The evaluation of policies toward innovative networks and Social Network Analysis

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Abstract

In this paper we show how Social Network Analysis (SNA) can be used to evaluate the opportunity that governments subsidize innovative networks through Network-Based Policies (NBP). We argue that, although SNA is helpful to assess how efficiently information is transferred within a network, it does not by itself provide a clear estimation of the generated welfare effects. We propose a methodology that integrates SNA indicators with an evaluation of the welfare generated by both direct and indirect effects.

In the first part of the paper we discuss the conditions under which a policy towards innovative networks is additional or, conversely, a waste of resources. We then apply our methodology to an empirical case and evaluate ex post the effects of the Italian policy in support of technological districts. Our results confirm the necessity to integrate social network indicators with a more appropriate measure of the welfare effects of NBPs. We also suggest that the lack of such integration may explain why previous empirical analyses have given conflicting answers as to the questions of whether public R&D is additional to private spending or rather a substitute for it, and whether even additional public policy might be inefficient.

JEL Classification: O30, O32, L13
Keywords: Innovation Networks, Policy Evaluation, R&D Cooperation, Social Network Analysis

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1 Introduction

In many countries, institutional arrangements have been designed to promote research and development activities. One of the main areas of intervention is public funding in the business sector through direct (mission oriented) subsidies to firms. Recently, public funding has been used to directly support the creation of networks between heterogeneous agents that concur in the design or implementation phase of innovation policies. The purpose of this paper is to analyse the conditions under which such network-based policies (NBPs) could be successful.

The evaluation of network-based policies focuses on the efficiency and additionality of the subsidized network: the aim is to assess whether subsidies have helped establishing a network of innovative firms and organizations that, in the absence of public support, would have achieved weaker economic results or would not have existed at all. Previous analyses of policies to promote innovation networks fall in two main areas. The theoretically-oriented industrial organization (IO) literature has explored the private and social benefits of R&D collaboration; the Social Network Analysis (SNA) literature has analyzed the formation and evolution of networks as the result of the cost and benefits analysis of actors that strategically decide to establish and maintain network ties. These streams of literature express different views about the drivers of innovation networks formation, resilience and evolution; the two views have to date been rarely reconciled. The objective of this paper is to propose a more comprehensive framework for the evaluation of network-based innovation policies that combines insights from both approaches.

2 SNA and innovative networks

There are different approaches to the analysis of innovative networks. The IO approach focuses on the effects of spillovers on social welfare, on R&D expenditure, on the typology of networks and on the profits of firms and industries. Firms produce knowledge and transmit this knowledge either formally through direct partnerships, or informally through spillovers. In the IO models, the informal transmission of knowledge has a negative effect on the profits of the firm. In the presence of spillovers, an increase in the R&D efforts of firm i decreases not only the costs of firm i but also the costs all other firms in the network. This effect has a negative influence on the R&D effort of firm i. If spillovers are internalized through cooperation, profits and welfare could increase. There is therefore a positive relationship between the level of spillover and the probability of R&D joint ventures.

While the IO approach primarily deals with the production of knowledge, the Social Network Analysis (SNA) literature focuses instead on the transmission of knowledge. In the SNA view, direct links are thought to have a positive rather than a negative effect on the benefits a firm receives from a link. In these models the amount of benefits accruing to a firm belonging to a network is affected by the geodesic distance between two nodes (the shortest distance in the shortest path between them). These models distinguish between benefits due to direct relationships and benefits due to indirect relationships. A formal agreement between two firms determines a direct links; formal direct ties are particularly relevant in high-tech sectors such as biotechnology and semiconductors. Indirect relationships happen where a first actor (firm) is directly connected to a second actor that is in turn directly connected to a third; in this case the first and the third actor are indirectly connected and, even in the absence of any formal agreement, some knowledge exchange occurs between them.[1] A study by Ahuja (2000) shows that both direct and indirect ties have a positive influence on innovation, although the impact of indirect ties is smaller than the impact of direct ties.

Another aspect discussed in the SNA literature concerns the characteristics of the transmission of knowledge between actors. Knowledge can be differentiated in explicit knowledge and tacit knowledge. Explicit knowledge is highly codified as in blueprints, recipes, manuals or in the form of training. Formal contractual relations (i.e. subcontracting relationships, strategic alliances or participation in research consortium ties) favour the production and the transfer of explicit knowledge. Tacit knowledge lacks this kind of codification; personal contacts that arise as a consequence of common membership in a professional or trade association, or through affiliation to other kinds of communities, permit the transfer of tacit knowledge.

We have summarized the previous discussion in Figure 1. A firm j produces a given knowledge as a result of its effort and this knowledge could be transmitted or not transmitted. Knowledge that is not transmitted gives firm j some monopolistic power. If knowledge is transmitted, the transmis-

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[1] The main concepts used to analyse inter-firm networks are extrapolated from interpersonal relations. A first distinction is made between strong and weak ties (Granovetter, 1973). In interpersonal terms, a strong tie is a person with whom you interact on a regular basis, while a weak tie is an acquaintance or a friend of a friend. In inter-organizational terms, strong ties are equated to formal relationships and weak ties to informal relationships. Powell and Grodal (2006) further articulate this distinction, suggesting that relational ties in an inter-firm network can be based on contractual or market considerations, or on less formal relationships such as common membership in a technology community or a regional economy.

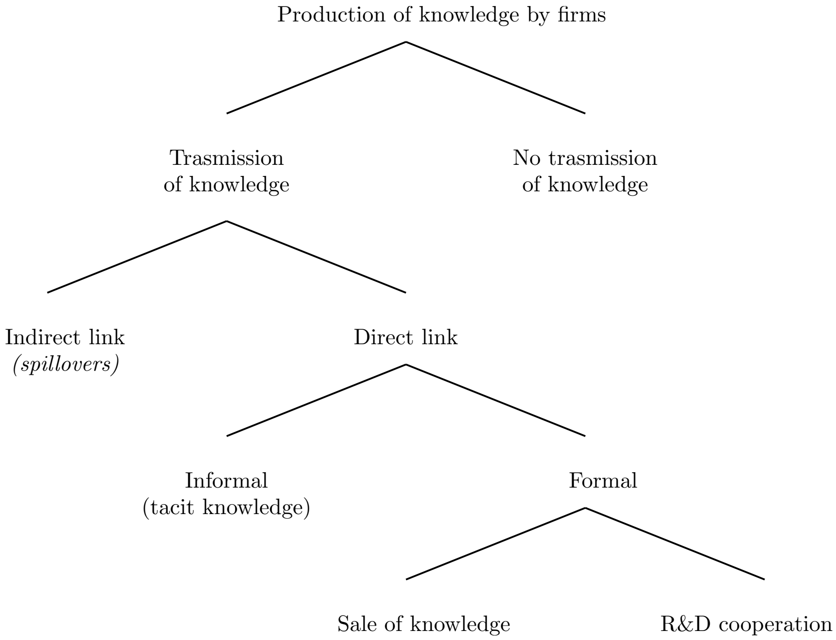

Figure 1: Production, transmission of knowledge and typology of links

sion could be voluntary or involuntary as an effect of direct and indirect links. In this last case, firm j will get no profit from the transmission while the firms that receive the knowledge for free will get benefits at zero cost (these are the so called spillovers effect). In the presence of spillovers, any incentives to encourage firm j to spend more in R&D will have a negative effect on the overall R&D effort, since they concurrently act as a disincentive to other firms in the network. The transmission of knowledge could alternatively be the result of formal links; this can happen through two main mechanisms of transmission. In the first case, firms transmit their knowledge through some contractual agreement that is generally expensive for the receiving firms; in the second case, there is a mutual exchange between the involved parties. As an effect of cooperative joint projects and of a division of labour in the production of knowledge, both firms produce knowledge that is mutually transmitted. According to the IO models, the indirect knowledge transfer is then a disincentive for the single firms to invest in R&D and an incentive to establish formal cooperation agreements.

Social Network Analysis, while also considering the possibility that networks arise as the result of formal ties, insists that the creation of networks is mainly driven by the benefits of indirect effects. While formal links are very important for the production of knowledge, informal links can be very important for the transfer of knowledge. The effect of innovative networks on technological progress is therefore not only linked to the production of technology but also to its transfer.[2]

From the above discussion it follows that SNA literature evaluates the effectiveness of innovative networks mainly in terms of information communication. The capacity to transmit and share information is a core benefit of participating in self organized networks (Cowan and Jonard, 2003; Gulati, 1998; Verspagen and Duysters, 2004; Vonortas, 2013), and networks characterized by small-world properties are relatively efficient in transmitting and sharing information. Therefore the average distance between all couples of nodes in a network (measured as the shortest path that connects them) could be seen a good indicator of the efficiency of a network.[3] A recent work by Vonortas (2013) has used social network methodology to evaluate R&D programs.

Given the emphasis on the transmission of information that underlies the SNA approach to innovation networks, most previous studies on the evaluation of network-based policies through SNA tools focus on the assessment of flow and connectivity within networks. This usually implies the calculation of positional attributes of the nodes through numeric indexes related to their location within the network. Node-level positional attributes provide the basis for calculating global network statistics that synthesize those topological features of the network that are thought to affect connectivity and information flow.

We will briefly introduce the indicators used more frequently in the SNA literature. Among them we can list density (related to the average degree of individual actors) and centrality (tied to different measures of actors' prominence within a network). More in detail, density is a network-level measure used to assess the degree of connectedness in a partnership network. Network

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[2] Some authors have used richer typology of links to introduce different definitions of innovative networks. Powell and Grodal (2006) have proposed a typology based on two dimensions: the connections among actors, that can vary from open, episodic or fluid to recurrent and dense; the degree of purposiveness, that ranges from informal to contractual. The two dimensions can be combined to describe four types of innovative networks. Closed membership and informal ties determine a primordial type network. Highly fluid and informal ties determine the invisible college (i.e the network of scientists). Closed membership and contractual ties determine the supply chain (i.e. Toyota supply chain network, buyer-supplier relations and subcontracting). Highly fluid and contractual ties determine strategic alliances network (i.e. partnership) associated with formal, direct, strong ties and with explicit knowledge.

[3] Average distance could also be seen as a good indicator to compare the efficiency of networks with different number of nodes. In fact if we add many nodes to a network, the average distance will not increase much; it is necessary to increase the size of a network by several order of magnitude to notice that paths to new nodes are longer.

density is defined as the proportion between the actual number of ties in a network, and the maximum possible number of ties in a network of the same size (i.e., the number of ties that would be present if each actor was connected to every other actor). Density varies between 0 and 1; when density is close to 1, the network is said to be dense, otherwise it is sparse.[4] Density provides information on how well connected are the nodes in a real network relative to the theoretical number of possible connections; in denser networks, more opportunities and alternatives are available to actors.

Whereas density describes the general level of connectedness in a network, centralization metrics describe the extent to which this connectedness is organized around particular focal nodes. Centralization and density are therefore complementary measures. Most analyses consider two measures of network centralization: degree centralization, i.e. the variation in the degrees of nodes divided by the maximum degree which is posible in a network of the same size (Freeman, 1979); and betweenness centralization, i.e. the variation in the betweenness centrality of vertices divided by the theoretical maximum variation in betweenness centrality scores in the network of the same size (Freeman, 1977; Gould, 1987).[5] When taken in their aggregate (i.e., network-level) form, both indicators ultimately aim at assessing the distance between an empirically-observed network and a theoretically-defined highly centralized structure (in the case of betweenness centrality, a star-shaped network) that would be the most efficient in trasmitting information in a network of a given size. Degree centralization varies between 0 to 1; a high value of degree centralization implies that a relevant number of links pertains to one or a few nodes, while a low value of the index characterizes a decentralized network in which there is little variation between the number of links each node possesses. Betweenness centralization also varies between 0 to 1; a high value of betweenness centralization means that one or few actors play a crucial role in the control of the information flow inside the network.

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[4] Since density measures are normalized in relation to the number of actors in a given network, they can be used to compare the connectedness of different networks. In the case of an innovation network, however, it is reasonable to expect that the network density will tend to decrease as the network size increases because of the presence of coordination costs. While the size of an innovation network can theoretically grow without constraints, the number of collaborations that each actor can activate is bound by its capacity to sustain larger and growing coordination costs. We can also express this constraint by saying that the degree distribution (i.e., the distribution of the number of incoming or outgoing links for each actor) of an innovation network is somehow rigid.

[5] In the terminology of Social Network Analysis, centrality refers to indexes calculated for individual nodes within the network, whereas centralization refers to the entire network. Centralization scores provide an indication of the extent to which a whole network has a centralized structure with prominent nodes.

Although, as already noted, we certainly concur with the SNA literature that information flow is a key element for the diffusion of benefits within an innovation network, the production of valuable information (knowledge) is a necessary pre-condition for the generation of benefits. Furthermore, links in real-world collaboration networks entail costs that constrain the degree (i.e., the number of connections) of individual nodes, in this way shaping the degree distribution of the entire network. For this reason, our aim in the remainder of this study is to bridge the SNA and the IO approaches by integrating positional analysis with calculations of the costs and benefits associated with direct and indirect links.

3 A model of social networks, R&D cooperation and public policy

We will start from the simple Jackson-Wolinsky (J-W) model of social connections (Jackson, 2010; Jackson and Wolinsky, 1996). This model assumes that the net utility or payoff that a player receives from a network is the sum of the benefits that the player gets from his direct or indirect connections to other player less the cost $c > 0$ of maintaining such links. The main hypothesis is that there is a benefit for a link that deteriorates with the distance of the relationship. The J-W model assumes that the value of the direct benefit d lies between 0 and 1, and that the benefit of the indirect effect deteriorates with the distance of the relationship. The simpler hypothesis is that d is raised to higher powers for more distant relations.

In this paper the J-W model will be adapted to the evaluation of the performance of a policy to create Technological Districts (TDs); this requires several changes to the original model and a number of assumptions that will be spelled out in the following paragraphs. Our key assumptions are summarized in Table 1 below. For the purposes of this study, Technological Districts will be seen as *partnership networks* defined by a set of projects, a set of actors (firms, universities etc.) and a set of links recording the participation of actors to projects.[6]

Following Vonortas (2013), we assume that all participants in a R&D project are directly connected to, and exchange information with, each other.

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[6] Partnership networks can be seen as a specific form of *affiliation network* – a general class of networks in which actors are linked to each other through their joint participation in events. In our case, the members and partners of a TD are the actors, while the R&D projects to which they participate constitute the events. Affiliation networks are two-mode networks with just one set of actors; the second mode of the network is the set of events (Wasserman and Faust, 1994).

Table 1: Key assumptions of our model for partnership networks

	Assumption	Possible alternatives
1	Symmetric linkages among all actors within projects	Random assignment of an activity flag
2	Co-participation in a project creates direct links	
3	Direct links generate payoffs d, whose value is equal for all actors in a project	Payoffs d modified by a multiplier $a_i \in (0, 1)$ representing absorption capacity
4	Direct links entail costs c, whose value is equal for all actors in a project	Multiplier $s_i \in (0, 1)$ representing actors' share of total costs
5	Indirect links between actors and projects generate payoffs that decay with the power of the two-mode distance	
6	Multiple indirect ties to the same project are redundant (perfect knowledge and equal willingness to share)	Transmission coefficient $t_i \in (0, 1)$ for mediating actors

This implies that the direction of the links is irrelevant, hence that the links between actors are undirected.[7] The assumption of symmetric linkages among all participants in a project is realistic for Technological Districts, where district members that are not interested in participating in a project can do se while maintaining access to other services provided by the district (finance, support, training and so on). It seems therefore reasonable to assume that all actors formally involved in a project are connected. In future extensions or in empirical applications that require a distinction between formal and actual participation in collaborative research activities, the symmetric linkages assumption can be relaxed by assigning an "activity flag" valued 0 or 1 to individual actors. In simulation studies the flag could be randomly assigned according to some pre-defined probability distribution, while for empirical applications it could be assigned depending on some known features of the actors.

We assume that links between actors within a projects are of a formal type. We expect that the benefit $d \in (0, 1)$ from a direct (formal) link is always higher than the benefit from an indirect (informal) one, because codified knowledge can be transmitted in a more precise way than not codified knowledge; so we have $d^2 < d$. We also assume that only direct links are associated to transmission and sending costs (trasmission, maintaning, production etc) so that $c > 0$ only for direct links.[8]

Benefits d and costs c are considered to be constant for all project participants. This is of course a simplification that does not take into account the heterogeneity of actors involved in cooperative R&D projects. It is in fact reasonable to expect that a small start-up, a multinational enterprise and a research university, even when involved in the same project, have different utility functions (for example, due to their different absorption capacity) and contribute unevenly to project costs. As in the previous case, this assumption can be relaxed by assigning each actor an absorption coefficient $a_i \in (0, 1)$ and, possibly, a contribution coefficient $s_i \in (0, 1)$ capturing the share of costs borne by each actor.

The partecipation of an actor i to several projects creates indirect links between the actors belonging to the project and other actors that do not belong to the same project. As in the J-W model we assume that benefits from indirect links decay with the power of the distance; hence a link to a project located at distance 2 generates a benefit d^2 and so on. It is here worth noting one major difference between our model and the original J-W formulation.

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[7] In SNA terminology, a network is said to be *undirected* if all links are necessarily reciprocal or symmetric, i.e. if actor i is linked to actor j, then also j is linked to i.

[8] For an empirical confirmation of these hypotheses see Ahuja (2000).

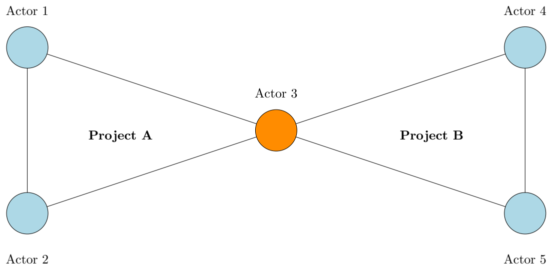

Figure 2: An example network (fiver actors, two projects)

Indirect links in our model are not established between actors, but between actors and projects; this implies that the relevant distances are to be calculated on the two-mode network (actor by project). The methodology will be explained in detail in Section 5.

A further difference between our formulation and the J-W model concerns the fact that multiple indirect ties to the same project (indirect ties mediated by different actors) are redundant.[9] In other words, being indirectly linked to a project by one actor or by more than one actor bring the same benefit. The redundancy assumption implies that all actors in the project share the same knowledge and that they are equally willing to transmit it, through informal channels, to all their partners in other projects. Also this assumption can be relaxed by assigning each actor a transmission coefficient $t_i \in (0, 1)$ and by calculating indirect benefits as a weighted flow equal to $\sum_k (d_j \times a_k \times t_k)$ for all actors k that lie on the (possibly multiple) shortest paths between actor i and project j.

We now illustrate the model and start to trace its implications for public policy design by making reference to a simple network with five actors and two projects A and B; the one-mode (actor by actor) representation of the network is given in Figure 2. Direct links to each project generate a benefit equal to d and entail a cost $c > 0$. The collaborations of each actor and the benefits they derive from direct and indirect links are shown in Table 2. Actor 1 participates to project A and has a benefit equal to d. Actor 3 participates to project A and to project B and gets a benefit equal to d from each project. Actor 4 does not participate to project A but participates to project B together with actor 3. Actor 1 and actor 4 participate to only one project and each gets a benefit from direct effects equal to d. On the other hand each of the two actors has an indirect effect equal to d^2 due to

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[9] More formally, multiple indirect ties between actor i and project j can occurr when there are multiple paths (i, j). The redundance assumption implies that, whenever there is more than one shortest path of length l between i and j, the indirect benefit is only counted once and its value is equal to d^l.

Table 2: Benefits from collaboration to project A and B

Actors	Project A*	Project B*	Total Welfare
1	1	0	$(d-c)+d^2$
2	1	0	$(d-c)+d^2$
3	1	1	$2(d-c)$
4	0	1	$(d-c)+d^2$
5	0	1	$(d-c)+d^2$
Social welfare	-	-	$6(d-c)+4d^2$

(*)1 indicates that actor participates in the project (0 otherwise).

the participation of actor 3 to the two projects A and B. The net benefit for actors 1 and 4 is therefore $(d-c)+d^2$. Actor 3 gets a benefit equal to $2(d-c)$ because it directly takes part in both projects.

Table 2 reports the benefits that each actor derives from direct and indirect links. The last row of the table shows the total social welfare that results from the two projects A and B. If $(d-c)>0$, actors have an incentive to realize the two projects; in this case, there is no need for a policy. If $d<c$, however, the two projects will not be spontaneously realized since costs are higher than benefits and Actor 3 has no convenience to participate. In this case, a policy to promote the simultaneous realizations of the two projects could increase social welfare.

If $d<c$ but $6(d-c)+4d^2>0$, a policy to promote the realization of the network is useful. We call d^{**} the value of d that satisfies such condition (i.e., the value of d for which the social welfare is positive), and we call d^* the value of d that satisfies the condition of profitability of a single actor so that $(d-c)+d2>0$. As the value of c increases, the value of d^{**} and d^* will also increase. If d_e is the effective benefit and $c>d_e>d^*>d^{**}$, it will be necessary to give a subsidy to Actor 3 in order to have the projects A and B realized. If $c>d^*>d_e>d^{**}$, a subsidy must also be given to the actors that participate in a single project (actors 1, 2, 4 and 5) to encourage them to realize the projects.

The model that we have presented can be generalized to the case of projects with a number of actors per project v higher than 3. We will consider a typology of network with a *pivot actor* that participates in all projects, while all remaining actors only take part in one project each. The $v-1$ actors are indirectly connected to all actors in the other projects through the pivot

Table 3: Direct and indirect effects in a network with a pivot actor

Term	Value
Direct effect of pivot actor	$P(d-c)$
Direct effects of other actors	$(v-1)P(d-c)$
Indirect effects of other actors	$P(v-1)(P-1)d^2$
Total welfare	$vP(d-c)+P(v-1)(P-1)d^2$

actor.

For illustration purposes, we assume 4 projects with v equal to 4 for each project. Project participants receive a direct benefit $(d-c)$, while the benefits from indirect effects are d^2. The pivot actor that participates to 4 projects has a benefit equal $4*(d-c)$. Each of the other actors has a benefit equal to $(d-c)+3d^2$, because they directly participate to only one project and indirectly to 3 projects. The total number of actors is equal to $3*4+1=13$.

We can generalize these results to network with an arbitrary number of projects P, all involving v actors. If P is the number of projects and v the numbers of actors for project, the total number of actors A is

$$A=(v-1)P+1 \tag{1}$$

The benefits from direct and indirect effects for each actor, as well as the total welfare for the network, are reported in Table 3.

The total welfare W of the network can be computed as follows:

$$W=P*[v(d-c)+(v-1)(P-1)d^2] \tag{2}$$

In Equation 2, the first term in parentheses represents direct effects and the second term indirect effects. If $(d-c)>0$ the benefit for each actor is positive and also the value of W is positive. Therefore all actors have an incentive to participate in the projects and we do not need a specific policy for the creation of the networks. Different is the case in which $(d-c)<0$; the pivot actor will have no convenience to create the network since direct effects are negative. On the other hand, it is still possible that $W>0$ if indirect effects are higher than directs effects. This will depend from the value of d; we could find the value $d^{0]}$ that makes W positve by solving Equation 2 in d. The value d^0 will depend from c, v and P:

$$d^0=\frac{v\pm\sqrt{v^2+4vc(v-1)(P-1)}}{2(v-1)(P-1)} \tag{3}$$

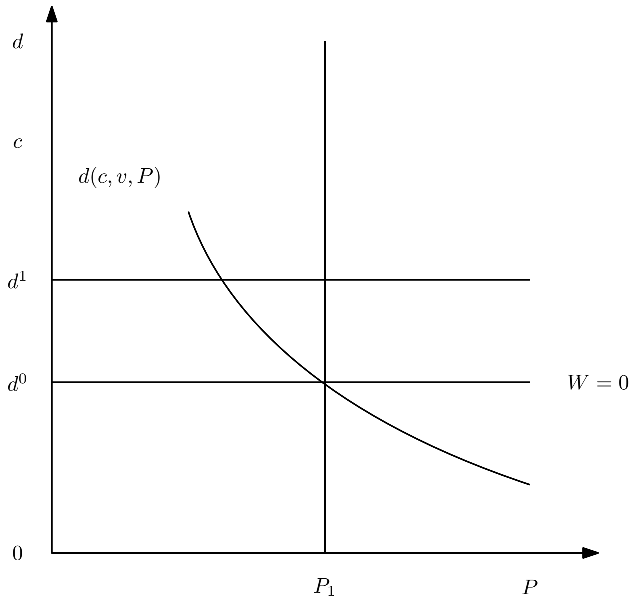


Figure 3: Relationship between d^0 and P

If we consider only the positive root for d, we find a decreasing relationship between d^0 and P. In Figure 3, the value of

If the effective net benefit of a project d^e is higher than d^1 we could have the cases illustrated in Table 4. If we are in case (2) we must consider the opportunity to finance the pivot actor. The government expenditure for this policy will be $f = c - d_e$ for each project; in total, government expenditure would be $P(c - d_e)$. This sum must be deducted from the value W of the social welfare previously computed. We could now calculate the value of d for which the sum of direct effects (negative) plus the public expenditure for the subsidies is equal to the value of indirect effects (positive). The value of d could be computed as the positive root of Equation 4 below.

$$W = P * [v(d - c) + (v - 1)(P - 1)d^2] - Pf \tag{4}$$

If $d^0 < d_e$ the welfare of the network is positive and the policy could be sustained. In case (2) we have $d^1 > d_e$, and other actors have an incentive to participate in the network. The announcement that the pivot actor has the intention to participate to all P projects could push each of the $(v - 1) * P$ actors to participate to a project. If the government assumes that the effect of the announcement by the pivot actor to participate to all projects is not strong enough to induce other actors to participate to the projects, it must give to each actor a subsidy $f = (c - d_e)$. Therefore the total expenditure for subsidies will be fPv. The value of such sum must then be deducted from

Table 4: Network policies and additionality

Case	Additionality
(1) $c < d_e$	The creation of the network increases welfare and there is no need to give a subsidy to realize the network
(2) $c > d_e > d^0$	The creation of the network increases welfare but must be subsidized
(3) $c > d^0 > d_e$	The creation of the network does not increase welfare

the social welfare computed above:

$$W = P * [v(d - c) + (v - 1)(P - 1)d^2] - Pvf \tag{5}$$

In Table 5 we have shown the value of welfare for a network with $v = 4$ with a different number of projects, a different value of d and a different level of subsidy f. In all cases $d < c$, therefore if one consider only the direct effects it would not be worth to finance a network policy. A first result is that the existence of indirect positive effects could make convenient a policy to create innovative networks even if the direct effect for each actor is negative. As the number of projects increases, coeteris paribus, the value of welfare increase and with 6 projects it becomes positive (row 7). This means that with six projects it is worth to finance a network policy.

It could be interesting also to evaluate the effect on welfare of a marginal project. From an analytical point of view we have from previous analysis (equation 2) that the welfare generated with $t + 1$ projects, of which the last one has a value of d_{t+1} different from the d_t of previous projects, could be written as in Equation 6 if c and v are the same for all projects. The second term in Equation 6 is the direct effect of the new project, and the third term represents indirect effects.

$$\begin{aligned} W_{t+1} &= \\ P_t v(d_t c) + v(d_{t+1} - c) + P_t(P_t - 1)(v - 1)d^2 + P_t(v - 1)(d_t^2 + d_{t+1}^2) &= \\ W_t + v(d_{t+1}^2 - c) + P_t(v - 1)(d_t^2 + d_{t+1}^2) \end{aligned} \tag{6}$$

An interesting results of our analysis is that in the ex ante evaluation, if the objective is welfare maximization one cannot choose the projects to finance looking only a single project but must evaluate all projects together. The previous analysis could be used, in the case of a call for projects to participate in a program that gives access to subsidies, for the ex ante evaluation. We assume that different actors participate to the announcement to get a subsidy and for each projects there is a given number v of actors. Therefore it will be possible to evaluate the links of each actor participating to a project with other actors, and this will permit the estimation of indirect effects. The information about c and v are documented in the project proposal. We assume, to simplify our analysis, that c and v are equal for all projects. The Agency that must evaluate the projects does not however know the true value of d. On the other hand from the knowledge of the links and of the value of c and v it is possible to compute the minimum value of d necessary to increase welfare. We could compute the value of d from Equations 5 and 6. The problem is that the true value of d is not known. Therefore it is necessary to build a revelation mechanism assuming that actors know the true value of d.

The agency could ask the actors to indicate the value of the subsidy f they ask as percentage of the known value of c. Such value of f will be different for the various projects. The difference between c and f could be used to calculate the value of d. The higher the value of the requested subsidy, the lower the value of the estimated d. Lower the value of d, lower the social welfare and lower the probability to be financed. The existence of a trade-off between the amount of subsidy requested and the probability to be financed will probably push participants to declare a value of f not very far from that needed.

As shown in Table 5, different values of the requested subsidies affect social welfare. The results listed in the Table provide an indication of how the methodology could be applied to chose ex ante between different projects. Importantly, all the project applications must be evaluated simultaneously.

4 Social Network indexes and social welfare

We will discuss the relation between social network analysis indexes and welfare generated by a network through the case of a network with three projects. We assume that, due to coordination costs (Capuano and Del Monte, 2013), there is an optimum number of actors for each project. We assume that such number is equal to v for all projects. Given the value of v and the number of projects P, such projects could be realized with a different number of actors and through a different network typology. Each network typology will be characterized by a different number of indirects links. We assume the same

Table 5: Value of W in pivot networks with different characteristics

Actors per project (v)	Number of projects (P)	Costs per actor (c)	Benefits per actor (d)	Public subsidy (f)	Social Welfare (W)
4	1	0.6	0.3	0.3	-1.2
4	2	0.6	0.3	0.3	-1.86
4	3	0.6	0.3	0.3	-1.98
4	4	0.6	0.3	0.3	-1.56
4	5	0.6	0.3	0.3	-0.60
4	6	0.6	0.3	0.3	0.90
4	6	0.6	0.2	0.4	0.14
4	6	0.6	0.15	0.45	-0.37

values of d and c for all projects. We compute for each network typology the value of social welfare and the value of different network indicators. We want to check whether there is a relationship between network indicators and the the value of social welfare. It is easy to understand that differences in the value of social welfare between the different typologies only depend from indirect links. The results of our simulations are shown in Table 6. In Table 7 we have ranked the different cases according to the values of social welfare and to the network characteristics resulting from Table 6.

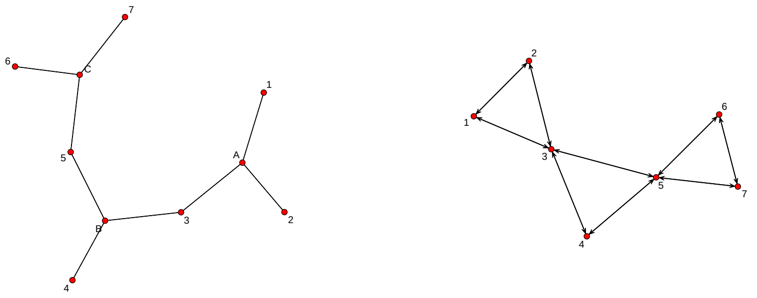
The conclusions from Tables 7 and 6 are interesting. Given the number of projects of the same quality and size, an increase in the number of actors does not imply an increase in social welfare. Social welfare is in fact higher in Case 3 than in Cases 5 and 6. The other interesting aspect is that the network index that shows the higher correlation with social welfare is betweeness centralization. Our conclusion is that it is very important for ex ante and ex post evaluation of the policy for innovative networks to analyze the direct and indirect costs of knowledge transmission. Some network characteristics that will result from these policies and some characteristics of the sectors and firms considered could help in the choice ex ante of the policy to be followed. Another implication from Table 7 is that for the evaluation of an industrial district, network characteristics often do not offer valuable indications. As we will show later, this conclusion can also be deduced by applying a similar methodology to empirical network data collected in Italian Technological Districts.

Table 6: Typology of partnership networks and social welfare

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Projects	3	3	3	3	3	3
Actors	5	6	7	7	8	9
Actors per project	3	3	3	3	3	3
Active actors	100%	100%	100%	100%	100%	100%
Edges	7	8	9	9	9	9
Average degree	2.8	2.66	2.57	2.57	2.25	2
Network density	0.70	0.53	0.42	0.43	0.32	0.25
Betweenness centraliz	0.29	0.54	0.80	0.44	0.19	0
Degree centralization	0.50	0.40	0.80	0.33	0.33	0
Social welfare	$9(d-c)$ $+5d^2$ $+d^3$	$9(d-c)$ $+6d^2$ $+3d^3$	$9(d-c)$ $+12d^2$	$9(d-c)$ $+8d^2$ $+4d^3$	$9(d-c)$ $+3d^3$	$9(d-c)$

Table 7: Ranking according to social welfare and SNA indexes (decreasing)

	Case 3	Case 4	Case 2	Case 1	Case 5	Case 6
Actors	7	7	6	5	8	9
Average degree	2.57	2.57	2.66	2.8	2.25	2
Network density	0.42	0.43	0.53	0.70	0.32	0.25
Betweenness centraliz	0.80	0.44	0.54	0.29	0.19	0
Degree centralization	0.80	0.33	0.40	0.50	0.33	0
Social welfare rank	1	2	3	4	5	6



(a) Two mode (actor by project) (b) One-mode (actor by actor)

Figure 4: A hypothetical network ($n_a = 7$, $n_p = 3$)

5 A generalization through the geodesic distances matrix

The approach to the calculation of direct and indirect benefits proposed in the preceding sections can be generalized to any class of collaboration networks. The payoffs of individual actors and social welfare levels can in fact be calculated starting from the geodesic distances matrix of any two-mode (actors by projects) network. In the case of innovation networks (such as joint R&D networks in a technological district), the data required to apply the methodology include: (a) relational data recording the participation of actors (e.g., firms) to projects; and (b) financial data reporting the entity of the received subsidies and the total cost for each project.[10]In this section we illustrate the general methodology by making reference to a hypothetical small network composed of seven actors (firms) participating to three projects (see Figure 4). We will then apply the proposed methodology to two real-world innovation networks in Italian Technological Districts.

Let n_a be the number of actors in an innovation network (e.g., the members of a TD), n_p the number of projects and n_n the total number of nodes in the two-mode network ($n_n = n_a + n_p$). To construct the hypothetical two-mode (actor by project) network in Figure 4a, we assign a consecutive numeric ID to each node in the network (firms and projects). Actors

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[10] As a simplifying assumption, subsidies and costs can be considered costant across projects. This assumption might prove useful for simulation studies focusing on the impact of network topology on the individual and social benefits. In empirical applications, costs and subsidies can instead be allowed to vary across projects.

(firms) will be numbered as $1, 2, \ldots n_a$, while projects will be numbered as $n_a+1, n_a+2, \ldots n_n$. The participation of actors to projects in the innovation network can then be represented through an affiliation matrix with dimensions $(n_a \times n_p)$, in which the n_a rows correspond to actors (i.e., firms) and the n_p columns correspond to projects. The affiliation matrix for the network in Figure 4a is reported in Equation 7; each non-zero cell $\mathcal{N}_{(i,j)}$ indicates that actor i participated in project j.[11] A one-mode (actor by actor) projection of the same network can be obtained by multiplying $\mathcal{N}$ for its transpose $\mathcal{N}^{\mathcal{T}}$; the resulting one-mode graph shows the linkages between actors that jointly participate in the same projects (Figure 4b).

$$\mathcal{N} = \begin{bmatrix} 1 & 0 & 0 \\ 1 & 0 & 0 \\ 1 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \end{bmatrix} \tag{7}$$

Starting from the affiliation matrix $\mathcal{N}$, we can calculate the two-mode geodesic distances between actors and projects using the bimodal approach proposed by Borgatti and co-authors (Borgatti and Everett, 1997; Borgatti, 2009).[12] In order to do so, we generate the transpose of $\mathcal{N}$ (hereafter $\mathcal{N}^{\mathcal{T}}$), and two square null matrices of dimensions $(n_a \times n_a)$ and $(n_p \times n_p)$ which we will refer to as, respectively, 0_a and 0_p. We build a square matrix $\mathcal{N}_{\mathcal{N}}$, with dimensions $(n_n \times n_n)$, as follows:

$$\mathcal{N}_{\mathcal{N}} = \begin{bmatrix} 0_a & \mathcal{N} \\ \mathcal{N}^{\mathcal{T}} & 0_p \end{bmatrix} \tag{8}$$

When the standard algorithm for the calculation of geodesic distances (Brandes, 2008) is applied to $\mathcal{N}_{\mathcal{N}}$, we obtain a geodesic distances matrix $\mathcal{G}$.

---

[11] The representation of relational data through an affiliation matrix is cumbersome for even moderately large networks. A more manageable approach involves the use of an edgelist containing the ordered couples $(actorID, projectID)$ for each link in the network. The ordered couples (i, j) in the edgelist represent the row and column numbers of all non-zero cells in the affiliation matrix. For all practical purposes, the two data formats are equivalent and both are readily accepted as input by most social network analysis software.

[12] The *geodesic distance* between two nodes in a network is defined as the length of any shortest path between them. A *path* between nodes i and j is a sequence of lines and nodes, starting with node i and ending with node j, in which: (a) each node is incident with the lines following and preceding it in the sequence; and (b) all nodes and all lines are distinct (Wasserman and Faust, 1994, 105-111)

The matrix $\mathcal{G}$ can be divided into four quadrants as shown in Equation 9. The quadrants represent: the one-mode distances between actors (quadrant 1,1); the two-mode distances between actors and projects (quadrant 1,2); the two-mode distances between projects and actors (quadrant 2,1); and the one-mode distances between projects (quadrant 2,2). It must be noted that: (a) the one-mode geodesic distances obtained through this method are double the distances that would have been obtained if the algorithm had been applied to the one-mode affiliation matrices; (b) the distances in two-mode quadrants need to be transformed by substracting one before dividing by two, to account for the fact that an actor and a project to which it participates are still divided by one edge.

$$\mathcal{G} = \left[\begin{array}{ccccccc|ccc}
0 & 2 & 2 & 4 & 4 & 6 & 6 & 1 & 3 & 5 \\
2 & 0 & 2 & 4 & 4 & 6 & 6 & 1 & 3 & 5 \\
2 & 2 & 0 & 2 & 2 & 4 & 4 & 1 & 1 & 3 \\
4 & 4 & 2 & 0 & 2 & 4 & 4 & 3 & 1 & 3 \\
4 & 4 & 2 & 2 & 0 & 2 & 2 & 3 & 1 & 1 \\
6 & 6 & 4 & 4 & 2 & 0 & 2 & 5 & 3 & 1 \\
6 & 6 & 4 & 4 & 2 & 2 & 0 & 5 & 3 & 1 \\
\hline
1 & 1 & 1 & 3 & 3 & 5 & 5 & 0 & 2 & 4 \\
3 & 3 & 1 & 1 & 1 & 3 & 3 & 2 & 0 & 2 \\
5 & 5 & 3 & 3 & 1 & 1 & 1 & 4 & 2 & 0
\end{array}\right] \tag{9}$$

The quadrant of interest for our analysis is the topmost right quadrant (actor-project distances); this corresponds to the first n_a rows and to the last n_p columns of matrix $\mathcal{G}$. If we apply the transformation $(g_{i,j} - 1)/2$ on the elements of $\mathcal{G}$, we obtain a corrected geodesic distances matrix that we will call Γ, with dimensions $(n_a \times n_p)$:

$$\Gamma = \begin{bmatrix}
0 & 1 & 2 \\
0 & 1 & 2 \\
0 & 0 & 1 \\
1 & 0 & 1 \\
1 & 0 & 0 \\
2 & 1 & 0 \\
2 & 1 & 0
\end{bmatrix} \tag{10}$$

The elements $\gamma_{i,j}$ of this matrix represent the corrected geodesic distance between actor i and project j. This value varies between 0 (if actor i participates in project j) and the diameter of the network. If project j cannot be reached by actor i (which can happen in networks with separate components, hence with inifinite diameter), $\gamma_{i,j} = \infty$.

Table 8: Geodesic distances and payoffs

$\gamma_{i,j}$	$(\gamma_{i,j}+1)$	$max(0,-\gamma_{i,j}+1)$	payoff
0	1	1	$d^1 - 1c$
1	2	0	$d^2 - 0c$
2	3	0	$d^3 - 0c$
...			
n	$n+1$	0	$d^{n+1} - 0c$
∞	nd	nd	0

The payoff of individual actors and the social welfare generated in the network can now be calculated starting from the matrix Γ. We define a row vector $\mathcal{D}$ with dimensions $1 \times n_p$, whose elements d_i are the payoffs for actors who take part in project i; and a row vector $\mathcal{C}$ with dimensions $1 \times n_p$ whose elements c_i are the costs per capita c faced by actors that participate in project i. We can calculate a payoff matrix Δ with dimensions $(n_a \times n_p)$, whose elements $\delta_{i,j}$ are defined as follows:

$$\delta_{i,j} = \begin{cases} d_j^{(\gamma_{i,j}+1)} - max(0, -\gamma_{i,j}+1)c_j & \text{if } \gamma_{i,j} \neq \infty, \\ 0 & \text{if } \gamma_{i,j} = \infty \end{cases} \tag{11}$$

As shown in Table 8, the first formula links the actor-project geodesic distance to the costs and payoffs associated with direct and indirect links. The payoffs matrix $\hat{\Delta}$ calculated from the geodesic distances matrix Γ (Equation 10) for the hypothetical network in Figure 4 is given in Equation 12.

$$\Delta = \begin{bmatrix} (d-c) & d^2 & d^3 \\ (d-c) & d^2 & d^3 \\ (d-c) & (d-c) & d^2 \\ d^2 & (d-c) & d^2 \\ d^2 & (d-c) & (d-c) \\ d^3 & d^2 & (d-c) \\ d^3 & d^2 & (d-c) \end{bmatrix} \tag{12}$$

Starting from a payoffs matrix Δ, it is then possible to calculate the social welfare generated in the network, the payoffs obtained by each actor and the payoffs generated by each project as indicated in Table 9:

Table 9: Calculation of payoff terms from a payoffs matrix Δ

Payoff term	Symbol	Formula
Social welfare	Δ_{tot}	$\sum_{i,j} \delta_{i,j}$
Payoff for actor a	Δ_a	$\sum_j \delta_{a,j}$
Payoff generated by project p	Δ_p	$\sum_i \delta_{i,p}$

6 The Italian policy for Technological Districts

Italian Technological Districts (TDs) were established in 2002 by the Italian Ministry of Education, University and Research (MIUR) with the issuing of the Guidelines for Scientific and Technological Policy; the policy was further bolstered under the 2005 - 2007 National Research Programme (Programma Nazionale di Ricerca, PNR).[13] TDs are funded by the European Union (EU) as well as by central and local governments. MIUR estimates that nearly 500 million Euros of public funds have been distributed to TDs between 2004 and 2011, the majority of which came from the Italian government.

The TD policy aimed at addressing some well-known structural weaknesses of the Italian system of innovation, namely the low patent application rates of Italian firms, the inefficiency of public research institutions and the lack of technological transfer between universities, research centres and private firms . This approach is in line with the European Economic and Social Committee (EESC) strategy, which promotes TDs as one of the possible instruments that national governments can use to promote the development of knowledge-based economy by strengthening the exchange between technological research and local industrial development. TDs intend to combine the advantages of spatial agglomeration of high-tech activities (knowledge spillovers, creation of specialised labour and services), with the advantages of establishing networks (such as sharing the costs and risks associated with R&D). Starting from the technological specialization of a specific area (in many cases defined at the sub-regional scale), TDs should be able to trigger

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[13] According to the National Research Programme (2005-2007), TD are defined as “aggregations, on a geographic base, of firms, universities and research institutions, led by a specific government body and focused on strategic technological sectors, that are able to reinforce the competitiveness of the territories and, at the same time, that are strictly connected with existing excellences in other geographical areas of the country” (authors’ translation).

a virtuous process between research and industry, thereby leading to the development of scientific skills of importance even at the international level To date MIUR has recognized 29 TDs; about half of them (14) are located in the South of the country (the so-called Mezzogiorno), which is identified in the policy as a high-priority intervention area.[14]

The geographical distribution also reflects a certain degree of sectoral specialization: while districts in ICT, biosciences and biotechnology are distributed throughout Italy, southern districts specialize in agro-food and logistics. The creation of a public TD entails a complex decision-making process involving a diverse range of actors. The process is initiated by local governments (usually regional authorities)[15] which, through their joint action with other local stakeholders (firms, universities, financial institutions, etc.), identify an industrial sector, locate the actors that will participate in the future district, and take steps to obtain public funding. The composition of the districts is rather heterogeneous in terms of participants, and they generally involve private firms, public research institutes (universities and National Research Council institutes), private research centers and public administrations (regions and provinces). In addition, there is the presence of financial institutions (mostly banks and so-called banking foundations) and trade associations, especially chambers of commerce. This heterogeneity appears as a direct consequence of the policy design, whose aim is to promote cooperation among many different, yet complementary, organisations to enhance and promote knowledge transfer.

Given that the overall aim of the policy is to promote the creation of innovation networks among diverse actors, a key factor for its success concerns the management of the TDs itself. Innovative networks are not easy to control because of the dynamism and heterogeneity of the various actors that make up these networks. A well-defined organisational and management structure is therefore required; this formal governing body , created ad hoc, is responsible for the management and coordination of the TD and of the activities it performs.[16] The governing body plays a decisive role in setting out a common policy for the various stakeholders which, by their very nature, bring divergent objectives to the district thus causing agency problems (Wincent et al. 2012). In particular the governing body may perform a function of coordination and orientation in the formation of partnerships for

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[14] Following a MIUR proposal, the setting up of new TDs in the south was funded with 140 milion Euros by the Interministerial Committee for Economic Planning (CIPE) with Resolution 20 December 2004. The remaining districts are distributed as follows: 5 in the North-West, 5 in the North-East and 5 in the Centre. The regions with the largest number of districts are Sicily, Lombardy, Puglia and Lazio, each of which hosts three districts.

[15] Italian regions ("regioni") are administrative entities classified at the NUTS2 level.

participating in research projects.[17]

Belonging to a TD does not necessarily imply that a firm participates in a joint R&D project. In addition to fostering cooperation among members, TDs in fact also provide high-level training, support and assistance for start-ups and special financial support essentially in the form of venture capital. some firms may therefore join a district because they are interested in these ancillary services rather than in R&D cooperation.

The aim is to identify and discuss some positional network measures that might prove helpful in evaluating TD networks performance. The TDs we selected are all part of the ADITE meta-district, that pulls together several among the most prominent TDs established in Italy. In order to establish a useful conceptual framework for the evaluation of the TD policy – particularly of its relevance for the development of the South – we conducted an exploratory analysis on seven among the most important TDs recognised by the MIUR. For each district, we collected information about the participation of TD members and partners to the R&D projects undertaken during the period 2005-2010. Data on project participation and member lists were collected from the MIUR website and are updated to December 2011. Financial data on private and public contributions received by each project were collected from the OpenCoesione database.

Project participation data are inherently relational but, since we are not able to observe the nature of the interaction taking place between actors, we need to formulate some hypothesis about how the actors involved in an R&D project interact. As explained in Section 3, we assume that all participants to the same project are connected to each other. Starting from this assumption,

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[17] The governance authority or governance body, responsible for the management and coordination of the district and relative activities, is usually a cooperative society or foundation whose members are also members of the district.

[17] In this regard we can distinguish two main governance models implemented in Italian TDs: a market oriented model and a hierarchical model (Ardovino and Pennacchio, 2013). In TDs with a market-oriented governance model, R&D cooperation is the outcome of the spontaneous actions of the various actors, who predict the trends regarding the research activity, support government authorities in the planning of public financing to R&D and sponsor research projects themselves. In TDs operating with a hierarchical logic, the choice of actors to involve in projects is chiefly guided by the specific will of the governing body. Such districts represent knowledge integrators that design and develop specific network mechanisms to promote links between scientific research and companies, selecting organizations and promoting partnerships with the aim to direct the trajectory of development. The Article of Association of TDs makes explicit reference to the greater or lesser responsibility of the governance authorities in their intermediation role in partnership network formation. The choice between the two models can be related, among other things, to the degrees of interpersonal and interorganizational trust that characterize each region.

we used project participation data to construct the R&D cooperation network established within the sampled districts.

In terms of their nodesets, the networks in our sample are characterised by a common feature: on average more than 80 per cent of the participants (nodes) are private firms or research centres. Financial and public organizations are mainly present as co-financers; in our sample, only two per cent of them were involved in R&D projects with an operative role. The composition in terms of types of organizations shows a certain degree of heterogeneity in participation share. Looking at geographical differences, a greater involvement of firms is observed in northern districts than in southern districts; in the latter, a higher number of public organizations are involved.

Table 10 provides the main descriptive statistics about the two-mode networks (project by actors) established in the TDs. We focus more specifically on four network-level indicators: network density, centrality, betweenness and centralization. Methodologies draw from SNA have been applied to these cooperation networks in order to calculate the indicators that, according to the literature review presented in the previous sections, appear to be the most relevant for the analysis and evaluation of innovation policies. Table 11 shows, for each TD in our sample the basic characteristics of the TDs cooperation networks.

Table 10: Basic characteristics of the TD networks (two-mode)

	Dhitech	RDlog	Imast	TWireless	CBM	Veneto Nanotech	Siit
Region	Puglia	Calabria	Campania	Piemonte	FVG	Veneto	Liguria
Macro-region	South	South	South	NW	NE	NE	NW
Projects	7	7	15	10	10	10	7
Actors	25	31	49	73	63	135	66
Actors/project	2.71	6	4.93	9.6	6.7	11.7	14.9
Active nodes	48%	77%	76%	86%	78%	75%	83%

Table 11: Positional indicators for the one-mode TD partnership networks

	Dhitech	RDlog	Imast	TWireless	CBM	Veneto Nanotech	Siit
Nodes	25	31	49	73	63	135	66
Edges	22	102	122	513	237	1126	830
Avg degree	1.76	6.58	4.97	14.05	7.52	16.68	25.15
Density	0.073	0.22	0.1	0.19	0.12	0.12	0.38
Betweennes centr	0.021	0.16	0.14	0.12	0.19	0.23	0.04
Degree centr	0.15	0.51	0.39	0.45	0.32	0.22	0.45

Table 10 shows that network size (the number of nodes in the network) differs widely across TDs, ranging from 25 actors in Dhitech to 135 in Veneto

NanoTech; differences are evident across Northern and Southern TDs. This is probably due to the fact that southern TDs have a larger share of large firms than Northern TDs. However, if we look at the level of actors' involvement in R&D projects (as measured by the share of active nodes reported in Table 10, the differences among districts become gradually blurred except for Dhitech in Puglia region.

Table 11 shows the positional indicators calculated for the TDs networks. Average degree (the mean number of connection of nodes in the network) is higher in northern TDs than in southern Italy. If we interpret average degree as a measure of the capacity to transmit information between participating organizations, northern TD would seem more able to share information than southern TDs. On the other hand, average degree is not a measure of the efficiency to transmit information because it tends to increase with the number of partecipants. Network density could be a more correct measure of the efficiency to transmit information because it is normalized by the number of nodes: network density is positively linked with the average degree and inversely correlated with the number of partecipants:

$$\text{network density} = \frac{\text{average degree}}{N-1} \tag{13}$$

With the exception of R&D Log, network density is lower in southern TDs than in northern TDs. Therefore we could say that northern districts are more efficient than southern district to transmit information. If we consider only northern TDs, Siit is the more efficient in transmitting information looking at its average degree and network density. It could be interesting compare the efficiency to transmit informations in the case of three northern districts (TorinoWirless, CBM and Veneto Nanotech) that have the same number of projects (10). In this case, the efficiency to transmit informations is higher in the Torino Wirless network.

If we consider the indicators of centralization (network betweenness and degree centralization) which are related to the presence of prominent nodes, it is not possible to distinguish a clear macro-regional pattern. The social network indexes help us to evaluate efficiency in trasmission information and the stability of the network but they are not able to answer the questions on the efficiency of a policy toward innovative networks. The case of the R&D Log district in Calabria is very indicative of this problem R&D Log shows high values across all networks indices (see Table 11); in particular, it has the highest values for network measures among southern TDs. Moreover, for betweenness centrality and degree centralization, it shows higher values even compared to three of the four Northern districts. If we look only at the networks indices, the consideration about the district can only be positive.

But how can it be explained that this is the only district in our sample in liquidation? Perhaps, this is the case because the high amount of financial incentives has stimulated the creation of inefficient links. It is likely that the opportunity to fully take advantage from public financial incentives has attracted the participation at the district of “free riders” with a lack of skills and expertise, leading to research projects that could hardly have implications in terms of market. The district has seen a decrease in the number of shareholder members, both for the bankruptcy of some of them and for its inability to raise the interest of other companies, at local, domestic or international level.

The considerations that we have done regarding the use of social nework indexes to evaluate the efficiency of policy toward innovative networks further confirm the opportunity to find a methodology that could help to evaluate the welfare produced by different networks. In the next section, we will re-evaluate the performance of two TDs using the methodology proposed in this paper.

7 Payoffs and social welfare in two Technological Districts

We now apply the methodology for the calculation of payoffs based on geodesic distances to two real-world networks. The cases analyzed here are two R&D collaboration networks created in two Italian Technological Districts, Dhitech and R&D Log. In both cases, the networks was generated from two-mode affiliation matrices recording the participation of actors to R&D projects activated in the two TDs.[18] Data on the amount of subsidies received and on the total costs of each project were also available. For each of the j projects activated in a TD, we calculated the following values:

1. $Ctot_j$: the per capita cost of project j, obtained by dividing total project costs by the number of participants;
2. $Cpub_j$: the per capita public subsidy given to project j, obtained by dividing the total subsidy given to the project by the number of participants
3. $Cpriv_j = Ctot_j - Cpub_j$: the per capita private-born cost of project

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[18] Only active members (i.e. members that participate in at least one project) were included in the nodeset. For this reason, node numbers given in Table 12 do not match those provided in Tables 10 and 10.

Within each TD, the three values above have been normalized with reference to the project with the highest total cost $max(Ctot)$. In order to calculate the payoffs, we had to make some assumptions regarding the values of d and c, since their true value is not known. As explained before, we assume that the value of d is *at least* equal to the amount an actor is willing to contribute towards project costs. We also assume that each actor equally participates to the total private contribution for project j, indicated above as $Cpriv_j$. The values for d and c were calculated as reported in Equations 15 and 14. The values d_j can be said to represent a minimum threshold, and the real (unknown) value of d is above this level.

$$c_j = \frac{Ctot_j}{max(Ctot)} \tag{14}$$

$$d_j = \left(\frac{Cpriv_j}{Ctot_j}\right) c_j \tag{15}$$

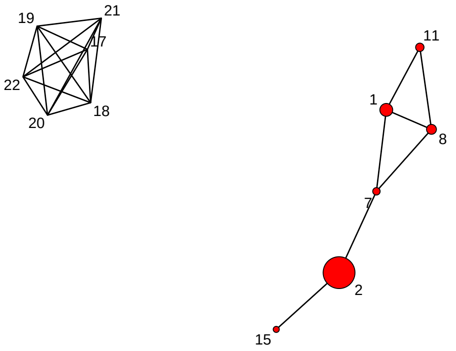
Results obtained by applying Equation 11 are presented in Table 12, alongside some descriptive network statistics for the two TDs. The results are also graphically reported in Figure 5, where node size is proportional to the (negative) payoffs obtained by each actor. The two networks are quite different. The Dhitech network is smaller, involving only 12 actors as opposed to the 25 actors of RDLog. Dhitech is also considerably less dense than RDLog, although the latter has fewer projects; this implies that on average projects in RDLog tend to involve more actors.

From a structural point of view, differences are even more striking. The RDLog network is connected in on giant component, with two highly prominent nodes acting as "bridges" between two otherwise separate groups of nodes. Dhitech is instead disconnected into two separate components, and the relevance of its nodes is somehow more balanced; this can also be seen by the rather different indicators for centralization in the two networks.

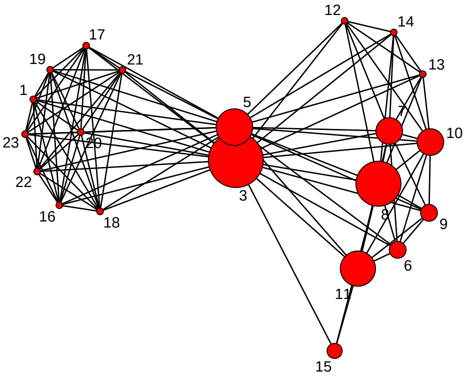
Notwithstanding these differences, in both cases social welfare (total payoff) is negative; even accounting for indirect effects, the subsidized projects do not increase total welfare in the network and need not to be financed. It is clear that these results depend from the way we have estimated the value of d and c; a knowledge of the true value of c_j and d_j would have given different results. Even with these limitations, our methodology suggests that the results obtained in the two networks are quite different. RDLog appears to have achieved much worse results both in terms of total (negative) payoffs, as in terms of individual payoffs. Although the average level of subsidy received in Dhitech is about half that reported for RDLog, the losses of social welfare in Dhitech appear to be only one quarter of those generated in

Table 12: Payoffs in two Italian TDs calculated through geodesic distances

	Dhitech	RDLog
Actors	12	25
Projects	8	6
Edges	22	31
Median actors/project	2	2
Mean actors/project	3.7	4.9
SD actors/project	2.2	5.3
Density (two-mode)	0.23	0.37
Degree centralization (normalized)	0.22	0.39
Strong components (one-mode)	2	1
Triad census (one-mode)		
Null	49	150
One edge	144	673
Two edges	5	237
Three edges	22	270
Project costs and benefits		
Mean c_j	0.32	0.69
SD c_j	0.32	0.23
Mean d_j	0.09	0.1
SD d_j	0.15	0.12
Payoffs		
Social welfare (Δ_{tot})	-3.1	-13.9
Mean payoff per actor (Δ_a)	-0.25	-0.66
SD payoff per actor	0.36	0.59
Correlation degree-payoffs	-0.71	-0.96



(a) Dhitech



(b) RDLog

Figure 5: Payoffs (negative) in the two TD networks

RDLog.[19] Furthermore, per capita negative payoffs in RDLog are strongly concentrated in the bridging actors that connect the two separate components, and in the group of actors on the left-hand side of Figure 5b. In the Dhitech network, the distribution of payoffs is somehow more egalitarian, with only one prominent node in the tail of the right-hand side component (as can also be observed in the values of standard deviations for individual payoffs). Importantly, actors in the densely connected left-hand component have achieved moderately positive individual payoffs. In general, we would conclude that RDLog has performed much worse than Dhitech from all points of view. Indeed, this has been the case and, as already mentioned, RDLog in currently the only TD in liquidation.

8 Conclusions

Our analysis has shown that SNA could be helpful to evaluate the efficiency of transfer of information in different networks, but that it does not allow a clear evaluation of the policy toward innovative networks. The reason is that such indexes does not allow to measure the welfare effects of these policies. A second aspect shown in our paper is that, if one wants to evaluate the welfare produced by a policy toward innovative networks, one must consider not only direct but also indirect effects on the participants of the networks.

In our paper we have developed a methodology to evaluate welfare determined by direct and indirect effects. The problem is that this methodology requires information about the returns of the projects and the cost to transfer information in a direct way that often are not common knowledge. On the other hand, our methodology has allowed to establish the conditions under which a policy toward innovative networks is additional and when is not additional and it is only a waste of resource. This methodology also allows us to explain why empirical papers have given conflicting answer to the question if public R&D is complementary and thus additional to private spending and increases welfare, and when it instead is a substitute for private R&D or when is not substitute but it is inefficient.

Many papers analyse differences in firms performance comparing firms that are involved in TDs with firms that are not involved in innovative networks.[20]Using matching techniques and difference-in-difference methods, some papers find clear evidence that firms involved in innovative networks perform better than other firms and other papers do not. An implication of our methodology is that also if treated and not treated sample considered in

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[19] Both indices are normalized by the value of the largest financed project in each network.

the empirical works share the same characteristics, one does not find input or output additionality because the financed projects ex ante did not satisfy the conditions to be financed (Case 1 in Table 6). In other situations (Case 2 in 6) we expect to find additionality because such conditions are satisfied. In other situations (Case 3) it is possible to find additionality but the project are not welfare enhancing. The problem is that, in order to interpret ex post results, we must also consider the ex ante conditions of the financing and this is done very rarely.

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[20] Bertamino et al. (2012) find for example that for southern firms involved in TDs there is an increase in the volume of business activities, but this result must be treated with caution because of sample size (approximately only 50 small firms). However, these types of analysis focus on individual firms, leaving aside the presence of indirect positive effects on firms absorptive capacity as consequence of the creation of long-lasting cooperation relationships, but this aspect regards long term analysis.

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