The Determinants of Cooperation in Government-sponsored Innovation Networks: Empirical Evidence from Italian Technological Districts

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[PRELIMINARY AND INCOMPLETE]

Abstract

This paper aims to identify the key drivers of inter-firm R&D cooperation in high-tech industrial sectors. Our research considered a particular type of innovation network, the technological districts created in Italy under a specific public policy to promote innovation and regional economic development. Such districts are located in certain areas of the country and involve several organisations belonging to industry, research and public administration. The empirical analysis used an original database containing information on research projects activated by the districts and on the characteristics of participating firms. The most interesting results concern the effect of the structural characteristics of the individual districts upon collaboration choices: the probability of cooperating is higher in districts in which universities and public research centres have a major weight and in districts with governance more geared to market logic. Network effects also play an important role in causing the propensity to cooperate. Our findings confirm the importance of factors identified by the industrial organization literature and which may be chiefly ascribed to the transfer and absorption of knowledge.

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1. Introduction

In the past decade public policies to promote research and development (R&D) have attached great importance to forming innovative networks insofar as they are able to accelerate the processes of knowledge creation and dissemination and boost economic development. With this in mind, in Italy specific state measures have been implemented to create technological districts (TDs), i.e. innovative networks in which various types of organisations participate (financial institutions and private firms, public and private research institutes, local authorities, etc.) that carry out intense R&D in technologically advanced sectors and which are geographically concentrated in specific areas of Italy.[1] Underlying this policy is the idea that the agglomeration of high-tech firms can generate considerable competitive advantages for geographical areas and beneficial effects for the firms operating in them, with a consequent boost to the entire local economic system.

From the theoretical standpoint various models may be used to contextualise the importance of such a policy to boost innovation. A significant contribution is made by the *Triple Helix* model which considers the close collaboration between *University*, *Government* and *Industry* as an essential engine of development for the local economy (Etzkowitz and Leydesdorff, 2000). This model may be aptly combined with other approaches derived from theories of innovative regional systems (Cooke *et al.*, 2004), with the systemic view of the firm (Freeman, 1984; Golinelli, 2005), and with social network analysis (Granovetter, 1985; Burt, 1992; Gilsing, 2005) to highlight the positive effect of cooperation within innovative networks on technological progress and hence on the growth and competitiveness of local production systems. Moreover, various empirical contributions (Branstetter and Sakakibara, 1998, 2002; Arranz and Arroyabe, 2008) have stressed the benefits of collaboration among organisations in R&D in terms of the output of the networks considered (patents, product innovations, process innovations, etc.).

This paper sets out to use econometric analysis based on a sample of Italian TDs in order to identify factors that promote cooperation among firms participating in the various TDs.[2] Our research is a contribution to the literature on the microeconomic choices to collaborate in R&D within innovative networks.

The first studies on the subject, chiefly of a theoretical nature, emphasised technological knowledge, identifying knowledge spillovers (Jaffe, 1986; Cassiman and Veugelers, 2002) and imperfect appropriability (d'Aspromont and Jacquemin, 1988; Shapiro and Willig, 1990) as the main factors leading to collaboration choices among firms. Recently, other contributions have identified two new dimensions able to affect cooperation in R&D, derived either from social

[1] Hereinafter we use the abbreviation TD for this specific form of technological district arising after state intervention.
[2] To indicate those participating in TDs we use the terms *actors* and *organisations* interchangeably.

network formation theory or from innovation geography (Maggioni and Uberti, 2011). Of the former, Bala and Goyal (2000) state that the involvement of actors within social networks, thanks to the creation of positive externalities, entails greater benefits than the case of bilateral links. From this point of view, the positioning of organisations within innovative networks is considered the decisive key to cooperation insofar as it increases the benefits of knowledge transfer and appropriability. In relation to innovation geography, Audretsch and Feldman (2004) stress that geographical proximity has a positive effect on cooperation among organisations as it enables closer and more frequent interpersonal relations which, in turn, boost knowledge transfer, especially of a tacit nature. To support such theoretical propositions, some studies which analyse research projects funded by the European Union Framework Programmes (Paier and Scherngell, 2011; Autant-Bernard *et al.*, 2007; Defazio *et al.*, 2008) supply empirical evidence on the importance both of geographical aspects and network effects.

Our contribution differs from previous papers since it considers the choices of collaboration within TDs, i.e. within highly concentrated innovative networks on a regional or provincial basis. Two main characteristics distinguish such networks: the participating actors belong to very different entities (private firms, public and private research institutes, local authorities, trade associations, financial institutes, etc.) and are also part of a long-lasting, well-defined organisational and management structure, namely that of the TD. The latter may perform a function of coordination and orientation in the formation of partnerships for participating in research projects, while collaborative relations considered in the existing literature appear chiefly the fruit of spontaneous decisions in which there is no intermediary. The particular characteristics of the reference situations outlined above thus suggest the analysis should include not only factors already identified elsewhere but also the elements characterising individual districts.

The results of our econometric analysis indicate that the structural characteristics of TDs play an important role in determining the propensity to cooperation. Estimates show that the presence of universities and public research centres in the TD promotes collaboration among the firms. Moreover, the management mode of the TD, in other words the type of governance, has a major impact: in particular, governance with a market approach increases the propensity to cooperate. Further results confirm the importance both of factors indicated by the industrial organization literature and on network effects.

The paper is structured as follows: section 2 provides an overview of public policy adopted to promote TDs in Italy, section 3 describes the data collected and the econometric model, section 4 presents the results of the analysis and section 5 concludes.

2. Public policy for technological districts in Italy

As an instrument able to produce development and growth the technological district (TD) was first introduced into Italy with the Guidelines for Scientific and Technological Policy of the 2002 government and then bolstered under the 2005 – 2007 national research programme (PNR). These planning documents stress the need to create, in certain areas of Italy, science parks in research and innovation able to promote collaboration between the various actors in the R&D production chain, drawing particular benefits from "*...public-private collaboration, supported by a process of institutional understanding between central, regional and local administration*".[3] The main aim of such a policy is to generate a virtuous circle able to have considerable influence on the local entrepreneurial fabric in terms of innovation and dissemination of technological knowledge and ultimately to boost economic growth and competitiveness of the local production system.

The area dimension of scientific research and technological development assumes a crucial role in such a public measure: the initiative to establish TDs lies with the individual regions which have to present a project to the Italian Ministry of Education, University and Research (MIUR) so as to promote collaboration on specific innovative research projects between large, small and medium enterprises on the one hand, and public and private research institutes on the other. It is thus a matter of creating science parks for research and innovation. Starting from area technological specialisations (in many cases in areas at a sub-regional scale), such districts should be able to trigger a virtuous process between the world of research and industry that may lead to the development of high scientific skills of importance even at the international level.

Thus TDs are intended to combine the advantages of spatial agglomeration (closeness) of high-tech activities, typically knowledge spillovers, and creation of specialised labour and services, with the advantages of establishing networks, such as sharing the costs and risks associated with R&D. Moreover, thanks to the creation of collaboration networks it is also possible to incentivise SMEs, decoupling from the classic view that sees mainly large firms as the driver behind innovation and development processes. Italy has long-standing experience with industrial districts: TDs may be viewed as the natural evolution of classical Marshallian industrial districts, yet differing in two substantial ways: *i)* the process with which they are formed or established *ii)* the composition of the participants.

As regards the first point, while the creation of an industrial district starts from the *bottom*, i.e. it is the firms which spontaneously decide to cluster so as to enjoy economies of agglomeration and external economies, the creation of a TD in most cases requires a decision-making process which

[3] Italian Ministry of Education, University and Research (MIUR): National Research Programme 2005-2007, p. 41.

starts from the *top*. This process is activated on the express will of local government – usually regional authorities – which, through joint action with other local stakeholders (firms, universities, financial institutions, etc.), identifies the industrial sector, as well as the actors to participate in the future district, and takes steps to obtain public finance which is a key factor in the creation of a TD.

As regards the second point, the participants involved in TDs are generally more heterogeneous than those of industrial districts, both because R&D usually requires cooperation among several different actors, and because it is the express will of the Ministry. One of the requisites for establishing TDs is the participation of universities and other public research centres able to establish partnerships with the fabric of local entrepreneurs, of private firms operating in the industrial sector which characterises the district, and of private financial institutions able to contribute additional financial resources over and above public funding.

Another fundamental criterion established by the government for setting up TDs is the creation *ad hoc* of a legally empowered authority to represent the TD and undertake the task of managing its activities according to a well-defined governance model.

A prerequisite for the establishment of a TD is also identifying a geographical area that has substantial resources and technological skills that are consistent with the activity of the future district. To this end, many contributions have sought to identify the key variables for suitable assessment of an area's technological potential. Lazzeroni (2010) identifies two methodological approaches: the first, starting from a large number of variables, uses multivariate analysis techniques (Bonavero, 1995; Miceli, 2010) or composite indicators such as the EU's *European innovation scoreboard* to measure the degree of local technological specialisation; with the second approach, variables are chosen *a priori* which might be representative of research potential in the areas in question (see, for example, Capuano and Del Monte, 2010). It is precisely this second approach, albeit more radical insofar as it is based on the construction of theoretical models, which would appear more suitable for analysis in local contexts where data are often unavailable. In this case, the factors deemed important are often identified through a comparison of existing situations (Monni and Spaventa, 2009), measuring the technological potential of various geographical areas also by means of qualitative variables.

The local variation in socio-economic structures in Italy has led to the creation of somewhat different TDs (Bossi *et al.*, 2006). However, we may identify a series of activities common to all TDs, namely: *i*) cooperation among the actors (networking), *ii*) local supply of high-level training, *iii*) support and assistance for start-ups through specialised finance, chiefly in the form of venture capital.

Table 1 supplies a picture of the TDs operating in Italy and created with the support of the MIUR. To date, 27 have been approved, 24 of which are already operative and the other three which are being set up.[4] Most of those TDs already active began their activity in 2005-2006, i.e. after the stipulation of the Programme Agreement.[5] As regards geographical location, 13 districts operate in the south of Italy, five in the centre and nine in the north. This is a direct consequence of government policy which identifies the *Mezzogiorno* as a high-priority intervention area.[6] The regions with the largest number of districts are Sicily, Lombardy, Puglia and Lazio, each of which has three districts, while Marche and Val d'Aosta have none.

Another interesting detail concerns the sectoral specialisation of TDs. The only TDs working in fields connected with the agri-food and logistics sectors are located in the south, while those working in ICT are distributed throughout Italy, as are those dealing with biotechnology and biosciences.

[4] The data were collected at the MIUR site www.distretti-tecnologici.it/centro_miur and are updated to December 2011.

[5] Both the Agreement Protocol and the Programme Agreement are necessary steps in setting up each TD. The former is a declaration of intent between the parties to carry out a specific project and is not legally binding. It typically envisages a subsequent study phase to identify the most suitable ways to carry out the future project. Instead, the latter, albeit voluntary in nature, becomes legally binding for the parties concerned once signed. Thus TDs begin their activity after the Programme Agreement has been stipulated.

[6] On the proposal of the Ministry of Education, CIPE, with the resolution of 20 December 2004, approved overall funding of Euro 140 million to set up new TDs in the south of Italy.

Table 1. Technological districts recognised by the MIUR (As of 2011)

District	Region	Agreement Protocol	Programme Agreement	Field
DT innovazione sicurezza e qualità degli alimenti	Abruzzo	-	-	Agribusiness
DT sulle osservazioni della terra e i rischi naturali	Basilicata	2005	2005	Environmental Risks
DT per il restauro dei beni culturali	Calabria	1999	2005	Cultural Heritage
DT della logistica e della trasformazione	Calabria	1999	2005	Logistic and Transportation
DT sull'ingegneria dei materiali polimerici e compositi e strutture	Campania	2003	2005	New and Advanced Materials
Hi-Mech - DT per l'alta tecnologia meccanica	Emilia Romagna	2003	2004	Advanced Mechanics
DT di biomedicina molecolare	Friuli	2003	2004	Biotechnology and Biosciences
DT Aerospazio e Difesa	Lazio	2004	2004	Aerospace and Defence
DT delle Bioscienze	Lazio	2008	2008	Biotechnology and Biosciences
DT per i Beni e le Attività culturali del Lazio	Lazio	2008	2008	Cultural Heritage
DT di Genova	Liguria	2003	2004	Integrated Intelligent Systems
DT per le biotecnologie	Lombardy	2003	2003	Biotechnology and Biosciences
DT ICT	Lombardy	2003	2004	Information and Communication Technology
DT dei materiali avanzati	Lombardy	2003	2004	New and Advanced Materials
DT per l'innovazione agroindustriale	Molise	-	-	Agribusiness
DT ICT - Torino Wireless	Piedmont	2001	2003	Information and Communication Technology
DT biotecnologico Pugliese	Puglia	2000	2005	Biotechnology and Biosciences
DT pugliese high-tech	Puglia	2000	2005	Nanoscience and Nanotechnology
DT meccatronico pugliese	Puglia	2000	2008	Advanced Mechanics
DT della biomedicina e delle tecnologie per la salute	Sardinia	2005	2005	Information and Communication Technology
DT agrobiopesca	Sicily	1999	2005	Agribusiness
DT trasporti navali commerciali e da diporto	Sicily	1999	2005	Logistic and Transportation
Etna Valley – DT Micro e Nanosistemi	Sicily	1999	2005	Nanoscience and Nanotechnology
DT ICT & Security	Tuscany	2005	2005	Information and Communication Technology
DT HABITECH Energie e Ambiente del Trentino	Trentino	2006	2006	Energy and Environmental
DT dell'Umbria	Umbria	2006	-	Energy and Environmental
DT Veneto Nanotech	Veneto	2002	2004	Nanoscience and Nanotechnology

Source: national monitoring unit on the TDs - www.distretti-tecnologici.it

3. Data description and econometric model

Data description

Our empirical analysis considered six of the most important technological districts recognised by the MIUR. Most of the data were initially collected via the Internet sites of the TDs and the Ministry. This information was subsequently verified and supplemented by interviews with those in charge of, or representing, the various districts. The availability of certified data and the degree of collaboration established with each district were essential elements for choosing the six TDs analysed herein. The sample in question, though only referring to some of the TDs operating in Italy, appears representative of the reference population both as regards the sectoral specialisation and with reference to geographical location: the districts considered belong to different technological sectors and to different regions, with a homogeneous split among the various areas of the country (Table 2). For each district, the information available concerns the projects undertaken during the period 2005-2010 and the participants.[7]

The composition of the districts is rather heterogeneous in terms of participants: private firms, public research institutes (universities and National Research Council institutes), private research centres and public administration (regions and provinces). In addition, there is the presence of financial institutions, mostly banks and so-called banking foundations, and trade associations, especially chambers of commerce. This heterogeneity appears the direct consequence of government policy to promote cooperation among many different, yet complementary, organisations that are able to enhance and promote knowledge transfer.

As can be seen from the statistics describing the participants in the various sample districts (Table 2), private firms and research centres (public and private) represent jointly over 70% of participants, while there is a residual percentage of participants belonging to public administration. However, the latter play a fundamental role in terms of funding.[8] An interesting aspect concerns the title of member or partner to be attributed to the various actors, where by member we mean a founder member of the district who participates regularly in activities and general management, while the term *partner* is used for an actor who only occasionally comes into contact with the district itself, perhaps participating in one or a few research projects without being involved in other management activities. From this angle a difference emerges between TDs consisting of mainly members and TDs with mainly partners. Such a distinction may be important when we come to consider the possibility that the choice of participants to be included in research projects is determined by policy decisions within the district rather than by a logic of complementarity and compatibility of the

[7] The data were collected in the context of the PRIN 2008: Network theories, assessment of technological districts and policies for their development.

[8] The same holds for private financiers (banks, banking foundations, etc.) featuring in the category "Other".

knowledge possessed by the various subjects. Any such dynamics in selecting participants in research projects would have a major distortion effect on the determinants of collaboration among the actors, and would be verified and evaluated in subsequent econometric analysis.

Table 2. TD composition by type of participant (2006-2010)

	TD 1	TD 2	TD 3	TD 4	TD 5	TD 6
Firms	13 (50)	19 (30.16)	48 (64)	21 (32.81)	45 (60.81)	31 (23.13)
Research Centres	9 (34.62)	34 (53.97)	14 (18.67)	35 (54.69)	8 (10.81)	75 (55.97)
Public Administrations	2 (7.69)	1 (1.59)	3 (4)	1 (1.56)	6 (8.11)	21 (15.67)
Others	2 (7.69)	9 (14.29)	10 (13.33)	7 (10.94)	15 (20.27)	7 (5.23)
Total	*26* *(100)*	*63* *(100)*	*75* *(100)*	*64* *(100)*	*74* *(100)*	*134* *(100)*
Members	20 (76.92)	40 (63.49)	23 (30.67)	23 (35.94)	21 (28.38)	38 (28.35)
Partners	6 (23.08)	23 (36.51)	52 (69.33)	41 (64.06)	53 (71.62)	96 (71.65)
Total	*26* *(100)*	*63* *(100)*	*75* *(100)*	*64* *(100)*	*74* *(100)*	*134* *(100)*

Note: percentage values in parenthesis.
Source: our elaboration.

Econometric model

Starting from the creation of various districts, mostly occurring in the two-year period 2005-2006, we collected data on research projects activated by the year 2010 using regional national or European public funds, in which the district governance authority played a leading and/or coordinating role.[9] We are thus referring to projects in the execution phase and projects already completed for which a list of participants is available. This information was used to construct the dependent variable of our econometric model: for each district we constructed an actor-project matrix containing the value 1 if the actor participated in the various research projects, and 0 otherwise; such a matrix, multiplied by its transpose (project-actor matrix), yields an actor-actor matrix containing for each possible pairs of actors the number of collaborations in the research projects of the DT.

The actor-actor matrix thereby created is thus a square symmetric matrix of dimension $n \times n$ whose elements on the main diagonal indicate the number of projects undertaken by each actor, and other

[9] By governance authority we mean the legally established entity, created ad hoc, responsible for the management and coordination of the district and relative activities. It is usually a cooperative society or foundation whose members are also considered members of the district.

elements indicate the collaboration links between each pair of actors. Given that more than 98% of pairs has 0 or 1 collaboration, we create a dependent variable equal to 0 for pairs with no collaborations and 1 for pairs with at least one collaboration. Therefore the variable thus created may be used to estimate the probability of collaboration between actors in the districts using what is known in econometrics as *binary regression models*.[10]

The models in question may be derived by hypothesising the existence of a latent variable linked to the explanatory variables with the structural equation:

$$y_i^* = \beta' x_i + \varepsilon_i \tag{1}$$

with the subscript i which indicates the observations, x the vector of the explanatory variables, β the vector of the relative coefficients and ε the error term.

The observable binary variable is linked to the latent variable y^* by the relation:

$$y_i = \begin{cases} 1 \text{ if } y_i^* > 0 \\ 0 \text{ if } y_i^* \le 0 \end{cases} \tag{2}$$

From (1) and (2) we obtain the probabilities relative to the observed variable:

$$\Pr(y_i = 1) = \Pr\left(y^* > 0\right) \tag{3}$$

where, substituting the structural equation, we obtain:

$$\Pr\left(y_i = 1\right) = \Pr\left(\varepsilon_i > -\beta' x_i\right) = 1 - F\left(-\beta' x_i\right) = F\left(\beta' x_i\right) \tag{4}$$

F is the distribution function of the error term. According to the assumption concerning the error distribution, we use the probit model (errors distributed normally) or the logit model (errors with logistic distribution). As underlined by Greene (2011) there is no theoretical justification which generally holds for choosing one or the other model and in many applications the results are very similar. From the empirical angle there may be different indications if the percentage of 1 or 0 of

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[10] For in-depth treatment of econometric models with discrete dependent variables, see Maddala (1983) or Long and Freese (2006).

the sample is extremely low and, additionally, if one of the model's explanatory variables has an extremely wide variance.

In our data the above two conditions do not exist. Hence the results are independent of the choice of logit or probit specification. Below we present the estimates obtained with the logit model.[11] The collaboration probability estimated in such models is given by:

$$\Pr(y_i = 1) = \Lambda(\beta' x_i) = \frac{\exp(\beta' x_i)}{1 + \exp(\beta' x_i)} \quad (5)$$

where Λ is the logistic distribution function.

As pointed out above, in our model the observations refer to possible collaborative links between firms in the technological districts. Due to the nature of the data in question, the order of the actors within the pair is unimportant, i.e. $y_{i,j} = y_{j,i}$ for every i and j or, expressed in words, the values of the dependent variable are the same irrespective of the direction of the link. Consequently, also the independent variables are calculated so as to respect the symmetry of the relations and have the the same value for pairs (i, j) and (j, i).[12] Following the approach of Fafchamps and Gubert (2007) the variables referring to the characteristics of the actors making up the various pairs (i, j) are calculated either as the absolute value of the difference or as the mean value of each actor forming the link. This ensures that the regressors do not depend on the order of the i's and j's.

The reduced form of the estimated model is as follows:

$$\Pr(Y_{i,j}=1)=\Lambda[\beta_0+\beta_1(Traditional_{i,j})+ \beta_2(Network_{i,j})+\beta_3(District_{i,j})+\beta_4(Control_{i,j})+\varepsilon_{i,j}] \quad (6)$$

and the maximum likelihood method is used to estimate the coefficients.

The motivations underlying the choices of collaboration among firms have been analysed in many theoretical and empirical studies. Following Belderbos *et al.* (2004) reference can be made to two approaches: the first concerns Industrial Organization and chiefly focuses on analysing knowledge spillover effects;[13] the second, of a managerial type, analyses the factors determining cooperation

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[11] Although both specifications were estimated, for reasons of space we report only the results obtained with the logit model.

[12] Summing the observations of the districts included in the sample and only considering the unique pairs between firms yields 3042 possible pairs of actors. Of these observations, about 32% have the value 1. In other words, about 32% of the pairs established at least one collaboration in the district projects.

[13] *Knowledge spillovers* may be of two types: *incoming spillovers* refer to an organisation's capacity to absorb and use information generated outside it by other organisations, while *outgoing spillovers* concern the possibility of third parties appropriating the information generated within the firm. The presence of *incoming spillovers* should incentivise collaboration, while the presence of *outgoing spillovers* should reduce the interest in collaborating due to the presence of possible free rider behaviour in appropriating the fruits of R&D. However, this intuitive result also depends on the cooperation type and strategy (e.g. firm-firm or firm-university) and evaluation of the size of spillover effects.

from the angle of transaction costs and Resource-Based Theory, and is thus more interested in aspects concerning the sharing of costs and risks which are typical of R&D.

Both approaches point to a firm's *absorptive capacity* as being decisive in cooperation strategies: it is stressed that the beneficial effects of R&D, both in the form of cooperation and if undertaken individually, depend on a firm's capacity to absorb and be able to use information effectively (Griffith *et al*., 2004, Bönte and Keilbach, 2005).

The explanatory variables of the model proposed in this work were chosen *i)* on the basis of the traditional literature cited above, *ii)* in line with the new strand of studies which recognises aspects of social network analysis as being crucially important in determining collaboration choices, *iii)* and so as to take account of the specific nature of the phenomena being studied, i.e. TDs.[14]

Traditional factors

The vector of covariates $Traditional_{i,j}$ chiefly refers to the characteristics of the individual firms forming the various pairs. An important aspect in determining cooperation choices, which falls within traditional factors, is the complementary nature of knowledge and skills of the various actors (Arora and Gambardella, 1990), especially in high-tech content. Such heterogeneity may promote diffusion of information and the sharing of indispensable resources for the innovative process.

Besides, a low level of heterogeneity could establish competitive dynamics among firms and limit their cooperation (Katz, 1986) in the moment in which there may be competition among such actors on the product market.

Such considerations suggest the existence of a positive link between the propensity to collaborate and the heterogeneity of the firms involved. However, such an effect does not appear generally to hold either at the theoretical or empirical level. For example, Cantner and Meder (2007) find the opposite effect, i.e. that technological proximity, hence greater homogeneity among firms, has a positive effect on collaboration in research in high-tech sectors.

We believe it is worth making a distinction between the concepts mentioned above. For this purpose, to measure the degree of technological and market proximity between firms participating in TDs we introduced the variables *Technological Proximity* and *Market Competition.* The former is a proxy of sectoral proximity and is calculated as in Caloffi *et al.* (2013). In particular, the variable assumes the value 1 if firm i operates in the same two-figure Ateco sector as firm j, and 0 otherwise.[15]

[14] For more details on the construction of the variables and for descriptive statistics see Appendix A.

[15] The classification used is Ateco 2007 at the division level. It should be pointed out that the classification in question does not contemplate all the business sectors in which our sample of firms operates (for example, there is no category for biotechnology). However, this does not generate practical problems for our purposes where what concerns us is whether both components of the pairs operate in the same sector and not the specific sector as such.

By contrast, the *Market Competition* variable aims to take into account the firms' retail market proximity and is the interaction term between the proxy of technological proximity and variable *Geographical Proximity,* a dichotomous variable which is equal to 1 if the firms of the pairs have their head office in the same province (NUTS 3 level). Hence, the category encoded with 1 of *Market Competition* variable comprises firms that could compete with one another since they are localized in the same province and belonging to the same industry.

The regressor *Geographical Proximity* also allows for the effect of spatial proximity on the probability of collaboration. Indeed, the importance of geographical proximity is highlighted by several studies which, in various forms, point to localized knowledge spillovers, i.e. the existence of positive externalities in space, as an important factor to promote and boost the innovative activity of firms (Breschi and Lissoni, 2001). However, in our model we do not stress the geographical aspects since the TDs are, by their very nature, characterised by a high geographical agglomeration of the participants.

The ability of TDs to foster the R&D cooperation between small firms is accounted by *Small Firms,* a dichotomous variable equal to 1 if both firms of the pair are small-entities with an annual turnover not exceeding 10 million euro.

The vector of covariates also comprises the variable *Research Potential* with which allowances are made for the fact that individual actors, in order to obtain a greater transfer of information, seek to collaborate with others that have high research potential, hence a possible baggage of knowledge. By contrast, the *Research Gap* variable refers to the absorptive capacity, i.e. the capacity of organisations to recognise the value of external knowledge and to assimilate it, thereby maximising the benefits derived from technology transfer. This learning process is not without its costs and usually presupposes resources that already exist within the firm (Barney *et al.*, 2001). As stressed by Cohen and Levinthal (1990), an organisation's learning capacity depends greatly on its previous level of specific knowledge. Moreover, the two authors provide empirical evidence for the negative effect of the gap between each organisation's learning capacity on the benefit derived from cooperation in R&D. Both regressors are calculated according to Autant-Bernard *et al.* (2007), i.e. as the mean between the projects in which firms *i* and *j* participated (*Research Potential*), and as the difference in absolute value, the second (*Research Gap*). On the basis of previous considerations, we expect a positive sign in the first case and negative in the second. In order to deepen the relationship between absorptive capacity and the probability of collaboration, we introduce in the model two further variable that refer to the gap between firms in age (*Age Gap*) and patent applications (*Patent Gap*).

Network effects

The second group of explanatory variables (*Network*$_{i,j}$) refers to network effects and concerns the variables relative to the position of firms within their own cooperation network.[16] To date there are few studies which verify whether the characteristics of a network affect the collaboration choices of firms on the same network or, to use a term from social network analysis, of its own nodes. Goyal *et al.* (2006), for example, show that the degree of involvement of organisations within its own network (what in the literature is called structural embeddedness) is a key factor in explaining cooperation choices. Underlying this result there is the idea that knowledge transfer may be achieved not only through direct collaboration between two actors, but also through indirect links which involve all the actors of a whole collaboration network.

To allow for the position of the firms within the network we use two indicators from social network analysis: degree centrality and closeness.

Degree centrality indicates to what extent an actor is connected via direct links with other actors and is generally the hallmark of active players on the network that often assume the role of hub (Bonaccorsi and Giuri, 2001; Powell *et al.*, 1996). In innovative networks degree centrality could be interpreted as a measure of the propensity of each actor to cooperate. In other words, a high degree centrality at time *t* may result in a higher collaboration probability at time *t+1* (Borgatti, 2005).

The second indicator, closeness, measures for each actor the closeness to other network actors (Freeman, 1979). A high level of closeness indicates that an actor is able to reach other network actors more rapidly; in the context of R&D collaboration, this concept means that actors with a high closeness value have a greater probability of receiving knowledge flows and hence, as stressed by Borgatti (2005), of developing innovations before others. The regressors are calculated both as arithmetic mean (regressor *Degree Centrality Potential* and *Closeness Centrality Potential*) and as difference in absolute value (*Degree Centrality Gap* and *Closeness Centrality Gap*) of the values respectively of degree centrality and closeness of firm *i* and *j* forming the pairs. Both indicators have some similarities with the variable that refer to the research potential. Indeed, degree centrality and closeness can be thought as further proxies, in terms of position within their network, of firms' research potential and absorptive capacity. In addition, from the point of view of social network analysis, *Research Potential* is a measure of centrality in one-mode networks, while degree centrality and closeness measure the centrality of actors in a two-mode network. A positive sign is

[16] In Appendix B we report the network graphs and the main measures of social network analysis.

expected for the variables expressed as the mean while a negative sign is expected when their expression is the absolute difference.[17]

Moreover, Paier and Scherngell (2011) provide empirical evidence concerning the positive effect of long-term relations and mutual knowledge on trust between organisations, and hence, on their propensity to establish strategic collaboration in R&D. To capture this aspect we inserted in the model the dichotomous variables *Interlocks* and *Shareholding.* The former refers to interlocking directorates, i.e. the practice of members of a corporate board of directors serving on the board of multiple corporations. Mizruchi (1996) argue that interlocks are a powerful indicator of network ties between firms and yield significant insight into the behaviour of firms. The variable assumes the value 1 if the firms in the pair share a director or an executive, and 0 otherwise. The second variable equal to 1 if a firm own a stake in the other firm of the pair or the two firms share at least one shareholder. Since long-term relations favour reciprocal learning and enhance the degree of trust between organisations, we expect a positive sign of the relative coefficient.

Characteristics of technological districts

The third group of regressors ($District_{i,j}$) refers to the characteristics of each TD. Mele *et al*. (2008) elaborate a theory to interpret the evolution of TDs based on the importance of governance: to promote the development of the district, the governance authority plays a decisive role in setting out a common policy for the various stakeholders involved which, by their very nature, bring divergent objectives to the district. Further, Wincent *et al.* (2012), in analysing government-funded innovative networks in Sweden, provide empirical evidence concerning the important role played by governance in determining the innovative performance of enterprises.

To allow for this aspect we thus constructed a dichotomous variable (*Governance*) which takes the value 1 if the occurrence of collaboration in district projects is left mainly to the spontaneous action of the various actors (market logic), and 0 if the choice of actors to involve in projects is chiefly guided by the specific will of the governance authority (hierarchical logic).[18]

A second variable (*University)* measures the weight of university institutions within the various technological districts. The positive effect of collaboration with universities on firm innovation is stressed by much of the economics literature. Establishing collaboration with universities allows firms both to reduce the costs and risks of conducting R&D, and to acquire new knowledge able to further boost their own innovative capacity. Brostrom and Loof (2008) also find empirical evidence

[17] To limit the possible distorting effect on the estimates due to endogeneity problems, the two variables refer to the networks originating from collaboration in projects on the part of all district stakeholders. Such networks are thus broader than those considered in our sample which refers only to collaboration between firms.

[18] See Table A1 of Appendix A for the computation mode of this variable.

that cooperation with university institutes allows firms to strengthen links with other firms, thanks to an improvement in their human capital and their capacities to internalise external opportunities.

Controls

Finally, the group of control variables ($Controls_{i,j}$) includes *TD Local Government* concerning the weight of local government in the governance authority of the TDs and the regressor *TD Projects* which measures the number of projects activated by each district, and hence the number of potential collaborations that each actor i may establish with the other actors j of the district.

4. Results

Table 3 reports the model estimates. We notice that degree centrality and closeness are highly correlated with the variable *Research Potential*, so we estimate alternatively their effects on the probability of collaborations: first column refers to the specification with *Research Potential* and *Research Gap* while column (2) and (3) include *Centrality Potential* and *Centrality Gap* that respectively, are measured in terms of degree centrality (2) and closeness (3). Lastly, column (4) reports the estimates of the more parsimonious specification where network indicators, as well as *Research Potential* and *Research Gap,* are excluded. Such a model avoid the possible endogeneity problem incidental to the the network indicators.

Among the most interesting results, there emerges the important role of the technological proximity between firms. In particular sectoral proximity shows a positive sign, indicating that similar firms in terms of their activity are more likely to collaborate.

The geographical proximity increases the probability of forming a link, as well as the small size of firms. As regards the geographical location of the firms, this is in line with expectations, seeing that the TDs are by their very nature territorially clustered and the participants are all geographically concentrated in one province or in one region. With respect to the size, the variable *Small Firms* is statistically significant, indicating that if both the firms in the pairs are small, then the probability of collaborate increases. This means that the districts are successful when encouraging SMEs to cooperate in R&D activities.[19]

An initial result is therefore that the propensity to collaborate is greater if firms of technological district are similar in sectoral terms, localized in the same province and small-sized. TDs operate in well-defined sectors (see table 1), which undoubtedly contributes to explain the higher collaboration propensity of similar organisations in terms of business sphere. The positive effect of technological, and hence sectoral proximity on collaboration choices is also confirmed by other empirical studies

[19] The result also holds if the firms of the pairs are large-large and large-small.

(Caloffi *et al*., 2013; Paier and Scherngell, 2011), thus indicating that the spillovers connected with research are greater among firms operating in the same sectors.

The variable *Market Competition* is not statistically significant and presents alternation of signs in the various specifications, excluding that competition on the product market may limit cooperation between firms.[20] The explanation could lie in the specific nature of TDs compared with other phenomena considered in the economics literature. The latter typically refer to collaborations between firms for individual funding competitions and hence to the forming of temporary consortia. By contrast, a characteristic element of districts is to promote and encourage cooperation between local actors in a long-term perspective. In addition, various projects undertaken by the districts may be classified as basic research projects which, by their very nature, are less subject to generating competitive tensions on the part of finished products. Lastly, technological districts can be thought as precompetitive innovation networks, which participants are not engaged in market competition.

The regressors *Research Potential* and *Research Gap* show the expected sign and strong statistical significance. Both the R&D potential and the absorptive capacity of i and j matter. The effect of absorptive capacity is confirmed also looking at variables *Age Gap* and *Patent Gap* that are statistically significant and with the negative signs. The more two firms differ in R&D potential, age and patenting activities, the less they collaborate.

As regards the network variables, the coefficients of *Centrality Potential* variables are statistically significant, with the expected signs, in both model specifications. Therefore, within innovative networks the firm i draws benefits not only from bilateral relations with other firms j, but also from its own network of collaborations and indirectly from those of each firm j. In addition, the negative signs associated to *Centrality gap* variables further support the role of similarity between firms, in terms of their position within the network, in fostering the probability of forming a link. The previous knowledge between firms (prior acquaintance) positively affects the probability of collaboration. As shown by *Interlocks* variable, firms that share a director or an executive have a higher probability to collaborate in the research project of the district. Such a result underlines the important role of personal ties in strengthening the R&D collaborations. On the contrary, the variable *Shareholding* is not statistically significant.

The variables referring to district characteristics supply interesting indications for the particular phenomenon in question. *Governance* has a positive sign and high statistical significance. This could suggest that the activity of intermediation on the part of the governance authority plays a non-secondary role upon firm cooperation strategies. For example, districts characterised by sizeable

[20] A negative link, albeit not statistically significant, between market proximity and research output was found Branstetter and Sakakibara (2002) with regard to Japanese research consortia. Our result, however, could be due to the inappropriateness of the proxy that we use to account for the market competition.

redistribution of public funds have a higher capacity to promote cooperation among participating firms. The result is in line with what was expected since such districts are distinguished by greater involvement of actors from outside the district itself (partners).

Moreover, also the presence of universities has the role of promoting collaboration among actors of the district.

Finally, the control variables are in general statistically significant, with the expected signs.

The results were subjected to two robustness checks. First of all, the equation reported in column (4) of table 3 was first estimated on a sample consisting exclusively of partners and then on a sample consisting only of district members. As mentioned in the previous section, this control is useful where it is suspected that participation of members in the various research projects is not the fruit of a free choice, but rather of political motivations within the district. However, the estimates do not indicate differences between the determinants of collaboration of members and partners.

Secondly, we implicitly assumed up to now that the observations of our econometric model were independent of one another. This assumption appears too restrictive in regressions that use dyadic data where, on the contrary, it is more reasonable to assume a certain correlation between the observations concerning each individual. In such cases, the estimates will still be consistent and not asymptotically biased but the standard errors will be inconsistent with the consequence of an incorrect inference. To obtain robust standard errors we replicated the estimates of columns (1) and (4), using the method of Fafchamps and Gubert (2007) which corrects not only for the presence of heteroskedasticity but also for the presence of a correlation among the observations involving individuals. This method brings about higher standard errors which, nevertheless, do not substantially modify the statistical significance of the various coefficients.

Tabella 3. Logit estimates on the determinants of R&D cooperation

	(1)	(2)	(3)	(4)
Technological Proximity	0.23** (0.111)	0.10 (0.093)	0.15** (0.069)	0.24** (0.119)
Geographical Proximity	0.57*** (0.163)	0.81*** (0.210)	0.52*** (0.209)	0.23* (0.125)
Small Firms	0.42*** (0.113)	0.21 (0.150)	0.25* (0.144)	0.20** (0.096)
Market Competition	-0.15 (0.201)	0.29 (0.248)	0.19 (0.238)	0.01 (0.169)
Age Gap	-0.08*** (0.003)	-0.01* (0.005)	-0.01 (0.007)	-0.04* (0.020)
Patent Gap	-0.04** (0.020)	-0.03* (0.019)	-0.03* (0.018)	-0.06*** (0.016)
TD Governance	1.89*** (0.700)	3.40*** (1.086)	3.48*** (1.153)	2.14*** (0.344)
TD University	0.04* (0.022)	0.08** (0.033)	0.11*** (0.036)	0.08*** (0.008)
Interlocks	1.56* (0.900)	2.25** (0.995)	2.77* (1.479)	1.83*** (0.760)
Shareholding	-0.47 (0.510)	-0.11 (0.536)	-0.31 (0.544)	-0.55 (0.454)
Research Potential	1.43*** (0.077)	-	-	-
Research Gap	-0.90*** (0.082)	-	-	-
Centrality Potential	-	10.82*** (0.511)	26.75*** (1.619)	-
Centrality Gap	-	-7.09*** (0.594)	-17.29*** (1.259)	-
TD Local Government	1.48*** (0.421)	1.54*** (0.580)	2.51*** (0.682)	0.50* (0.295)
TD Projects	-0.20*** (0.083)	0.71 (0.438)	0.31 (0.215)	-0.29*** (0.065)
Observations	2923	2923	2923	2923
Mc Fadden's R^2	0.263	0.498	0.507	0.188
χ^2	553	922	490	265

***, **, * Statistically significant at 1, 5 e 10% level.
Eicker-Huber-White standard errors in parenthesis.
Constant not reported.

5. Conclusions

We analysed the factors that lead to cooperation among firms in the main Italian technological districts. The structural characteristics of each district greatly affect the behaviour of the actors concerned. Indeed, estimates provided empirical evidence for the major role of district governance, and that the presence of universities may boost cooperation among the firms involved.

In addition, other findings shed light on several interesting aspects of TDs. Firms which have a sectoral and geographical proximity show a higher probability of collaborating amongst each other. If the first aspect is in contrast with part of the empirical and theoretical works concerning cooperation in high-tech activities, the second is in line with the nature of the technological districts. Indeed, the role of technological districts is precisely that of promoting cooperation between local actors, in many cases localized in the same reference province.

Moreover, our findings in part confirm what has been stressed by the traditional literature on the subject. Knowledge transfer and assimilation capacity of firms are important factors in explaining decisions to cooperate, as is prior acquaintance between firms.

Finally, also network effects, captured in the estimates with position indicators from social network analysis, play a key role in determining collaboration among firms.

In our opinion, these results constitute a useful starting-point for analysing the complex reality of technological districts. Future studies could - and should - deal with assessing their achievements and the public policy which led to their birth. This undertaking appears both stimulating and arduous. Indeed, it should not be forgotten that technological districts represent an experience which is still evolving and that the effects of R&D, as well as the economic returns tied to innovations, are only fully achieved in the long term.

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APPENDIX A: variables used in the econometric analysis

Table A1. Definition and expected sign

Variable		Definition	Expected sign
Dependent variable		Dichotomous variable equal to 1 for pairs (i, j) in which firms took part jointly in at least one research project of the district, 0 otherwise.	
Traditional factors	*Technological Proximity*	Dummy variable equal to 1 if the activity of firms i and j falls within the same Ateco 2007 division and 0 otherwise.	$(+/-)$
	Geographical Proximity	Dummy variable equal to 1 if firms *i* and *j* have their registered office in the same province and 0 otherwise.	$(+)$
	Small Firms	Dummy variable equal to 1 for pairs in which firms *i* and *j* have a total annual turnover below 10 million euro.	$(+/-)$
	Market Competition	Dummy variable equal to 1 if firms *i* and *j* have the same geographical reference market for their own products and 0 otherwise. Falling within category 1 are for example firms which chiefly operate on the same local market or firms that operate on the whole national market.	$(-)$
	Age Gap	Difference in absolute value between the age of firms *i* and *j*. The age is calculated as the difference between the logarithm of the year 2005 and the year of firm establishment.	$(-)$
	Patent Gap	Difference in absolute value between the logarithm of patent applications to the EPO of firms *i* and *j* before the year 2005.	$(-)$
	Research potential	Mean number of research projects in which firms *i* and *j* participated.	$(+)$
	Research gap	Difference in absolute value between the number of research projects in which firms *i* and *j* took part.	$(-)$
Network effects	*Interlocks*	Dummy variable equal to 1 if firms *i* and *j* in the period 2005-200 6share a members of the corporate board of directors or an executive, and 0 otherwise.	$(+)$
	Shareholding	Dummy variable equal to 1 if firms *i* and *j* in the period 2005-2006 own a stake in the other firm of the pair or the two firms share a common shareholder, and 0 otherwise.	$(+)$
	Degree centrality	Calculated as mean of degree centrality values of firms *i* and *j* and also as difference in absolute value. The degree centrality of each node (firm) is calculated as the ratio between the total number of its direct links and the total number of possible links within the network concerned (district).	$(+)$
	Closeness	Calculated as mean of closeness values of firms *i* and *j* and also as difference in absolute value. The closeness of each node (firm) is calculated as the inverse of the sum of the graph-theoretic distance from the other network nodes. This distance is understood in terms of links making up the shortest path connecting two nodes.	$(+)$

District variables	*TD Governance*	Dummy variable which takes a value of 1 if governance follows "market logic", 0 if governance is “hierarchical”. Each TD was assigned to one of the two categories by combining the following information: *i)* availability on the part of the TD of their own research structures, *ii)* management characteristics emerging from reading the Articles of Association, *iii)* information emerging from interviews with TD directors.	(+)
	TD University	Percentage of universities present in the TD compared with the total number of TD actors.	(+)
Controls	*TD local government*	Stake of local governments present in the TD governance authority.	(+)
	TD projects	Total number of projects activated by the DTs.	(+)

Table A2. Descriptive statistics

	Mean	Std. Dev.	Min.	Max.
Panel A: variables related to pairs				
Y	0.32	0.46	0	1
Research Potential	2.48	1.48	0	12
Research Gap	0.83	1.05	0	7
Technological Proximity	0.83	0.37	0	1
Market Competition	0.54	0.49	0	1
Small Firms	0.37	0.48	0	1
Age Gap	2.36	1.10	0	5.16
Patent Gap	-0.07	2.56	-9.13	9.2
Interlocks	0.05	0.07	0	1
Shareholding	0.01	0.11	0	1
Degree Centrality	0.26	0.16	0	0.82
Closeness	0.43	0.16	0	0.82
Geographical Proximity	0.33	0.47	0	1
Panel C: district variables				
Governance	0.54	0.49	0	1
University	0.26	0.18	0.15	0.43
TD Projects	9.77	2.72	7	15
TD Local Government	0.18	0.30	0.1	0.8

APPENDIX B: the collaborative networks within the analyzed TDs

Figure B1. Graphs of the collaborative networks

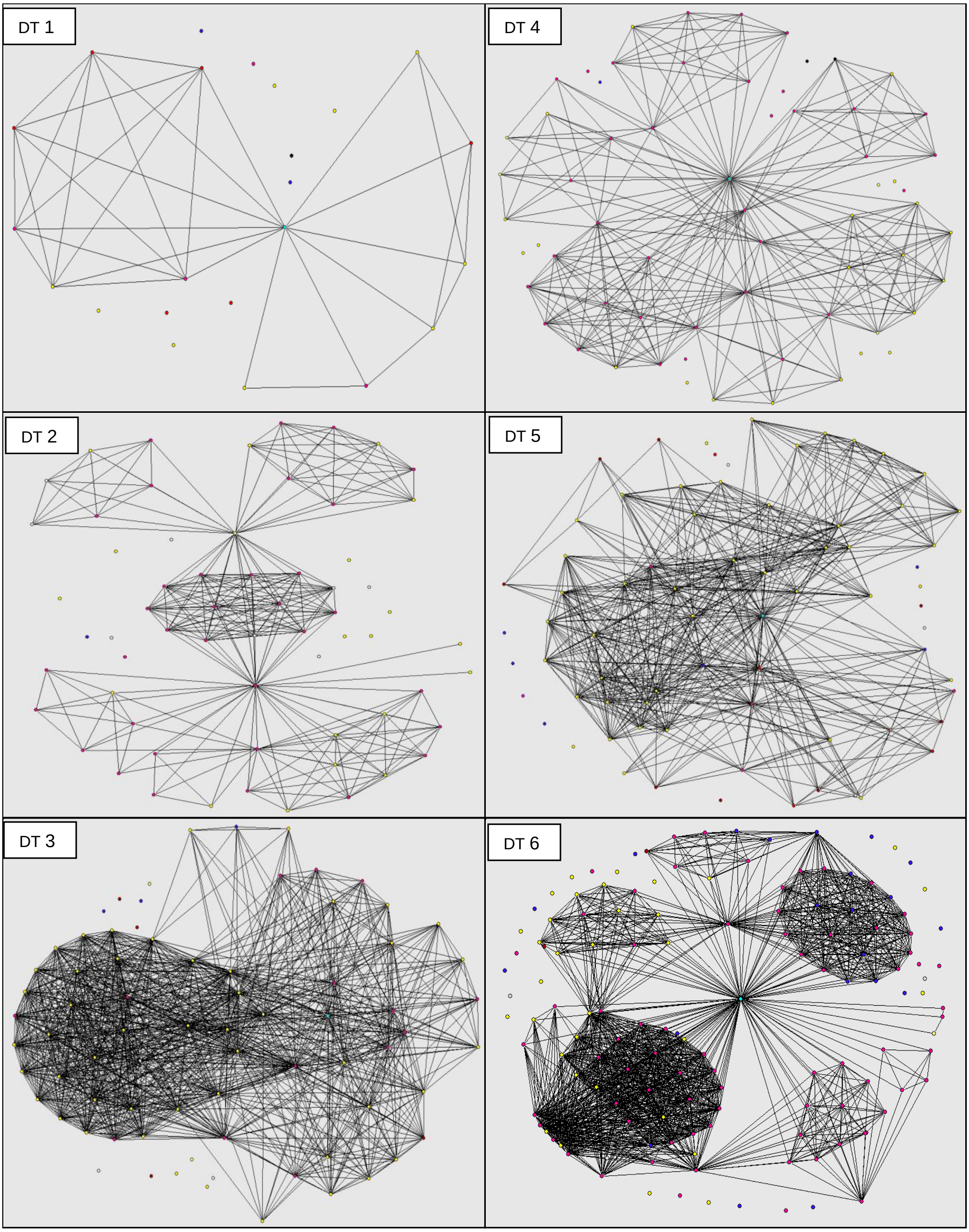

Table B1. Network indicators by districts

	Mean	Std. Dev.	Min.	Max.
DT 1 – number of projects 7; number of actors 26				
projects	1	1.55	0	7
degree	0.12	0.14	0	0.55
betweenness	0.01	0.04	0	0.18
closeness	0.18	0.19	0	0.57
links	3.31	4.34	0	19
DT 2 - number of projects 15; number of actors 63				
projects	1.4	1.94	0	13
degree	0.13	0.11	0	0.58
betweenness	0.01	0.06	0	0.38
closeness	0.33	0.17	0	0.63
links	9.94	10.28	0	62
DT 3 - number of projects 7; number of actors 75				
projects	1.57	1.47	0	7
degree	0.37	0.23	0	0.85
betweenness	0.00	0.01	0	0.05
closeness	0.50	0.22	0	0.85
links	33.23	24.37	0	111
DT 4 - number of projects 11; number of actors 64				
projects	1.21	1.58	0	11
degree	0.14	0.12	0	0.78
betweenness	0.01	0.04	0	0.35
closeness	0.35	0.19	0	0.78
links	9.84	10.27	0	67
DT 5 - number of projects 10; number of actors 74				
projects	1.43	1.55	0	10
degree	0.21	0.17	0	0.82
betweenness	0.01	0.02	0	0.19
closeness	0.41	0.20	0	0.82
links	17.73	16.86	0	96
DT 6 - number of projects 14; number of actors 134				
projects	0.95	1.19	0	13
degree	0.13	0.12	0	0.76
betweenness	0.00	0.03	0	0.34
closeness	0.33	0.19	0	0.76
links	18.53	17.18	0	117