Società italiana di economia pubblica
XVI CONFERENZA

POLITICHE PUBBLICHE, SVILUPPO E CRESCITA

Pavia, Università, 7 - 8 ottobre 2004

SOCIAL CAPITAL AND R&D AS JOINT DRIVING FORCES BEHIND TECHNOLOGICAL INNOVATIONS IN AN INDUSTRIAL DISTRICT

GIULIO CAINELLI, SUSANNA MANCINELLI, MASSIMILIANO MAZZANTI

pubblicazione internet realizzata con contributo della COMPAGNIA di San Paolo

Social capital and R&D as joint driving forces behind technological innovations in an industrial district

Giulio Cainelli, Susanna Mancinelli and Massimiliano Mazzanti

Abstract

The paper aims at testing the hypothesis that social capital is a crucial element in explaining technological innovation in an industrial district. The analysis on social capital is micro-oriented, and it is both applied and theoretical. The analysis helps shedding light on the ongoing social capital debate, as it studies the effective role of this capital input in stimulating innovation and consequently economic growth. Social capital is defined as the intensity of networking activities among economic agents and it is modelled as the public element of an impure public good.

We focus the attention on a specialized industrial district in the Emilia Romagna region – the biomedical district of Mirandola (Modena) – characterised by a strong pattern of innovative activity, from which we collect survey data on firm's performance, innovation practices, investment strategies, and cooperation efforts concerning firm's relationship within the local district. Using Logit models with a dummy variable for technological innovation as dependant variable, a positive relationship emerges between social capital (measured by a firm specific index of cooperation intensity within the district) and the innovative actions observed. Moreover, R&D and networking/social capital arises as complementary driving forces for innovation outputs.

Building up on this complementarity, a dynamic theoretical model which assumes social capital as the public component of the impure public good R&D is developed. It shows that the 'civic culture' of the area in which the firm works is not sufficient as an incentive to increase her investment in SC, because this investment depends also on the economic convenience in investing in the impure public good. If and only if the economic conditions which determine a favourable environment to the investment in the impure public good improve, it is possible to hope in an increase of the investments in SC by the agents. SC/networking dynamics might positively evolve only if the private opportunity cost of investing in innovation is sufficiently low. When empirical evidence confirms that this complementarity plays key role, and consequently strong links exist between market and non-market dynamics relating to firms, the role for policy actions targeted to Social capital is wider. It is a policy effort which should be targeted toward both market and non market characteristics taken together, rather than an effort directed to the production of (local) public goods (SC) or innovation inputs as independent elements of firm's processes. The difference is not purely speculative, but it matters as far as policy effectiveness is concerned.

Jel: O32, D92, H49

Keywords: Social capital, Innovation, R&D, Biomedical district, firm networking, input complementarity

September 2004

1. Introduction

This paper aims at testing the hypothesis that social capital is a crucial element in explaining technological innovations in industrial districts or, more generally, in firms' clusters. Based on the literature on social capital developed during the last decade, our aim is to explore new perspectives, rooting mainly in a microeconomic approach. The analysis conducted is both applied and theoretical and helps shedding light on the ongoing social capital debate, as it studies the effective role of this capital input in stimulating innovative activity and thus local economic growth.

We focus our attention on a Marshallian industrial district located in the Emilia Romagna region – the biomedical district of Mirandola (Modena) – characterised by a strong pattern of innovation activity. Administering a questionnaire to a representative sample of firms, we collect survey data on firm's performance, innovation practices, investment strategies, and cooperation efforts concerning firm's relationship and networking within and outside the district. A complementary positive effect of social capital and R&D investments emerges regressing a dummy for innovation on social capital indexes, R&D indicators, networking-R&D interaction variables and control variables, estimating a sort of 'knowledge production function'.

The added value of the paper is twofold: (i) first, we explicitly introduce social capital as an input into a knowledge production function, examining the complementarity between different forms of firm investments, networking and R&D, in a specific Italian case study, (ii) secondly, we analyse a specific social capital framework where empirical and theoretical investigations are 'complementary' and not consequential to each other. They point to somewhat different directions, although being joint tools for the purpose of the present paper. Empirical analysis SC and R&D as complementary inputs of innovation practices within a 'knowledge production approach'. This approach differs from introducing various indexes of social capital, as often found in the social capital empirical literature, without a robust conceptual underpinning. The main aim of the empirical analysis is to assess the degree of complementarity between social capital and R&D. Then, a theoretical model, which assumes complementarity between SC production and R&D, is developed, thus making roots on the aforementioned result. Theory and empirical analysis are then brought together and we may say that reinforce each other.

The paper is organized as follows. In section two, we first critically describes some of the principal results of the recent literature on SC. The most relevant definitions are presented and discussed. Hence a definition of SC is proposed, which is essentially based on the concept of

'intensity of networking activities' concerning network-involved agents. The framework for the theoretical and empirical analysis is presented. The framework largely draws upon works of impure public good production and non-cooperative agreements. In section three

Secondly, the applied analysis focuses the attention on a specialized biomedical district in the Emilia Romagna region, characterised by a strong pattern of innovation intensity, from which we collect survey data on firm performance, innovation practices, investment strategies, and cooperation efforts concerning firms relationship within the local district. Using logit models with technological innovation as dependant variable, a positive relationship emerges between the intensity of social capital (measured by a firm specific index of cooperation intensity within the district) and the level of innovative actions observed. Moreover, R&D and networking/social capital arises as complementary driving forces for innovation outputs. In section four, connecting to the complementarity between R&D and SC which emerges from the empirical model, a theoretical model is presented where the accumulation of Social Capital is assumed as the public component of the impure public capital R&D and the main implications of the model are discussed. The last section concludes the paper.

SC emerges from our contribution as the sustained joint effort instrumental (capital stock) to the production of quasi-*rents* associated to the private component of the impure-public good, from which non participants are excluded. The capital-like property lies in its instrumental value, which also differentiates the analysis from one of cooperation to producing public goods. If a comparison is to be made, SC shares some similarity with the idea of common goods, for which the efficient production is theoretically assured both by completely private or community property rights (Ostrom, 1999, 1990). Thus, incentives to join depend on dynamic quasi-rents produced by that *capital*, which rely on partial exclusion, since they are generated within a self-contained network. In the sense that participants, as long as they join the voluntary network, possess property rights on the intangible capital. Property rights are not alienable (re-sellable) by individual agents, at least in our present formulation.

It is worth noting that the main tasks for economic analysis on SC are, in our opinion, the definition of specific (bounded) SC concepts, and the consequential theoretical and applied analysis based on different conceptual definitions aimed at exploring diverse perspective son SC related issues. This is the only way to make SC an operational and robust field for integrated theoretical and empirical research.

2. Social capital: a framework for theoretical and empirical analysis

The main problem concerning the economic analysis of what has been termed 'social capital' is that the literature is strongly heterogeneous, and the notion of social capital is not always clearly assessed and described to be operative on theoretical and applied grounds. This is probably caused by the emphasis on inter-disciplinary research and the limited (so far) development of economic literature. Some definitions are too sociologically biased; others are too vague, or are not specific in terms of tools and objectives. Our first goal is thus to extract from the economic literature the definitions we retain consistent, then present our own definition.

Among the various definitions we came across in the literature, the followings are the most relevant for defining the boundaries of the issue in question: (i) "A variety of different entities with two *factors* in common: they all consist of some aspects of social structure, and they facilitate certain actions –whether personal or corporate actors- within the structure" (Coleman, 1988); (ii) "Those features of social organization, such as trust, norms, and networks that can improve the efficiency of society by facilitating coordinate actions" (Putnam, 1993); (iii) "A glue that holds societies together" (Serageldin, 1996).

Taking into account the above definitions, SC is possibly identifiable with the "culture" of a group of agents, a culture of economic reciprocity and cooperation.

More generally, two key issues arise up from the literature on SC, those of "trust" and "ease of cooperation".

Paldam (2000) specifically provides the following definitions, revolving around the notion of trust, cooperation and network: (i) *Ease of Cooperation*: "Social capital is the ability of a person belonging to a population to work voluntarily together with others (belonging to the same population), for a common purpose in groups and organizations*;(ii) Trust:* "Social capital is the quantity of trust a person (belonging to a population) has in other members of the same population".

Paldam also poses the assumption that the relationship between the concepts above presented is such that "trust"⇔"ease of voluntary cooperation" ± e_i, where e_i is a small error.

The author correctly defines SC as the glue generating excess cooperation; we here add "in excess" with respect to an equilibrium intended in a Cournot-Nash meaning.

Trust and ease of cooperation are two *factors* that simultaneously interact in the production of private and public goods, or forms of capital. We support the hypothesis that "norms of reciprocity, trust and institutions, as human artefacts, matter in the production of quasi public and pure public good" (Rudd, 2000, p. 132). The trust element is also pointed out by La Porta *et al* (1997), in their analysis of trust in large organizations. They claim that trust should be associated to greater cooperation, and is more essential in ensuring cooperation between strangers rather than among people who interact frequently and repeatedly. This means that trust is most needed to support cooperation in large and voluntary associations, where members interact infrequently to achieve private goals, which nevertheless need common forms of capital.

This last consideration is essential to our purposes concerning the definition of social capital, moving away from 'family' based and 'associative' based concepts as presented in Robison *et al.* (2002) and Putnam (1993), and from analysis of trust and cooperation relying on 'honesty' treated as a sort of public good (Nyberg, 1997).

Further, since the accumulation of social capital is by definition self-monitoring, it can be considered a factor that affects to some degree the level of monitoring costs. The costs are reduced if the cooperative agreement reaches an equilibrium which self-sustains itself on a bundle of incentives. For example, some authors argue that: "Social capital may be treated as the background factor (trust) that reduces the amount of free riding in certain well-defined games, for a given amount of third-part enforcement" (Paldam and Svendsen, 1999).

Accordingly and consequently, agents invest in SC since the stock produced reduces transaction costs. We may say that the formation of SC lies in between the *market* and *hierarchy* structures. Investments are made with the sole support of market institutions (where agents voluntary participate in exchanges), nevertheless, investments are asset specific and the opportunity cost of non investing in SC is sunk, specific to the voluntary agreement under analysis.

Along this line of reasoning, SC emerges as a stock of accumulating capital deriving from a process of voluntary cooperation for the fulfilment of common objectives[1].

Thus, SC may be included in a production function together with other inputs, linked with them to different degree of complementarity. The effects of SC are therefore analysed according

[1] Paldam (2000) stresses that even in business hierarchies SC cannot be enforced but must be developed accordingly to incentives, costs and benefits of dynamic cooperation. See also Leenders - Gabbay (1999).

to the shape of cost functions, returns to scale, factor productivity, market and shadow prices of capital investments[2].

Our intention is to concentrate on those two *factors*, trust and cooperation, specifically focussing on the voluntary nature of actions undertaken, and on the incentives schemes that support investment decisions in an environment where both market and non market returns are present.

A definition of SC strictly derives from the discussion presented above: SC is an intermediate capital good privately and intentionally produced, which endogenously accumulates from the flow of agents investments in voluntary cooperative effort. SC is also the equilibrium stock of the public component of an impure-public good, sustained by a set of private incentives. Its "production" and accumulation are self-enforcing and sustained by reciprocal benefits of cooperation.

SC as here defined gives robustness to the "Glue" metaphor, since it emerges as the stock of intangible capital, which increases the returns of production activities and is sustained by cooperative efforts. That is, it provides valuable market and non-market "services", specific to the agreement in force. Cooperation is sustained by non market investments, but the aim revolves around private appropriable benefits. SC is then the "sustainability" of cooperation aimed at generating innovation and rent creation for joining participants.

It is clear that the above definition hints at a microeconomic approach, differentiating the present analysis from that mostly found in the literature so far. It thus lies within the "narrow" definition of SC, following the World Bank (1997) terminology for microeconomic approaches, in opposition to wider meso and macro approaches[3]. Our framework is individual (agent) centred, preference based and incentives driven. In this sense it differs from the seminal work of Putnam and also, but on other grounds and to a lesser extent, from "development oriented" "community oriented" visions characterising the World Bank research and policy direction.

---

[2] The SC investments may also be treated as shifting downward the cost function of the firm, as a type of *collective external economies,* involving both scope and scale economies (Oughton - Whittam, 1997). In this sense, SC as a stock captures the idea that collective external economies of scale are realised by cooperation over input activities, such as research, technological development, organisational innovation, training and advertising, wherein fixed costs are pooled among agents who join (Caloghirou *et al.*, 2003).

[3] Wherein SC is included and studied as the "missing link", or residual and intangible capital factor, in explaining growth and development of economic systems. This is the "orthodox" approach to SC within economics. SC is the fourth form of capital, after man made, natural and human capital, in other words the "glue" which (i) may enhance other factor's productivity, (ii) reduces problems associated to "common property resources" and (iii) generically helps development to occur on sustainable basis (Cote and Healy, 2001). For an heterodox view on SC see Fine (2001).

As far as the capital-like properties[4] are concerned, SC as above defined owns a transformation capacity, in the sense that its accumulation is targeted toward the production of other forms of capital (man made or organizational) or final outputs[5]. It is durable as long as incentives exist to sustain it. In our case, the degree of durability is such that the stock elapses with the cooperative agreements established for specific objectives. Then, the breaking down of a coalition ends the value of the stock. Third, by "our" definition, SC accumulates or de-cumulates depending on the structure of individual incentives (benefits and costs), and it is subject to decay as a renewable 'collective resource'. In fact, decay depends on endogenous factors such as easy riding (non consistent actions of investment between agents) and on exogenous factors; investment flows are thus necessary for maintaining the stock. Contrary to Sandler's analysis of intergenerational club goods (Sandler, 1992, 1982), depreciation occurs because of a lack of strategic investment (reduced investment) in cooperation at any time *t*, rather than as a direct consequence of capital "use" (crowding externality). In other words, depreciation derives from "non use" rather than excessive use, as for many forms of collective manmade capital. Depreciation reflects the fact that much of SC investment is community-network specific.

The only capital-like property SC lacks is alienability, since we have shown that the stock of SC is intrinsically a relational dependent stock, consistently with Coleman's vision. It is not owned by individual agents or by the agents as a group, it is "asset specific" and an instrument for the purposes of the alliance[6]. Nevertheless, we argue the "inalienability" is the main specificity of SC indented as an intangible real asset. Inalienability is linked to non-marketability, in that agents invest in some imperfectly observable assets: costliness and imperfect observability are the main *factors* responsible for the systemic easy riding with respect to investment decisions. Thus, is Social Capital a real form of capital with respect to our definition? We believe it is[7].

---

[4] A stock of assets subject to an accumulation process, eventually associated to a depreciation rate, with a specific productivity impact on economic output, measurable in terms of net benefits (market and non market) over time.

[5] The definition of social capital as a stock of intangibles is not a completely shared vision. For instance, Arrow (1999) and Solow (1999) sharply conclude that the emphasis on *capital* is probably misplaced. SC derives instead from an association to the concept of human capital. In their view, the fact that *factors* such as trust, cooperativeness, and propensity to invest in a common effort have on the one hand a clear cut effect on total productivity, but on the other hand economics cannot consistently deal with SC as a proper form of capital. Other authors (Stiglitz, 1999) are more in favour of the SC consistency within economics.

[6] This point is also highlighted by Robison *et al.* (2000).

[7] A similar conclusion is reached by Westlund and Bolton (2003), who analyse factors like productivity, vintage aspect, maintenance. See also Galassi - Mancinelli (2004) for a discussion about the capital like properties of SC.

Moreover, the above definition clearly asserts that we consider SC not as an individual attitude towards "something good", but instead, as the public component of an investment in something else which implies private benefits too. Sc is here considered as the public component of an impure public good[8], in which agents invest.

For instance, the environment faced by firms willing of participating to a network may be depicted as follows: on the one hand a firm has the option of investing either in standard technology or in incremental innovations which do not require cooperative efforts within the network (the firm internalises investments and associated returns). Both options may be termed as Business As Usual (BAU) scenarios. On the other hand, the firm may invest in R&D involving radical innovations: in other words, innovations that involve structural breaks from the BAU (discrete changes concerning technological/organisational development) or that involve skills, knowledge and competences, which the firm only partially owns. In both cases, the innovation change usually requires a cooperative effort, and the investment may be thought as one on an impure public good, that is each unit of investment produces some percentage units of private benefits and some percentage units of public benefits. Private benefits are, for instance, technological amelioration appropriable by the firm and public benefits derive from the cooperative agreements among firms. The opportunity cost of the 'radical cooperative innovative' path is the value of investing in BAU options.

From the framework as depicted above emerges that what matters is that at some point agents need to join their efforts for achieving benefits which derives from and build on public-like forms of investments. This necessary joint effort to establish voluntary cooperative schemes, by which achieving goals specific to the network but appropriable by participants, characterises most forms of (i) voluntary agreements, (ii) inter-firms intra district cooperation, (iii) inter-firms inter-districts cooperation. The relevance of points (i)-(iii) as engines for innovation and growth at a regional level has increased over the last decades, following both the less prominent role of the state as "regulator" (top down approach), and the reshaping of governance and business strategies within the post-fordist society. Actually socio-economic changes occurring in the post fordist (post-industrial) era shift the focus of interest from man made forms of capital to human, environmental and social capital assets (Gerelli, 1999). Further, market and non-market 'horizontal' networks play a major role with respect to 'vertical' and

[8] In the economic literature, an impure public good, or mixed-public good, is a good which jointly gives private and public benefits (Cornes-Sandler, 1986). A typical example is that of an individual who, by being inoculated against an infectious disease, confers both a private benefit on himself and a public benefit by reducing the risk of spreading the disease through the community. In this case inoculation is the mixed-public good.

hierarchical relationships, bringing about a new scenario described by a cultural change in local and national production. Finally, "intentional" (multilateral) externalities turn over standard Marshallian "unintentional" externalities in explaining growth and innovation processes. The community benefits from positive network externalities[9]; nevertheless, differently from exogenous spillovers, the voluntary and intentional production of joint social benefits is costly; therefore incentives matter[10].

The public element of welfare function of one firm participating to the network agreement is, in our framework, the stock of SC on which the decision of action relies. SC is nevertheless strictly connected to private components of welfare (it is not a pure 'independent' public good), to which is linked by some degree of complementarity relationship. We may intend the investment on the private form of capital as a BAU choice, and the investment on the impure public good as network specific R&D generating radical innovations. As an example, the reader may refer to the usual situation characterised by the formation and development of voluntary agreements among firms, within a district or along a productive chain, aimed at reaching

[9] It is worth clarifying the issue of externalities in this context. The term *intentional* associated to that of externality may seem an oxymoron. Our purpose is nevertheless to differentiate between externalities generated within a public good model and externalities arising within the impure public good model, characterised by a certain degree of complementarity between some private and some public goods. In the first case, externalities are here defined as *unintentional*, since their production is separable with respect to the private good production from which they originate. It is obvious that both positive (Marshallian) externalities and negative externalities may be termed unintentional when the aim is to study the behaviour of agents within a network. In fact, agents may be or be not aware of the externalities they are causing to others; the crucial fact is that the private production and the public production of goods are conceptually and operatively separated: no complementarity exists. In the second case, the adjective intentional refers to the endogenous generation of spillovers; externalities can be defined as *intentional*, meaning that each agent's private production *intrinsically* involves, when complementarity is relevant, the production of public good units. As far as the analysis of network development and innovative clusters is concerned, this matters. Spillovers are not spreading "in the atmosphere" within the boundaries of the network, but they are produced by formal and informal agreements which constitute forms of specific sub-networks within the large network of clusters of firms. Intentionality thus refers to the *voluntary* setting up of social institutions, which do not characterise standard externalities. This feature also makes the empirical analysis more demanding.

[10] A further point could be added referring to Papandreou (1998), who correctly addresses all externalities as an incongruence (a mis-match) between the physical and institutional economic spaces: "the kinds of externalities and the institutional tools used to overcome them will vary according to how the physical and economic spaces are defined" (Papandreou, 2000, p.27). Along this line, unintentional externalities drive the creation of institutions (markets, price, incentives) which by definition do not exist ex ante, while multilateral forms of intentional externalities are entangled with the setting up of economic institutions. From the previous analysis it emerges as clearly relevant the role of "intentional cooperative strategies" as a form of demand for "new institutions", framed around new rules, endogenously created and bottom-up driven. Those bottom up coalitions share the risks of investing in community specific knowledge (vs. firm specific assets). Moreover, coalitions should usually rely on informal rules and non coercive incentives for sustaining *effective and efficient* agreements.

[10] From the previous analysis it emerges as clearly relevant the role of "intentional cooperative strategies" as a form of demand for "new institutions", framed around new rules, endogenously created and bottom-up driven. Those bottom up coalitions share the risks of investing in community specific knowledge (vs. firm specific assets). Moreover, coalitions should usually rely on informal rules and non coercive incentives for sustaining *effective and efficient* agreements.

environmental long run and policy-driven targets, for which existing knowledge and technology embodied in BAU capital are not sufficient (Mazzanti-Zoboli, 2005; Aggeri-Hatchuel, 1997).

It is worth underlining the voluntary element of the agreements in cooperation and production: social capital is self-enforcing, self-financing, in opposition to third-party enforcement frameworks. Thus, we may say that our SC environment belongs to a Coasian-like framework characterised by horizontal relationships, in opposition to third-party enforcement pigouvian-like institutional frameworks. Consequently, the notion of social capital is in our opinion strictly linked to the public good and externalities environments. It is external to the firm but internal to the network established. Models of public, mixed and club goods are useful to shape the problem at hand. SC is non-rival and non-excludable for the club members; to the extent that its provision is complementary to private good provision, a framework of impure public good emerges.

As far as measurement is concerned, we here want to stress (as a conclusion to the first section and opening a window to the following empirical analysis) how a proper measurement effort is fully dependant on (and consequential to) a clearer definition of what is meant by social capital, in its various possible forms, and on a clear assessment of its private and public *factors* of benefit (social welfare characteristics). Thus, models as designed by theory are instrumental to applied analysis. Further, in a micro-based framework, both the political and the economic jurisdiction of the SC network must be carefully established and assessed before starting any analytical and measurement effort. For a sound microeconomic analysis, both at theoretical and empirical level, a defined population of interest should be selected by assessing the "social network" boundaries.

As far as the measurement of SC is concerned, the main ways of approaching SC quantification at microeconomic level[11] are by: (i) specific case studies, using regional/national available dataset; (ii) revealed preference approaches (observing agent's behaviour), which includes both quantifying by observing choices (i.e. investment choices, participation rates, etc…); (iii) stated preferences methods (directly revealing behaviour when observation is difficult or we lack behavioural 'tracks'), which include quantifying by direct methods (i.e. interviewing and asking agent's).

[11] We do not address the macro-economic direction, which until recently has dominated the empirical measurement of SC, for two reasons. First, the focus is here strictly microeconomic. Secondly, the weaknesses of that direction, mainly the weak conceptual framework for SC, have recently been extensively highlighted by various authors, who state the greater added value of a microeconomic applied direction of research (Sobel, 2002; Durlauf, 2004; 2002).

The first method (by case studies) may be used to analyse specific firms or industries which are deemed to possess SC features. However, the main obstacle is that social capital features are usually non-market and non-accounted in regional and national dataset. Thus, the only consistent way to elicit the SC private and public characteristics is by way of survey-based approaches aimed at collecting the necessary data by means of structured questionnaires. The questionnaire should attempt to fill the conceptual definition, by recovering data on SC factors, R&D dynamics and other firm-specific factors possibly affecting innovation which we may use as controls, from stated responses. The next section presents an attempt of investigating the relationship between R&D and SC in fostering innovation by using a detailed ad hoc survey questionnaire eliciting information from firms belonging to an industrial network where innovation is the predominant factor for boosting growth and performance.

3. Social capital and R&D as engines for technological innovation: an empirical analysis

3.1 The data-set

The framework depicted above characterise different real-world situations where inter-firm cooperation is the primary and leading key to successful performance of the network, which we may also intend as an industrial district. Along this line, networking is a capital good and an intermediate input to production. Although we think the present analysis is highly specific concerning the elicited data, recent works which take a similar perspective are, among the others, Cassiman and Veugelers (2002), Becker and Dietz (2004), Fritsch and Franke (2004) and Negassi (2004). Those paper deal with innovation activities, R&D cooperation and (knowledge) spillovers, taking different perspectives and research directions. Summing up, they attempt to identify what the determinants of R&D intensity, R&D cooperation and innovation activities are specifying diverse reduced forms[12]. Building up on that research line, we here attempt to focus attention on the nexus of complementarity between networking and R&D as joint driving forces for technological innovation. Our contribution may find one inspiration in the concluding remarks of Cassiman and Veugelers (2002), who state that the relation between spillovers and

[12] Becker and Dietz (2004) estimate reduced forms for input and output innovation measures regressed over R&D cooperation and networking proxies. Fritsch and Franke (2004) use patent datasets to estimate the effect of both R&D intensity and R&D regional spillovers. Cassiman and Veugelers (2002) try instead to use R&D cooperation as dependant variable, explained by spillovers measures. Negassi (2004) exploits information concerning the budget spent on R&D cooperation and turnover based innovation measures.

cooperative agreements should be studied in the broader context of firm's innovation strategies, with a special focus on input complementarities[13].

Let us show how we set up the case study analysis for the biomedical industrial district of Mirandola (Modena). The empirical identification of the manufacturing firms belonging to this industrial district is carried out taking into account two different dimensions: (i) productive specialization and (ii) geographic area in which firm are located. Concerning productive specialization, we included in the sample all the manufacturing firms belonging to the ATECO classes 33.10[14]: *Manufacture of medical and surgical equipment and orthopaedic appliances*. With regards to the localization area of the district, we took into consideration the following seven municipalities of the *Provincia* of Modena[15]: Mirandola, Medolla, Concordia, Cavezzo, San Felice sul Panaro, San Possidonio e San Prospero. The reason behind this choice is that in these municipalities are concentrated the majority of the biomedical firms. We thus identified the 'biomedical district of Mirandola' (located within the Province of Modena) by taking into account only those firms which satisfy these two requirements: these firms operate in the sector 33.10 *Manufacture of medical and surgical equipment and orthopaedic appliances* and the headquarters of these firms is located in one the seven municipalities already indicated.

For this reason, we identified a sample of district firms, which we directly interviewed during a two-months period lasting from February to March 2004 with the aid of a structured questionnaire. We administered a short but focussed 4-pages questionnaire to a representative sample of firms, eliciting data on innovation practices, R&D investment, and cooperation efforts concerning firm's relationship and networking within and outside the local district. The selected period of reference was 2000-2002. As far as R&D data, are concerned, it was reasonably possible to ask firms annual data for each year from 2001 to 2003, while all questions regarding networking activities and innovation practices ask to determine a "trend" over the 2000-2002 period[16]. We decided not to elicit information on performance to minimise the

[13] Precisely " firms that decide to be innovation active need to understand the complementarities that exist between own R&D programs, cooperative agreements in R&D and external technology acquisition in order to take advantage of publicly available information within the innovation process".

[14] Economic activity classes defined by the Italian central agency of statistics (ISTAT).

[15] Modena is a central Province of the Emilia-Romagna Region. Emilia Romagna is an area of Italy characterised by a high density of industrial districts (more than 20 given official statistics), a value added per capita (22.738€ per capita in 2000) higher than the Italian average level (17.952€), and it represents the 7% of the Italian population with four millions residents. Thus, the Region is highly representative of the North-Central industrialised economic system.

[16] This is a key problem for empirical analysis concerning innovation and SC dynamics, since such data are difficulty, if not impossibly, revealed on an annual basis by firms. See Huselid and Becker (1996) for a contribution dealing

rejection rate; in addition, survey data on performance are known to be often lacking reliability. The first part of the questionnaire deals with general features of firms (typology, market orientation, revenue size, number of employees for the 3 years, age); the second part focussed on innovation practices (R&D expenditures over 3 years, employees involved in R&D, patenting, process and product innovations, sources of innovation, sources of information used); the third part on networking activities (firm formal and informal relationships with public authorities and other firms, internal or external to the district, involvement in production, market and innovation oriented networking).

The sample accounts for 40 of the 70 firms setting up the district "population" that we identified during an extensive research project realised some years ago on this district (Osservatorio sul settore biomedicale nel distretto mirandolese (*An investigation on the Mirandola biomedical district)*, 2001)[17].

As it turns out from tables 1-3, the coverage rate of our sample appears to be good. This is true both when considering all the firms (tab. 1), firms producing for final markets (tab. 2), and sub-contractors (Table 3).

Table 1 – A comparison between sample and population (year 2000)

	POPULATION(*)				*SAMPLE*			
	Firms		Employees		Firms		Employees	
	N.	%	N.	%	N.	%	N.	%
Final firm	35	50.0	3,114	85.1	18	45.0	1,812	77.2
Sub-contractor	35	50.0	546	14.9	22	65.0	536	22.8
Total	**70**	**100.0**	**3,660**	**100.0**	**40**	**100.0**	**2,348**	**100.0**

(*) Source: Osservatorio sul settore biomedicale nel distretto mirandolese (2001)

Table 2 – The distribution of final firms by employees class (year 2000)

	POPULATION(*)				*SAMPLE*			
	Firms		Employees		Firms		Employees	
	N.	%	N.	%	N.	%	N.	%
0-49	24	68.5	461	14.8	12	66.8	184	10.2
50-249	7	20.0	692	22.2	3	16.6	304	16.8

with empirical problems in frameworks where one has to face mixed qualitative, quantitative data, in both panel and cross sectionals settings.

[17] As stated in the final part of the first section, we argue that the main added value of current empirical analysis on SC may derive from focused survey study eliciting specific and often "latent" information which are not accounted for in market transaction and official data (i.e. Community Innovation Survey, national or regional statistics). With this respect, our analysis differs from studies using large, public but not focussed dataset (Cassiman and Veugelers, 2003). The trade off between large-public dataset with low specific data and small datasets which include non-market information is common to most analysis concerning innovation dynamics and firm relationships. The questionnaire is available on request.

>249	4	11.5	1,961	63.0	3	16.6	1,324	73.1
Total	**35**	**100.0**	**3,114**	**100.0**	**18**	**100.0**	**1,812**	**100.0**

(*) Source: Osservatorio sul settore biomedicale nel distretto mirandolese (2001)

Table 3 – The distribution of sub-contractors by employees class (year 2000)

	POPULATION(*)				*SAMPLE*			
	Firms		Employees		Firms		Employees	
	N.	%	N.	%	N.	%	N.	%
0-9	11	31.4	50	9.2	7	31.8	23	4.3
10-19	15	42.9	196	35.9	9	40.9	120	22.4
>20	9	25.7	300	54.9	6	27.3	393	73.3
Total	**35**	**100.0**	**546**	**100.0**	**22**	**100.0**	**536**	**100.0**

(*) Source: Osservatorio sul settore biomedicale nel distretto mirandolese (2001)

2.2 The empirical analysis

This section illustrates the econometric methodology we used to empirically assess the aforementioned complementarity between R&D and SC/networking. In order to perform this exercise, we estimate a "knowledge production function" (Griliches, 1979), modified to account for both the effects of R&D and networking on innovation[18]. The knowledge production function expresses the relationship between R&D output and R&D input within the 'conceptual' framework[19] of a production function (Fritsch and Franke, 2004). The reduced form is as it follows.

$$INN_i = \Theta\left(R\,\&\,D_i, Networking_i\right) \tag{1}$$

where INN_i represents the firm 'performance' output (innovation activity) while $R\&D_i$ and $Networking_i$ the firm inputs. Econometrically speaking, this knowledge production function is estimated by means of a Logit specification, shown by (2) and (3) below.

$$\begin{aligned}\Pr ob\left(INN_{i,t}\right) = \alpha + \beta\mathbf{X_i} + \phi_1 \cdot \left(R\,\&\,D\right)_{i,t-1} + \phi_2 \cdot \left(Networking\right)_i + \\ \phi_3 \cdot \left[\left(R\,\&\,D\right)_{i,t-1} \cdot \left(Networking\right)_i\right] + v_{i,t}\end{aligned} \tag{2}$$

A brief description of main covariates is necessary. $INN_{i,t}$ is a binary variable taking the value of one if the firm introduced product or process technological innovation over the 2000-

[18] We recall that networking is here intended as an input, hence as an intermediate capital good privately and intentionally produced, which endogenously accumulates from the flow of agent's investments in voluntary cooperative effort.

[19] Even without assuming the usual neoclassical properties concerning production inputs.

2002 period[20]. R&D is the expenditure level of the firm in research innovation activity. In order to cope with endogeneity problems, we decided to use the 2000 value as independent variable proxy for R&D. Networking is a variable capturing the networking effects concerning the social capital oriented activity of the firm, which was addressed by a specific and focussed part of the questionnaire. Two dummies are introduced as proxies of social capital, on the one hand, and information spillovers on the other[21]. The first takes the value of one when a firm is associated to formal or informal networking relationships dealing with both production issues, innovation issues and market strategies. The second dummy (see also table 5) takes the value of one if a firm exploits as a main source of information other firms belonging to the same district (exchanging flows of critical information). The vector X_i includes a set of control variables (firm typology, firm size, market orientation, etc..) which we included to fully specify the specification of theoretically possible innovation determinants. Otherwise, the effect of R&D and networking could be overestimated.

Before presenting the findings of the econometric investigation, we present some descriptive statistics concerning the variables used. Table 4 reports the findings.

Table 4 – Descriptive statistics

	N. OBS.	*MEAN*	*STD. DEV.*	*MIN.*	*MAX.*
Log (employees)	40	2.996	1.435	0	6.526
Typology	40	0.6	0.496	0	1
Age	40	13.8	8.811	2	34
Dummy networking [b]	40	0.725	0.452	0	1
Dummy information spillovers[c]	40	0.2	0.405	0	1
R&D expenditure in 2000 (€)	40	225.359,7	901.958,5	0	5.500.000

The first regression tests the effects of R&D and networking entering as independent variables, together with control variables. The second regression (3) instead includes the interaction term [R&DxSC] in order to test the 'complementarity' hypothesis.

The estimation poses at least two problems. First, heteroskedasticity, as it is often fund when cross sectional data are used, may reduce the efficiency of econometric estimates. Thus, all estimates are carried out adopting a "robust" estimator for the Logit Model which addresses

[20] See Negassi (2004), among others, for a critical debate over the various innovation proxy measures, on the input and output side.
[21] See Cassiman and Veugelers (2002) for a discussion on the role of incoming (information) spillovers as an engine for R&D cooperation and, indirectly, for innovation.

such source of distortion. Secondly, there is a potential endogeneity of R&D in the regression. In fact, as many contributions have shown a lag between R&D input and innovation output is a general plausible assumption often verified by empirical assessment. As already said, we thus use the R&D data for 2000 as an explanatory factor for innovation over 2000-2002, introducing a "lagged" term into the regression (thus specifying an hybrid cross sectional model)[22].

Let us now go back to the econometric findings. In Table 5, we report results for various estimates related to different specifications of equation (2) above. In particular, column [1] reports the reduced form when only control variables are included. In this case, the only significant factor is the variable regarding market orientation: whether the firm produces for the market or it is a sub-contractor. Innovation is associated to final market production, as expected ex ante. Other controls, like age and size, do not seem to play a major role.

Focussing on other specifications, we note that the impact of R&D and networking as determinants of innovation is highly significant. It is worth noting two points. First, both the *networking dummy* variable and the *information spillover* dummy variable arise significant when included separately as added covariate to the control variables of [1] (columns 2 and 5). Secondly, the two variables emerge statistically significant, overwhelming the effect of other firm characteristics captured by control variables, when both are included (column 4 and 6). This could be a first assessment of the joint/complementary driving stimulus provided by R&D and SC.

In order to further assess such result, we present the estimates for equation (3) above, entering the interaction variable term R&D*networking[23] as (additional) explanatory factor in regressions. Column 7 in table 5 shows results. The nexus of complementarity is thus reinforced by the significance of the interaction term as explanatory factor of innovation.

We may conclude this section summarising the outcome of the econometric exercise. Social capital investments, proxied by two variables concerning networking activities, emerges a crucial driving force for product and process innovation. Innovation is also triggered by (past) expenditures in R&D, confirming what expected *ex ante*. Further, a more important, social capital/networking and R&D arise jointly determining innovation intensity. The outcome is robustly confirmed by different econometric specifications of the knowledge production function. Those aforementioned driving forces appear to overwhelm here the effect of other explanatory factors of innovation, like firm size- which it is usually a key driving force of

[22] See Huselid and Becker (1996) and Cassiman and Veugelers (2002) for more insights on the issue.

innovation practices and high-performance practices. Only the dummy capturing the market orientation of firms (value one if firms sell the product on the final market) is significant in some of the regressions. This result, although circumscribed to the district observed, is in contrast to the size effects often emerging from studies on innovation practices and with other evidence, which tend to reduce the emphasis on R&D cooperation with respect to size, market share ad other firm-specific characteristics (Negassi, 2004). Further empirical evidence is thus necessary for a generalisation. We observe that usually the studies analyse R&D intensity and R&D cooperation or specific networking activities as separate and independent factors, without investigating the joint role of the two R&D-related elements for innovation.

This evidence is the basis for the theoretical analysis, which assumes a complementarity link between social capital and R&D within a dynamic framework. As it will be highlighted in the conclusions of the paper, the empirical evidence on the relevancy of the joint effort in networking and R&D investments is a key element which on the one hand it confirms the co-evolutionary dynamics of innovation, networking and R&D (often simply assumed) and on the other hand it should affect the implementation (the targets) of local/industrial public policies.

[23] Interacting R&D in 2000 with the dummy that takes value 1 if the firm is characterised by formal or informal networking relationships dealing with both production issues, innovation issues and market strategies.

Ta*ble 5 - Econometric estimates*

	Dependant Variable *Innovation dummy (2000-2002)*						
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
ESTIMATION METHOD	LOGIT(A)	LOGIT(A)	LOGIT(A)	LOGIT(A)	LOGIT(A)	LOGIT(A)	LOGIT(A)
Constant	-1.130 [0.971]	-3.104** [1.253]	-0.357 [1.141]	-3.363** [1.515]	-2.577* [1.409]	-2.556* [1.582]	-0.156 [1.341]
Log (employees)	0.211 [0.314]	0.509 [0.383]	0.019 [0.357]	0.398 [0.387]	0.530 [0.351]	0.525 [0.349]	0.204 [0.325]
Typology (d)	1.930** [0.831]	1.308 [0.383]	1.053 [0.894]	0.095 [0.998]	2.532** [0.905]	1.624* [0.981]	1.480* [0.892]
Log (Age)	-0.012 [0.044]	-0.011 [0.048]	-0.060 [0.075]	-0.044 [0.075]	-0.039 [0.053]	-0.809 [0.084]	-0.588 [0.688]
Dummy networking (b)	…	2.119** [0.952]	…	2.931** [1.030]	…	…	…
Information spillovers (c)	….	…	…	…	3.368** [1.619]	3.812** [1.767]	…
R&D expenditure in 2000	…	…	0.0001** [0.00005]	0.0001** [0.00009]	…	0.0001** [0.00008]	…
Dummy networking(b) * R&D expenditure in 2000	…	…	…	…	…	…	0.0001** [0.00005]
N. Obs.	40	40	40	40	40	40	40
Pseudo-R^2	0.182	0.281	0.361	0.471	0.328	0.510	0.287

** significant at 5%; * significant at 10%

(a) Standard errors [in brackets] are computed with the White method in order to correct for heteroschedasticity.

(b) This dummy takes value 1 if the firm is characterised by formal or informal networking relationships dealing with both production issues, innovation issues and market strategies.

(c) This dummy takes value 1 if the firm exploits and receives critical information from agents belonging to the same network.

(d) This dummy takes value 1 if the firm sells its products on the final market, 0 if the firm is primarily a sub-contractor.

4. Private and public benefits from social capital

Econometric analysis highlights, in the present case study, that the two inputs of innovation, R&D and networking/social capital, consistently arise as complementary driving forces.

The aim of this section is to focus on this nexus of complementarity with the purpose of analysing the accumulation of SC by firms joining a network (or a district), through the development of a dynamic theoretical model where SC is assumed the public component of an impure public good, following the conceptual framework depicted in section one.

4.1 The firms in the industrial district

We assume that there is an industrial district composed of N firms[24]. Each firm invests in two kinds of capital, y_i and R_i. y_i has mere private characteristics and R_i has the characteristic of an impure public good. It has (produces) either a private characteristic, z_i (which has no effects on the other firms) and a public characteristic, s_i (which has effects also on the other firms).

The investment in the private kind of capital, y_i, can represent an investment in a BAU (business as usual) capital stock, and at the investment in the 'impure public' capital[25], R_i, as investment in R&D involving (radical) innovations. In this case we can take as example of the "public component", s_i, the formation of voluntary and self enforcing agreements among firms.

Therefore, the public component, s_i, is consistent with the definition of social capital have presented in section 1. Actually, s_i is an intermediate capital good privately and intentionally produced, which endogenously accumulates from the flow of agents investments in voluntary cooperative effort; and it is also the public component of an impure-public good.

Since R_i has the characteristic of an impure public good, each unit of investment by the firm i in R_i is such that:

$$z_i = \alpha R_i \qquad 0 \leq \alpha \leq 1 \text{ } given \tag{1}$$

$$s_i = \beta R_i \qquad 0 < \beta \leq 1 \text{ } given \tag{2}$$

Where α and β are exogenously given coefficients reflecting a simple process, whereby z_i and s_i are jointly generated in fixed proportion by the investment in R_i.

We are hence assuming that whenever a firm invests in one unit of R_i, she invests in α given units of a private characteristic and in β given units of social capital[26], s_i.

That is whenever a firm invests in one unit of R_i, her investment is in some percentage the creation of a private asset and in some percentage the creation of social capital and the two components of the stock are complementary, hence increasing either one makes increasing the other more attractive.

[24] Each firm is indexed by the subscript $i=1,...,N$.

[25] Notice that we do not deal with club goods because here the size of the community (network) consuming the public good is exogenously fixed. This characteristic (community size) does not appear explicitly in the analysis.

[26] Notice that, by equation (2) we assume that s_i can never be zero, because we suppose that each firm inside the network invests at least a minimum positive amount in "networking" and establishing even the simplest form of relationships or agreement.

Moreover, since s_i exert effects also on the other firms inside the network and vice versa, we define:

$$S_{\neq i} = \sum_{j \neq i} s_j = \sum_{j \neq i} \beta R_j \qquad \forall\, i, j$$

(3)

and:

$$S = \sum_{i=1}^{N} s_i = \sum_{i=1}^{N} \beta R_i = s_i + S_{\neq i}$$

(4)

The whole quantity of the public characteristic (S) is given by the sum of the single contributions by any firm.

We adopt the Nash-Cournot assumption that the single firm i regards $S_{\neq i}$ as exogenously given.

From equations (1), (2), (3) and (4) the investment of firm i in one unit of R_i has therefore three effects: (i) an increase in i's private benefits due to the private characteristic, z_i ($=\alpha R_i$); (ii) an increase in i's private benefits due to the public characteristic, s_i; (iii) an increase in the total amount of the public component available to any firm inside the network (S).

Hence, we can define firm i's benefit function of the investment in the impure public capital, R_i as:

$$B_i = B_i\left[S, z_i, I_{R_i}\right]$$

and, from equations (1), (3) and (4), it can be written as:

$$B_i = B_i\left[(s_i + S_{\neq i}), \alpha R_i, I_{R_i}\right] \qquad \forall i$$

(5)

It depends on the firm i's choice about the flow variable (I_{R_i}), on the consequent choice on the stock variable (R_i), on the complementary choice about s_i, and on the other firms choice about $S_{\neq i}$.

We assume that the benefit function of firm i is continuous, strictly increasing, strictly quasi-concave, and everywhere twice differentiable with respect to all its arguments.

Since, from equation (2) we have assumed that R_i and s_i are complementary, we can write the condition of *Edgeworth complementarity* as:

$$\frac{\partial^2 B_i}{\partial R_i \partial s_i} \geq 0.$$

We can define the investment cost function of any firm *i* regarding the impure public capital R_i as:

$$C_i = C_i(I_{R_i}) \qquad \forall i$$

(6)

with $C_i^{'}(.) \geq 0$, and $C_i^{''}(.) \geq 0$.

Since the variation of R_i stock in time is:

$$\frac{\partial R_i}{\partial t} = \dot{R}_i = I_{R_i} - \delta R_i \qquad \forall i$$

where δ is the exogenous depreciation rate[27], we can write firm's investment cost function in R_i as[28]:

$$C_i = C_i(\dot{R}_i + \delta R_i) \qquad \forall i \qquad (7)$$

4.2 The accumulation of SC inside the industrial district

We assume that each firm inside the industrial district has a known lifespan of *T* periods and that she discounts the future with the discount factor ρ.

Each firm wants to maximise her net benefit function[29], in the interval of time[0, *T*]:

$$Maximize \int_0^T \left\{B_i\left[(s_i + S_{\neq i}), \alpha R_i, I_{R_i}\right] - rC_i\left(I_{R_i}\right)\right\} e^{-\rho t} dt$$

s.t.:

$$s_i = \beta R_i$$

$$\dot{R}_i = I_{R_i} - \delta R_i .$$

Where the transversality conditions are: $R_i(0) = \bar{R}_i$, $R_i(T)$ free ($\bar{R}_i$, *T* given), and $\lambda(T)=0$.

The Hamiltonian is:

$$H(t, R_i, I_{R_i}, \lambda) = \left\{B_i\left[(s_i + S_{\neq i}), \alpha R_i, I_{R_i}\right] - rC_i\left(I_{R_i}\right)\right\} e^{-\rho t} + \lambda(t)(I_{R_i} - \delta R_i)$$

---

[27] Since R_i is characterised by both a private component, z_i and a public component, s_i (social capital), also the depreciation rate will concern both the depreciation of usual capital and the depreciation of social capital (that it is a depreciation which derives from non use rather than excessive use).

[28] Moreover we assume that firms are symmetric: they have identical investment cost functions. We put the opportunity cost of the investment in R_i equal to *r* (that is the value of the private capital, y_i).

[29] For each firm, R_i is the state variable and I_{Ri} is the control variable.

From the second maximum principle condition (equation of motion for λ, $\dot{\lambda} = -\frac{\partial H}{\partial R_i}$), we get[30]:

$$\lambda^*(t) = \frac{\left[\frac{\partial B_i(.)}{\partial(s_i + S_{\neq i})}\beta + \frac{\partial B_i(.)}{\partial R_i}\alpha\right]}{(\rho+\delta)}(e^{-\rho t} - e^{-(\rho+\delta)T+\delta t}). \quad (8)$$

Substituting in the first maximum principle conditions($\frac{\partial H}{\partial I_{R_i}}$), we have:

$$\frac{\partial H}{\partial I_{R_i}} : e^{-\rho t}\left[\frac{\partial B_i(.)}{\partial I_{R_i}} - r\frac{\partial C_i(.)}{\partial I_{R_i}}\right] + \frac{\left[\frac{\partial B_i(.)}{\partial(s_i + S_{\neq i})}\beta + \frac{\partial B_i(.)}{\partial R_i}\alpha\right]}{(\rho+\delta)}(e^{-\rho t} - e^{-(\rho+\delta)T+\delta t}) = 0 \quad (9)$$

Differentiating eq. (9) (which represents, in each period *t*, the equilibrium level of investment in R_i) with respect to *r*:

$$\frac{\partial^2 H}{\partial I_{R_i}\partial r} : -e^{-\rho t}\frac{\partial C_i(.)}{\partial I_{R_i}} < 0 \quad (10)$$

In each period t firm i's optimal level of investment in R_i *decreases at the increasing of the opportunity cost of the investment in* R_i.

Moreover, if we totally differentiate equation (9) with respect to s_i and $S_{\neq i}$, we get[31]:

$$\frac{\partial s_i}{\partial S_{\neq i}} = \frac{\beta B_{i_{S_{S\neq i}}}}{\left[\beta B_{i_{S_{s_i}}} + \alpha B_{i_{R_{s_i}}}\right]} \quad (11)$$

The sign of the numerator of eq. (11) depends on the sign of $\beta B_{i_{S_{S\neq i}}} = \beta\frac{\partial^2 B_i\left[(s_i + S_{\neq i}), \alpha R_i, I_{R_i}\right]}{\partial(s_i + S_{\neq i})^2}$, which is certainly non-positive, since we have assumed the strictly quasi-concavity of the benefit function of firm *i*.

[30] The analytical steps to get equation (8) are shown in Appendix 1.

[31] Remind that: $s_i = \beta R_i$ and $S = s_i + S_{\neq i}$.

The sign of the term that appears in the square bracket at the denominator in equation (11) depends on the sign of $(\beta B_{i_{S_{si}}} + \alpha B_{i_{R_{si}}})$. Whereas $\beta B_{i_{S_{si}}} = \beta \frac{\partial^2 B_i\left[(s_i + S_{\neq i}), \alpha R_i, I_{R_i}\right]}{\partial (s_i + S_{\neq i})^2}$ is certainly non-positive, $B_{i_{R_{si}}}$ is nonnegative, since we have assumed that R_i and s_i are complementary, hence $\frac{\partial^2 B_i}{\partial R_i \partial s_i} \geq 0$. Since the technological parameters, α and β, are independently determined, one cannot rule out the possibility that $\alpha B_{i_{R_{si}}} > \beta B_{i_{S_{si}}}$. In this way, complementarity between R_i and s_i can produce, in each period *t*, a positive response:

$$\frac{\partial s_i}{\partial S_{\neq i}} > 0 \qquad (12)$$

Hence, in the case depicted above ($\frac{\partial s_i}{\partial S_{\neq i}} > 0$), *the reaction curve may have positive slope*: in this case, an increase in $S_{\neq i}$ raises the single firm's marginal valuation for the private characteristic αR_i. The single firm now wishes to increase her investment in R_i. To do this, the single firm must increase her stock of R_i, which has the effect of increasing s_i (via $s_i = \beta R_i$), her own generation of the public characteristic (social capital).

The conclusion is that if the other firms' investment in SC ($S_{\neq i}$) increases, also the investment in SC from the single firm *i* may increase. Hence a positive "culture" in a network may have positive effects on the investment of SC by the single firm.

But the increases of the investment in s_i pass through firm *i*'s investment in R_i.

And from equation (10) we get that in each period *t* firm *i*'s optimal level of investment in R_i decreases at the increasing of the opportunity cost of the investment in R_i.

Hence if the opportunity cost of R_i is too high, the single firm *i* does not invest in R_i and, as a consequence, she does not invest in SC too.

From the third maximum principle conditions (equation of motion for R_i, $\dot{R}_i = \frac{\partial H}{\partial \lambda}$) we get[32] the optimal state path:

[32] The analytical steps to get equation (13) are shown in Appendix 2.

$$R_i^*(t) = \left(\bar{R}_i - \frac{I_{R_i}}{\delta} \right) e^{-\delta t} + \frac{I_{R_i}}{\delta}$$

(13)

Substituting with $I_{R_i}^*$:

$$R_i^*(t) = \bar{R}_i\, e^{-\delta t} + \frac{I_{R_i}^*}{\delta}(1 - e^{-\delta t}) \qquad (14)$$

In the case depicted in equation (12) ($\frac{\partial s_i}{\partial S_{\neq i}} > 0$), since $R_i = \frac{1}{\beta} s_i$, we can assert that, in each period t, R_i^* is positively related to $S_{\neq i}$.

From the results of the model we can deduce that if SC is the public component of an impure public capital, an increase of the other firms' investment in the public component (SC) may induce firm *i* to increase her own investment of the impure public capital R_i, and, as a consequence, to increase her own investment of SC (s_i). If we consider high levels of investments in SC by the firms of a network, which may be strictly associated to the level of "civic virtue" of that network, this confirms what part of the literature on SC[33] asserts: the level of "civic virtue" of a geographic area is positively correlated to the level of investments in SC by economic agents.

Nevertheless, as it is shown above, this happens only until the "price" of the investment in the impure public capital is convenient: if the opportunity cost of the investment in R_i is too high, the single firm will not increase her investment in R_i, and as a consequence, will not increase her investment in SC, even if the availability of SC provided by the other firms is high.

Hence, if SC is definable as the public component of an impure public capital, the "civic culture" of the area to which the firm belongs is not sufficient to increase her investment in SC, because this investment depends also on the economic profitability in investing in the impure public capital. And this is true for each firm inside the network. As a consequence, the whole

[33] We refer to that line of analysis which mainly stems from the famous contributions associated to the work of Fukuyama (1995) and Putnam (1993). The latter is indeed famous for a study on SC taking Italy as case study. The interest of both approaches is nevertheless on "culture" and "institutions". No attempt is made to analysing what the causes of SC formation and development are: the interest is here on effects and on comparative analyses between areas and regions. The main risk of this approach is to explain social phenomenon only by the (observed) status quo culture, with minor attention to economic and political dynamic elements. What often emerges from this approach to social capital is that geographic areas in which investments in SC are low are typically characterised by a low level of "civic virtue". The reasons for which this happens are not explored and, as a consequence, the economic incentives behind the investments in SC are not investigated. This is a "grey" area which needs further empirical analysis. This paper provides a starting piece of the puzzle.

level of investment in SC inside the network tend to be correlated to the opportunity costs of economic actions. The higher the opportunity costs (conversely, the lower the profitability of innovation), the lower the stock level of SC.

As a conclusion, if and only if the economic conditions which determine a favourable environment to the investment in the impure public capital improve, it is possible to hope in an increase of the investments in SC (and R&D, as driving forces of innovation and then possibly firm performance) by economic agents. If SC is assessed as the public component of an impure public good which is a crucial intermediate capital good for firm performance and innovation practices, the incentive devices to invest in SC are economic-biased, and they are not linked to the "civic culture" of the geographic area, which may be or not be a correlated socio-economic element.

5. Conclusions

The main aim of the paper was to verify the hypothesis that social capital is a crucial, though not the only, element in explaining technological innovation in industrial districts. A strong degree of complementarity between usual production and innovation inputs (R&D) and social capital - defined within a networking-oriented framework- is expected a priori following the SC literature. Empirical results confirm this hypothesis of complementarity between R&D and networking activities, and help shedding light on the ongoing social capital debate, in assessing the effective role of this capital input in stimulating innovation and consequently economic growth.

We focused our attention on the biomedical industrial district of Mirandola (Modena), characterised by a strong pattern of innovation activity, from which we collect survey data on firm's performance, innovation practices, investment strategies, and cooperation efforts concerning firm's relationship within the local district. Econometric analysis shows that R&D and networking/social capital consistently arise as complementary driving forces for innovation outputs.

Building up this nexus of complementarity, a dynamic theoretical model then shows that if social capital demonstrates to effectively be the public component of the impure public capital R&D, then the 'civic culture' of the area in which the firm works is not a sufficient explanatory factor to increase the firm investment in social, since this investment strictly depends on the economic profitability linked to innovative non BAU strategies. If and only if the economic

conditions which determine a favourable environment to the investment in the impure public capital improve, it is possible to hope in an increase of the investments in SC by the agents.

It is worth noting that the outcome arising from the empirical and theoretical analysis –the pivotal role of complementarity associated between R&D and SC/networking on the input side of the production-innovation process, affects the perspective concerning policy action. If empirical evidence confirms that this complementarity is present and plays key role (further evidence is needed to generalise the result) and consequently strong links exist between market and non-market dynamics relating to firms, then the role for policy actions targeted to Social capital is clearer and larger. It is a policy effort which should be targeted toward both market and non market (i.e. R&D *and* SC) characteristics taken together, rather than an effort directed to the production of (local) public goods (SC) or innovation inputs as independent elements of firm's processes. The difference is not purely speculative, but it matters as far as policy effectiveness is concerned. SC/networking dynamics might positively evolve only if the private opportunity cost of investing in innovation is sufficiently low. This leads to new research lines, given the necessity of investigating what the opportunity cost threshold may be in a specific environment. Empirical analysis should bring together market and non-market survey based information.

The results of the theoretical model deserve other future empirical analysis. Particularly, it will be helpful to compare the accumulation of social by firms joining districts situated in two different geographic areas characterized by different opportunity costs of investing in the impure public capital.

We think that only a joint theoretical-empirical effort can provide benefit for the Social capital framework. Otherwise, the risk is of focussing attention on not tested hypothesis as guidance for policymaking. We recommend further work on the applied direction, where there is great space for providing new evidence stemming from specific and micro-oriented survey studies.

References

AGGERI F., HATCHUEL A. (1997), A Dynamic Model of Environmental Policies. The Case of Innovation Oriented Voluntary Agreements, Nota di Lavoro No 24.97, FEEM, Milan.

ARROW K.J (1999), *Observations on Social Capital*, in Dasgupta P., Serageldin I. (eds.) (1999), *Social Capital. A Multifaceted Perspective*, The World Bank, Washington D.C.

BARACCHI M., BIGARELLI D. (2001), *Osservatorio sul settore biomedicale nel distretto mirandolese, Seconda rilevazione*, Ricerche e Interventi di politica industriale e del lavoro (R&I), Carpi.

BECKER W. DIETZ J. (2004), R&D cooperation and innovation activities of firms. Evidence for the German manufacturing Industry, *Research Policy*, vol. 33, pp. 209-23.

CASSIMAN B.,VEUGELERS R. (2002), R&D Cooperation and Spillovers: some Empirical Evidence from Belgium, *American Economic Review*, vol.92, n.4, pp.1169-1184.

CALOGHIROU Y., IOANNIDES S., VONORTAS S. (2003), Research Joint Ventures, *Journal of Economic Surveys*, vol.17, n.4, pp. 541-70.

COLEMAN J. (1988), Social Capital in the Creation of Human Capital, *American Journal of Sociology*, n. 94, pp. 95-120

CORNES R., SANDLER T. (1986), *The Theory of Externalities, Public Goods, and Club Goods*, Cambridge University Press, Cambridge, MA

COTE S., HEALY T. (2001), *The Well Being of Nations. The Role of Human and Social Capital*, OECD, Paris

DASGUPTA P., SERAGELDIN I. (eds.) (1999), *Social Capital. A Multifaceted Perspective*, The World Bank, Washington D.C.

DURLAUF S., FAFCHAMPS M. (2004), Social Capital, NBER paper n.10485, NBER.

DURLAUF S (2002), On the Empirics of Social Capital, *The Economic Journal,* vol. 112, pp. 459-79.

FINE B. (2001), *Social Capital vs Social Theory: Political Economy and Social Science and the Turn of the New Millenium*, Routledge, New York.

FRITSCH M. FRANKE G. (2004), Innovation, regional knowledge spillovers and R&D cooperation, *Research Policy*, vol. 33, pp. 245-55.

FUKUYAMA F. (1995), *Trust: the Social Virtues and the Creation of Prosperity,* The Free Press, New York

GALASSI F., MANCINELLI S. (2004), Why is Social Capital a "Capital"? Public goods, co-operative efforts and the accumulation of intangible assets, in Bianchi P., Labory S. (eds.) (2003), *The Economics Importance of Intangible Assets,* Ashgate, London, *forthcoming*

GERELLI E. (1999), Thinking about the Future: Economic Aspects, paper presented at the seminar *Scenarios: the art of thinking the unthinkable*, University of Pavia, Pavia, *mimeo*

GLAESER L., LAIBSON D., SACERDOTE B. (2002), The Economic Approach to Social Capital, *The Economic Journal,* vol.112, pp.437-458.

GRILICHES S. (1979), Issues in assessing the contribution of R&D to productivity growth, *Bell Journal of Economics*, vol. 10, pp. 92-116.

LA PORTA, R., LOPEZ DE SILANES, F., SHLEIFER, A., VISHNY, R. (1997), "Trust in Large Organizations", *American Economic Review*, papers and proceedings vol. 87, n.2, pp. 333-38

LEENDERS R.A.J., GABBAY S.M. (eds.) (1999), *Corporate Social Capital and Liability*, Kluwer, Dordrecht

MAZZANTI M., ZOBOLI R. (2005), The Choice of Environmental Policy Instruments and Induced Technological Innovation. The case of End-of-Life Vehicles, *Ecological Economics*, forthcoming.

MCCONNELL K.E. (1997), Does Altruism Undermine Existence Value?, *Journal of Environmental Economics and Management,* vol. 32, n. 1, pp.22-37.

NEGASSI S. (2004), R&D cooperation and innovation in a microeconometric study on French firms, *Research Policy*, vol. 33, pp. 365-384.

NYBERG S. (1997), The Honest Society: Stability and Policy Considerations, *Journal of Public Economics*, vol. 64, pp. 83-99.

OSTROM E. (1999), Social Capital: a Fad or a Fundamental Concept, in Dasgupta P., Serageldin I. (eds.) (1999), *Social Capital. A Multifaceted Perspective*, The World Bank, Washington D.C

(1990), *Governing the Commons. The Evolution of Collective Action,* Cambridge University Press, Cambridge

OUGHTON C., WHITTAM G. (1997), Competition and Cooperation in the Small Firm Sector, *Scottish Journal of Political Economy*, vol. 44, n. 1 pp. 1-30

PALDAM M. (2000), Social Capital: One or Many? Definition and Measurement, *Journal of Economic Surveys,* vol. 14, n. 5, pp. 629-653

PALDAM M., SVENDSEN G. T. (2000), An essay on social capital: looking for the fire behind the smoke, *European Journal of Political Economy*, vol. 16, pp. 339-366

PAPANDREOU A. (2000), Externality, Convexity and Institutions, wp n.48, Fondazione ENI Enrico Mattei, Milan.

- (1998), *Externality and Institutions*, Clarendon Press, Oxford.

PUTNAM R.D. (1993), The Prosperous Community-Social Capital and Public Life, *The American Prospect*, n. 13, pp. 35-42

ROBISON L.J., SCHMID A., SILES, M. (2002), Is Social Capital really Capital?, *Review of Social Economy,* vol.60, n.1, pp.1-21.

RUDD M.A. (2000), Live long and prosper: Collective Action, Social Capital and Social Vision, *Ecological Economics*, vol. 34, pp. 131-44

SANDLER T. (1992), *Collective Action. Theory and Applications*, Wheatsheaf

SANDLER T. (1982), A Theory of Intergenerational Clubs, *Economic Inquiry,* vol. 20, pp. 191-207

SERAGELDIN I. (1996), Sustainability as Opportunity and the Problem of Social Capital, *The Brown Journal of World Affairs,* n. 3, pp. 187-203

SOBEL J. (2002), Can we Trust Social Capital?, *Journal of Economic Literature*, vol. XL, pp. 139-154

SOLOW R. M. (1999), *Notes on Social Capital and Economic Performance,* in Dasgupta P., Serageldin, I. (eds.) (1999), *Social Capital. A Multifaceted Perspective*, The World Bank, Washington D.C.

STIGLITZ J. (1999), Formal and Informal Institutions, in Dasgupta P., Serageldin, I. (eds.) (1999), *Social Capital. A Multifaceted Perspective*, The World Bank, Washington D.C

WARNER M. (2001), Building Social Capital: the Role of Local Government, *Journal of Socio-Economics*, vol.30, pp.187-192.

WESTLUND H., BOLTON R. (2003), Local Social Capital and Entrepreneurship, *Small Business Economics*, vol.21, pp.77-113.

WORLD BANK (1997), "Social Capital: the Missing Link?", in *Monitoring Environmental Progress: Expanding the Measure of Wealth,* The World Bank, Washington D.C.

Appendix 1

(Equation of motion for λ).

The equation of motion for λ, $\dot{\lambda} = -\frac{\partial H}{\partial R_i}$, is:

$$\dot{\lambda} = -\frac{\partial H}{\partial R_i} = -e^{-\rho t}\left[\frac{\partial B_i\left[(s_i + S_{\neq i}), \alpha R_i, I_{R_i}\right]}{\partial(s_i + S_{\neq i})}\beta + \frac{\partial B_i\left[(s_i + S_{\neq i}), \alpha R_i, I_{R_i}\right]}{\partial R_i}\alpha\right] + \delta\lambda(t)$$

from which:

$$\frac{\partial\lambda}{\partial t} - \delta\lambda = -\left[\frac{\partial B_i\left[(s_i + S_{\neq i}), \alpha R_i, I_{R_i}\right]}{\partial(s_i + S_{\neq i})}\beta + \frac{\partial B_i\left[(s_i + S_{\neq i}), \alpha R_i, I_{R_i}\right]}{\partial R_i}\alpha\right]e^{-\rho t}$$

The complementary function is:

$\lambda_c(t) = Ae^{\delta t}$ (*A arbitrary*)

To find the particular integral we put:

$$\lambda' - \delta\lambda = -\left[\frac{\partial B_i(.)}{\partial(s_i + S_{\neq i})}\beta + \frac{\partial B_i(.)}{\partial R_i}\alpha\right]e^{-\rho t}$$

and:

$\lambda(t) = -De^{-\rho t}$

$\lambda'(t) = \rho De^{-\rho t}$ $\rho De^{-\rho t} + \delta De^{-\rho t}$ = *left side*

From which:

$$D = -\frac{\left[\frac{\partial B_i(.)}{\partial(s_i + S_{\neq i})}\beta + \frac{\partial B_i(.)}{\partial R_i}\alpha\right]}{(\rho + \delta)}$$

$\lambda_P = -De^{-\rho t}$

The particular integral, hence, is:

$$\lambda_P = \frac{\left[\frac{\partial B_i(.)}{\partial(s_i + S_{\neq i})}\beta + \frac{\partial B_i(.)}{\partial R_i}\alpha\right]}{(\rho + \delta)}e^{-\rho t}$$

The sum of the complementary function and the particular integral then constitutes the general solution of the complete equation:

$$\lambda(t) = Ae^{\delta t} + \frac{\left[\frac{\partial B_i(.)}{\partial(s_i + S_{\neq i})}\beta + \frac{\partial B_i(.)}{\partial R_i}\alpha\right]}{(\rho+\delta)}e^{-\rho t} \qquad (A \text{ arbitrary})$$

(1A)

From the transversality conditions ($\lambda(T)=0$), we can assert that in T:

$$0 = Ae^{\delta t} + \frac{\left[\frac{\partial B_i(.)}{\partial(s_i + S_{\neq i})}\beta + \frac{\partial B_i(.)}{\partial R_i}\alpha\right]}{(\rho+\delta)}e^{-\rho t}$$

from which:

$$A = -\frac{\left[\frac{\partial B_i(.)}{\partial(s_i + S_{\neq i})}\beta + \frac{\partial B_i(.)}{\partial R_i}\alpha\right]}{(\rho+\delta)}e^{-(\rho+\delta)T}$$

Hence, substituting in equation (1A), we get equation (8):

$$\lambda^*(t) = \frac{\left[\frac{\partial B_i(.)}{\partial(s_i + S_{\neq i})}\beta + \frac{\partial B_i(.)}{\partial R_i}\alpha\right]}{(\rho+\delta)}(e^{-\rho t} - e^{-(\rho+\delta)T+\delta t}).$$

Appendix 2

(Equation of motion for R_i).

The equation of motion for R_i, $\dot{R}_i = \frac{\partial H}{\partial \lambda}$, is:

$$\dot{R}_i = \frac{\partial H}{\partial \lambda} = \frac{\partial R_i}{\partial t} = I_{R_i} - \delta R_i$$

The complementary function is:

$$R_{i_c}(t) = Ae^{-\delta t}$$

and the particular integral is:

$$R_{i_P} = \frac{I_{R_i}}{\delta} \qquad (\delta \neq 0)$$

The sum of the complementary function and the particular integral then constitutes the general solution of the complete equation:

$$R_i^*(t) = Ae^{-\delta t} + \frac{I_{R_i}}{\delta} \qquad (A \text{ arbitrary})$$

Moreover, by setting t=0 in this result, it is easily shown that $A + \frac{I_{R_i}}{\delta}$ represents the initial stock of R_i ($= \bar{R}_i$).

Hence the optimal state path is:

$$R_i^*(t) = \left(\bar{R}_i - \frac{I_{R_i}}{\delta} \right) e^{-\delta t} + \frac{I_{R_i}}{\delta}.$$