghiou, 1995; Georghiou, 2002) may help us to capture this point. In fact, this concept refers to the possible learning effects of a policy on an organization's behaviour during and/or after the project's implementation (Clarysse, Wright and Mustar, 2009).

The present article contributes to the debate on the assessment of the behavioural effects of policies by investigating which features of policy interventions in support of innovation networks, if any, improve the participating firms' ability to form subsequent relationships. It does so by analyzing the evolution of dyadic relationships within a set of policy interventions implemented by the Italian region of Tuscany between 2002 and 2008, aimed at supporting innovation projects performed by networks of heterogeneous agents. These interventions displayed the following three features: i) the requirement that participants set up heterogeneous

partnerships; ii) the possibility for participants to develop repeated relationships with external partners; iii) the involvement of intermediaries to facilitate the creation of linkages between different partners (e.g. among firms and universities). These are recognised as important ingredients in order to generate effective networks both by a wide literature on innovation networks (Arora and Gambardella, 1990; Burt, 1992; Dyer and Singh, 1998; Nooteboom, 2000; Powell and Grodal, 2006), and by a number of policies inspired by the "cooperative paradigm" (Bozeman, 2000): our aim is to understand whether they are also instrumental in facilitating the development of participants' relational abilities, and to draw some implications for policies in support of innovation networks.

The paper is structured as follows. Section 2 briefly reviews the empirical literature on the behavioural additionality of network-based policies and in particular on the networking effects of such policies. Section 3 describes the set of interventions implemented by Tuscany's regional government between 2002 and 2008, presenting the main features of the policy programmes and their objectives in the broader context of the region's innovation policies. Section 4 introduces the data and methodology. In section 5, we investigate empirically whether firms' participation in policy programmes in the first phase of network formation affected their likelihood to engage in new or pre-existing relationships in subsequent programmes. The analysis is focused on the relationships between firms or between firms and other organizations. Particular attention is paid to the heterogeneity of the agents involved in the relationships and to the role of intermediaries that can facilitate the development of such relationships. Section 6 concludes by drawing some general implications for implementing more effective network-based policies and for monitoring and evaluating such policies.

2. Do firms learn how to network? Some evidences from the policy literature

In recent years, several empirical contributions have explored the issue of publicly-funded collaborations for innovation (consortia, JVs, innovation networks). However, only a few of them have focused on the interactions

among agents within such networks in order to assess how policy-driven collaborations form and evolve, and what are their main drivers. These analyses are consistent with a behavioural additionality approach to policy analysis and evaluation (Buisseret, Cameron and Georghiou, 1995), which focuses on the learning effects of a policy on the participants' behaviour during and/or after the project's implementation (Clarysse, Wright and Mustar, 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).

The behaviour we focus on is the participants' relational skills. In particular, we analyze empirically which features of policy interventions in support of innovation networks, if any, improve the participants' ability to form subsequent relationships.

Empirical applications of the concept of behavioural additionality are in a relatively small number, and only a few of them refer to the networking effects of network-based policies (Fier, Aschhoff and Löhlein, 2006; Chávez, 2011). However, a number of studies on network-based policies – particularly on European Framework Programs (FP) (Breschi and Cusmano, 2004; Wagner and Leydesdorff, 2005; Barber et al., 2006), but also on regional policies (Russo and Rossi, 2009; Bellandi and Caloffi, 2010) – provide us with some hints on the networking results of such interventions, as well as on the participants' networking abilities. These studies highlight different aspects of agents' networking behaviour that may be affected by the presence of network-based policies: the creation of relatively stable partnerships, and the multiple participations that give rise to the emergence of central agents. While the former type of behaviour is observed at individual level, the latter is often analysed as an emergent property of the whole policy-elicited network. A few studies also tried to provide some details on the kinds of partnerships that are formed by the participants to the policy.

In their analysis of an R&D collaboration programme implemented in Germany, Fier, Aschhoff and Löhlein (2006) show that public policies stimulated agents to form new type of collaborations. Moreover, partnerships that formed thanks to the policies were more likely to last more than

partnerships that formed before the beginning of the policies. Drawing on empirical results from Spain, Chávez (2011) found that regional policies seemed more effective than national ones in stimulating firms not previously engaged in R&D collaborations to establish new linkages with universities or technology centres, while national subsidies stimulated collaborations on the part of firms that were already involved in R&D collaborations. Studies on European Framework Programmes (FP) show that networking among the participants to the policies increased over time, as a self-enforcing mechanisms (Barber et al., 2006). The formation of FP collaborations is influenced by a preferential attachment mechanisms such that the most central agents in terms of collaborations are those which attract a greater number of new collaborations. This mechanism, associated with the presence of repeated participants and stable collaborations, gives rise to the formation of an oligarchic core, surrounded by a number of peripheral organisations (Breschi and Cusmano, 2004). The formation of a central core of stable collaborations is also facilitated by the regional policies analysed by Russo and Rossi (2009) and Bellandi and Caloffi (2010). Again on European FPs, Wagner and Leydesdorff (2005) found that these programmes facilitated the creation of partnership among agents that belonged to different sectors.

The analyses we have mentioned so far have focused either on the whole network of relationships between the organizations involved in the policy interventions, or on the individual organizations that participated in them, or both. In what follows, we will take the dyad as our unit of analysis and we will try to identify which features of the observed collaboration (for example: is it a new collaboration or a pre-existing one?, does it form between heterogeneous/ heterophilic agents or homogeneous/ homophilic agents?) are associated with a greater likelihood that the relation endures over time.

3. Tuscany's regional policy in support of innovation networks

3.1 General features of programs and participants

Our analysis focuses on a set of recent policies supporting networks of innovators implemented by the regional government of Tuscany, mostly 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, with a succession of tenders supported by European regional development funds (ERDF) since the early 2000s (Russo and Rossi, 2009; Bellandi and Caloffi, 2010). In particular, in the programming period 2000-2006 it promoted a set of nine programmes aimed at supporting innovative projects carried out by networks of heterogeneous economic agents. These policies were adressed to a regional economic context characterized by the prevalence of SMEs with no R&D activity, some of which operated in low or medium technology sectors affected by harsh international competition. Networking among local firms was limited to firms active in some specific sectoral and territorial areas of the region (the industrial districts specialized in textiles, leather, jewellery). Networking among firms and universities or research centres was also particularly weak (Caloffi and Mariani, 2011). In order to support the upgrading of the innovation skills of these firms and to support the realisation of innovation projects, the regional government supported the development of non-transitory forms of collaboration among micro enterprises, SMEs, large firms, universities, research centres, business services providers and other organizations acting as intermediaries.

The set of policy programmes can be divided into two major periods. The first period, which included the majority of programmes and participants, ran from 2000 to 2005 (the last projects were completed towards the end of 2006). It included six programmes: a Regional Programme of Innovative Actions (RPIA) launched in 2002 (Technological Innovation in Tuscany, hereafter: 2002_ITT) and five programmes funded by two lines of the regional SPD (lines 171 and 172) launched in 2002 (2002_171 and 2002_172), 2004 (2004_171 and 2004_171E) and in 2005 (2005_171). In the vision of policy makers, these programmes would have led to the development and strengthening of innovation networks made of SMEs and large companies working together with universities, innovation service providers and other organizations supporting innovation and local development (we call this the "network formation" stage). Strongly inspired by the regional innovation

system framework – which was dominant in the European innovation strategies of the time – the regional policy maker considered the emergence of such clusters as the first step towards the formation of Tuscany's innovation system.

The second period started in 2006, and ended with the last intervention implemented in 2008. It included three programmes: a second RPIA, launched in 2006 (Virtual INnovation and Cooperative Integration, hereafter 2006_VIN), and two waves of the SPD, 171 line (2007_171 and 2008_171) [1]. The policymaker's goal with these programmes was to consolidate the networks formed in the previous period (we call this the "network consolidation" stage). Interestingly, these interventions had not been planned at the beginning of the programming period. Rather the region was able to procure additional funds which allowed it to implement a further RPIA and two more waves of one of the SPD lines supporting innovation networks (programme 171).

Overall, the nine programmes were assigned almost € 37 million, representing around 40% of the total funds spent on innovation policies[2]. 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 (79 in the first and 89 in the second period).

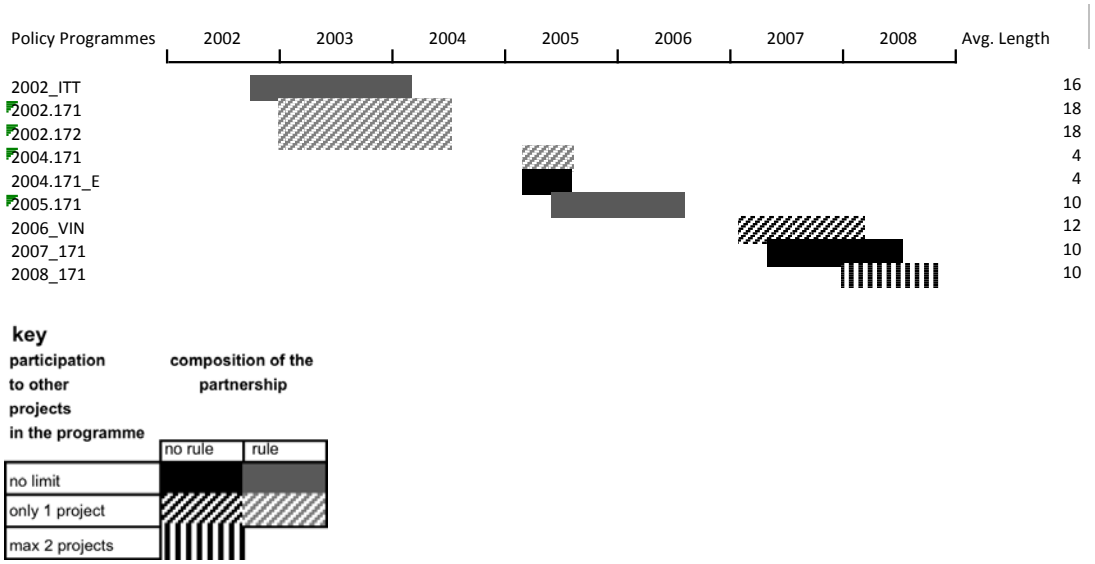
Both the size and the composition of individual networks were partly influenced by the rules set by the regional government, and specified within each tender: some programmes required the candidate networks to fulfil certain criteria in terms of minimum number of participants and/or minimum composition of the partnership (number of SMEs and research centres, and sometimes also local governments) as well as maximum number of different

[1] Although some of the observed interventions were issued on the basis of the same policy line (e.g. the same line of the SPD), each of them had its own peculiarities. That is why we always use the term programme, even when we are dealing with a policy wave.

[2] The remaining part of the SPD (lines 1.1 and 1.8, funded in 2002, 2003, 2004, 2006) provided incentives to individual firms. For an evaluation of these policies, see (Mealli et al., 2010).

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



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: 2002_ITT (Regional Programme of Innovative Action issued in 2002, whose acronym was ITT – Tuscany Technological Innovation) and 2006_VIN (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 our analysis we shall consider only the funded projects[3]. The total amount of different organizations involved in the nine programmes was 1,127[4], a subset of which (205) had taken part in projects in both periods. Instead, 651 organizations only participated in projects in the first period and 271 only participated in the latter. Table 1 shows the numbers and shares of organizations involved in the programmes in either only the first, only the second or both periods, classified into nine categories according to their

[3] See Russo and Rossi (2009) for a comparative analysis of funded and not funded project applications submitted to the RPIA_ITT programme.

[4] 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.

nature: firms, business service providers (generally private companies); private research companies; local (business) associations; universities (and other public research providers); service centres (generally publicly funded or funded via public-private partnerships); chambers of commerce; local governments; and other public bodies. Firms represent 35.6% of the organizations involved in tboth periods, but much higher shares of organizations involved in only one period. The share of participanting firms 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 (171_2004).

Table 1. Participants by type of organization

Type of organization	Both periods		Only 2002-5		Only 2006-8	
	n.	%	n.	%	n.	%
Firm	73	35.6%	417	64.1%	190	70.1%
University	28	13.7%	44	6.8%	21	7.7%
Private research company	4	2.0%	12	1.8%	6	2.2%
Service centre	18	8.8%	14	2.2%	3	1.1%
Business service provider	21	10.2%	42	6.5%	23	8.5%
Local government	18	8.8%	49	7.5%	10	3.7%
Local association	24	11.7%	51	7.8%	10	3.7%
Chamber of commerce	10	4.9%	0	0.0%	1	0.4%
Other public body	9	4.4%	22	3.4%	7	2.6%
Total	205	100.0%	651	100.0%	271	100.0%

The various programmes addressed a set of technology/industry targets, among which the most prevalent were ICT and multimedia (48.2% of the total funds), opto-electronics (16.4%), mechanics (7.5%) and others (among which biotechnologies, new materials, nanotechnologies). Compared with the organizations that participated in only one period (either the first or the second) the 205 organizations that participated in both periods were more engaged in projects in optoelectronics, organic chemistry and biotech and less engaged in projects in mechanics.

Table 2 below shows that the organizations that participated in both periods, compared with those that participated in only the first or only the second period, participated in more projects and in projects that included, on average,

larger (but not necessarily more diverse) partnerships. Compared with those that only participated in one period, the organizations that participated in both periods had higher average Bonacich centrality, that is they were better connected.

Table 2. Participants by type of projects and partnerships

	Average n. projects	Average n.partners	Average Bonacich centrality	Average diversity of project partnership	Average duration of projects (in months)
Both periods	2.16	30.43	31.02	3.23	14.39
Only 2002-5	1.22	24.16	27.26	3.27	16.61
Only 2006-8	1.19	8.72	17.83	2.40	10.93

Note to table 2: To compute the Bonacich (1987) centrality index (or power index) for each organization, in each period, we constructed the network of relationships between all the organizations taking part in all programmes in that period. The network was constructed as a two-mode network linking each organization to the project(s) in which it participated, and then transformed into a one-mode network linking each organization to the organizations that also participated to the same project(s). For the organizations participating in both periods, we averaged their Bonacich centrality indexes in the two periods. The diversity of each project was computed as the reciprocal of the Herfindahl index calculated on the types of organizations involved (belonging to nine possible categories as listed in Table 1).

3.2. The main policy requirements

The policies that we observe are characterized by the presence of some particular features, some of which are of a binding nature. They may be described as follows:

i) *Stability*: many of the observed programmes admitted multi-participations, both in terms of agents' participation in different projects included in the same programme, and in terms of agents' participation to several programmes (some of them running almost in parallel, as shown in the previous figure 1). Repeated participation was seen as a means to facilitate the formation of relatively stable networks that could be the core of a future regional innovation system[5]. The granting of multiple loans to the same pairs / triads / larger groups of agents was considered a tool to achieve this goal.

[5] For a theoretical discussion of the impact of relational stability on innovation see, among others: Gulati, 1995; Powell, Koput and Smith Doer, 1996; Dyer and Singh, 1998; Nooteboom, 2000.

ii) *Heterogeneity*: many of the programs that were launched from 2002 to 2005 imposed constraints in terms of minimum number of agents having a certain nature that must be part of the project partnership. In some cases, a minimum number of participating firms and/or universities was required, while in other cases also a number of service centers or other service providers must be included in the project partnership. The presence of such constraints was intended to encourage the formation of heterogeneous partnerships, in the belief - also supported by much of the literature (see, among others: Arora and Gambardella, 1990; Lane and Maxfield, 1997; Dyer and Singh, 1998; Nooteboom, 2000; Powell and Grodal 2006) - that partnership formed by agents who have heterogeneous knowledge, skills and abilities have a high innovative potential. In addition to imposing constraints, policy makers encouraged the formation of heterogeneous partnerships through a number of "softer" activities, such as giving public speeches or circulating policy documents that highlighted the need to re-combine different knowledge and skills of regional agents in order to promote innovation. In fact, the network was seen as a powerful tool to promote the rebalancing of the disparities among regional agents having different innovation propensity and different capacities to invest in R&D, or agents operating in different sectors or in different geographical areas of the region.

iii) *Presence of intermediaries*: The presence of intermediaries was required in many programmes as a fundamental component of the project partnerships. The policy-maker - as suggested by the literature (Howells, 2006) - believed that such agents (they are not only KIBS, but laso Chamebr of Commerce and local business associations) could play a bridging role among agents endowed with different knowledge, skills and abilities, and facilitate learning and innovation processes within the project partnerships. As we shall see in the next section, their involvement was also required by the policy maker in many aspects related to the preparation and implementation of the programmes.

Stability, heterogeneity, and presence of intermediaries are often recognized as three basic ingredients of well-performing innovation networks (Pyka and Saviotti, 2002; Powell et al., 2005 Fritsch and Kauffeld-Monz, 2010; Graf and

Kruger, 2011). These elements are often included in the network-based policies that have been implemented in several European regions (Shapira and Kuhlmann, 2003; Eickelpasch and Fritsch, 2005). We will explicitly take into account the role they have played in stimulating the participants' relational abilities.

3.3. The policies' learning aspects

The interventions were characterized by a strong potential for learning, both on the part of the policy maker and on the part of the participating organizations.

As for the first aspect, it must be pointed out that the early programmes were launched in a period in which regional policy makers in Italy had just acquired a range of new responsabilities in the field of, among others, industrial and innovation policy. Therefore, in the early 2000 the regional policy maker was almost new to the design and the implementation of such policies, and needed to learn more about the possible beneficiaries of their interventions, and how they would have reacted to the policy stimulus.

As for the second aspect, in the early 2000 the policy tool was quite innovative, at least for the Italian context. In fact, only in very rare cases had the Italian regions begun to experiment with measures that were different from the incentives to individual enterprise that had characterized the previous period of national policies. Therefore, agents needed to learn how to use this type of public incentives, how to establish formal partnerships and how to manage collaborative R&D projects. Also for this reason, the interventions designed and implemented in the first period (2000-2005) provided many constraints, both in terms of number of participants and in terms of required presence of certain types of agents.

In order to meet these different learning needs, the first interventions were preceded by a phase of scouting, which allowed the policy maker to "survey" the most relevant innovators of the region, put them into contact with each other and solicit project proposals (see Russo and Rossi, 2009, for a more detailed description of the scouting phase of the first RPIA). For this scouting phase, the regional government mainly relied upon the service centres that were localized in the region. Over time, the regional policymakers gradually

moved their focus from scouting to providing assistance and support to learning and networking. The mission of the service centres changed accordingly. It is important to note that only a limited number of firms had relations with the other participants before the policies were launched[6].

Learning activities characterized the whole period of policy implementation. In all the observed programmes, and particularly until 2006, participants to funded projects were regularly invited to present their progress in programme meetings, which often included - in addition to project participants and the programme managers - external experts discussing some particular features of the programmes or presenting some best practices.

In addition to monitoring the projects' progress, and to teach the policy participants how to manage the different aspects of the projects (from administrative procedures to external communication and dissemination), these meetings served to strengthen networking, facilitate the recombination of skills and knowledge possessed by the regional agents and thus facilitate the initiation of further innovation processes. In fact, the regular meetings (approximately one every four months) were used to exchange information on the innovative skills possessed by the different agents, the technologies developed and used in the projects, the sector of application of such technologies. The participation of all project participants – and not only that of the project leader – was highly recommended. Moreover, in order to maximize the diffusion of information, the region funded the publication of the final project reports, to be distributed to participants in the various programmes and in public events.

In our empirical analysis we will try to analyse if and to what extent the programmes implemented in the first period generated learning effects which benefited the agents participating in the programmes implemented in the second period, when all the policy constraints were removed (see Figure 1 for a summary of the policy constraints applied in the various programmes).

[6] See the following section 4. Only 22 out of the 73 firms that participate in both network formation and in network consolidation stages report having had previous relations with some of the other organizations involved in the policy programmes, before policies were implemented.

4. Data and methodology

In order to build our database on dyadic relations we have adopted the following procedure. First, we have selected the couples of agents participating in the same programmes (not simply in the same projects) both in the network formation and in the network consolidation stages. Then, we have mapped both the "actual" and the "potential" relationships developing among them, keeping only the firm-firm or firm-other agent relationships. As for actual relationships, we have considered the co-participations to the same innovative project. The potential relations are those that could have developed among agents that participate to the same programme, but that did not realize because such agents participate to different projects[7]. In so doing, we obtained a database made of 6,391 dyads composed of agents that had at least a potential relation both in the first and in the second stage. Each record of our database is a dyad that includes a firm (always the first node of the dyad) and another type of agent (including firms)[8]. As we see from table 3, 378 out of the 6,391 dyads are actual in the second period, while the remaining are only-potential relations (i.e. relations that have not realized). Table 4 provides some details on the 73 manufacturing firms (and software producers) and 131 other agents that take part in the various dyads[9].

[7] We have not considered as "potential relations" all the relations that might have developed between agents who participated in the same period (of network formation or consolidation), but we have restricted our observation to the agents participating in the same programme. We believe that the latter definition is the one that best fits the concept of a "truly" potential relationship, because it identifies a relationship that involves agents who have chosen to participate in the same period in the same policy programme (though not to the same project).

[8] Relations are bidirectional: if firm A participates in a project with agent B, we have a unique relation connecting both A with B and B with A. Multiple relations, which can occur when two agents meet in more than one program (project) at the same stage of network formation or network consolidation are not recorded as separate relations (we do not generate a duplication of the record-dyad). As we will discuss in the following section, we consider the repeated co-participation as a specific feature of the observed dyad.

[9] The agents participating both in the first and in the second period are 205, but only 204 of them have at least one potential relation with the same partner both in the first and in the second period (in other words: only 204 of them co-participate with the same agent to the same programmes developing both in the first and in the second stage).

Table 3 – The actual and only potentiali dyads

		Network consolidation (time t)		
		Actual	**Only potential**	**Total**
Network formation (time t-1)	**Actual**	229	5660	582
	Only potential	149	353	5809
	Total	378	6013	**6391**

Table 4 – The agents in the dyads

Type of activity	N. of agents
Manufacture of textiles, clothing and footwear	8
Other “made in Italy” goods: furniture, jewellery, food	4
Manufacture of chemical, rubber and plastic products	7
Manufacture of other non-metallic mineral products	9
Manufacture of fabricated metal products	6
Manufacture of machinery and equipment	6
Manufacture of medical devices	6
Manufacture of motor veichles and other transport equipment	3
Manufacture of electrical equipment	3
Other manufacturing firms	4
Software producers & other activities related to informatics	17
R&D services	14
Professional, scientific and technical services	57
Public administration	18
Activities of membership organizations	12
Cultural activities	3
University departments	18
Education and training	7
Other	2
TOTAL	204

Note to table 4: In the category “firm” we have included the 73 agents that belong to the first 11 rows of the table (that is from manufacture of textiles to software producers).

The following table 5 provides some descriptive statistics and a detailed description of the variables included in the database.

The variable *relation*, measured on the total of 6,391 observed dyads, is a dummy variable taking value 1 when the relationship between the two agents realizes during the second stage of network consolidation, and zero otherwise. The subsequent variable (*relation_D*), adds some details to the

previous one, indicating whether each relation involves, respectively, only firms, firms and universities or firms and other types of agents[10].

The first group of independent variables provides some evidence on the history of collaborations between the agents of the dyad, that is on the stability of the dyad over time. The variable *previous* takes value 1 if the dyad has co-participated to the same innovative project during the network formation stage (and zero if the relation is only potential). The intensity of the previous relation is measured by the variable *multiple*, which takes value 1 when the observed relation was repeated more than once during the network formation stage (in different programmes, or in more projects of the same programme, when allowed by the policy). To these basic variables we add an information which refers to the instant before the agents took part in the policies: the variable *prior* takes the value 1 when the partners of the dyad have had a relation before their participation to the policies. As in the other variables we have used, a relation does exist when the two agents co-participate in an innovation project.

The degree of heterogeneity among agents is defined by a set of variables measuring the differences (distances) between agents with respect to different criteria: i) the sectors in which agents operate (*sector_het*); ii) the agents' degree of centrality in the formation stage (*power*); iii) the ability of agents to lead a project network (*leader*); iv) the difference between the amount of funds that have been collected by the two agents (*funds*) in the formation stage. The first variable is a simple measure of sectoral heterogeneity, while the other three variables try to capture other elements of heterogeneity – or heterophily - which can have an influence on agents' networking ability. The variables *power*, *leader* and *success* provide a measure, respectively, of how agents are heterogeneous with respect to the centrality they had in the previous period (as measured by the difference between their Bonacich index of centrality calculated on the network of relationships between all the organizations involved in each of the

[10] The variable is categorical and takes value 0 when the relation is only potential and does not realize (see table 5). We focus on firm-firm relations and firm-university relations, but we consider also a third group of firm-other agents relations because we want to capture the relevance of the first two groups, net of the other kinds of relations as well as of the non-relations.

programmes running in the first period 2000-2005[11]), to their abilities in the management of network relationships (proxied by their capacity to be project leaders) and to the success they have achieved in network-based projects (proxied by the amount of public funds they have collected)[12]. All these variables, as well as the others that we describe below, are measured with respect to the network formation stage (at time t-1).

Table 5. Descriptive statistics on the potential and actual relations linking agents participating both in network formation and in network consolidation stages

Variable	Description	Obs	Mean	Std. Dev.	Min	Max
Dependent variables						
relation	Dummy variable taking value 1 when the relation between the two agents realizes during the consolidation stage (time t). Dependent variable in model 1	6391	0.059	0.236	0	1
relation_D	Categorical variable detailing the type of agents involved in the relation in the consolidation stage (time t). Dependent variable in model 2 relation_D=1 when the relation develops among two enterprises.	6391	0.015	0.122	0	1
	relation_D=2 when the relation involves a firm and an university.	6391	0.015	0.124	0	1
	relation_D=3 when the relation involves a firm and another type of agent.	6391	0.029	0.167	0	1
Stability						
previous	Dummy variable taking value 1 when the two agents have had at least one relation in t-1	6391	0.091	0.288	0	1
multiple	Dummy variable taking value 1 when the two agents have had multiple relations in t-1	6391	0.009	0.096	0	1
prior	Dummy variable taking value 1 when the two agents have had a relation (of co-participation into an innovation project) before the beginning of the observed policies	5903	0.006	0.081	0	1
Heterogeneity						
sector_het	Categorical variable measuring sectoral heterogeneity among the two agents: sector_het=LOW identifies the relation linking two agents operating in the same 3 digit Nace Rev.2	6391	0.012	0.110	0	1

[11] The centrality index is calculated on each programme-network, that is on the network of actual relationships developing among all the organizations taking part in each programme.

[12] Also the variable *funds* is connected to the agents' heterogeneity in terms of their networking capabilities. In fact, the amount of public funds an agent collects can be influenced by the number of networks the agent is involved in, which in turn can depend from the agents' networking capabilities. However, the variable also tries to capture a slightly different aspect in the behaviour of agents. In fact, at the second stage of network consolidation, the agents can select a partner to collaborate with on the basis of the success (as measured by the amounts of public funds they have received) they have achieved at the first stage. Therefore, a large value of the index can signal that a firm has "jumped on the bandwagon".

	sector_het=MEDIUM identifies the relation linking two agents operating in different 3 digit belonging to the same 2 digit Nace sector	6391	0.01	0.1	0	1
	sector_het=HIGH identifies the relation linking two agents operating in different 2 digit Nace sectors	6391	0.976	0.154	0	1
power	Difference between the Bonacich (1987) eigenvector measure of network centrality indices of the two agents, calculated on each of the programmes running at t- t-1* (the formation stage)	6391	-25.663	60.419	-313	102
leader	Dummy variable taking value 1 when only one of the agents has been leading partner of at least one project developing in time t-1	6391	0.274	0.446	0	1
funds	Difference between the amount of funds that have been collected by the two agents in time t-1	6391	-41495	84221	-391158	81913
Intermediaries						
intermediaries	Dummy variable taking value of 1 when at t-1 the two agents were indirectly connected through an intermediary (service centres, private services providers, business associations and chamber of commerce)	6391	0.484	0.5	0	1
sc	Dummy variable equal to 1 when the two agents at t-1 were indirectly connected through an innovation centre.	6391	0.215	0.411	0	1
other_interm	Dummy variable equal to 1 when the two agents at t-1 were indirectly connected through an intermediary which is not an innovation centre.	6391	0.183	0.386	0	1
Controls						
2006_VIN	Programme into which the two agents (might) meet: 2006_VIN	6391	0.038	0.191	0	1
2007_171	Programme: 2007_171	6391	0.577	0.494	0	1
2008_171	Programme: 2008_171	6391	0.563	0.496	0	1

The presence of intermediaries is captured by a dummy variable (*intermediaries*) taking value one when the observed agents are indirectly linked through an intermediary, that is through an agent who, by its nature, could perform an intermediation role (service centres and similar, private services providers, business associations and chamber of commerce). The two subsequent variables detail the nature of intermediaries. The variable *sc* focuses on one particular type of intermediaries that are supposed to play a prominent role in the context of innovation, that is, innovation centres and similar kind of organizations (incubators, technology parks and other service providers, often involving both public and private agents), while the variable *other_int* considers all the other types of intermediaries.

The dataset also includes some control variables such as the specific policy programme in which the relation has formed or could have formed, given that both agents participate in that programme.

Starting from the database we have collected, we define a model that seeks to determine whether and to what extent the degree of heterogeneity of agents, the presence of previous relations and the presence of intermediaries of the relationship are associated with a greater likelihood that, in the period of consolidation, the agents actually establish a relationship. In the first model, the dependent variable is the *relation* dummy variable that takes value 1 when the two agents have a relation in the consolidation phase, while the independent variables are as described above. After having controlled for correlations among variables, we run a logit regression model on the total number of observed dyads.

In the second model, we disaggregate the analysis for different types of agents, considering relations between firms, between firms and universities and between firms and other types of agents. Here, the dependent variable is a categorical variable that takes on values from one to three to identify the three different types of relationships mentioned above (while it takes on value zero when the agents do not establish any relationship in the consolidation stage). In addition to presenting a more detailed analysis for the type of agents involved in the relationship, the second model differs from the first also because it discriminates between the type of intermediaries that indirectly link the two agents. We argue that while intermediaries having a broad and political mission (as business associations or chambers of commerce) can play an important role in creating connections between firms, which are their main target of the policy, more specialized organizations (such as innovation or service centres) may be more effective in creating connections between firms and the world of research.

We hypothesize that, net of what we measure with the before mentioned covariates, the observed dyads are independent. However, as each agent included in the database can be repeated several times, we adopt a

specification of both models that uses the Huber-White sandwich estimators of the standard errors[13].

5. Results

The following table 6 illustrates our results. The first model (table 6, column 2) has as its dependent variable the presence (absence) of a relation linking two agents in the network consolidation phase. The results of the logistic regression that we have run on the whole set of relations tell us that the presence of a previous relation has a positive impact on the probability to form a new relation, and this is particularly true when the previous relation was strong (*multiple*). On the contrary, the presence of a relationship formed before the observed policies does not seem to have any kind of impact on the likelihood of collaborating within the policy-sponsored projects.

Heterogeneity does not play a positive role in fostering the formation of relations during the consolidation phase. In fact, the coefficient associated with the maximum sectoral heterogeneity of the dyad – which is expressed in terms of the log odds – tell us that a one unit increase in sectoral heterogeneity results in a -1.8 unit change in the log of the odds. Also when measured in terms of leadership capabilities, heterogeneity proves to have a negative impact on the probability of forming a relation in the second phase.

The presence of intermediaries (whoever they are) brokering the relation at time t-1 has a positive influence on the formation of a new relation in the phase of network consolidation.

[13] We have run some post-estimation tests that have allowed us to assess the models' goodness-of-fit, and to exclude the presence of multicollinearity.

Table 6. Regressions results

	Model 1 (y: relation)		Model 2 (y: relation_D)					
			y: firm-firm relations		y: firm-university relations		y: firm-other agents	
Variables	Coef. (rob st err)		Coef. (rob st err)		Coef. (rob st err)		Coef. (rob st err)	
previous	2.8780	***	2.9259	***	3.7820	***	3.0764	***
	(0.1585)		(0.4026)		(0.6695)		(0.2545)	
multiple	3.8457	***	4.5181	***	3.6261	***	3.9084	***
	(0.8843)		(0.8452)		(0.9192)		(0.8253)	
prior	0.3996		0.4175		0.7921			
	(0.5159)		(0.7494)		(0.6552)			
sector_het=MED	-0.6486		n.i.		n.i.		n.i.	
	(0.5708)							
sector_het=MAX	-1.8548	***	n.i.		n.i.		n.i.	
	(0.3268)							
power	0.0003		0.0089	***	-0.0035	**	0.0000	
	(0.0013)		(0.0026)		(0.0017)		(0.0000)	
funds	0.0000	*	0.0000	**	0.0000	***	0.0000	
	(0.0000)		(0.0000)		(0.0000)		(0.0000)	
leader	-0.6463	***	-2.2329	***	-1.6355	***	-0.0116	
	(0.2028)		(0.7645)		(0.4570)		(0.1810)	
intermediaries	0.3803	**	n.i.		n.i.		n.i.	
	(0.1787)							
cs	n.i.		0.3238		1.4623	**	0.4855	
			(0.4712)		(0.6998)		(0.2836)	
other_int	n.i.		0.3764		-1.3045	*	0.7391	**
			(0.4175)		(0.6717)		(0.2855)	
2006_VIN	0.6842	*	0.4795		-0.2820		0.4508	
	(0.4108)		(0.3918)		(0.6329)		(0.4150)	
2007_171	0.2464		-0.5385		0.3926		0.2037	
	(0.1914)		(0.4191)		(0.2872)		(0.2107)	
2008_171	0.5971	***	0.0562		0.8295	***	0.8297	**
	(0.1879)		(0.4154)		(0.3179)		(0.2138)	

Note to table 6: Model 1: Log pseudolikelihood = -890.19; Wald chi2(12) = 606.63; pseudo R2 = 0.314. Model 2: Log pseudolikelihood = -1192.18; Wald chi2(33) = 794.51; pseudo R2 = 0.2779; n.i. stands for variable not included in the model. Robust standard errors are in brackets. Significance levels: *** = 1%; ** = 5%; * = 10%.

In the second model we consider the categorical variable measuring the presence of firm-firm relations, firm-university relations or firm and other types of agents (*relation_D*) as our dependent variable.

The results show that firms seem to have learned how to make some relations more stable. In fact, the presence of a previous relation (developing at time t-1) has a positive effect on the probability to form a new relation, and this happens for all the observed types of dyads. In the case of university-industry

relationships the fact that the two agents already had a strong relation in the formation phase is associated with a larger positive impact. As in model 1, the presence of a relation developing before the beginning of the observed policies do not have any influence on the formation of subsequent relations at time t.

This second model does not include the categorical variable measuring sectoral heterogeneity, because it largely overlaps with the definition of the nature of the agents involved that we have used to build our dependent variable. As for the other types of heterogeneity, we observe that in the case of relations between firms, heterogeneity – as measured by differences in *power* (agents' centrality) – increases the chances to form a new relation in the consolidation stage. Therefore, in line with what was initially aimed at by the policy makers, dyads between firms that develop in the second period combine more and less central firms, and more and less successful firms (in terms of funds they have collected). However, such dyads are often composed of firms that have a similar capacity for network management (*leader* has a negative impact). For the case of industry-university relations, heterogeneities in networking abilities (*power*) and in network management (*leader*) seem to play a negative role. This suggests that firms that have relationships with the universities have attributes (capacities, skills, etc..) in networking which are similar to those of universities.

Agents' behaviour in the second period is influenced by the activity of the various types of intermediaries. However, in the case of university-industry relations it is the brokering activity of a service centre in the first phase that increases the probability of forming a relation in the second phase of network consolidation, while the "best" type of intermediaries are business associations or chamber of commerce in the case of the relations between firms and other types of agents. On the contrary, the latter play a negative role in connecting firms and universities.

The analysis shows that participation in the policies somehow changes the relational pattern of the firms. In fact, having collaborated on innovative projects before the participation in the policies did not affect the probability of having subsequent (policy-funded) collaborations. On the contrary, the presence of policy-driven partnership developing at time of network formation

did have a positive effect on the probability of new collaborations. This result seems to suggest that the observed waves of policies had an effect on the way in which firms choose their partners in innovative projects and keep them. At the same time, the programmes offered firms the opportunity to strengthen relationships over time.

In the socio-economic context of the Tuscany region, where the regional agents showed a relatively low level of networking, especially in innovative industries (Caloffi and Mariani, 2011), the presence of these behavioural effects is not particularly surprising. We observe that the policies encouraged networking with a very wide range of agents, including chambers of commerce, local governments and others. Relations with these agents - even when already present before the beginning of the policies - were not directed to the development of innovative projects. Therefore, for many of the observed firms these were completely new partners in innovation projects.

The peculiar characteristics of the policy - the fact that they encouraged networking with a number of very diverse agents – contributes to explaining why the sectoral heterogeneity had a negative effect on the probability of networking at time t. Once the policy constraints were removed, firms resumed to cooperate with agents that were most similar to them. This result may still indicate that learning had taken place: that is, firms may have learned that heterogeneous relationships imposed by the policymakers were not particularly efficient or were not fulfilling their needs, and hence when the constraints were removed they sought out more effective partnerships.

The results of the second model let us focus on two interesting aspects of firm-university relations, relations that most worries policy makers in many European regions. First, keeping our attention on heterogeneity, we observe that firms that are stronger from the point of view of the ability in networking and in network management are the best able to collaborate with the university. Secondly, focusing on intermediaries, we note that only some types of specialized intermediaries (service centers for innovation and technology transfer, incubators, science and technology parks) are able to play an effective bridging role between firms and universities.

6. Conclusions

In this study we analyzed empirically the extent to which the organizations involved in a set of successive policy interventions have learned how to set up relationships on innovation projects with other organizations, either by engaging in new relationships or by consolidating existing ones, by investigating the evolution of dyadic relationships between firms and other organizations participating in several policy interventions over time.

Although our dataset does not allow us to extend the analysis of such behavioural effects beyond the period of implementation of the policy interventions themselves nor to have a counterfactual analysis, this exercise has allowed us to derive some lessons on the extent to which policy programmes with certain characteristics are able to induce learning processes in the participants (with respect to their ability to engage in subsequent relationships), thus capturing some behavioural effects.

Our analysis shows that the observed policies have somehow changed the relational pattern of the firms, pushing them to collaborate – often in a stable way – with a variety of agents. Overall, the findings suggest that while certain features of the policy programmes did increase the participants' likelihood to form relationships in the second period (the possibility to participate in more than one programme and form stable relationships with certain organizations; the involvement of innovation centres) other features of the programme did not have any positive effect (such as the imposition of a sectoral heterogeneity constraint).

These result are interesting from the perspective of policy makers, even if they do not tell us whether the observed changes in behaviour are desirable or not. It is on this last point that we want to focus our future research. This exercise was useful in seeking to identify some behavioural effects of the policies and in showing how such objective can be pursued by using in innovative ways some established concepts, methods and indicators from social network analysis. As a further step, we could assess whether and to what extent the interventions have had a lasting effect even after the termination of public funding. Moreover, we believe that the behavioural perspective can be fruitfully completed with the understanding of the impact

that the change in agents' behaviour will have on both individual and aggregate performances. Finally, our results can be used in designing a counterfactual analysis to assess the policy impact of relational learning in the context of a regional innovation system.

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