Issues on the policy to implement innovative networks

Carlo Capuano
Alfredo Del Monte

Dipartimento di Scienze Economiche e Statistiche
Università di Napoli Federico II

October   2013

54° Riunione Scientifica Annuale della SIE
Bologna 24-26 ottobre 2013

Summary

In this paper we have examined the conclusions of different approaches about the effects of a policy to subsidize Innovative Networks (NPP policy). The implications of the I-O literature is that, if the objective government function is to subsidize only efficient network structure that the market would not spontaneously realize, in many cases a NPP policy is not appropriate because cooperation will be spontaneously realized. On the other hand the implications of social networks approach is that, if there is perfect information and firms do not behave strategically, a NPP policy could be needed in sectors where codified knowledge is or low or high. Conversely, sectors characterized by an intermediate level of codified knowledge do not need NPP policies because market gives incentives for the creation of a stable network. The same happens if codified knowledge is either very low or very high and an NPP policy could be a waste of resource.

In the previous approaches coordination costs and the problems of the complementarity of resources of different partners are not specifically considered. Therefore we have proposed an alternative approch that analyzes the case in which the research costs of a project could be shared by firms that cooperate. Even thought we do not consider explicitely the problem of strategic behaviours, in such approach the research cost of the project decreases higher is the complementarity of resources of cooperative partners. Furthermore as the numer of partners increases, the costs of the project is shared by an higher number of firms and therefore it decreases for any single enterprise. This happens in a context where the coordination costs of each firms increases with the number of partners and the total cost of each firms first decreases and then increases. Also the revenue curve of each firms is affected by the number of partners .If entreprises are in not homogeneous markets the revenue of each firms does not decrease very quickly as the number of cooperative partners increases. But if they are in homogeneous markets their revenues decreases very quickly as the numbers of cooperative partners increases because they must share the advantage of the technical progress with firms that operate in the same market. This approach shows that in many case R&D cooperation increases profits of the partners and social welfare but only in a limited number of case a subsidy to R&D cooperation is welfare enhancing. In the last case a NPP policy could be useful if (a) the fixed costs of the project is higher than total revenue when the projects is realized only by one firms; (b) the total cost curve of each firms decreases at an higher speed than the revenue costs as the number of partners increases and (c) the difference between the slope of the two curves are not very high.

In last part of the paper we have extended our analysis to differentiated oligopolies where firms invest for increasing the quality of the produced goods enhancing endogenously the level of differentiation too. We characterized scenarios where given the level of resource complementarity public subsidy are not needed since welfare improving networks are spontaneously created and we compute the optimal dimension of networks. Moreover focusing on the problem of observability of investments in network we stress a different role to public intervention finalized just to verify effectual cooperation and avoid some types of free ridings.

JEL Classification: O30, O32, L13.

Keywords: Innovative Networks; Government Policy, R&D cooperation.

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 policies to create innovative networks started. Such policies are based, either in the design and decision phase or in the implementation phase, on a network of agents who concur in the policies. The purpose of this paper is to analyse the conditions under which these policies could be successful.
Two are main aspects to be considered. The first one is that a subsidized network must be an efficient network. The second one is that the network must be additional. One must evaluate if subsidies allow creating a network of innovative firms that without subsidies would not existed or if existed the characteristic would be different and economic results weaker.
Two are the main sources of the literature to analyze the implementation of the policy to promote innovative networks. One is the theoretical industrial organization literature that has explored the private and social benefits of R&D collaboration and the other is the social network literature that has analyzed the start and evolution of networks as result of the cost and benefits analysis of actors to establish and maintain network ties.

2 **Efficiency and innovative networks in the IO literature**

.
Theoretical IO literature has shown that R&D activities suffer from three sources of market failure: externalities, indivisibilities and uncertainty. Cooperative R&D venture could alleviate such problem because:

(a) It allows sharing knowledge about new technology (cost reducing technology, technology related to new products);
(b) It avoids the duplication of fixed costs;
(c) It allows, if firms are not symmetric, the advantages of strong complementarity of R&D activities.

Ttheoretical IO literature has built models of research joint venture, RJV, that share the characteristics a group of firms pool resource to conduct a R&D project that will lead to a technology that each firm will use independently and that there is no coordination on production and price decisions.

Theoretical IO literature has shown that a Joint Research Venture (RJV) in which firms not only coordinate their decisions but also share their information completely so as to eliminate duplication efforts yields superior performance compared to non-cooperative for all possible criteria: propensity of firms to invest in R&D, firms profit, consumer surplus, social welfare. Such literature (Katz 1986, D'Aspremont and Jacquemin 1988) has also proved that high spillovers, low product market concentration, low direct competitions between the actors, facilitate cooperation in R&D. These results have been generally obtained in a situation of duopoly. There are not many works that analyse R&D networks (Goyal S. and Moraga Gonzales J., 2001; Amir R., Evstigneev I. and Wooders J., 2003).
The most important feature of the theoretical model of innovative networks that we find in the I-O literature is the following: *rival firms often exert positive externalities on one another through their research activities*. The formation of cooperative R&D ventures allows firms to internalize their externalities.

When the number of firms that could cooperate is higher than three it is possible to have different typology of networks (empty star, intermediate cooperation, complete) and therefore is important both for an ex ante and an ex post evaluation of the policy to have a criterion that allow to ranks the different typology of networks in relation to their efficiency and stability. It would be therefore possible to evaluate if a network that started as effect of a specific policy is efficient or not. Interesting results for the evaluation of a policy to promote cooperation in R&D could be deduced by the work of Goyal et al. (2001). This model consider an oligopoly with (ex ante) identical firms. In collaboration network firms choose a (costly) level of effort unilaterally, aimed at reducing production costs. Given these cost the firms operate in the market by setting quantities. Two types of market interactions are considered, in one firms operate in independent markets, while in the second they compete in a homogeneous product market. When symmetric network (every firms has the same number of collaboration links), is considered the paper shows that if firms operate in independent markets every pairs of firms has an incentive to form links, and the complete network is the unique stable and efficient network. On the other hand when firms operate in the same market aggregate profits are the highest for an intermediate level of collaboration. The paper shows that in this last case industry-profit maximizing symmetric networks exhibit an excessive level of collaborative activity from a welfare viewpoint. The empty and the complete networks are not socially efficient and there is some intermediate level of collaborative activity for which social welfare is maximized. Due to analytical problems the asymmetric network is analysed only for n=3. The paper shows that empty network and star networks are never stable. On the other hand the partially connected network always dominates the complete network in terms of social welfare. The partially connected networks is efficient in the interval 0,B* where B is the spillover parameter.
The empty network is efficient for all B* € (B*,1).
The policy implications of the above analysis are quite interesting. As shown in Table 1, a network public policy (NPP) is appropriate if it allows reaching an efficient network structure that the market would not spontaneously allow. If there are profit incentives that allow the market to reach an efficient and stable network equilibrium there no need of a NPP. In the Goyal et al. (2001) model when firms are operating in independent markets, in the class of all networks symmetric as well not symmetric, the complete network is the unique strategically stable equilibrium. In this situation a NPP policy is not appropriate.

When firms operate in a homogeneous market in the class of symmetric networks there are higher benefits under collaboration networks that under empty networks but industry-maximizing symmetric networks exhibit an excessive level of collaborative activity from a welfare point of view. The complete network is stable, as is consistent with individual incentives, but it is not welfare optimal. Intermediate level of collaboration allows maximizing industry profits but exhibiting an excess level of collaboration activity from a welfare point of view. Welfare is maximized under an intermediate level of collaboration different from the previous one. Under the above assumption a NPP policy is not necessary as firms will spontaneously tend to collaborate .On the other hand such policy could be useful to reach the optimal level of intermediate collaboration. But this is very difficult to implement. Therefore one could say that a NPP policy for symmetric networks is generally not appropriate as firms will collaborate in any case.

Table 1 – Spillovers, Structure of the Markets end Public Policy (Goyal et al., 2001).

	Value of spillover of parameter		Markets		Typology of the network		Public Policy NPP
	High	**Low**	**Independent**	**Homogeneous**	**Efficient**	**Stable**	
Symmetric network	X	X	X		Complete	Complete	NO
	X	X		X	Intermediate	Complete	YES but difficult to implement
Asymmetric network	X	X	X		Complete	Complete	NO
	X			X	Empty	Complete	NO
		X		X	Intermediate	Complete	YES but difficult to implement

In the case of asymmetric networks for a high value of the spillover parameter the empty network is efficient and therefore NPP policy is not appropriate. For a low value of the spillover parameter the partially connected network is efficient, and firms have incentive to form a partial connected collaborative level also if the value of this level is not necessarily the same corresponding to the welfare maximizing network. From these results we could say that a NPP policy is in general not appropriate.

IO theoretical models lead to the conclusion that R&S coordination in most case yields on a superior performance compared to non cooperative case and that lower is the value of the spillover parameter higher the advantages of cooperation. Goyal et al. (2001) has also shown that R&D networks will be created spontaneously by the market and only in few cases the network created by the market is no welfare enhancing. Therefore under the hypothesis considered in these models (no opportunistic behavior, zero cost of transactions, certainty about the effects of R&D) a NPP policy must be adopted only in few cases and also in these cases the difficulty to implement the NPP policy must make politicians very careful to propose them.
If one assumes lack of trust between firms and /or high level of uncertainty about the return of R&D expenditure, and /or high cost of coordination, arguments in favors of a NPP policy could be proposed. In this case the problem is what kind of public policy to choose. A mild choice is when

public authorities choose and coordinate different firms to create joint projects but there are not specific (fiscal or financial) incentives .The presence of public authorities could increase the trust between firms and reduce the risk of opportunistic behavior. In other cases, as in the defense industry, Cohen (1994) shows that the main incentive could be on the demand side. Public authorities would buy products of the R&D joint ventures.

A more interventionist policy is to give special subsidies to projects of firms belonging to R&D joint ventures .This policy is supported by the paper of Yi and Shi (2000) that maintain that only with a subsidy we could insure the stability of R&D joint ventures. Arguments against a subsidy to R&D joint ventures are similar to those used in other cases. Subsidies could be used to increase other expenses (i.e. wage of R&D workers) not useful for a productive R&D (Reinthaler and Wolff, 2004). Subsidies could determine a distortion in the use of production factors .A further problem is that is very difficult that a public authority is able to distinguish between a R&D joint venture that spontaneously would be formed and one that starts as effect of the subsidy .In this last case there is the further problem to decide if the R&D joint venture is welfare enhancing or not.

Summing up we can conclude that theoretical IO models do not help very much the implementation of a NPP policy. In the following section we will examine the conclusions a different approach based on social network analysis.

3 Social network analysis and innovative networks

There are many differences between the IO approach and the social network approach (SNA) to innovative networks. The models considered in the previous section have focused on the effects of spillovers on the typology of networks, on R&D expenditure, on profits of firms and industry and on social welfare. Firms produce knowledge and transmit this knowledge or through direct partnership or through spillovers. In the IO models the informal transmission of knowledge has a negative effect of the profits of the firm. If there are spillovers, an increase in the R&D efforts of firm i decreases not only costs of firm i but also costs all other firms of the network. Such effect has a negative impact on R&D effort of firm i. If such spillovers are internalised through cooperation profits and welfare could increase. Therefore there is a positive relationship between the level of spillover and the probability of R&D joint ventures.

A different approach, that we will call social network analysis of innovative networks (SNA) is based on the idea that production and transmission of knowledge are strongly interrelated. Innovation capabilities result from the formation of mutually reinforcing inter-organizational relationship between key actors involved in innovation process (Daniel and Metcalf, 2007). Such relationships are very important to produce learning process that consequently stimulates production of knowledge. Network studies (Powell, 2006; Uzzi 1996) show that the presence of collaboration networks among different typologies of actors, with different competencies, is very important to create value and innovation. Therefore in network literature heterogeneity of actors and learning process caused by interrelationship are very important features.

The SNA approach considers also that relational ties could be based on contractual or market considerations, or on less formal relationships such as common membership in a technology community or a regional economy. The main concepts to analyze inter-firm networks are extrapolated from interpersonal relations. A first distinction is between strong and weak ties (Grannovater, 1973). In interpersonal terms a strong ties is a person you interact with on a regular basis, while a weak ties is an acquaintance, or a friend or a friend of a friend. In inter organizational terms and strong ties are the formal ones and informal ties the weak ones.

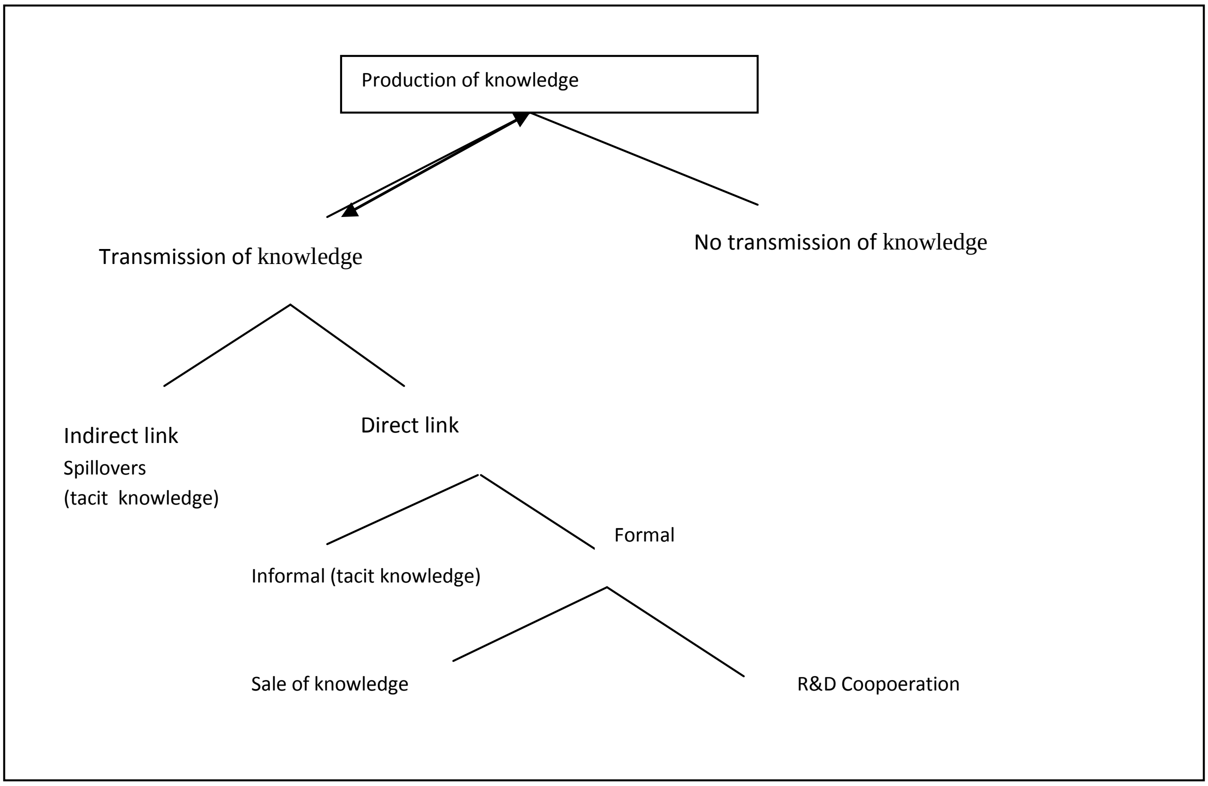
A formal agreement between two firms determines a direct links. Indirect relationship happens where a first actor (firm) is directly connected to a second one that is directly connected to a third, then the first and the third are indirectly connected and, without any formal agreement between the two, we observe some knowledge exchange. Another aspect discussed in the network analysis concerns the characteristics of transmission of knowledge between actors.

Knowledge could be differentiated in explicit knowledge and tacit knowledge. Explicit knowledge is highly certified as in blueprints, recipes, manuals or in the form of training. Formal contractual relations (i.e. subcontracting relationship strategic alliances or participation in research consortium ties) allow the production and the transfer of explicit knowledge. Tacit knowledge lacks this kind of codification. Personal contacts, that arise as a consequence of a common membership in a professional or trade association, or to affiliation to other kinds of community, allow the transfer of tacit knowledge.

The distinction between the two types of knowledge is important because the cost to transfer different types of knowledge could be different. Many studies point to the relative transferability of explicit knowledge in contrast to tacit knowledge (e.g. Powell and Grodal, 2006). These authors hypothesize that when knowledge is highly codified the transfer is inexpensive and the gains are small. Tacit knowledge demands considerably more trial and error learning to apply in different context. When knowledge is very sticky (Von Hippel, 1998) and has a large tacit component the cost of transfer could be high. Consequently the expected gains realized from this information are uncertain, as the cost of obtaining may exceed its value. Powell and Grodal (2006) suggested an inverted U relationship between innovation and codification. The cost of knowledge transfer increases with the degree of knowledge codification, reaches a maximum for intermediate degree of certification and then decreases as the degree of codification increases. Therefore the cost of transferring knowledge depends on the type of knowledge transferred. On the other hand the cost of production of new knowledge could increase with the degree of codification and therefore the advantage of collaboration (direct ties) could increase.

Empirical studies confirm the importance of direct and indirect ties. A study by Ahuja (2000) shows that both direct and indirect ties have a positive influence on innovation, though the impact of indirect ties is smaller than the impact of direct ties. In their survey on innovative networks Powell and Grodal (2006) sustain that both direct and indirect ties have positive effects on innovation but that the effect of indirect ties is moderated by the prevalence of direct ties. In manufacturing and in many high tech sectors as biotechnology and semiconductors, the number of patents is positively linked with formal (direct) link. Such studies show that success collaboration R&D alliance are based on formal and informal ties but that the benefits of the first one is much higher than the benefit of the second one.

Figure 1 – Production, transmission of knowledge and typology of links.



In Figure 1 we have summarized the previous discussion. A firm j produces a given knowledge as effect of its effort. Such knowledge could be transmitted or not. If it is not transmitted, it gives to the firm j some monopolistic power. The transmission of knowledge could be voluntary or involuntary as effect of direct link and indirect links. In this last case the firm j will get no profit from this transmission. The firms that receive free this knowledge will get benefits (these are the so called "spillovers effect") at zero cost. In this case the effect of incentive of firm j to spend in R&D will be negative.
The transmission of knowledge could be the result of formal links. Two are the main mechanisms of transmission. In the first one the firms through contractual agreement, generally expensive for the receiving firms, transmit their knowledge. In other cases there is a mutual exchange in the transmission of knowledge. As effects of cooperative joint projects and of a division of labor in the production of knowledge, both firms produce a knowledge that transmits mutually.

Actor's heterogeneity and different characteristics of the relationships are the main aspects of models of innovative networks proposed by SNA and determine different results from that obtained by IO models. In the previous models of IO the indirect transfer of knowledge is seen as disincentive for the single firms to invest in R&D and an incentive to consider formal agreement to cooperate. SNA, on the opposite, considers the possibility that networks arise as effect of formal ties but stresses on the benefits of indirect effect for the creation of networks. While formal links are very important for the production of knowledge, informal links could be very important for the

transfer of knowledge. The effects of innovative networks on technology progress therefore are not only linked to the production of technology but also to the transfer of technology.[1]
Unfortunately the different characteristics of SNA model are not easy to be formalized. In the next section we will consider a model based only on some of these aspects and we will see what is the prescription for NPP policy derived from this model.

4 A simple SNA model of R&D cooperation and public policy

Analytical models based on some hypothesis of social networks could be used to analyze the impact of firm cooperation. In particular, a simple model of social connections has been developed by Jackson and Wolinsky (1996) and Jackson (2009). 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.
Other models, with quite similar characteristics, have been developed by Doreian (2006). These models have been used to explore the nature of the equilibrium of ties and the shapes of the networks in equilibrium. In any case such models could be used to analyse some specific aspects of innovative networks and to deduce some policy considerations .

According to Jackson--Wolinsky model, we consider a context where $n \geq 3$ firms (actors) create collaboration agreements that represent the direct links of the network. Collaboration agreement between firms (direct link) offers benefits in terms of informations, etc., and involves some costs. A firm could get benefits if collaborates with a firm that already collaborates with a third firm (indirect link). Firm i and firm j, and firm j and firm k have a collaborative relationship. Firm i and firm j, and firm j and firm k have a direct benefit from such collaboration. But i and k because of these relationships whith firm j have an indirect benefit too.

The Jackson--Wolinsky model assume that the value of the direct benefit is $d \in (0,1)$, and the benefit of the indirect effect deteriorates with the distance of the relationship. The simpler hypothesis is that d is raised to higher power for more distant relationship.

We start with the star network typology. A star network of $n \geq 3$ firms is characterized by the presence of a central node, the so-called *trustee*, labelled with A, that, directly connected with all the others, receives and sends information from/to all the $n-1$ peripheric nodes, the so-called *trustors*. In a star network, any couple of nodes is linked by at most two links (a direct link and, eventually, an indirect one). The role of the trustee is crucial for the network: without this node, no network exists. Since we expect that the benefit from a direct (formal) link, $d \in (0,1)$ is always higher than the one from an indirect (informal) one, $d^2 < d$, because codified knowledge could be trasmitted in a more precise way than the not codificed, and that only direct links are associated to

[1]Some authors have used the richer typology of links to introduce different definitions of innovative networks. A typology based on two dimensions has been proposed by Powell-Grodal 2006 varying from open, episodic or fluid to recurrent, dense connections among a fairly closed group (Grannoveter, 1985), and degree of purposiveness ranging from informal to contractual. The two dimensions allow describing 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 determines 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) are associated with formal, direct, strong ties and with explicit knowledge.

sending cost, c>0.

The payoffs of trustee and trustors in in a star network are the following:

$$I_A(n) = (d-c)(n-1) \quad (1)$$
$$\forall b \neq A,\ I_b(n) = (d-c) + d^2(n-2) \quad (2)$$

While, the aggregate net benefit of the network is:

$$BS = I_A(n) +_{b\neq A} I_b(n)$$
$$= (n-1)(2(d-c) + d^2(n-2)) \quad (3)$$

We consider now a complete network. In this case each player is directly connected to any other player. Firm benefit inside the network is

$$\forall i, \quad I_i(n) = (d-c)(n-1) \quad (4)$$

while the total benefit of the complete network are

$$BS = (d-c)(n-1)n \quad (5)$$

It is possible to have also other kind of network structure but, given the hypothesis of the model, it is possible to characterize the set of efficient in the following way:

(1) Costs are so low that it make sense to add all links (complete network)
(2) Costs are so high that no links make sense (no network)
(3) Costs are in the middle range; efficient architecture is a star network that minimizes the number of direct links..

As shown in Table 2, in Cases 1 and 2 a policy to promote a network, if there is perfect information and not strategic behavior of the players, is not necessary. Firms will collaborate spontaneously. In Case 3, $c > d$ and c is not too high relative to d ; the efficient (star) network is not stable, because the center firms gets only a marginal benefit of $d - c < 0$ from any of theses links. This is the only situation in which a public policy to promote a networks of firms is efficient. In Case 4 networks are not efficient. Therefore a public policy to create a network is a waste of resource.

We will use a very simple scheme that starts from the results of Table 2 to show the differences in the relationship between the value of indirect ties (spillover) and the typology of networks under the two aproaches .

In the IO approach an indirect link has a negative impact; if d> c, higher is the value of the indirect link higher the probability of creation of a complete network. When d < c, it there are no private incentive to create any kind of network also if it is efficient. In this situation NPP policy could be welfare enhancing

.

Therefore one could say the IO approach offers more cases in which a NPP policy is useful than the SNA approach. In the SNA approach the benefit of two agents directly connected is increased if they are indirectly connected with other agents. If the direct benefit d is higher than the cost c to maintan the direct link the agents are interested to cooperate. For low value of the indirect link there will be incentives to create a complete network. As the value of the indirect link increases there is an incentive to create a star network, that is stable and efficient. If the cost to mantain the direct link is lower than the direct benefit, d<c ,for low values of the indirect link there is no

incentive to create a network. As the value of the indirect link increases it will exist a star networks that is efficient but there are no individual incentive to collaborate. In this case a NPP policy could be useful.

Table 2 - Efficiency and stability of different typology of networks.

Relationship between c, d, m	***Efficient network***	***Stability***	***NPP policy***	
$c < d$ $c \leq (d-d^2)$	Complete network direct links	Complete network	No need of a NPP policy	Case 1
$c < d$ $c>(d-d^2)$	Star network	Star network	No need of a NPP policy	Case 2
$c \geq d$ $d^2(n-2) >(c-d)$	Star network	Star network is not stable	Need of a NPP policy	Case 3
$c > d$ $d^2(n-2) <(c-d)$	Empty network	Star and complete network are not stable	No need of a NPP policy	Case 4

The previous discussion allows to set more precise guidelines for a NPP policy. If we assume perfect information and firms do not behave strategically, a NPP policy could be needed in sectors where codified knowledge is or low or high (Case 3). Sectors characterized by an intermediate level of codified knowledge do not need NPP policies because market gives incentives for the creation of a stable networks (Cases 1 and 2). On the other hand, regarding to sectors for which a codified knowledge is or very low or is very high, a NPP policy could be a waste of resource (Case 4).

Most of traditional sectors are characterized by a very low level of codified knowledge. In some case we could be in Case 3 and in other in Case 4. Also in high tech sectors where formal ties are very important we could be or in a situation as Cases 3 or 4.

One problem with the simple model we have already discussed is that benefits of the network increase with the size (n). There is not optimum size. This is a not realistic result. From an economic point of view we could think that as increase the number of links, the coordination cost increases. Therefore we could write c as an increasing function of n. On the other hand not all firms will get the same benefit if they decide to join a network. We could make the hypothesis that the firms that first join the network are those that get the higher benefits (complementary of resources); firms which resources are less complementary could get lower benefits. If the distribution of benefits is not equal many firms will find no convenient to join the networks.

5 A simple IO model of R&D cooperation and public policy

The approaches considered in the previous sections focused on the importance of spillovers for the creation of innovative networks. We instead have built a very simple model where cost and benefit of ties depend on market structure, the complementarity of resources and the cost of coordination. Our model assumes, as large part of the literature does that government sponsored collaborations are equivalent to spontaneous ones. Such hypothesis has been discussed by some authors that assumes that sponsored collaborations and spontaneous ones are clearly distinct in strategic terms[2]. Therefore substitution between strategic spontaneous projects and public policy should not be a major issues. In the last part of our paper we develop a model where such hypothesis is partially removed .

Our model allows us to identify a relationship between the number of actors that participate to a project and the incentive to collaborate. The main difference with respect to the previous model considered before is that collaboration causes the reduction of production costs due to complementarity of resources. In our model, differently from IO literature, there are not spillovers. Each actor could decide if realize a project alone (No Collaboration–NC) or in collaboration with other subjects (C). If an actor realizes a project alone it will have a surplus, quasi rent, **E** and will spend **f** for production of knowledge. Therefore the profit of actor i that produces alone the project is

$$\Pi(i) = E - f \qquad (6)$$

We assume that j actors decide to collaborate to realize a project s and that the j actors are identical as concern costs and benefits. The cost of an actor j that participates to a project is given by two elements. The cost of production of knowledge and the cost of transmission of knowledge. The cost of production of knowledge decreases as the number of participants increases. This happens for two reasons: the first one is that the fixed cost of a project is shared with a higher number of participants, the second one is that an increase in the number of actors increases the possibility of complementarity of R&D activities between actors. Complementarity of skills useful for R&D activities is a very important reason for a decrease in costs as the number of participants to the

[2] A recent articles by M.Matt,S,Robin,S.Wolff ,Journal of Technology Transfer 2012, ,shows that EU-sponsored inter-firms collaboration on the one hand ,and not sponsored spontaneous inter-firm collaborations are different. The first type of collaborations are characterized by a longer term R&D horizon and concern more the peripheral activities and less the core competence of the participating firms.

project increases. It is excessively costly for any one firm develop all the necessary expertise itself. Developing the expertise to operate on a small scale require significant up-front investments in

information acquisition and training. Therefore the cost of production of knowledge of each actor is a decreasing function of the number of actors that participate to the project. Furthermore we expect that higher is the skill and assets complementarity steeper will be the cost curve as the number j of participants increases (complementarity effects, **CA).**

The cost to transmit knowledge increases with the number of participants (coordination cost). We could expect that this effect is weak when the number of participant is low but then it become dominant. Therefore we could expect that the total cost of production and transmission of knowledge (cost of participation to a project) first decreases and then increases as the number of participant increases (see Figure 2).

The total cost of each actor to participate to a project is

$$TC(j)= C(j) + (j-1) *t \qquad (7)$$

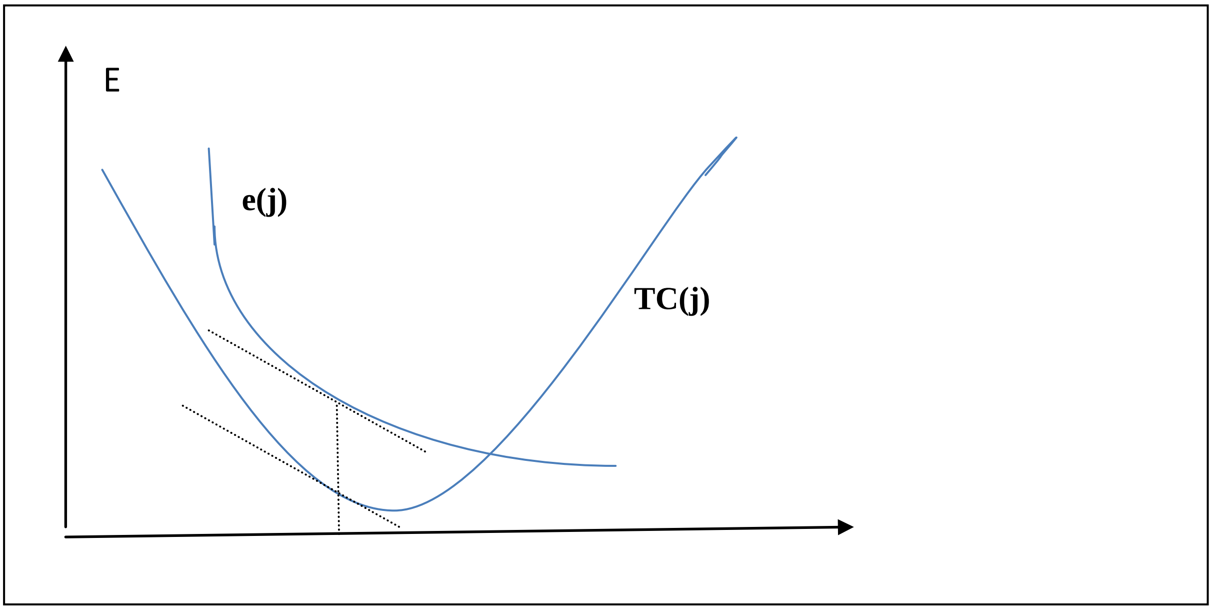
The first element is a cost of production of knowledge of each of the j participant; such cost is fixed given j and decreases as the number of participant increases; C'(j) < 0 and C''(j) > 0. We assume that the cost production C(j) for each actor is given by the fixed costs of the project divided by the number of actors. We assume that due to the complementarity of research assets of different actors and high specialization of research assets the fixed cost f of the total project is a decreasing function of j; therefore we have f'(j)< 0 and C(j)=f(j)/j.

The second element of equation 2 is the transmission cost and we assume that such cost is constant and equal to **t** for any new participant. The marginal cost TC'(j) is given by $t+ ((j*f'(j)-f(j))/j^2$. The total cost TC will reach a minimum for a value of j such that $((j*f'(j)-f(j))/j^2)=t$.

The profit of each of the j actors that collaborate to the project will be

$$\Pi(j) = e(j) - TC(j) \qquad (8)$$

Figure 2 -The optimal number of actors for project.



If an actor collaborate with other actors it will have a surplus e(j)=< E where j is the number of actors that collaborate in the project. The revenue curve e(j) could have different trend. And will depend from the structure of the market (collusive oligopoly, competitive oligopoly) and from the degree of heterogeneity of the market in which the actors operate.

We could have many different cases. In one case actors operate in complete separate markets; therefore the revenue of the project for each actor is not affected by the number of participants to the project; and e(j) is a line parallel to the horizontal axis. Actors will have only advantage in participating to a joint project since total cost will be reduced. This is a very strong hypothesis of Complete Heterogeneity in the Markets (CHM) and we have maximum probability that actors agree to participate to a joint project. The other extreme case is a homogeneous market with Cournot competition. Higher the number of firms that collaborate to an innovation lower will be the possibility that each firm has a monopolistic power on the new product. Therefore we expect that e(j) is a decreasing function of j. We could also have intermediate situations, collusion oligopoly in homogeneous market, and oligopoly in differentiated markets. In this last case we assume that if an actor produces knowledge with other actors, it could not full appropriate the benefit of the new knowledge and must share at least partially the benefits of the new knowledge. The slope of the revenue line decreases as heterogeneity in the markets increases.

From the previous analysis we have built Table 3 where we show how the probability of cooperation is affected by different combinations of CA and CHM effects.

Table 3 - Probability of RJV collaboration.

		Heterogeneity in the markets	
		High	Low
Skill and R&D assets complementarity	High	*Very high*	*high*
	Low	*Very low(close to zero)*	*Low*

We assume that complementarity effect, **CA**, could be high and low and that heterogeneous effect, **CHM**, could be high and low .When CHM is high the revenue curve relative to j is very flat. If **CA** is low also the total cost curve relative to j is quite flat. It is possible that the total cost curve is under the revenue cost but this is not sure and the probability of R&D collaboration is low. If CA is high the total cost curve is very steep and decreasing, it will be under the revenue curve that is flat and the probability of collaboration is very high. If CHM is low and CA is low the revenue curve will be under the cost curve and the probability of collaboration is zero. If CHM is low and CA is high the revenue and total cost curve relative to j will be steep and the probability of collaboration will depend from the relative slope.

It is possible to extend our analysis to the different determinants of innovating firm's decision to engage in R&D cooperation .In Table 4 we have shown the effects of factors that determine innovating firms decision to engage in R& D cooperation on the total cost and total revenues of participating firms.

It is necessary if one want to make Table 4 an useful instrument s for policy purposes to develop empirical studies that allow to evaluate the strength of different effects.On the other hand is possible to build models that simulate the different effects.

In the next section we will show how a very simple model could be used to simulate advantages and disadvantages of a public program to sustain R&D collaboration

Table 4 Effects of an increase of the value of some variables on the shape of cost and revenue curves of participating firms.

Variables(VRC) that affect firms cooperation	Total cost curves	Total revenue curve
Resource complementarity	-	?
Market heterogeneity		+
Level of fixed costs	-	
Degree of collusion		+
Level of spillovers		+
Coordination costs	+	
Trust	-	
Codified knowledge	-	

6 Subsidization policy to RJV in homogeneous markets

The model that we have discussed could be described in the following way. In a *homogeneous good market* with quantity-setting, assuming linear demand the profit function of firm j is the following.

$$\Pi_{j} = (A-bX)\, x_j \; - f(j)/j - (j-1)t_i \tag{9}$$

where $\sum x_j = X$.

In the *independent market case* we have that $X=x_j$ and the profit function of j becomes

$$\Pi_{j} = (A-bx_j)\, x_j \; - f(j)/j - (j-1)t_i \tag{10}$$

The main results of our analysis are shown in Table 4 and Table 5, but in the following pages we will develop the previous model under the hypothesis of collusion. This case is interesting because the general opinion is that the policy of subsidization of RJV between competitors is not welfare enhancing because competition is limited. A consortium that maximize joint profits of members will have a number of members lower than the number that maximize social welfare (Cohen 1994) and higher is the subsidy lower the number of members .Therefore a policy to finance R&D joint ventures , generally, is not appropriate .

Our model will show that these results are not always true. In fact, since in our model there are only fixed costs, a monopolist will maximize its profits when marginal revenue is zero. Under the collusion hypothesis the quantity produced and total revenue will not change as the number of participants to consortium increases. Actors see their share market decreasing as the number of participants increases; e(j) is given by E/j. An additional member will decrease revenue of old members but it will decrease also total fixed cost that any members sustain. It is convenient to have a new actor collaborating in the project if revenues decrease as j increase at a slower rate than that of costs. The value of profit Π(j) will be maximum when marginal benefit will be equal to marginal total cost

$$e'(j)=TC'(j) \tag{11}$$

This will happen if, as shown in Figure 2, e(j) decreases as j increase at a lower rate than TC(j). The profit of an actor j is maximized with respect to the number of participant when the e(j) function and the TC(j) function have the same slope (see Fig.2).

The social welfare of the project is given by the sum of the profits realized by j actors. In the collusive case the total revenue E of project is fixed and does not change with the number of participants. Because E depends on the quantity produced and on the price we could also assume that consumer surplus does not change as the number of participants increases. Therefore we have not calculated consumer surplus in the computation of the welfare.

We have assumed that actors are equal.

$$W(j)= \Pi(j) * j = (e(j) - TC(j))*j \tag{12}$$

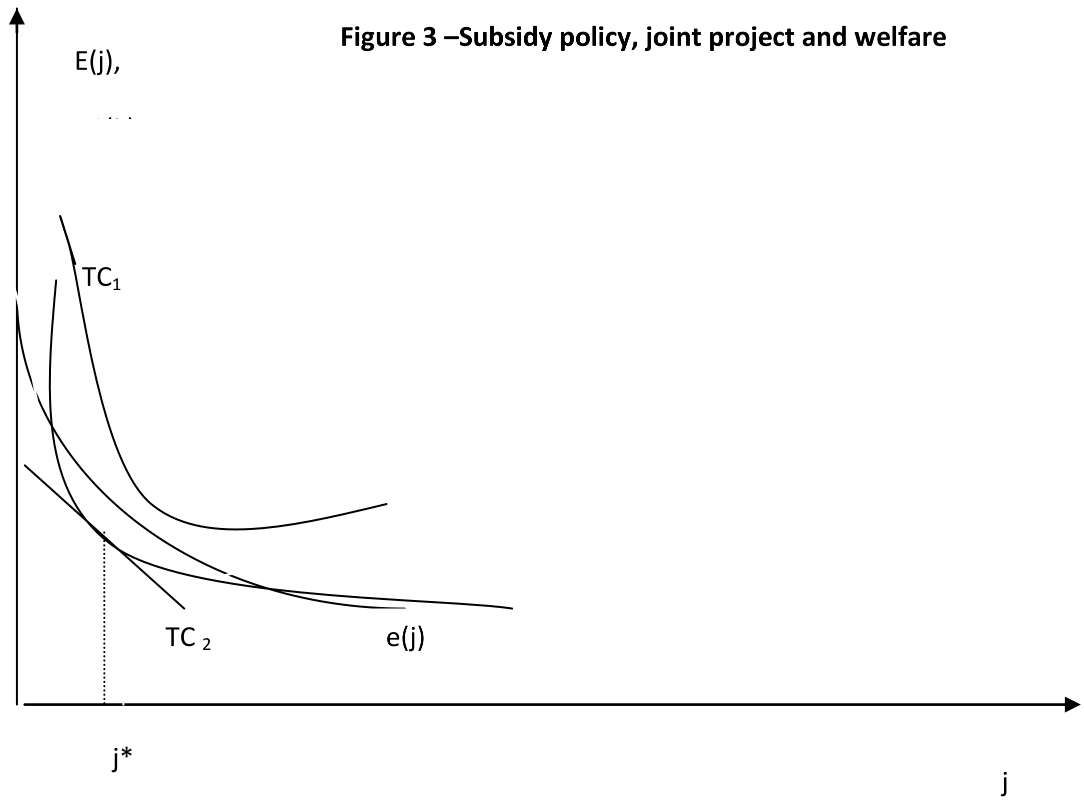
The first order condition for the maximum of the social welfare of a project is realized when

$$W'(j)=-f'(j)- 2j +t =0 \tag{13}$$

Since j *e(j) is equal to E and does not depend on j, the welfare is maximized when TC'(j) =0, or total cost reach a minimum. We will have different values of j as solutions of equation (11) and equation (13). The first is the number of actors that participate to a project that maximize actor profits j_{1s} ,the second is the number of actors that maximize the welfare caused by the project, j_{2s} . The relation between these two threshold values is not always clear as it depends on the kind of function f(j) that describe fixed costs.

We could have different situations that affect the choice of an actor to participate or not to a RJV and the necessity or not of a subsidy policy for R&D cooperation.
In a first situation the revenue curve e(j) is higher at least, as in Figure 3, for some interval of j , than the total cost curve TC_1 (relative to a given project). In this situation an actor alone will not realize the project since he gets negative profit, while actors would receive higher profits if they cooperate. In this case it is true that the number of actors, $j_{1,s}$, that participate to a project is lower than the optimal one $j_{2,s}$, but it is difficult to implement a subsidy policy to increase the number of participants to the project.
In a second situation the revenue curve e(j) line is always lower than TC_1(j) curve and therefore no projects will be realized neither as joint project nor as an alone project. If the distance between the two curves is high there no is worth to give a subsidy.
We could have a third situation similar to the previous one with the distance between the two curves is not very high. In such case a subsidy that covers part of the fixed cost of the project will determine a shift downwards of the new total cost curve, TC_2(j) (Figure 3). This increases the profit of actors that participate to the projects and the project will be realized with an increase in profits of the firm and in the welfare too. Therefore we could say that the project is additional and it is worth to subsidize the project.
We could repeat the above analysis in case of Cournot competition. In this case the revenue curve is always lower than the revenue curve in the case of collusion. With Cournot competition social welfare increases as the number of participants increase, and we have an optimum number of participants. But unless total costs decreases very quickly as j increases is high probable that there is no incentive for firms to collaborate. Profits could be always negative and lower than the ones in the collusive case.

Figure 3 –Subsidy policy, joint project and welfare



In Table 5 we show numerical examples for collusive and Cournot oligopoly when demand curve is linear p= 1000- B and the total curve costs of each participant is TC=225000 /j^1,2 +(j -1)*100 (case a) and TC=260000 /j^1,2 +(j -1)*100 (case b). In case revenue when the project is realized by only one actor is higher than fixed costs and in the case b is lower.
Social welfare ifs the sum of profits of actors that participate to the project and of consumer surplus.

Table 5 - Incentive to cooperate , social welfare ,and NPP policy in models with Cournot and collusive oligopoly.

.

Case a) –Collusive oligopoly		
Number of actors	Social welfare (profits +consumer surplus)	Profits of each actor
1	150000	25000
2	178926	26963
10	224034	9903
Case a)- Cournot oligopoly		
1	150000	25000
2	248370	13074
10	344902	-6832
Case b)-Collusive oligopoly		
1	115000	-10000'
2	148456	11728
10	201951	7695
Case b)- Cournot oligopoly		
1	115000	-10000
2	217901	-2160
10	322818	-9040
Case b)- Cournot oligopoly with a subsidy of 2500 for actor j>1		
Number of actors	Surplus less total subsidies	Profit + subsidy
1	115000	-10000
2	212901	339,54
10	297818	-6540

Table 5 shows that in cases (a) and (b) there is an incentive to cooperate when firms collude since profits for actor are higher in cooperation than when the project is realized alone. In this case a NPP policy is not necessary. In addition, cooperation in presence of collusion is welfare enhancing and therefore it must be not forbidden by antitrust commission.

In the case of Cournot competition there is no incentive to cooperate also if cooperation is welfare enhancing. In the case (a) a subsidy could increase welfare but one agent will have a higher profit if realize alone the project. With a subsidy of 13000 for each agent it will be convenient for two agents cooperate to realize the project. The welfare will increase and will be 222453 but there is no additionality.

If we are also interested that the project is additional, case b, a NPP policy could be useful. Table 5 shows that a subsidy of 2500 for actor will induce the cooperation of two actors and that the welfare net of the expenditure for subsidies will be positive.

We try to derive from our analysis some general conclusions that could help to establish if NPP policy is necessary or not. The main results are shown in Table 6.

Table 5 shows the conditions under which RJV (Research Joint Ventures) determines higher profits for the actors and higher welfare compared to non cooperative R&D.
A necessary condition is that the costs of the whole project decrease at a higher rate than revenues as the number of participants to the projects increases. A more clear description of the different cases could be done if we assume that the f(j) function, that shows the behaviour of the fixed costs as j increases ,is given by f/j^b where b>1 .
If total revenue is higher than fixed costs of the project, the RVJ will increase social welfare and actor profits. Therefore the market spontaneous will create RJV and there is no need of a subsidy policy. It is also interesting to consider that the optimal number of actors from a welfare point of view is higher than the level market forces will determine.
When total revenues are lower than fixed costs of a non cooperative R&D and the difference between the absolute value of the slope of total cost curve and the absolute value of the slope of total revenues relative to j is high the RVJ will increase social welfare and actor profits .Therefore the market spontaneous will create RJV and there is no need of a subsidy policy . It is also interesting to consider that the optimal number of actors from a welfare point of view is higher than those that market forces will determine..
When total revenues are lower than fixed costs of a non cooperative R&D and the difference between the absolute value of the slope of total costs curve relative to j and the absolute value of the slope of total revenues curve is low the RVJ will increase social welfare but not actors' profits. Therefore the market spontaneously is not able to create a RVJ and a subsidy policy is necessary.
Our analysis shows that a policy to create cooperative R&D through subsidies in many cases is not efficient and that we must evaluate ex ante if exists the conditions that the project have welfare and additionally effects.

Table 6 - Analysis of the conditions under which RJV determines higher profits for the actors and higher welfare compared to non cooperative R&D and the necessity of a subsidy policy for RJV.

Relationship between parameters	Profit for agent s in a RJV compared with a non cooperative R&D	Social welfare in a RJV compared with a non cooperative R&D	Relationship between optimal number of actors from a social welfare compared to the market equilibrium	Welfare and Additionality effects of a policy that subsidize R&D
E > f Slope TC = slope e(j)	Lower (collusive and Cournot oligopoly)	Lower		No
E > f slope TC > slope e(j)	Higher (collusive oligopoly in homogeneous market and oligopoly heterogeneous markets)	higher	higher	No
E > f slope TC > slope e(j)	? Cournot oligopoly	higher	higher	yes
E<f< H H is an upper limit and the difference between the absolute value of slope of Tc and the slope of e(j) is low	Lower (collusive oligopoly in homogeneous market and oligopoly in heterogeneous markets)	higher	?	?
E<f< H H is an upper limit and the difference between the absolute value of slope of Tc and the slope of e(j) is low	Lower Cournot oligopoly	Higher	?	Yes

E= Surplus of the project if it is realized by one actor
F=fixed cost of the project if it is realized by one actor

7 Differentiated oligopoly and resources complementarity.

In this section we extend our analysis to a differentiated oligopoly. One essential difference relative to the previous model is that we allow that sponsored collaboration and spontaneous one are clearly distinct and that also the level of investments and quality of the products are different. We assume the cost of investment is endogenous and the total cost for the industry is endogenous too. In particular we consider firms that invest in quality in order to differentiate their products and reduce the level of substitution in terms of demand function. Cooperation in R&D allows firms to coordinate their investment choices and obtain synergy from complementarity of their know-how. Intuitively, resource complementarity plays a similar role of spillover but only when firms cooperate. We parameterize the level of complementarity and analyze how the latter affects private and public incentives to create RJVs and cooperate in R&D. Differently for previous analysis we don't consider collusive equilibria in quantity definition and restrict our analysis to a Cournot competition. We derive some results in simple case when j=2 (duopoly); then we generalize some results to j>2 firms.
The model setting is the following. Firms produce differentiated goods with a constant return to scale technology. For simplicity we assume that for all firms marginal and average cost of productions are equal to zero. The demand of each good is linear and described by the following function.

$$\forall j, \quad p_j = A - \frac{x_j}{l_j} - b\sum_{i \neq j} \frac{x_i}{l_i} \tag{14}$$

where lj is the level of quality implemented by firm j investing in R&D. The cost of investment is

$$T_j = \frac{s_j^2}{2} \text{ where } l_j = \begin{cases} s_j \text{when firms do not cooperate} \\ s_j + d\ \sum_i s_i \text{ when firms cooperate} \end{cases} \tag{15}$$

Notice that d is the parameter that measures the complementarity in resources and that we restrict our analysis to symmetric equilibria.

Assuming that creating an R&D agreement, to each firm, costs k times the number of firms involved, Given the (14) and (15) each firms chooses xi and sj in order to maximizes the following profit function.

$$\forall j, \quad \Pi_j = \left(A - \frac{x_j}{s_j + d\sum_{i \neq j} s_i} - b\sum_{i \neq j} \frac{x_i}{s_i + d\sum_{w \neq i} s_w} \right) - \frac{s_j^{\ 2}}{2} - c(j-1) \tag{16}$$

It relevant in equilibrium the role played by some exogenous variables as b, that measures the exogenous level of market differentiation, d, that measures the complementarity of resources ,or c, that measures the unitary cost of any direct link between firms.

Firms' interaction is described by a two stage game. In the first firms chooses the level of R&D investment, in the second they sets their quantities. We compare two different scenarios considering that in the first stage firms can cooperate or not.

Putting any algebraic details in appendix, from the duopoly analysis we obtain the following results:

- In the cooperative scenario, quantities, investments, profits and social welfare are increasing in d and decreasing in b, while c negatively affects the level of profits and social welfare.
- When c is lower than a threshold value $\underline{c}(d)$ creating the RJV is profits and welfare improving even if without observability of investments, free riding behaviors can emerge as part of non-cooperative equilibria. In this case a public intervention can be justified only if this guarantee verifiability of investment. When firms' investments are observable, public intervention is not needed since RJV is spontaneously created.
- When c is higher than $\underline{c}(d)$ but lower than a second threshold value $\bar{c}(d)$ creating the RJV is not profitable for firms unless public subsidies. In this case RJV is welfare enhancing but it is not spontaneously created by firms.
- When c is higher than $\bar{c}(d)$, creating the RJV is not profitable for firms and public subsidies are a waste of resource. In this case RJV is not welfare enhancing.

Extending our analysis to the j>2 oligopoly case we find out that given c, there is a maximum number of firms j such that the RJV is profitable for firms that can alternatively play in a non cooperative way in both stages of the game.; this number is decreasing in c. Other evaluations strictly depend on the values associated to the different parameters and it is very hard to generalize some results. For example, when b=1, the cooperation profits before the total cost for direct links, $\Pi^C(j)+c(j-1)$, computed for different values of d, is always strictly decreasing in j; this means that the optimal dimension of the RJV is j=2, for any values of c. Conversely, when we consider b=0.5 the same curve is increasing and convex. This means that the optimal dimension of the RJV is not defined.

- .

8 Conclusions.

In this paper we have examined the conclusions of different approaches about the opportunity to finance NPP policies. The IO literature has focused on strategically aspects and on the effects of spillovers on the relative profitability of cooperation and on the social welfare. Such approach leads to the conclusions that R&D coordination in most cases yields to a superior performance compared to non-cooperative case. If the objective government function is to subsidize only efficient network structure that the market would not spontaneously realize, such literature finds that in many cases a NPP policy may not be appropriated since cooperation would be spontaneously realized. This happens in particular when firms are symmetric and are operating in independent markets. Conversely, a NPP policy leads to an increase in the welfare when firms are asymmetric, the value of the spillover is low and markets are homogeneous (horizontal cooperation).

On the other hand the SNA approach, moving from different hypothesis on the heterogeneity of partners and of characteristics of relationship, has a more positive approach to a NPP policy. If the underlying technology is not well specified, the relevant knowledge is tacit, or it is not easy to allocate costs and benefits between actors, it could be difficult that a network arises spontaneously. If one of the main obstacle to creation of a networks is the lack of information, a government agency, that contacts potential members and informs them about existing treat or opportunity that is best addressed by collaborating, could be useful a policy to create a network. If we assume perfect information and firms do not behave strategically a NPP policy could be needed in sectors where codified knowledge is or low or high. Sectors characterized by an intermediate level of codified knowledge do not need NPP policies because market gives incentives for the creation of a stable networks On the other hand sectors if codified knowledge is or very low or is very high an NPP policy could be a waste of resource.

Most of traditional sectors are characterized by a very low level of codified knowledge. The above consideration could change if we consider two other aspects: the distance problem and the strategically (opportunistic) behavior. In the first case we must consider that difference between benefits and the cost of transfers of the information is inversely related to the distance between actors of the network if codifies knowledge is relative low. In this case proximity of actors could make an NPP policy improving total welfare. In the second case it is possible that a network could not exists, also if convenient from the point of view of single actors and total welfare because firms behave in an opportunistic way. Another important opportunity for a public intervention to promote networks is when lack of trust prevents collaboration. Following transaction cost economics because opportunistic agents will not self-enforce open ended promise to behave responsibly an efficient network will be realized only if dependencies are supported by credible commitments. A public policy could create safeguards within links between actors. Cost effective contractual safeguards could mitigate hazard and efficient links would be realized.

In the previous approaches coordination costs are not explicitely considered and also the problems of the complementarity of resources is not analyzed. Therefore we have proposed a third approch focused on complementarity in which the research costs of a project could be shared by firms that cooperate. In such approach the research cost of the project decreases higher is the complementarity of resources of cooperative partners. Furthermore as the numer of partners increases the costs of the project is shared by an higher number of firms and therefore it decreases for any single enterprise. The total cost of each firms first decrease and then increases because the number of partners increases coordination cost. Also the revenue curve of each firms is affected by the number of partners. If entreprise are in non-homogeneous markets the revenue of each firms does not decrease very quickly as the number of cooperative partners increases. But if they are in homogeneous markets their revenues decreases very quickly as the numbers of cooperative partners increases because they must share the advantage of the technical progress with firms that operate in the same market. Therefore the probablity of collaborations will depend on the relative trend of revenue and total costs of each firms. This approach hows that in many case R&D cooperation increases profits of the partners and social welfare but only in a limited number of case a subsidy to R&D cooperation is welfare enhancing. A NPP policy could be useful if (a)the fixed costs of the project is higher than total revenue when the projects is realized only by one firms ; (b) the total cost curve of each firms decreases at an higher speed than the revenue costs as the number of partners increases; (c)the difference between the slope of the two curves are not very high. Therefore we expect that a NPP policy could be more appropriate in the case of horizontal cooperation than in the case of vertical cooperation because the condition (c) will be more easily present in the first case.

We have extended our analysis to differentiated oligopolies where firms invest for increasing the quality of the produced goods enhancing endogenously the level of differentiation too. We characterized scenarios where given the level of resource complementarity public subsidy are not need since welfare improving networks are spontaneously created and we compute the optimal dimension of networks. Moreover focusing on the problem of observability of investments in network we stress a different role to public intervention finalized just to verify effectual cooperation and avoid some types of free ridings.

Our analysis show that a generalized subsidy to any cooperative R&D project is not efficient and that we need an a priori analysis of the projects not only from a technological point of view but also from an economic point of view. This analysis is necessary if we do not want subsidize projects that are not additional because the market spontaneously in these cases stimulate cooperation. When the amount of resources are limited the projects that are the best from a technological point of view not necessarily are those that must be financed. Therefore it is important to analysis the performance of different R&D cooperative projects to find some criteria that could empirically help the evaluator to choose ex ante the projects to be financed. .

Bibliography

Ahuja, G. (2000) "Collaboration Networks, Structural Holes, and Innovation: A Longitudinal Study", *Administrative Science Quarterly*, 45, pp 425-455.

Amir, R., Evstigneev, I. and Wooders, J. 2003 "Non cooperative versus cooperative R&D with Endogeneous spillover Rate". *Games and Economic Behaviour*,42, pp.183-207.

Branstetter, L.G, Sakakibara "When Research Consortia Work? Evidence from Japanese Panel Data", *American Economic Review* , 92, 1, pp.143-160.

Caloffi, A., Mariani, M. and F Mealli, 2013 "What kinds of R&D consortia enhance SMEs productivity ?Evidence from a small –business innovation policy" ,*Workshop University of Naples Federico Secondo* 14 January.

Cohen, L., 1994 "When Can Government Subsidize Research Joint Ventures? Politics, Economics, and Limits to Technology Policy", *AEA Papers and Proceedings* ,84, n2 .pp.159-163.

D'Aspremont, C. and Jacquemin A., 1988 "Cooperative and Noncooperative R&D in Duopoly with Spillovers", *American Economic Review,* 78,5,pp.1133-37l.

David, P.A., Metcalfe S., 2007 "Universities and Public research organisations in the ERA", Draft Report(v.3) prepared for the Knowledge for Growth (K4G) Expert Group, EC(DG-Research), June 8.

Doreian, P. 2006, "Actor Network Utilities and Network Evolution", *Social Networks*, 28, pp.137-164.

Goyal, S., Moraga-Gonzalez, J.L. 2001 "R&D Networks", *The Rand Journal of Economics*, 32, 4, pp 686-707.

Grannoveter, M. 1973 "The Strenght of Weak Ties", *American Journal of Sociology 78, pp.1360-80.*

Grannoveter, M., 1985, "Economic Action and Social Structure: The problem of Embedness", *American Journal of Sociology*, 91, pp.481-510.

Hagerdoorn, J., 2002, "Inter-Firm R&D Parternship: An Overview of Major Trends and Patterns since 1960", *Research Policy* ,31,pp.477-492.

Jackson, M.,O., 2008; *Social and Economic Networks*, Princeton University Press.

Jackson, M.O.; Wolinsky A. 1996 "A Strategic Model of Social and Economic Networks", *Journal of Economic Theory* 71,pp.44-74.

Kamien, M.I., Muller, E., Zang, I., 1992; "Research Joint Ventures and R&D", *American Economic Review,* 82, pp.1293-1306.

Katz M.L. 1986, "An Analysis of Cooperative Research and Development", *Rand Journal of Economics* 17,4,pp.527-43

Kilduff, M. and W. Tsai, 2003, *Social networks and Organizations*, Sage, London.

Oxley, J.E; 1997 "Appropriability hazards and the Governance of Strategic Alliances: a Transaction Cost Approach" *Journal of Law, Economics, & Organization*, 13, 2, pp. 387-409.

Powell, W.W.; Grodal S. 2006, "Networks of Innovators", in *The Oxford Handbook of Innovation,* Fabergerg J.,Mowery D.G., Nelson R.R. eds., Oxford University Press.

Reinthaler, V. and G.B. Wolff, 2004, "The effectiveness of subsidies revised accounting for wage and employment effects in business R&D", Center for European Integration Studies (ZEI) working paper no.B21-2004, Rheinische Friedrich-Wilhems-Universitat, Bonn.

Tyler, B.B. and Steensma, K.H. 1995 “Evaluating Technological collaborative Opportunities .A cognitive Modelling Perspectives”, *Strategic Management Journal*, 16, pp.43-70.

Von Hippel, E., 1998 “Economics of Product Development by Users :The Impact of “Sticky” Local Information” *Management Science* , 44, pp.629-44.

Yi, S., Shin, H., 2000; “Endogeneous Formation of Research Coalitions with Spillovers “International *Journal of Industrial Organization*. 18, pp 229-256.

Appendix.

(a) Duopoly.

In the case of duopoly (14) becomes (A1) and (16) becomes (A2)

$$p_1 = A - \frac{x_1}{l_1} - b\frac{x_2}{l_2} \tag{A1}$$

$$\forall j = 1,2, \quad \Pi_j = \left(A - \frac{x_j}{s_j + ds_{-j}} - b\frac{x_{-j}}{s_{-j} + ds_j} \right) - \frac{s_j^{\ 2}}{2} - c \tag{A2}$$

Assuming at t=2 Cournot Competition, given the investments chosen at t=1, crossing firms best reply we get

$$\forall j = 1,2, \quad x_j(s_j, s_{-j}) = \frac{1}{b+2} A\left(s_j + ds_{-j}\right) \tag{A3}$$

Substituting (A3) in (A2), by backward induction we derive the optimal level of R&D Investments when firms cooperate (C). Assuming s_j=s_{-j}, we get

$$s_1^C = s_2^C = A^2 \frac{d+1}{(b+2)^2} \tag{A4}$$

$$\Pi_1^C = \Pi_2^C = \frac{1}{2} A^4 \frac{(d+1)^2}{(b+2)^4} \text{-c} \tag{A5}$$

$$x_1^C = x_2^C = A^3 \frac{(d+1)^2}{(b+2)^3} \tag{A6}$$

It easy to check that all equilibrium variables are increasing in d that measures the complemntarity of resouces. In place of cooperation firms can play non-cooperatively in both stages (N). In this case, at t=2, under Cournot conjectural variation we get

$$s_1^N = s_2^N = \frac{A^2}{(b+2)^2} \tag{A7}$$

$$\Pi_1^N = \Pi_2^N = \frac{1}{2} A^4 \frac{2d+1}{(b+2)^4} \tag{A8}$$

$$x_1^N = x_2^N = A^3 \frac{d+1}{(b+2)^3} \tag{A9}$$

The incentives to cooperate is computed as the difference between (A5) and (A8)

$$\Delta\Pi = \Pi_1^C - \Pi_1^N = \frac{1}{2}A^4\frac{(d+1)^2}{(b+2)^4} - \frac{1}{2}A^4\frac{2d+1}{(b+2)^4} - c = \frac{1}{2}A^4\frac{d^2}{(b+2)^4} - c \quad \text{(A10)}$$

From (A10) we get the threshold values of c for cooperating

$$c \le \underline{c}(d) = \frac{1}{2}A^4\frac{d^2}{(b+2)^4} \text{ where } \frac{\partial\underline{c}(d)}{\partial d} > 0 \quad \text{(A11)}$$

In this case cooperating is profits improving and RJV is sponaneously created.

For computing the threshold values of c from a welfare enhancing point of view, we have to compare the welfare, as sum of profits and consumer surplus, in the case firms at t=2 cooperate or not. Given (A4)-(A6) and (A7)-(A9) we get

$$W^C = \left(2\int_0^{\frac{1}{27}A^3(d+1)^2}\frac{1}{3}\frac{4A^3d+2A^3d^2+2A^3-27x}{A^2(d+1)^2}dx\right) - 2\frac{\left(\frac{1}{9}A^2(d+1)\right)^2}{2} - 2c$$

$$= \frac{2}{81}A^4(d+1)^2 \text{-2c} \quad \text{(A12)}$$

$$W^N = \left(2\int_0^{\frac{1}{27}A^3(d+1)}\frac{1}{3}\frac{2A^3d+2A^3-27x}{A^2(d+1)}dx\right) - 2\frac{\left(\frac{A^2}{9}\right)^2}{2} == \frac{1}{81}A^4(3d+2) \quad \text{(A13)}$$

$$\Delta W = W^C - W^N = \frac{2}{81}A^4(d+1)^2 - \frac{1}{81}A^4(3d+2) - 2c = \frac{1}{81}A^4(2d^2+d+12) - 2c \quad \text{(A14)}$$

Then, cooperation is welfare improving if

$$c \le \bar{c}(d) = \frac{1}{162}A^4(2d^2+d+12) \text{ where } \forall d>0,\ \ \underline{c}(d) \le \bar{c}(d) \quad \textit{and} \quad \frac{\partial\bar{c}(d)}{\partial d} > 0 \quad \text{(A15)}$$

Indeed when $\underline{c}(d) \le c \le \bar{c}(d)$, subsidies let cooperation be profitable and this policy increases welfare too.

Checking for strategic stability of cooperation at t=1, we compute the firm incentive to deviate (D) in the investment stage when the chetear believes that the other plays the cooperative outcome. In this case we get

$$s_j^D = \frac{1}{9}A^2 \quad \text{(A16)}$$

$$x_j^D = \frac{1}{27} A^3 \left(d + d^2 + 1\right) \quad \text{(A17)}$$

$$\Pi_1^D = \frac{1}{162} A^4 \left(2d^2 + 2d + 1\right) - c \quad \text{(A18)}$$

$$\Pi_j^D - \Pi_j^C = \frac{1}{162} A^4 \left(2d^2 + 2d + 1\right) - c - \frac{1}{162} A^4 \left(d + 1\right)^2 + c = A^4 \frac{d^2}{162} > 0 \quad \text{(A19)}$$

From (A23) we infer that when investment decisions are non observable a free riding behaviour emerges, independently on c. In this case a public intervention can be needed when $c \leq \underline{c}(d)$ only to the extent that makes the investment decisions verifiable.

(b) j>2 firm oligopoly.

From (16), assuming at t=2 Cournot Competition, given the investments chosen at t=1, crossing firms best reply we get

$$x_i(j) = \left(A \frac{1 - j + bj}{bj + 1} \right) \left(s_i + d \sum_{z \neq i} s_z \right) \quad \text{(A20)}$$

$$\Pi_i(j) = \left(A - \frac{jA}{bj + 1} \right) \left(A \frac{1 - j + bj}{bj + 1} \right) \left(s_i + d \sum_{z \neq i} s_z \right) - \frac{s_i^2}{2} \quad \text{(A21)}$$

By backward induction we derive the optimal level of R&D Investments when firms cooperate (C) assuming at t=1 $s_j = s_{-j}$, we get

$$s^C(j) = A^2 (1 - j + bj)^2 \frac{1 - d + dj}{(bj + 1)^2} \quad \text{(A22)}$$

$$\Pi^C(j) = \frac{1}{2} A^4 (1 - j + bj)^4 \frac{(1 - d + dj)^2}{(bj + 1)^4} - c(j - 1) \quad \text{(A23)}$$

Again we assume that In place of cooperation firms can play non-cooperatively in both stages (N). In this case, at t=2, under Cournot conjectural variation we get

$$s^N(j) = A^2 \frac{(1 - j + bj)^2}{(bj + 1)^2} \quad \text{(A24)}$$

$$\Pi^N(j) = \frac{1}{2} A^4 (2dj + 1) \frac{(1 - j + bj)^4}{(bj + 1)^4} \quad \text{(A25)}$$

The incentives to cooperate is computed as the difference between (A23) and (A25)

$$\Pi^C(j) - \Pi^N(j) = \frac{1}{2} A^4 d(1 - j + bj)^4 \frac{d + dj^2 - 2dj - 2}{(bj+1)^4} - c(j-1) \qquad \text{(A26)}$$

From (A30) we get the threshold values of c for cooperating

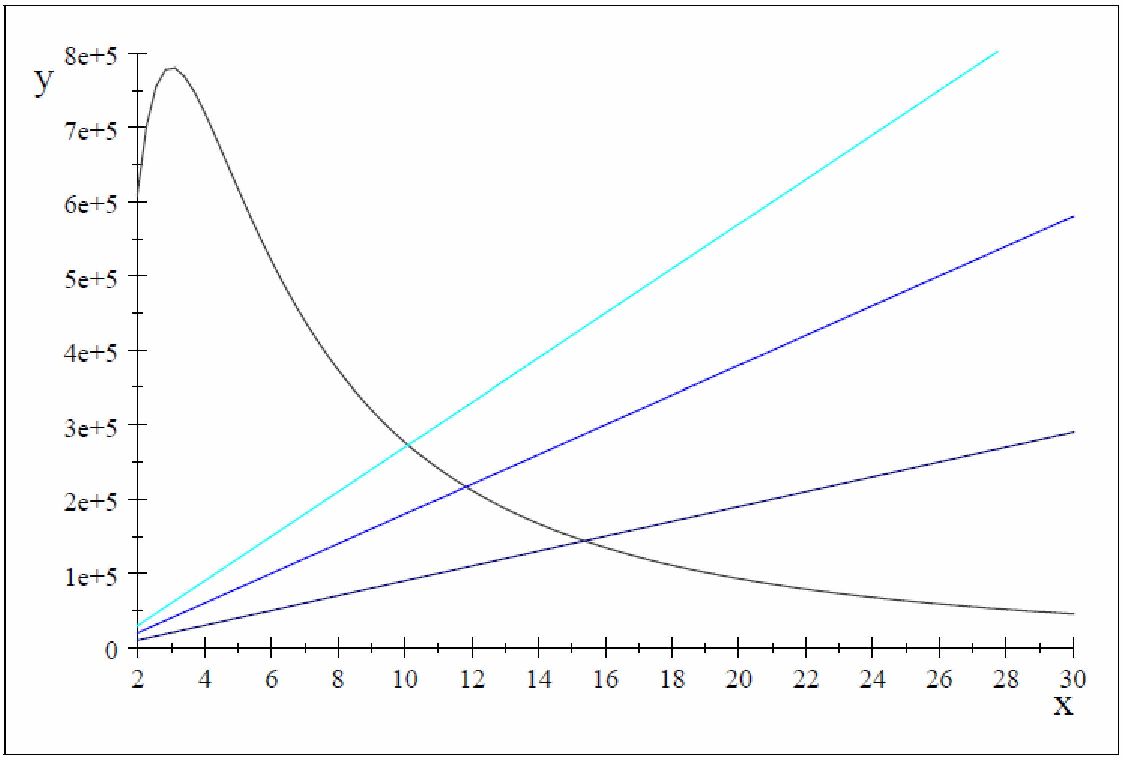
$$c \leq \underline{c}(d, j) = \frac{1}{2} \frac{A^4 d(1 - j + bj)^4 \dfrac{d + dj^2 - 2dj - 2}{(bj+1)^4}}{j-1} \qquad \text{(A27)}$$

where $\dfrac{\partial \underline{c}(d, j)}{\partial j} < 0$ and $\dfrac{\partial \underline{c}(d, j)}{\partial d} > 0$

Now we want to compute the dimension of the RJV that maximizes firm profts. Given the complexity of the functions considered we focus our analysis on some espicative examples.

In Figure (A1), Assuming A=100, b=d=1, we present the curve graph of the function $(\Pi^C(j) - \Pi^N(j)) + c(j-1)$ with different linear graph of c(j-1) computed for increasing values of the unit cost of direct link in the RJV (c is equal to 100, 50, 25 respectively). The intersections represent, given c, the maximum dimension of RJV such that it is more profitable than the case of non cooperation in both stage of the game. From the graph we can deduce a positive relationship between the unit cost of any direct link and the maximum dimension of a profitable RJV.

Figure A1 - Determination of the maximum dimension of profitable RJV.



We expect that the optimal dimension of the RJV would be lower than the maximum one considered before, but that would be again a positive relationship of the unit cost of any direct link. In Figure (A2), assuming A=100, b=1, we represent the cooperation profits before the total cost for direct links, $\Pi^C(j)+c(j-1)$. The set of this curves, computed for different levels of resources complementarity (moving from the origin of the axis to the northeast, d is equal to 0.5, 1, 1.5 respectively) are all strictly decreasing in j; this means that the optimal dimension of the RJV is j=2, for any values of c.

Figure A2 - The cooperation profits before the total cost for direct links.