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THE NETWORK OF SUBSIDIZED AND SPONTANEOUS R&D CO-OPERATION BETWEEN BELGIAN AND FOREIGN FIRMS, RESEARCH INSTITUTES AND UNIVERSITIES : A GRAPH-THEORETICAL APPROACH

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Introduction

In this paper we present the preliminary results of a graphtheoretical analysis of the network of R&D co-operation between firms, research institutions and universities in Belgium within an international context.
The information contained in the available databases on international R&D co-operation in formal projects and less formal agreements ('CORDIS', EUREKA, MERIT-CATI) is combined with information on personal linkages ('interlocking directorates'), so as to be able to differentiate between 'strong' and 'weak' R&D alliances between companies and other actors of the Belgian knowledge infrastructure (research institutes, universities and government agencies).
The proposed methodology stresses, in accordance with recent literature on innovation, the importance of R&D alliances for firms in order to benefit better from innovation opportunities, and for the economy as a whole in terms of the entailed activation of the process of knowledge and technology diffusion.

The reasons for embarking on a study of joint R&D projects as an approach to the national innovation system are twofold. The first reason is of a purely practical nature. Data on joint R&D projects and agreements are relatively easily available, and they can be quantified in a straightforward way in a network context. The second reason is a fundamental one. Joint research projects often give access to funds, equipment and new potential markets. But most of all, they give nearly always access to new information. They can be seen as one of the most powerful ways to disseminate knowledge and know-how within a NIS, and indeed might be considered as a knowledge vehicle. Often, especially when the set of partners is mixed, and contains universities and research labs as well as private companies, projects will be carried out in a legal framework where project-results are differentiated according to whether they take a directly marketable form or the form of basic knowledge or new methodologies. The former become the intellectual property of the participating firm(s), the latter become part of the knowledge basis of the universities and/or research lab, but also very often become freely available, along with the rest of the knowledge background, for the private partner(s). In other words, joint R&D projects in such a case allow participating firms to tap in on a knowledge stock which was until then unavailable. An example of such a legal setting is IMEC's 'IPR R1-R2' contract model (IMEC, a Belgian IT research laboratory, is - as we shall show - very central in the network).

But network analysis applied to technological systems is still - despite a burgeoning literature -

in a poor, underdeveloped state. A word of caution is therefore appropriate at this stage. It should be clear at the outset that the ambition of the present paper is limited. We give answers to ‘who co-operates with whom ?’, and look at a number of characteristics of this co-operation, but we do not deal with the direct results of joint R&D projects. We do not try to discriminate between successful and unsuccessful projects, and assume for the time being that the Law of Large Numbers somehow applies : we neglect possible biases across industrial sectors, technological disciplines and programme-types as to the proportion of joint projects that have yielded the expected results with respect to innovation.
In section 1 we characterise in general terms the graph which is analysed and describe in some detail the data which are used. In section 2 we present a summary of a number of (descriptive) results obtained so far and address in a tentative way a number of theoretical issues. We conclude in section 3 by anticipating on further analytical steps, and on the research questions which we should be able to answer in the future stages of the study.

1. The model and the data

The observations are defined on the level of microeconomic agents : companies, research institutions, universities and government institutions, i.e. the nodal points of the graph.
The network- (or ‘co-occurrence-’, or line-) criterion is primarily the fact that two actors are partners in the same joint research project or agreement. We consider also, secondarily, personal linkages : two actors who are partners in at least one joint research project may also be connected through one or more ‘personal’ lines if a same person sits on the board of directors or managing board of the two partners.

The set of personal linkages can help to reveal two major aspects in the description of the NIS. Personal linkages between companies lend an extra dimension to the S&T relationship, if they coincide with such a relation. Personal bonds between different companies (‘interlocking directorates’) not seldomly reflect a financial link or at least reveal a certain influence that, if it coincides with a technological link, may facilitate the transfer of knowledge or information. Through the analysis of ‘co-occurence’ on the level of research projects *and* personal linkages we can therefore distinguish between relatively ‘weak’ and relatively ‘strong’ technological lines in the NIS network. Moreover the analysis of personal links gives a deeper understanding of the links between the government in a broad sense (semi-governmental institutions included) and the other participants of the NIS network.
It should be stressed that in order to avoid inconvenient informational redundancy and needless complexity of the analysis, ‘interlocking directorates’ that do not coincide with some kind of S&T relationship will not be considered for analysis.

The obtained graph can be specified as being :

- **valued** : individual lines may be weighted.
- a **multigraph** : two entities can be linked by several lines with different weights.

Apart from the aspect of being backed or not by a personal line, the connection between two actors can therefore also be evaluated according to the number of project lines which run between them. Each project line in its turn can be weighed by the size of the project : proportional to the money value of the research contract, if available, and inversely proportional to the number of partners in the project.
The graph will contain **directed** as well as **undirected** lines. More specifically, a line will be directed if it relates to the link between the main contractor of a research project and one of the

other partners. It will be undirected if it corresponds to a link between the other partners, and in those cases where no main contractor can be identified.
The graph consisting of nodes and lines, together with their corresponding information is defined as a *network*.

We go now into some more detail with respect to the different types of actors, the different types of projects and agreements (primary lines), and the variables with are attached to the different nodes and lines of the graph.

We distinguish between *4 different projects and agreements (lines)* :

1. R&D projects in one of a selected list of EU R&D Framework programmes ;
2. EUREKA projects ;
3. Nationally subsidised R&D projects ;
4. Non-subsidised forms of R&D co-operation such as joint development agreements, joint ventures, licensing and cross-licensing, technology sharing, and explicit research contracts without external funding or other forms of support.

So as not to overburden the graph and avoid crossing computational thresholds, we discarded the project-lines between the foreign partners in the project or agreement. In other words, each foreign actor in a project or agreement with at least one Belgian private partner is part of the pointset considered (with a small exception relating to universities and institutes of higher education - see below), but the lineset only contains the links of these foreign actors with their Belgian partners.

The source for the first and the second type of project-lines is the CORDIS database distributed by EUROSTAT, and the EUREKA-database respectively. The source for the third type of project-lines are the annual reports of the subsidising agencies of the Belgian regional authorities responsible for the implementation of S&T policy (IWT for the Flemish Region and the respective regional Ministries responsible for R&D for the Walloon and Brussels Regions). The source for the fourth type of lines is the 'Belgian' part of the MERIT/CATI databank compiled at the University of Maastricht.
All projects and agreements which have at least one private Belgian company as one of its partners and started or completed its activities after 1-1-1990 are considered.
MERIT/CATI and CORDIS, two important sources, start in 1986. It seemed advisable however to start the analysis later than that : the year 1990 coincides with the year in which, as one of the results of the radical constitutional reform of 1989, the regionalisation of the Belgian S&T policy took place.
The source for data for the personal lines in the graph is the databank of the 'Balanscentrale' of the National Bank of Belgium, and the annual reports of the research organisations and universities.
The fact that we focus our analysis on those contracts that contain at least one national *company* means that we discard the (numerous) projects where the national partners are exclusively universities or institutions of higher education. This limitation is especially relevant for co-operation in the framework of the (pre-competitive) EU-programmes falling under DG-XIII.

We distinguish between *4 different types of actors (points)* :

1. Companies : the 200 largest companies in Belgium, ranked according to value added, supplemented with all (*national* and *non-national*) companies participating in a technological research co-operation project or agreement considered in our analysis,

whether it is funded by the national government or the EU or not-funded.
The first part of the selection ensures that we get a representative picture of the segment of the national economy which is involved in joint R&D projects or technological co-operation agreements. The latter addition to the core set guarantees that high-tech companies with a size below the implied threshold value are considered in our analysis as well and that the international context of the national innovation system is covered.
2. Research institutes and laboratories : the national and non-national research institutes and universities that participate in at least one technological research project or agreement in which at least one national company is involved.
3. Universities and other institutes of higher education. Individual non-Belgian universities and institutes of higher education are - for simplicity purposes - aggregated into one actor for each foreign country.
4. Advisory committees with direct or indirect relevance to the national science and technology policy and national and international subsidising organisations in the field of science and technology.

The actors in the point-set of the graph are identified by a 8-character acronym. The first character of the acronym is a country code ([1]). The lines of the graph (in the line-set) are identified by the 'head-tail' sequence of the corresponding acronyms.

In addition to the basic point- and line data the values of a number of variables are attached to the points and lines.
With respect to the points : qualitative and quantitative data in relation to the different points (the type of point, a label (the full name); company data of the 'Dun and Bradstreet' type ; company data from the national R&D surveys carried out for the OECD, company data from the CIS survey, etc. (the last two databases are at present not yet integrated in the data-set)).

2. Description of the complete graph

2.1. General features

The complete graph at present contains 3885 nodes and 16288 lines, including the IWT nodes and lines, and 3753 nodes and 14918 lines excluding ([2]). We discarded the IWT project-lines (i.e. the 'Flemish' lines relating to the R&D projects subsidised by the Flemish regional government) in the present stage of the analysis for reasons of symmetry since at this moment the necessary information from the Walloon and Brussels Ministries responsible for R&D could not yet be incorporated in the graph. For the same reason we did not yet incorporate already available information on nodes and lines relating to governmental and semi-governmental agencies.

Of these lines 3078 were directed (i.e., lines which connect a main contractor with a partner). 11840 were undirected.
These figures actually give an inflated picture of the density ([3]) of the graph, since a relatively large number of nodes are connected through multiple lines. After having combined all multiple lines between two points into one (aggregated) line, 10634 single lines remained, which means that the density of the (combined) graph is equal to .0015.
Of the 3885 actors, 776 were Belgian, 626 of which were private companies (private research institutes and consulting firms not included). Tables A2 and A3 in appendix give the details of

the composition of the point-set per nationality, organisation type and project/agreement type. In tables A4 and A5 the nodes of the private Belgian companies are classified by size and NACE sector.

The representativeness of the firms included in the pointset of the graph can be judged from the share of the Top200 companies present in the graph related to the total of the Top200. Table A6 in the appendix contains these proportions, per sector, in terms of value added.
Although only 84 Top 200 companies belong to the graph they account for 65.78 % of the generated added value in that set. Furthermore all high-tech Top 200 companies, recognised as such in the Top-30000 Trends directory used for this purpose, are represented.
The table confirms broadly preconceived ideas on the innovativeness of different sectors and technology disciplines. IT and Telecommunication, Metallurgy, Chemical Industry and Pharmaceuticals, and Transport Equipment all score highly. The traditional metal-using firms in the Top200 on the contrary are apparently not active in joint R&D projects. The zero share for the sector of informatics services (NACE 72) comes as a surprise, but can be explained by the fact that the firms concerned in the Top200 are in the consultancy business, and that the very many software producing firms that are present in the graph all have small size, and therefore are not present in the Top200.

Of the 16288 lines in the uncombined graph
13151 were 'CORDIS' lines, covering 972 projects,
1156 were EUREKA lines, covering 117 projects,
104 were MERIT/CATI lines, covering 75 agreements,
1370 were IWT lines, covering 287 projects, and
507 were personal lines.
More details on the different sorts of lines are in appendix (table A7).
The distribution of the lines over the points is very skew : a small group of actors takes care of a large number of lines and there is therefore a large group of actors with low involvement (cfr. Steurs & Kesteloot, 1991). The 20 Belgian actors (9 of which are private companies) with the highest degree centrality are involved in 44.9 % of all lines ; the 30 actors (15 of which are companies) with the highest degree centrality are involved in 50.7 % of all the lines. There is obviously - as a result of the very nature of the R&D Framework programmes of the EC - a large and important participation of research institutes and universities : the 20 Belgian firms with the highest degree centrality account for only 20.8 % of all lines.

2.2. Centrality indicators

Freeman (1975) distinguishes between three types of point-centrality indicators based on degree, closeness and 'betweenness', respectively.
Degree-centrality is the most straightforward of the three. A node is considered to be more central than others if more nodes are adjacent to it. This leads to the following expression for the degree-centrality of a node :

$$C_i^D = \sum_{\substack{j=1 \\ j \neq i}}^{n} a(i,j)$$

where $a(i,j)$ is 0 or 1 ; 0 if i and j are not connected, 1 if they are.
Closeness is a related concept, but looks at distances $d(i,j)$, i.e. the length of the shortest path from i to j ('geodesics').
'Betweenness' or 'rush' is an indicator for the strategic position of a node in a graph and is

based on the number of 'geodesics' between two nodes j and k that pass through i.
Memory constraints with the software used most of the time does not permit us - given the size of the graph - at the present stage of the analysis to compute 'closeness' and 'betweenness' centrality indicators.
In the following table we present the 30 actors with the highest degree-centrality for the complete graph, the complete graph at multiplicity level 6, and the subgraphs of 'CORDIS', EUREKA and MERIT-CATI.

Table 1 : Degree-centrality for the complete graph and some subgraphs

	Compl. Graph		Compl. Graph Mult6		CORDIS		EUREKA		Cati
BUG	437	BIMEC	37	BUG	391	BPHILIPS	78	BSOLVAY	19
BIMEC	335	BALCATEL	28	BIMEC	317	BBARCO	77	BPGS	8
BALCATEL	306	UEDU	16	BALCATEL	275	BVISION	76	BSOCGEN	6
BUCL	299	GEDU	15	BUCL	268	BKUL	59	NDSM	5
BKUL	282	BUG	12	BWTCM	236	BUM	56	BUCB	5
BWTCM	259	BKUL	11	BKUL	229	BRADENG	52	BPETROFI	5
BBARCO	199	BUCL	11	BVUB	191	BUG	50	FELF	4
BVITO	197	BBELGACO	11	BUNIVL	187	BUCL	43	UBP	4
BVUB	195	BMIETEC	11	BVITO	161	BALCATEL	41	IENIMONT	4
BUNIVL	193	SEDU	9	BBELGACO	158	BBELGACO	34	GBENZ	3
BBELGACO	182	BVITO	7	BBARCO	140	BVITO	32	UROLLS	3
BSOLVAY	159	NEDU	7	UEDU	133	BSOLVAY	26	FSNECMA	3
UEDU	135	BVUB	7	BMIETEC	129	BELT	22	ULAPORTE	3
GEDU	132	FCNRS	7	GEDU	128	FMATRA	19	BPRB	3
BMIETEC	130	FEDU	6	BSCK	119	BCHAMP	16	JINBANK	3
BSCK	120	HEDU	6	BSOLVAY	109	BBOSAL	16	JNIPKAY	3
BCRM	114	IEDU	6	BCRM	91	BINFTEC	15	BIMEC	2
BUM	105	FTHOMSON	4	SEDU	91	BLMSINT	14	BINNOGEN	2
BPHILIPS	103	BUNIVL	4	BE2S	85	GEDU	13	GSIEMENS	2
SEDU	94	BSCK	4	FEDU	82	BMETALOG	13	BELECTRA	2
FEDU	87	BUNIGEM	4	BKARMAN	79	BMEDOC	13	BAMYLUM	2
BE2S	85	PEDU	4	BWTCB	78	BOPL	13	BBEKAERT	2
BLMSINT	82	BTIENSE	4	BLMSINT	73	BIMEC	12	BELENCO	2
BWTCB	82	GSIEMENS	3	BUNIGEM	72	BSIDMAR	12	UBRITST	2
BKARMAN	79	NPHILIPS	3	IEDU	71	VEDU	11	NBROCADE	2
BVISION	76	ITHOMSON	3	HEDU	66	CEDU	10	GVARIA	2
BUNIGEM	72	UBT	3	BLABOREL	64	BINNOGEN	10	UBEAMECH	2
IEDU	71	STELEFON	3	BHYGEPI	63	SEDU	9	UDELTA	2
HEDU	69	DEDU	3	BULB	62	BACSET	9	UOXFINSI	2
BULB	69	FALCATEL	3	BRIC	61	BRHONE	9	KFOAMEX	2
NEDU	65	YEDU	3	NEDU	61	BULB	8	KTANDEM	2

Note : the first character of the acronym indicates the country-origin. Actors like UEDU, GEDU etc. relate to 'aggregated' foreign universities and institutions of higher education.

Degree-centrality as computed in table 1 gives of course only a rough measure of the importance of an actor in our graph of R&D co-operation. No account is taken of the multiplicity of the lines between nodes, and with the different weights that each line may carry.

There are several possible ways to evaluate the weight of a line.
We might consider to - assess projects according to their financial value (subsidy in the case of publicly supported research) ;
- give more weight to lines backed by a personal tie ;
- give more importance to lines in programmes which are 'nearer to the market' ; presumably R&D agreements such as the ones contained in the MERIT-CATI database carry more weight than 'CORDIS' projects because the latter will often relate to more exploratory research, and also because of their semi-public and less spontaneous character ;
- discriminate between directed and undirected lines, where lines would be defined 'directed' if going from the co-ordinator of a joint R&D project (the 'tail' of the

arrow) to a partner (the 'head') ; lines between simple partners would then be 'undirected' ;
- take the number of partners into account.

The formula for this weighted degree centrality measure then takes the following form :

$$C_i^W = \sum_{\substack{j=1 \\ j \neq i}}^{n} \sum_k w_{ij}^k$$

where w_{ij}^k is the weight of the *k*-th line running between i and j .

With the data which are at our disposal only the last four options are available : we only have subsidy data for EUREKA projects.
In table 2 we recompute degree-centrality in the set of the 200 most central actors in table 1 and report the result for the 50 most central ones in the new definition : we and actually account for multiple lines while combining the last two criteria giving the undirected lines in a project the weight *1/NP* , where *NP* is the number of partners in the project, and the directed lines a double weight of *2/NP*. By doing so we stress the fact that projects with a large number of partners suggest less 'intimacy' between the partners. An alternative would have been to leave the directed lines unweighted (w_{ij}^k = 1) ; in that case we would have emphasised that large projects (in terms of the number of partners) will most of the time be more heavily subsidised and will often have a technological scope that is more important.
We indirectly (at to some extent) also take account of the third criterion. CATI-type agreements count few partners and their lines will therefore be heavily weighted. The same is however not true for most EUREKA projects.
We deal with personal lines in the next section.

<u>Table 2 : The 50 actors with the highest weighted degree-centrality (complete graph)</u>

BIMEC	51,52	BVITO	6,11
UEDU	30,35	YEDU	5,87
BALCATEL	28,16	GFRAUN	5,81
GEDU	26,44	FMATRA	5,71
BKUL	19,41	FCEA	5,24
BUG	17,48	BSOLVAY	5,07
BMIETEC	14,56	BEURDEV	4,82
SEDU	13,16	FRANTEL	4,52
NPHILIPS	13,03	BBARCO	4,47
FEDU	12,51	CEDU	4,47
NEDU	12,06	BPGS	4,35
BUCL	11,65	DEDU	4,30
GSIEMENS	11,44	BWTCB	4,09
FTHOMSON	10,57	BULB	4,05
BWTCM	10,37	BKARMAN	3,92
FALCATEL	9,69	UBT	3,92
BUNIVL	9,45	ZEDU	3,91
BVUB	8,98	BEEIG	3,69
IEDU	8,60	BSOCBIO	3,60
HEDU	8,38	GALCATEL	3,51
BBELGACO	8,11	VTT	3,50
BSCK	8,03	ICSELT	3,47
FCNRS	7,41	SALCATEL	3,40
BLMSINT	7,11	PSISTEM	3,20
PEDU	6,52	STELEFON	3,04

Another centrality measure is based on ‘distance’ : the so-called Beauchamp centrality index is defined as $(n-1)/D_i$, where D_i is computed as the sum of the distances of point i to each other point of the subgraph, distance being in its turn defined as the length of the shortest path between the two points considered (this particular type of path is defined as a ‘geodesic’). The distance between two nodes in different components of a graph is, somewhat arbitrarily, considered to be equal to n , the size of the graph. The logic behind this centrality concept is that a point is more central when its average distance to the other points is small. We report on Beauchamp centrality in section 2.6.2.

2.3. Coincidence of different types of lines

In the complete graph 13151 of the 15781 project-lines relate to RTD Framework programmes financed by the EU. These projects are labelled pre-competitive as they are often more close to basic research than to development, production or marketing of new products or to the introduction of new processes. This is, as we saw, reflected in the large participation of research institutes and higher education institutions in the EU Framework programmes (58.7% in the 2nd Framework, 61.8% in the 3rd Framework (see *The European Report on Science and Technology Indicators 1994*, p.225)). The high number of ‘CORDIS’ lines is not only explained by the considerable number of RTD projects in our graph (972) but also by the relatively high number of participants in some of these projects. With respect to innovation the ´near-market´ EUREKA projects and the private agreements on innovation and R&D contained in the MERIT-CATI database provide in this respect more relevant information, albeit that they only account for 1156, respectively 104, of the 15781 project-lines. Notwithstanding this, we should probably not be over-worried by the present asymmetry in the data with respect to the types of R&D co-operation. Especially with respect to IT projects and agreements, which, as we shall see, are very prominent in the graph, it was shown by Hagedoorn and Schakenraad (1993) that ‘private’ and publicly subsidised networks show high congruence.

With regard to the pre-competitive RTD-lines it is - particularly because of the relatively recent character of the phenomenon of joint European R&D projects ([4]) - interesting to analyse the extent to which they coincide in the global graph with EUREKA- and CATI-lines and how often they precede these lines in time. The ‘linear’ causal model of innovation would lead us to expect that near-market co-operation between firms would follow an earlier phase where this co-operation follows the more loose and informal channels of pre-competitive research, and not the other way round. From the evaluation of EUREKA, quoted in the *European Report on Science and Technology Indicators 1994*, we learn however that “The original policy conception of a ’pipeline model’, whereby pre-competitive EC projects are followed by nearer-market EUREKA projects has not materialised to date. Rather there has emerged a complex picture in which involvement in EC programmes could either precede or follow a EUREKA project”.

The evidence in our data is not very conclusive, one way or another.
In our graph only 36 Belgian firms (on a total of 637) appear both in at least one RTD project and at least one EUREKA project and there is a coincidence of 256 EUREKA and ‘CORDIS’ lines. The RTD projects in the area of Information Technology and Telecommunications (ESPRIT, ACTS, RACE, TELEMATICS) by far coincide the most with EUREKA (IT or COMM) with 234 lines, where other technological disciplines account for only 22 coinciding lines.

This is not all too surprising, given the importance of Information Technology and Telecommunications both in the EU Framework programmes and EUREKA. Nevertheless there seems to be a disproportional coincidence between RTD and EUREKA lines in these disciplines. Of the 256 'CORDIS' lines 149 (58.2%) precede coincident EUREKA lines ([5]). Moreover involvement in some specific RTD programmes seems even more often to precede involvement in EUREKA projects (e.g. 74 of 88 ESPRIT lines precede EUREKA lines). So in our graph it would seem that the 'pipeline model' to a certain extent is materialised, especially for those projects in the area of IT and Telecommunications.
If however we concentrate on a more meaningful subset of the coincident 'CORDIS'-EUREKA lines, and focus on those which are directed, we get a different picture : out of the 31 directed 'CORDIS' lines which are coincident with EUREKA lines only 12 precede.

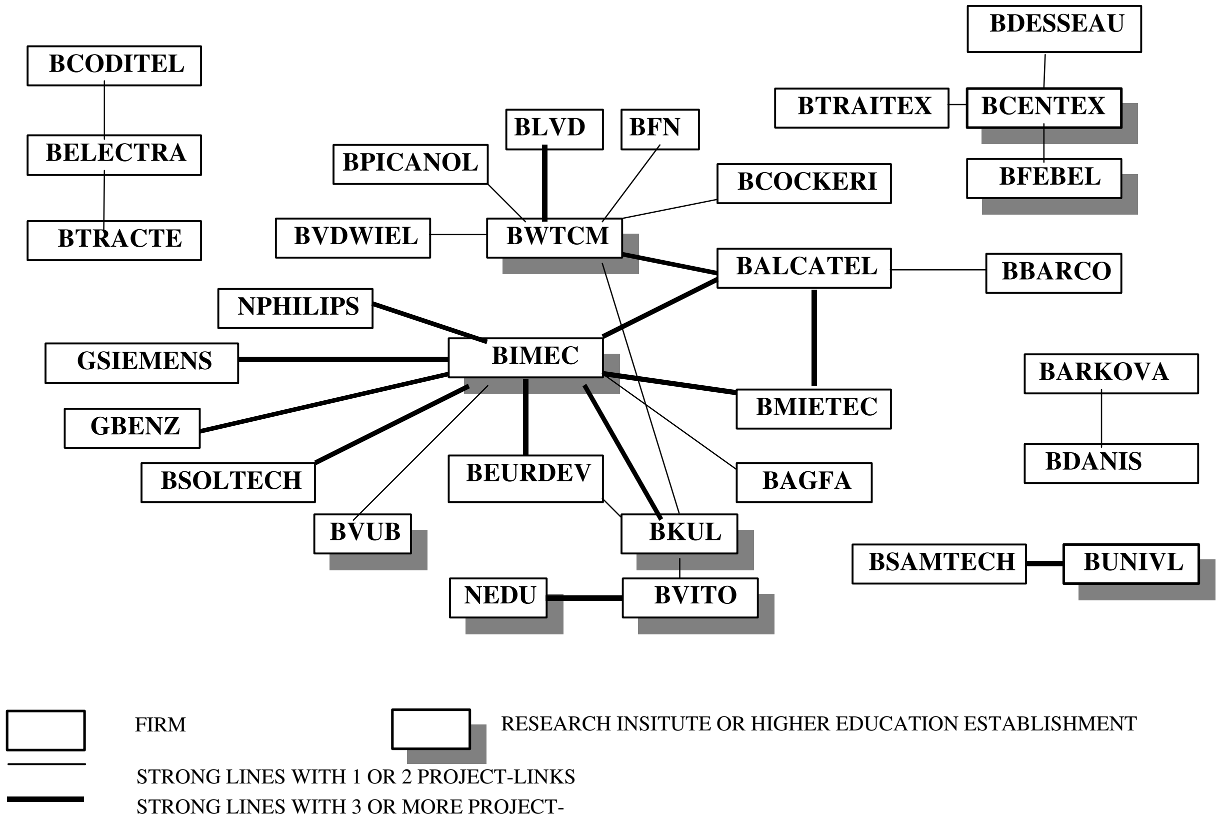
There is very little coincidence of CORDIS with CATI. The Belgian biotechnology company Plant Genetic Systems (a spin-off of the University of Ghent) was involved in 2 RTD projects (started in 1991 and 1992) with the Dutch company Mogen. In 1994 both companies signed an agreement concerning a patent exchange in pesticide technology. In the period 1987-1988 the Belgian research institute IMEC concluded an agreement with Dutch Philips as a follow-up of an ESPRIT1 project(1983-1988). IMEC and Philips, along with Mentor Graphics own the European Development Centre (EDC) which was to commercialise the results of the ESPRIT project.
No EUREKA lines coincide with CATI lines.

Finally we analysed the coincidence of project-lines with personal lines ('interlocking directorates') (see figure 1). There is only a moderate number of 'strong lines' : a set of 31 actors, 22 of which are private firms, are interlinked through 173 project-lines which are backed by at least one personal line. In total the line-set comprises 225 lines (173 project-lines and 52 personal lines). Most of the actors in the 'strong line' set are actors who are together involved in relatively many joint projects.
Most of the project-lines backed by a personal link are 'CORDIS'-lines (170 out of 173) and relate to IT or Telecommunications. The Belgian Interuniversity Microelectronics Centre IMEC has a central position in the graph (2nd highest degree centrality in the complete graph, highest degree centrality in the graph at multiplicity level 6) and in the IT and Telecommunications subgraphs. IMEC has personal links with several of its most active projectpartners among which are 2 foreign MNEs (Philips, involved in 46 projects with IMEC and Siemens involved in 42 projects with IMEC). The thick lines in figure 1 represent the strong lines with 3 or more project-links.

It is noteworthy that a relatively large proportion of the 'strong' project-lines are directed : 38 % (66 out of 173), as compared to the complete set of project-lines (21 % : 3078 out of 14411). This lends support to the hypothesis that 'strong' R&D lines, i.e. lines backed by a personal tie, are more meaningful than others.

Although 'strong' R&D lines indeed seem to be stronger than others, the results of their analysis do not support the idea that personal influence becomes more important as R&D co-operation moves closer to direct market applicability. On the other hand we find it difficult to believe that personal influence would be more often instrumental in obtaining 'easy' government subsidies for more or less noncommittal research, than in making strategic choices with respect to the development of new products and the entry on new markets. The issue merits further attention.

Fig. 1 : Strong Lines



2.4. Intra- and intersectoral R&D co-operation

Innovation practice increasingly transcends not only borders of firms but also borders of industrial sectors, technological disciplines and nations. This evolution raises some questions on the relevance of analysis on the level of traditionally defined sectors and nations.
The study of cross-sectoral R&D co-operation between firms may help to clarify this issue.

In Table 3 we present a matrix with the intra- and intersectoral project-lines of Belgian companies. Project-lines between Belgian firms account for only 2.3 % of all project-lines in the graph and 216 Belgian companies (out of 505) do not co-operate with another Belgian company. These low numbers can be explained by the very nature of the databases used, i.e. by the fact that the data mainly relate to international pre-competitive projects financed by the EU or to international agreements (CATI). For the 2nd and the 3rd Framework programmes links between organisations within Belgium account for 5 % respectively 7.1 % of all collaborative links, which is on average for the EU for the 2nd Framework and even above EU average for the 3rd Framework programme (*European Report on Science and Technology Indicators 1994*, Table IV.9 & IV.10 in the Statistical Annex).

Table 3 clearly shows that, except for the textile industry (NACE 17), most lines are between 2 companies belonging to a different sector.
This might to a certain extent reflect the user-supplier characteristic often attributed to technology transfer and R&D co-operation. The relatively large number of intersectoral links, especially those in sectors related to IT and Telecommunications, certainly indicates that innovative activity transcends sectoral borders.

Table 3 : Intra- and intersectoral project-lines (Belgian companies)

NACE	1	15	17	24	25	26	27	28	29	31	32	33	35	45	515	516	64	70	72	73	74	B	F	B/F	B/ NC	F/NC	INTRA
1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	17	0,06	0,2	3,4	0.00
15		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	5	37	0,14	0,4	2,6	0.00
17			19	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	23	127	0,18	1,0	5,5	0.83
24				1	0	0	0	0	0	0	1	5	0	0	0	1	0	0	2	1	0	12	220	0,05	0,4	7,9	0.08
25					0	0	0	2	0	1	0	0	0	0	0	0	0	0	1	0	1	5	23	0,22	0,6	2,9	0.00
26						2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	30	0,07	0,3	5,0	1.00
27							3	4	1	0	4	0	0	0	0	0	0	0	1	0	4	17	110	0,15	1,3	8,5	0.18
28								7	5	1	1	0	0	0	0	0	0	0	0	0	10	30	62	0,48	1,9	3,9	0.23
29									2	1	2	0	0	0	0	0	0	1	2	0	5	20	68	0,29	1,2	4,0	0.10
31										0	2	0	0	0	0	0	1	0	0	0	0	6	52	0,12	0,4	3,5	0.00
32											11	2	0	0	0	9	9	0	4	0	6	52	909	0,06	4,0	69,9	0.21
33												1	0	0	0	0	0	0	1	0	1	10	88	0,11	1,7	14,7	0.10
35													0	0	0	0	0	0	0	0	0	0	74	0,00	0,0	14,8	0.00
45														0	0	0	0	0	0	0	1	1	3	0,33	0,2	0,6	0.00
515															0	0	0	0	0	0	0	0	15	0,00	0,0	3,0	0.00
516																3	1	0	3	0	2	19	104	0,18	1,3	6,9	0.16
64																	1	0	0	0	2	14	211	0,07	3,5	52,8	0.07
70																		0	1	0	0	2	2	1,00	0,5	0,5	0.00
72																			5	2	3	25	370	0,07	0,6	8,8	0.20
73																				0	0	6	36	0,17	1,2	7,2	0.00
74																					2	39	279	0.14	0.8	6.2	0.05
Total																						169 *	2843	0.06	0.6	9.4	0.34
Average																						8	135	0,19	1,1	11,6	0.15

B : Total number of project-lines between Belgian companies (with known NACE classification)
F : Total number of project-lines between Belgian companies (with known NACE classification) and foreign actors
NC : Number of companies classified in this NACE sector
INTRA : Percentage of intrasectoral lines

* This total is not equal to the sum of the column but is the total number of project-lines between Belgian companies with known NACE classification, i.e. the sum of the cells in the upper triangle displayed.

The table can, in our view, be used to test the significance of innovation megaclusters detected on the basis of input-output tables of intersectoral flows of capital goods and technology. The reason is that IO cluster-lines which coincide with R&D co-operation ('project') lines carry a different meaning than the ones that do not. In other words, if it is the intention to analyse innovation clusters by means of client-supplier relations, R&D project-lines can be used as a filter to eliminate redundant lines, or at least to discriminate between 'R&D supported' and simple client-supplier lines.

2.5. The role of firm size

A similar cross-tabulation as for industrial sectors (table 3) can be made with respect to firm size (table 4).

Table 4 : distribution of lines between size-classes of Belgian firms

TOTAL NUMBER OF LINES					
	NP1	**NP2**	**Belgian non-firm**	**FOREIGN**	**BELG/FOREIGN**
NUMBER OF EMPLOYEES < 250 (NP1)	229	263	328	4095	0,20
NUMBER OF EMPLOYEES >= 250 (NP2)		241	214	3154	0,23
NUMBER OF PROJECTLINES					
	NP1	**NP2**	**Belgian non-firm**	**FOREIGN**	**BELG/FOREIGN**
NUMBER OF EMPLOYEES < 250 (NP1)	166	101	295	4095	0,14
NUMBER OF EMPLOYEES >= 250 (NP2)		51	159	3154	0,10

The subgraph of the CRAFT programme lets us look at another angle to the role of small and large firms on the international R&D scene.
CRAFT, which is a BRITE/EURAM initiative aimed at co-operation between SMEs, yields 125 of all 332 project-lines between Belgian companies, and 23 % of all the CRAFT lines in the graph link Belgian Companies, whereas ESPRIT, with 3000 lines in the graph, has only 43 lines (1.4 %) linking Belgian companies.
Both approaches illustrate the fact that Belgian SMEs are responsible for a sizeable percentage of the total amount of joint R&D projects, but that, in relative terms, they are more domestically oriented than large firms.

2.6. Clusters and cliques

In studies dealing with the fashionable subject of innovation clusters and cluster-based policies a wide variety of cluster definitions and concepts is used. A clear distinction must be made between cluster approaches using traditional cluster analysis techniques to detect objects that are similar or proximate as to some relevant characteristic(s) (i.e. cluster-analysis in the traditional, statistical, sense), and those approaches that focus on relationships between actors or groups of actors (firms, sectors, branches) in networks. Another distinction concerns the level of aggregation used in the analysis ([6]).
Since *The Competitive Advantage of Nations* (Porter, 1990) most research has been carried out on the macro- or meso-level of aggregation (e.g. by means of I-O techniques) with the intent to detect and analyse the technological disciplines in which nations are specialised due to favourable factor conditions. However the globalisation

of the economy, European economic integration and the fusion of technological disciplines raise questions on the relevance of the analysis based on national borders and traditional sectoral classifications (see Petrella (1989), Imai and Baba (1991), Grupp (1992), Bidault and Fischer (1994), Papanastassiou and Pearce (1994), Elam (1997), Meyer-Krahmer (1997), Caracostas and Soete (1997) ; see also the 'World Investment Report 1995'). As mentioned in section 2.4 the network-analysis of R&D relations between NIS-actors may help to clarify the innovative nature of clusters found at higher levels of aggregation.

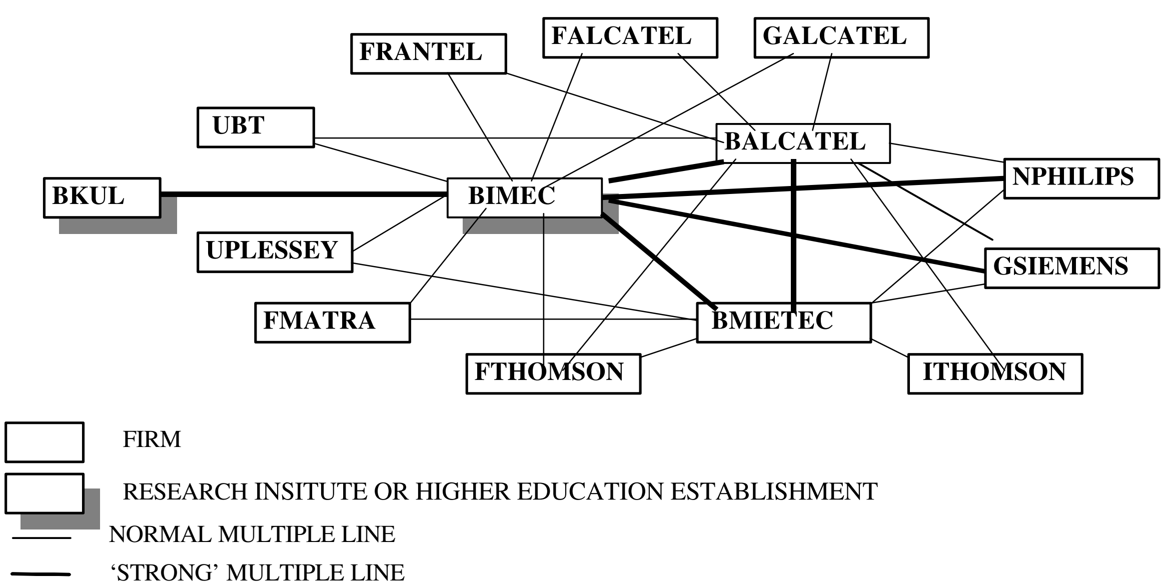
The graph-theoretical method for the detection and analysis of micro-clusters, presented in this paper, as already stressed in the introduction, starts from the assumed importance of R&D co-operation between firms and other actors of the Innovation System as one of the main mechanisms weaving the network-tissue of the NIS. This is in accordance with recent literature on innovation and international competitiveness (Ouchi and Kremen Bolton (1988), Imai and Baba (1991), Teece (1992), Schott (1994), Hagedoorn (1995), Duysters (1996), Dunning (1997)).
Dunning uses the term ´alliance capitalism´ to describe what he sees as an important new phase of developed economic systems (Dunning, 1997). A main feature of this ´alliance capitalism´ is the coexistence of competition, sharpened by globalisation and liberalisation, with an increasing number of network relations of R&D co-operation and strategic alliances between competitors. Carlsson and Jacobsson (1997, p. 271), following Håkansson (1989), give a rationale for this. Technological networks, through the reciprocal flow of information, result in a 'blending of visions' on the future technological evolution of markets. This leads to a reduction in perceived risk and to a better co-ordination of investments between competitors. Innovation and diffusion turn into a collective action.
Explaining the benefits of technological networking is one thing, the 'prisoner's dilemma' aspects of the situation another : competitors may end better off by co-ordination, but why should they make the first move ? This is where government, resp. European, subsidies for joint R&D come in, enabling the creation of an atmosphere of trust in joint R&D projects of the pre-competitive type, and pushing the competitors over the threshold in near-market R&D projects.
Porter (1990, p. 635) qualifies this point of view : firms will usually try to bring their own proprietary technologies on the market and will only divert a modest part of their R&D facilities to joint projects. Also Geroski (1994) remains reluctant to the idea of horizontal relationships.

In what follows we specialise the rather loosely defined concept of 'cluster' to the graph-theoretical concept of 'clique'. N-Cliques can be defined as subgraphs of which all points are linked with one another through a path with maximal length equal to n in a way that no point outside the subgraph has the same quality.
As links between foreign actors, due to constraints in the use of the computer programme, are not considered, 2 foreign actors cannot be in the same clique in the present analysis. This introduces, as will become apparent below, a downward bias in the size of the cliques which are identified.

2.6.1. Cliques in the complete graph

The detection of n-cliques poses some problems for the complete graph due to the size of the graph and programme limitations with respect to central memory. In order to reduce computational complexity the multiplicity of lines was taken into account. For the complete graph 1-cliques could be detected from a multiplicity level of 8 onwards. The subgraph at multiplicity level 8 (containing all actors inter-linked by at least 8 lines) has 4 components. The largest contains 56 actors and 108 multiple lines and the 3 other components each contain 2 actors and 1 multiple line. At the multiplicity level of 12 2 components remain. The largest contains 35 actors and 53 multiple lines.
At the multiplicity level 8 there are 20 1-cliques, 3 of which contain 4 actors and 17 contain 3 actors. The 20 cliques without exception are generated by RTD projects related to IT or telecommunications (ESPRIT, ACTS, RACE, ...) and are themselves highly linked to one another.
In figure 2 the interlinkage of the cliques is shown. All actors (except foreign education establishments) appearing in at least one clique are shown with their links in the cliques. The thick lines are 'strong' lines (project-lines backed up by a personal link between the actors). The central triangle IMEC, Alcatel Telecom and Alcatel Mietec consists of these strong lines. The multiple line (46 projects) between IMEC and Dutch Philips and the multiple line (42 projects) between IMEC and German Siemens are also backed up by a personal link.

Fig. 2 : Interlinkage of the cliques in the complete graph (multiplicity ≥ 8)



The dominance of links related to Information Technology and Telecommunications clearly reflects the dominance of these disciplines in the EU Framework programmes. In the 2nd Framework Programme (1987-1991) 42.2 % of the total RTD budget was attributed to IT & Telecommunications (2275 Mecu). In the 3rd Framework Programme (1990-1994) the share decreased to 37.7 % (2491 Mecu). In the 4th Framework Programme (1994-1998) the share further decreased to 27.7 % (3405 Mecu) but remained the largest area of RTD funding (*European Report on Science and Technology Indicators 1994*, p.214-216).

Furthermore a large number of projects in the area of Industrial and Materials Technology (BRITE/EURAM) are also related to these disciplines.
For EUREKA the share of IT and Communications in the total value was 69 % for the ongoing projects and 40 % for the finished projects. This high share is primarily explained by the high value per project as the areas 'medical & biotechnology and environment' generate more projects than IT or Communications but have a lower share in total value.

The table in appendix A8 shows that the overall participation of Belgian organisations in RTD programmes is above EU average in the areas of IT, Telecommunications and Materials (cfr. Lichtenberg, 1996) and below EU average in the areas of Energy Technology, Biotechnology and Environmental Technology. Table A9 shows the same pattern of participation for EUREKA where only Communications differs with a participation degree below the European average. On the contrary, the lines that belong to the Belgian part of MERIT-CATI show that most agreements relate to Biotechnology, followed by Chemicals. IT-related agreements only account for 16 % of all agreements and none of these agreements seem to coincide with IT related projects in the pre-competitive phase, except for the joint development agreement (1987-1988) between IMEC and Philips, as a follow-up of an ESPRIT 1 project ([7]).

In order to detect cliques at lower multiplicity levels and clusters in different technological disciplines we created some specific subgraphs.
In what follows we will limit ourselves to the IT and Telecommunications discipline. A comparable analysis for other disciplines can be found in Meeusen and Dumont (1997).

2.6.2. Information Technology and Telecommunications

Information Technology is a term given to the discipline that covers different but increasingly related technological areas like electronics, data processing, software and related services, and in some publications it also includes Telecommunications.
Imai and Baba add two new categories to the Pavitt taxonomy, namely the new information-intensive services industry and the emergent generic-complex industry (IT). The last category is characterised by multi-layer cross-border networks with joint R&D as an important feature (Imai and Baba, 1991).
Faced with the importance of IT and Telecommunications for economic growth and the relative weakness of Europe vis-à-vis Japan and the US, the European Union launched cost-sharing programmes of considerable magnitude aimed at fostering R&D co-operation between firms, research institutes and higher education establishments of different EU countries in these fields (ESPRIT, RACE, ACTS). As shown in the previous chapter IT is by far the most important area of EU Framework programmes and also very important in EUREKA. The IT & Comm. subgraph contains therefore a large number of points and lines : 5767 lines (40 % of all project-lines) and 1485 actors (38 % of all nodes). The largest component contains 1453 actors and 4072 single or multiple lines.
IMEC with degree centrality equal to 263, Alcatel (208), Belgacom (141), the KUL (123), Alcatel Mietec (120), Barco (119) and the UCL (111) are the most central actors (see Meeusen and Dumont (1997) for more details).

The Telecommunications subgraph contains 2340 lines (some lines coincide with project-lines in the IT subgraph) and only 1 component of 598 actors and 1723 single or multiple lines. Some of the most central actors in the IT subgraph are present here as well : Alcatel (139), Barco (135) and Belgacom (99).

Table 5 shows the time-evolution of some network indicators for a subset of 20 important actors in the field of IT (accounting for 44.8 % of all ESPRIT lines) from ESPRIT 1 (1984-1988) to ESPRIT 3 (1990-1994). All measures indicate an increase in density of the network over time (cfr. Duysters, 1996).
In addition to the usual degree centrality measure we also report the so-called Beauchamp centrality. This is possible because the subgraph concerned is relatively small and fully connected.

Table 5 : Evolution of the network of 20 important IT actors

	ESPRIT 1 (1984-1988)	ESPRIT 2 (1987-1992)	ESPRIT 3 (1990-1994)
DENSITY	0.17	0.26	0.28
NUMBER OF CLIQUES of size 3	3	20	6
NUMBER OF CLIQUES of size 4	1	0	12
AVERAGE DEGREE CENTR.	2.3	3.6	5.1
BEAUCHAMP	0.179	0.192	0.579
ADJACENCY (INTEGRATION)	46	72	106

A very similar time pattern can be found for Telecommunications (see Meeusen and Dumont, 1997).

The high density and the thick lines in the IT subgraph can be given an interpretation in terms of the shift away from strategic alliances motivated by the desire of better market access, to technological partnerships in order to cope with rapidly rising investment costs, steeper learning curves and shortening product life cycles. These phenomena are more important in IT and telecommunications, and subgraphs for this technological discipline may therefore be expected to be more dense and to have grown more rapidly than for other technological disciplines (see also Duysters (1996, ch. 7)).
The absence in the subgraph of corporations like IBM, very prominent in a global (world-wide) MERIT-CATI analysis (Duysters), is of course explained by the European bias in the data, but perhaps also by what Porter (1990) sees as one of the main aspects of technological partnering, i.e. 'second-tier' competitors trying in a defensive way to catch up with the leaders on the market (see Chesnais (1988) for a dissenting view).

3. Further analytical steps and research questions

In this early phase of the research at least one thing became abundantly clear, and comes for that matter – in the light of previously published research - as no surprise for those studying national innovation systems. The (international) network aspects of R&D activities are very pronounced and 'markets and hierarchies' are obviously transcended . There is however some irony in the high connectedness of the graph of R&D co-operation. The linear causal model of innovation in which fundamental scientific research leads to the actual implementation of new technologies in production and the introduction of new products on the markets for final goods, over applied technology research, first industrial prototypes and upscaling, was taken as inspiration for governments, and indeed for the European

Commission, to promote liaison functionality through cross-national funding of pre-competitive research jointly undertaken by firms, universities and research laboratories (the Framework programmes) and the stimulation of 'near-market' research (the EUREKA initiative). In doing so they acted as a powerful catalyst in turning this same linear structure into a systemic (network) structure.
One might say that 'new' industrial policy is essentially reduced to government funding and stimulation of R&D and innovation.
In other words, if we now take the systemic approach for granted, then this is – among other things surely - much so *because of* the same type of government action that many economists working in the field now put forward as adequate in the light of the network, that is 'systemic', aspects of present R&D.

Arguing in the same vein, we cannot but realise that the shape of the network that we find gives a somewhat biased view of national innovation systems. Because in the last decade the EC selected a number of S&T fields which they considered of being of growing importance in terms of international competitiveness and future growth potentiality, heavy emphasis was placed in the EU Framework programmes on fields such as information technology, telecommunication, new materials, bio-engineering, new forms of energy etc. The result is of course a R&D co-operation network in which the highest connectivity can be found in precisely these fields.
Should we therefore not consider to put more weight on the information contained in databases of the MERIT/CATI type, since they do not reflect this bias resulting from governmental policy ?

A number of relevant research questions were already (tentatively) addressed in this paper, such as the question whether there is a difference across 'CORDIS'-type pre-competitive programmes in the way the research is carried through to 'near-market' and competitive research, and the question whether backing by personal links becomes more frequent as one approaches marketability.
A number of others issues (e.g. many of those formulated by Duysters (1996, Chapter 7)) can only be answered by means of a comparative analysis of the structure of the innovation systems in different countries.
Some other topics, however, remain still unexplored, or could be tackled with the obtained description of the national network, once the pointset information of the database is completed with variables from the OECD R&D statistics at firm level, and with CIS data. For example:

- Is there a connection between pointcentrality on the one hand and performance, innovativity and R&D-intensity on the other ? Is this relation significantly different in the case of pre-competitive, 'near-market' and competitive research ?
- Is 'co-operative' R&D a substitute or a supplement to 'non-co-operative' R&D ?
- What is the time-evolution of the graph ?
- Do large firms more frequently engage in R&D co-operation than small firms ?
- Does a high centrality aim at a large control span of the company concerned, or at a better exploitation of existing market opportunities (Walker, 1988) ; i.e. do central companies have a great control span ?
- Is there a relation between the sort of co-operation (with or without state support) and the performance of the companies involved ?

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Appendix A1 : List of actors

LABEL	NAME	TYPE	NAT
BACSET	ACSET	IND	BE
BAGFA	Agfa-Gevaert	IND	BE
BALCATEL	Alcatel Telecom	IND	BE
BAMYLUM	Amylum	IND	BE
BARKOVA	Arkova	IND	BE
BBARCO	Barco	IND	BE
BBEKAERT	Bekaert	IND	BE
BBELGACO	Belgacom	IND	BE
BBOSAL	Bosal	IND	BE
BCENTEX	Centexbel	ROR	BE
BCHAMP	Champion Spark Plug	IND	BE
BCOCKERI	Cockerill-Sambre	IND	BE
BCODITEL	Coditel Brabant	IND	BE
BCRM	Centre for Research in Metallurgy	ROR	BE
BDANIS	Danis	IND	BE
BDESSEAU	Desseaux	IND	BE
BE2S	Expert Software Systems (E2S)	IND	BE
BEEIG	European Renewable Energy Centers Agency	NCL	BE
BELECTRA	Electrabel	IND	BE
BELENCO	Elenco	IND	BE
BELT	E.L.T.	IND	BE
BEURDEV	European Development Centre	IND	BE
BFEBEL	Febeltex	NCL	BE
BFN	FN-Herstal	IND	BE
BHYGEPI	Institute for Hygiene and Epidemiology	ROR	BE
BIMEC	Interuniversity Micro-electronics Centre (IMEC)	ROR	BE
BINFTEC	Information Technologies & Services	IND	BE
BINNOGEN	Innogenetics	IND	BE
BKARMAN	Von Karman Inst. For Fluid Dynamics	ROR	BE
BKUL	Catholic University of Leuven	EDU	BE
BLABOREL	Laborelec	IND	BE
BLMSINT	LMS International	IND	BE
BLVD	LVD company	IND	BE
BMEDOC	Medoc-Media	IND	BE
BMETALOG	Metalogic	IND	BE
BMIETEC	Alcatel Mietec	IND	BE
BOPL	Opl Benelux	IND	BE
BPETROFI	Petrofina	IND	BE
BPGS	Plant Genetic Systems	IND	BE
BPHILIPS	Philips Belgium	IND	BE
BPICANOL	Picanol	IND	BE
BPRB	PRB SA	IND	BE
BRADENG	Radius Engineering	IND	BE
BRHONE	Rhone-Poulenc	IND	BE
BRIC	RIC AI	IND	BE
BSAMTECH	Samtech	IND	BE
BSCK	Study Centre for Nuclear Energy	ROR	BE
BSIDMAR	Sidmar	IND	BE
BSOCBIO	Société Européenne de Biotechnologie	IND	BE
BSOCGEN	Sociéte Générale de Belgique	IND	BE
BSOLTECH	Soltech	IND	BE
BSOLVAY	Solvay	IND	BE
BTIENSE	Tiense Suikerraffinaderijen	IND	BE

Appendix A1 (continued)

BTRACTE	Tractebel	IND	BE
BUCL	Catholic University of Louvain	EDU	BE
BUG	University of Ghent	EDU	BE
BULB	Université Libre de Bruxelles	EDU	BE
BUM	Union Miniere	IND	BE
BUNIGEM	University of Gembloux	EDU	BE
BUNIVL	University of Liège	EDU	BE
BVDWIEL	Michel van de Wiele	IND	BE
BVISION	Vision 1250	IND	BE
BVITO	Flemish Institute for Technological Research (VITO)	ROR	BE
BVUB	Free University Brussels	EDU	BE
BWTCB	Scientific Technological Centre of the Forest Industry (WTCB)	ROR	BE
BWTCM	Scientific Technological Centre of the Metal Industry (WTCM)	ROR	BE
FALCATEL	Alcatel-Alsthom	IND	FR
FCEA	Commisariat à l'Energie Atomique	NCL	FR
FCNRS	Centre National pour la recherche scientifique	ROR	FR
FELF	ELF-Atochem	IND	FR
FMATRA	Matra Cap systemes	IND	FR
FRANTEL	France Telecom	IND	FR
FSNECMA	Snecma	IND	FR
FTHOMSON	SGS-Thomson	IND	FR
GALCATEL	Alcatel Sel AG	IND	DE
GBENZ	Daimler-Benz	IND	DE
GFRAUN	Fraunhofer Gesellschaft	IND	DE
GSIEMENS	Siemens	IND	DE
GVARIA	Varia	IND	DE
ICSELT	Centro studi e Laboratori Telecomunicazione	IND	IT
IENIMONT	Enimont Spa.	IND	IT
ITHOMSON	SGS Thomson	IND	IT
JINBANK	Industrial Bank of Japan	IND	JP
JNIPKAY	Nipkaya	IND	JP
KFOAMEX	Foamex LP.	IND	US
KTANDEM	Tandem	IND	US
NBROCADE	Gist-Brocades	IND	NL
NDSM	DSM	IND	NL
NPHILIPS	Philips	IND	NL
PSISTEM	Instituto de Enghenheria de Sistemas	ROR	PT
STELEFON	Telefonica de Espana	IND	ES
UBEAMECH	Beamech Ltd.	IND	GB
UBP	BP	IND	GB
UBRITST	British Steel	IND	GB
UBT	British Telecommunications	IND	GB
UDELTA	Delta Group Plc.	IND	GB
ULAPORTE	Laporte	IND	GB
UOXFINSI	Oxford Instruments Group	IND	GB
UPLESSEY	Gec Plessey	IND	GB
UROLLS	Rolls-Royce Ltd	IND	GB
VTT	Technical Research Centre of Finland	ROR	FI

Appendix A2 : Classification of Belgian and foreign actors by organisation type

COUNTRY	IND	ROR	NCL	CON	EDU	OTH	TOTAL
BELGIUM	631	38	47	11	18	36	**781**
FRANCE	245	61	45	6	1	195	**553**
GERMANY	294	53	47	1	1	157	**553**
GREAT BRITAIN	261	26	47	6	1	110	**451**
ITALY	122	30	32	0	1	105	**290**
SPAIN	103	27	26	0	1	72	**229**
NETHERLANDS	117	26	26	6	1	51	**227**
DENMARK	56	20	22	2	1	20	**121**
GREECE	56	9	10	1	1	28	**105**
SWEDEN	42	17	13	1	1	15	**89**
SWITZERLAND	46	15	7	0	1	7	**76**
PORTUGAL	23	9	12	1	1	22	**68**
IRELAND	31	4	7	0	1	24	**67**
FINLAND	29	5	6	0	1	7	**48**
NORWAY	15	8	4	0	1	15	**43**
AUSTRIA	20	6	5	0	1	9	**41**
LUXEMBOURG	15	0	4	0	1	4	**24**
US	16	0	1	0	1	5	**23**
24 OTHER COUNTRIES	31	15	16	0	12	27	**101**
TOTAL	**2153**	**369**	**377**	**35**	**47**	**909**	**3890**

IND : private company (private research institutions and consultancy firms not included ;
ROR : research institutions and laboratories ;
NCL : non-commercial organisations ;
CON : consultancy firms ;
EDU : universities and institutions of higher education ;
OTH : others.

Appendix A3 : Classification of nodes by country and project/agreement type

COUNTRY	'CORDIS'	EUREKA	CATI	IWT	TOTAL
BELGIUM	506	131	39	251	**781**
FRANCE	479	97	8	0	**553**
GERMANY	506	69	4	1	**553**
GREAT BRITAIN	413	46	10	0	**451**
ITALY	268	38	2	0	**290**
SPAIN	195	46	0	0	**229**
NETHERLANDS	178	58	8	0	**227**
DENMARK	115	13	0	0	**121**
GREECE	104	3	0	0	**105**
SWEDEN	80	12	0	0	**89**
SWITZERLAND	62	17	2	0	**76**
PORTUGAL	66	4	0	0	**68**
IRELAND	65	2	0	0	**67**
FINLAND	41	12	2	0	**48**
NORWAY	34	10	0	0	**43**
AUSTRIA	33	11	0	0	**41**
LUXEMBOURG	23	1	0	0	**24**
US	7	0	16	0	**23**
24 OTHER COUNTRIES	64	27	13	0	**101**
TOTAL	**3239**	**597**	**104**	**252**	**3890**

Note : the row-totals do not correspond because an actor can be active in more than one type of programme.

Appendix A4 : Classification of Belgian companies according to size (# of employees and ranking by value added)

	#	%
NUMBER OF EMPLOYEES (n)		
n > 1000	56	9
1000 > n > 500	31	5
500 > n > 250	45	7
250 > n > 100	66	10
100 > n > 50	65	10
50 > n , OR UNKNOWN	368	58
NATIONAL RANKING BY VA		
TOP 100	41	6
TOP 500	108	17
TOP 1000	143	23
TOP 5000	258	41
TOP 10000	303	48
TOP 30000	373	59
NOT RANKED in TOP 30000	258	41

Appendix A5 : Belgian private companies classified by NACE code

SECTOR(NACE)		#	%
Other business services	(74)	66	15,64
Informatics	(72)	50	11,85
Chemical industry	(24)	37	8,77
Textile industry	(17)	27	6,40
Manufacture of metal products	(28)	28	6,64
Machinery & Tools	(29)	37	8,77
Electrical machines	(31)	16	3,79
Wholesale trade machinery	(516)	21	4,98
Audio-, video- & Telecommunications	(32)	14	3,32
Food & Beverages	(15)	20	4,74
Metallurgy	(27)	17	4,03
Rubber&Synthetic materials	(25)	14	3,32
Manufacture of Non-metallic mineral products	(26)	11	2,61
Medical& Optical instruments,Finemechanics	(33)	10	2,37
Manufacture of Other means of Transport	(35)	7	1,66
Building industry	(45)	10	2,37
Wholesale trade intermediate goods	(515)	7	1,66
Post&Telecommunications	(64)	4	0,95
Rent&Sale of real estate	(70)	4	0,95
Research&Development	(73)	6	1,42
Agriculture	(1)	7	1,66
Manufacture of Motor vehicles	(34)	4	0,95
Furniture industry	(36)	5	1,18
Total		**422**	**100**
Other or at present unkown		215	

Appendix A6 : Added value generated by the graph's Top200 companies as a share of added value of all Top200 companies

NACE	AV Graph200	AV Top200	%	#GR200	#TOP200
15	40	67	59,70	6	15
17	5	7	71,43	2	3
24 (excl. 244)	153	182	84,07	12	23
244	40	40	100,00	3	3
25	5	5	100,00	2	2
26	30	67	44,78	5	7
27	84	105	80,00	5	10
28	0	8	0,00	0	3
29	27	31	87,10	5	7
31	3	10	30,00	1	3
32 (excl.321)	44	44	100,00	5	5
321	3	3	100,00	1	1
33	3	3	100,00	1	1
34	6	12	50,00	4	9
353	8	8	100,00	3	3
40	168	179	93,85	1	19
45	3	10	30,00	1	3
515	15	62	24,19	4	7
516	14	16	87,50	3	4
60	84	92	91,30	3	5
62	19	19	100,00	1	1
64	124	124	100,00	4	4
72	0	5	0,00	0	2
74	2	42	4,76	2	12
Other	35	250	14,00	10	48
Total	**915**	**1391**	**65,78**	**84**	**200**

AVGRAPH200 : Added Value of the Top 200 Companies represented in the graph, belonging to the given NACE sector
AVTOP200 : Added Value of all Top 200 Companies belonging to the given NACE sector
% : AVGRAPH200/AVTOP200*100
#GR200 : Number of Top 200 companies in this NACE sector represented in the graph
#TOP200 : Number of Top200 companies in this NACE sector

Source: BNB, 1996

Appendix A7 : Number of lines in the graph according to type of project/agreement

	# Projects	# Lines	# Belg. Companies	# Other Belg. Actors
'CORDIS'	972	13151	386	120
EUREKA	117	1156	114	17
MERIT/CATI	75	104	38	1
IWT	287	1370	222	29
INTERLOCKING DIRECTORATES		507		
TOTAL	1451	16288	631	105

Appendix A8 : Distribution of some major RTD projects (Belgium compared to EU average)

	BELG	%	SELPROJ	%	SELPROJ/BELG(%)	ALL	%
IT	**329**	**25,64**	**274**	**36,63**	**83,28**	**1643**	**23,87**
ESPRIT	329	25,64	274	36,63	83,28	1643	23,87
MATERIALS	**241**	**18,78**	**170**	**22,73**	**70,54**	**1237**	**17,97**
BRITE/EURAM	241	18,78	170	22,73	70,54	1237	17,97
COMM.	**161**	**12,55**	**123**	**16,46**	**76,40**	**586**	**8,51**
RACE	51	3,98	48	6,43	94,12	215	3,12
ACTS	39	3,04	35	4,68	89,74	114	1,66
TELEMATICS	63	4,91	32	4,28	50,79	243	3,53
ENS	8	0,62	8	1,07	100,00	14	0,20
ENERGY	**169**	**13,17**	**81**	**10,82**	**47,93**	**1103**	**16,03**
JOULE/THERMIE	115	8,96	55	7,35	47,83	855	12,42
RENA	10	0,78	9	1,20	90,00	70	1,02
NFS	44	3,43	17	2,27	38,64	178	2,59
BIOTECH.	**207**	**16,14**	**50**	**6,68**	**24,15**	**1192**	**17,31**
AIR	103	8,03	28	3,74	27,18	436	6,33
ECLAIR	12	0,94	10	1,34	83,33	42	0,61
BRIDGE	24	1,87	6	0,80	25,00	97	1,41
BIOTECH	45	3,51	5	0,67	11,11	203	2,95
BIOMED	23	1,79	1	0,13	4,35	414	6,01
ENVIRONM.	**135**	**10,52**	**18**	**2,41**	**13,33**	**908**	**13,19**
ENV	115	8,96	8	1,07	6,96	821	11,93
AIM	20	1,56	10	1,34	50,00	87	1,26
TRANSPORT	**41**	**3,20**	**32**	**4,27**	**78,05**	**214**	**3,11**
TRANSPORT	17	1,33	9	1,20	52,94	79	1,15
DRIVE	24	1,87	23	3,07	95,83	135	1,96
TOTAL	**1283**	**100,00**	**748**	**100,00**	**58,30**	**6883**	**100,00**

BELG: Total number of projects with at least one Belgian participant
SELPROJ: Total number of projects restrained for analysis (at least one Belgian company)
ALL: Total number of projects in this RTD area

Appendix A9 : Distribution of EUREKA projects (Belgium compared to EUREKA average)

AREA	BELG	%	ALL	%
Information technology	27	23,08	202	16,93
Biotechnology	20	17,09	217	18,19
Environment	20	17,09	233	19,53
Robotics	16	13,68	199	16,68
New materials	15	12,82	128	10,73
Transport	8	6,84	81	6,79
Laser	5	4,27	28	2,35
Communications	3	2,56	48	4,02
Energy	3	2,56	57	4,78
Total	117	100,00	1193	100,00

BELG: Total number of projects with one Belgian participant
ALL: Total number of EUREKA projects in this area

Notes

[1] B (Belgium), C (Switzerland), D (Denmark), F (France), G (Germany), H(Greece), I (Italy), J (Japan), K (USA), N (the Netherlands), P (Portugal), S (Spain), U (UK), V (Finland), Y (Ireland), Z (Sweden).

[2] The software used is GRADAP v. 2.10, a social network analysis programme developed at the University of Groningen (C.J.A. Sprenger and F.N. Stokman (1989)).

[3] The density of a graph is defined as the actual number of lines in proportion to the number which is maximally possible ($n(n-1)/2$).

[4] A sequence analysis looses meaning as the period in which joint projects have been set up grows longer. The reason is a ‘demographic’ one : R&D initiatives set up between two partners which are in a mature stage will be more often coexistant with new initiatives between the same partners as time proceeds.

[5] The observed difference between 149 lines where RTD Framework projects precede EUREKA projects and 107 where the opposite is true or RTD and EUREKA projects started in the same year, is statistically significant (compared to a 50-50 proportion) at a level of 99 %.

[6] ‘Clusters’ is also a term which sometimes is used in a a-prioristic, non-analytical, context. An example is the cluster-concept used by the Flemish regional government, which considers (and in a number of cases, finances) clusters as formal organisations of firms in a particular industrial sector or active in the same field, formed on a voluntary basis, and taking care of co-ordination and advisory tasks with respect to product and process innovation on behalf of its members (see Debackere and Vermeulen (1997) who place this cluster-concept in a more general perspective).

[7] This result may possibly be caused by the fact that at this stage we only had access to a small part of the MERIT-CATI database.