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Internal integration and collaboration in European R&D projects

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Abstract. Since 1984, the European Union has established seven Framework Programmes for research and technological development, in which funding activities are seen as a key concept to link Europe's research excellence in transnational R&D networks. The rise of European technology policies is due to the fact that the innovation process is perceived as a complex and highly dynamic process, in which market failure can be prevented by creating linkages between science and technology. To gain leadership in key scientific and technology areas, the research Framework Programmes support cooperation between universities, industry, research centres and public authorities, aimed at creating durable cooperation links and better integration and coordination of research efforts across the European Union.
The FP6 funded research project NEMO - Network Models, Governance and R&D collaboration networks - aims to investigate the interplay between political governance, structure and function in the European Framework Programmes. NEMO focuses on R&D collaboration networks both at the programme and project levels. In this paper we take a closer look at intra-project collaboration that has been induced by EU Framework Programmes and focus on individual projects and researchers. We look at expectations and motivations of organisations in participating in collaborative R&D projects; we study criteria for partner choice in current and future R&D projects and we look at intra-project linkages especially in terms of doing joint research. Also the perceived problems, challenges and rewards of multidisciplinary and inter-organisational collaboration are discussed.

Keywords. European Framework Programmes, R&D collaboration, political governance, intra-project structure, project performance

1 Introduction

The European-wide cooperation in research and development has gradually taken shape since the late 1950's, with the first attempts at providing support to R&D activities focussed on research related to coal and steel, agriculture and nuclear energy. The joint policy developed throughout the 1970's with the first European Cooperation in the field of Scientific and Technical Research Programme (COST), established in 1971, and the establishment of the community level political initiatives such as Committee for Research and Development (CERD) and European Science Foundation. The first of the multi-annual Community-level Framework Programmes for research and development was established in 1984 with a budget of 4,5 billion ECU. Five criteria were established for research to be funded by the new initiative. Those included research beyond the capacity of individual member states, research with financial profit if carried out in cooperation, national level research which would contribute to solving transnational problems and research contributing to the cohesion of the common market and the unity of European research and technology. Finally, research is expected to contribute to the strengthening of economic and social cohesion within the European community. (van der Wende & Huisman 2004, 36-39, Luukkonen 2001). The aims of the Framework Programmes have stayed largely the same over the years.

The Framework Programmes have steadily grown in size and scope, especially after the establishment of The European Research Area in 2000 as part of the new Lisbon agenda aimed at making Europe the most competitive knowledge-based economy in the world. The ERA aims to achieve seven targets: optimal use of material resources and facilities at the European level, coherent use of public instruments and resources, more dynamic private investment in R&D, a common system of scientific and technical reference for policy implementation, more abundant and more mobile human resources, establishment of a dynamic European landscape, open and attractive to researchers and investment, and finally creating a European area of shared values pertaining to questions of the relationship between science, technology and society (EC 2000). This is accompanied by the aim of increasing the overall spending on R&D in the European Union to 3% of the

GDP by 2010 (Presidency Conclusion 2002). The Sixth Framework Programme introduced new instruments, such as the networks of excellence and integrated projects, and had a budget of 17,5 billion Euros. The Seventh Framework Programme has seen a reorganisation of the key programmes, introduction of investigator-led research opportunities, and a significant increase of the budget to over 53 billion Euros over seven years.

The Framework Programmes aim at focussing and integrating the research activities within the European Union. The efforts to achieve this include selected thematic priorities, structuring the European research area through stimulating research and innovation, utilisation of research results, transfer of knowledge and technology, supporting development of human resources and encouraging mobility of researchers, boosting infrastructure and strengthening the foundations of the European research area through a better coordination and coherence of national policies aimed at stimulating research, development and innovation (European Parliament 2002). The Framework Programmes should contribute to a better coordination of the European research and technological development activities and policies, and contribute to the development of scientific and technological excellence in Europe. They should also contribute to a better integration and durable networking of the organisations producing and exploiting knowledge (European Parliament 2002).

The EU Framework Programmes have significantly advanced international research collaboration in Europe (Luukkonen 2001). The integration between collaborating R&D organisations has increased over time, as has the involvement of organisations within simultaneous multiple projects. The size and length of the ventures has increased. The networks have shown themselves to be highly durable with cooperation, both between individual researchers and between research institutions, continuing after the initial joint projects. All this indicates a move towards a more integrated European Research Area, and that collaboration within European funding frameworks has lead into more durable links between collaboration partners (Pohoryles 2002b, Barber et al 2006, Georghiou 1999, Caloghirou et al 2001). There has also been a significant tendency for the same organisations to participate in consecutive Framework Programmes and that there is recurring collaboration between the same organisations within the Framework Programmes. Furthermore, the clustering of organisations seems to have increased over time (Roediger-Schluga & Barber 2006).

Current analysis and modelling of the structure of R&D networks assumes that all partners in an EU project collaborate with each other with equal intensity, i.e. the projects are interpreted as fully connected sub-networks of participants (Barber et al. 2006). This assumption may be adequate for some network processes, such as preparing the ground for future collaboration. However, for many types of interaction – e.g. doing joint research or sharing jointly produced outcomes – the assumption of fully connected sub-networks overestimates the number of existing relations within an EU project. Empirical findings from an evaluation exercise in the Information Society Technologies Programme support this conjecture (Malerba et al. 2006).

In this paper we take a closer look at intra-project collaboration that has been induced by EU Framework Programmes and focus on individual projects and researchers. We look at expectations and motivations of organisations in participating in collaborative R&D projects; we study criteria for partner choice in current and future R&D projects and we look at intra-project linkages especially in terms of doing joint research. We aim to understand the linkages of communication and joint knowledge production between the partners within different EU-funded R&D collaboration projects. To this end, we combine different quantitative and qualitative methods in order to draw a more detailed picture of the patterns, motivations and challenges of inter-organisational cooperation within larger Integrated Projects (IPs) and smaller Specific Targeted Research Projects (STREPs), as well as small Networks of Excellence (NoEs).

The structure of the paper is as follows: Section 2 describes the qualitative and quantitative approaches as well as the three different sources of data: a set of projects from the FP6 NEST programme, a set of Integrated Projects in FP6, and a survey of FP5 participants that is intended to generalise the findings of the qualitative approach. In Section 3, the main results of the study are presented, focusing on the motivations for collaboration, the criteria for partner choice, the self-assessment of joint knowledge production within the projects, and a discussion of factors promoting and impeding collaboration. Section 4 concludes with a summary and a discussion of the implications for further research within NEMO as well as potential implications for European R&D policy.

2 Data and methodology

In order to study intra- and inter-project linkages in communication and knowledge production, we draw from three different sets of quantitative and qualitative data, covering different thematic priorities and programmes, as well as different funding instruments within the fifth and sixth Framework Programme. The quantitative data provides the broad perspective of the patterns of collaboration and joint knowledge production. The qualitative data allows us to concentrate on the in-depth analysis of the individual collaboration paths histories, motivations for cooperation and non-cooperation with specific potential partners, and descriptions of interaction within the projects.

2.1 R&D collaboration in NEST projects (FP6)

The first dataset is focussed on the EU's New and Emerging Science and Technology programme (NEST) in the Sixth Framework Programme (FP6). The NEST programme is a new initiative introduced in the FP6, which aims to support unconventional and visionary research with the potential to open new fields for European science and technology. The NEST projects are characterised by high risk and high reward. Interdisciplinarity is encouraged and there are no restrictions on the scientific fields to be addressed except that the research carried out under NEST should cut across or lie outside the thematic priority areas. The NEST programme is divided into three parallel action lines. Adventure projects are 'visionary' research projects that will develop new scientific and technological opportunities in areas identified by the researchers themselves, Insight projects assess new discoveries or newly-observed phenomena which could indicate risks or problems to society; and finally Pathfinder initiatives focus on specific, highly challenging objectives in emerging scientific and technological fields, and involve groups of complementary projects. The NEST projects may be Networks of Excellence or Specific Targeted Research Projects. They are mostly small, more often academic than industrial projects. The NEST projects included in this study comprise three to ten partners from three to six countries. The projects represent Adventure or Insight action lines, and comprise multidisciplinary applications in physics, medicine and biology, basic research in physics and application in engineering.

The dataset includes 22 in-depth qualitative interviews with 25 actors in seven collaborative research projects. For all projects, we interviewed the coordinator and at least one work package leader, but also managers ordinary participants and subcontractors representing universities and research institutes. We conducted most of the interviews by telephone, the remaining eight we conducted face to face. In order to analyse self-organisational features of the projects, we transcribed the interviews, then coded them using the qualitative data analysis software ATLAS.ti. The coding produced 83 first order codes, most of which were compiled into six second order categories. The second order categories outlines broader rules pertaining to the internal organisation of the collaboration projects at the different stages of the collaboration process. The second order categories include issues such as principles for (1) consortium formation, (2) proposal submission, (3) funding decision and (4) task division, (5) intra-project collaboration structures, processes and context, and finally, (6) the future collaboration and its framework conditions. This paper draws primarily categories one, five and six.

2.2 R&D collaboration in Integrated Projects (FP6)

Within the second dataset we focus on collaboration structures in five Integrated Projects (IPs) in the Sixth Framework Programme (FP6). IPs are introduced in FP6 as a key policy instrument to generate, demonstrate and validate new knowledge in various priority themes through objective-driven research. Our sample of IPs represents three thematic fields: information society technology, sustainable development, and aerospace.

IPs are multi-national, multi-partner, and multi-functional RTD ventures. They are characteristically large-scale projects in terms of the number of participants with an obligatory minimum of three partners from three different countries. The average duration of an Integrated Project typically ranges from three to five years depending on the thematic priority. Integrated Projects may span the whole research spectrum, i.e. from basic to applied research and specifically address different research issues with a 'programmatic approach'. The detailed internal architecture may depend on the complexity and scope of the project, the topic it addresses, and the managerial approach taken. IPs should comprise a coherent set of components: They must contain a research component and, as appropriate, technological development and/or demonstration components including training.

Although not obligatory, the nature of Integrated Projects will often require them to be multidisciplinary. Our sample is diverse in terms of size and mix of organisation types. Network size ranges from 16 partners to 56 partners. Partners come from a minimum of six different countries to a maximum of 15 countries. The mix of partners reflects the strategic orientation of the network projects: they focus on science-industry (62% universities and 28% industry); basic research (48% research organisations and 45% university), or industrial application (58% industry; 62% other partners).

In order to explore intra-project structures in IPs empirically we applied a case study approach, which is based on a mix of quantitative and qualitative analyses:

- Quantitative analysis was applied to the formal collaboration structures, i.e. collaboration as foreseen in the project proposal. To this end, we identified co-operation structures between the partner organisations based on joint work-packages and tasks, as specified in Annex I of each project proposal ('Description of Work'). This involved the analysis and visualisation of intra-project structures in a project network map.

- Qualitative analysis was then based on structured interviews with project partners. It focused on the identification of key knowledge functions, actual project sub-structure, and the network impact of the project. Due to resource limitation, for each case three partners with different roles in the project were interviewed: the co-ordinator for a 'global' view of the network, a work-package (WP) leader for a 'regional' view, and a partner for a 'local' view. The interviewees were provided with a list of partners and the project network map for use during the interview which lasted for about an hour. The first issue we addressed is whether formal co-operation structures reflect effective structures in a project.

Here, the findings from quantitative analysis of formal co-operation structures were compared with qualitative analysis on effective (i.e. actual, real-life) collaboration structures.

2.3 R&D collaboration in the Fifth Framework Programme (FP5)

The third approach represents an econometric analysis of the determinants of partner selection, intra-project collaboration and output performance of Framework Programme projects. The analysis is based on a comprehensive collaboration database of EU Framework Programmes (the sysres EUPRO database[1] (Barber et al. 2008) and a representative survey among FP5 participants on the researcher level. This survey was conducted in 2007 as an on-line survey by the Austrian Research Centers GmbH, Vienna, Austria.

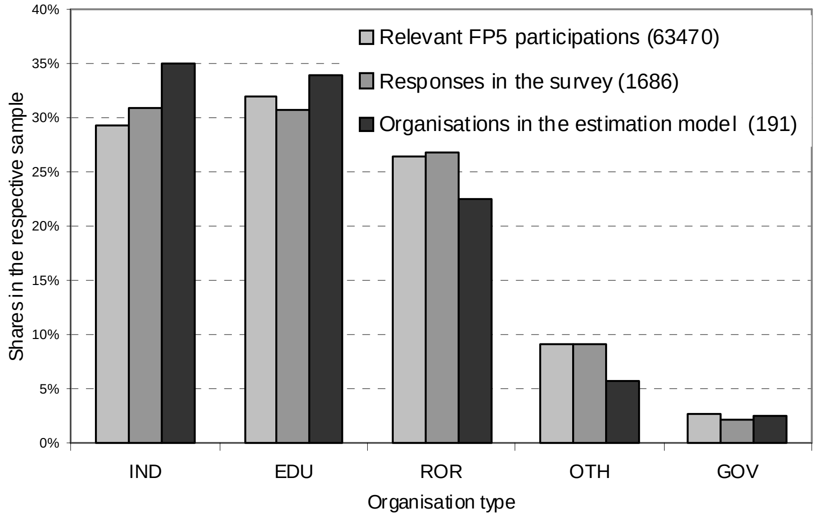
The survey is based on a questionnaire that was harmonised with the interview guidelines used in the qualitative studies so as to assure comparability of the results. With FP5 (1998-2002), a past programme was chosen to leave enough time in between for potential effects to emerge from the projects, be it subsequent collaboration, be it scientific or commercial outcome. For technical reasons, the survey had to be restricted to small projects (i.e. collaborative projects with a maximum of 20 partners). It yielded 1,686 valid responses, representing 3% of all relevant FP5 participants, and covering 1,089 (12% of all relevant) FP5 projects.

With this sample, a complementary dataset to the in-depth, interview-based studies focusing on NEST projects and Integrated Projects was created, which is representative of the thematic priorities, contract types, and organisation types of the participants´

[1] The sysres EUPRO database was built up and is maintained by the Austrian Research Centers GmbH by substantially standardising raw data on EU FP research collaborations obtained from the CORDIS database. It currently (v.1.0.3) comprehends 49.624 projects and 55.555 organisations. It covers management as well as content-related information on the projects and various characteristics of the participating organisations including contact data and geographical location.

affiliations (see Figure 1), so that we are able to test some of the hypotheses from the case studies.

Figure 1: Distribution of analysed entities by organisation type



Note: IND…industry, EDU…university, ROR…public research, OTH…other organisations, GOV…government.

In a first econometric analysis, we employed a discrete choice model estimating the determinants of collaboration, including actor characteristics, relational and network effects as well as geographical effects. This analysis uses cross-section data on a sample of 191 organisations that are selected from the survey data[2]. We are able to identify determinants of collaboration, including actor characteristics, relational and network effects as well as geographical effects, whereby we distinguish between formal collaboration (i.e. the participation in a joint project as given by the sysres EUPRO database), and close scientific collaboration between two partners as stated by at least one of these partners (Paier and Scherngell 2008).

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[2] We employed the collaboration network of the respondents on the organisation level (this network comprises 1,173 organisations collaborating in 1,089 projects) and extracted the 2-core (deNooy et al. 2004) of its largest component (203 organisations representing 17% of all vertices). Finally, another 12 organisations are excluded due to non-availability of geographical distance data, so that we end up with a sample of n=191 organisations that are used in the regression model. It is important to note that the regression does not make use of the network properties on this – somewhat arbitrary – sub-network but only of the properties of the global FP5 network.

3 Collaboration experiences in FP-funded research projects

This section summarises and compares the results that we obtained in the three different approaches. After a general overview of motivations for engaging in collaborative R&D, we focus on criteria for partner choice, learning and knowledge production in collaborative projects, and the factors promoting or impeding the various forms of intra-project linkage.

An organisation takes up R&D collaboration – as we may assume to happen within an R&D consortium – with other organisations to reduce technological or scientific uncertainty and to gain access to useful knowledge from its partners. The network form of organising knowledge production and exchange is an adequate response to the conditions of asset specificity, demand uncertainty, task complexity, and frequency of interaction (Borgatti 2003; Jones et al. 1997). Motives for collaboration in networks may be diverse among network partners, depending on their institutional background (e.g. science and industry) or organisation-specific context. In our own empirical approach, we elicited individual project participants' expectations from collaboration.

- **Knowledge networking and exploration** turned out to be the strongest motivation. It refers to the interest of expanding the organisation's co-operation potential with new partners from industry or research. Within this category the organisations intended to increase their international networking and visibility and to enter co-operations mainly with partners from research. To a minor degree they proposed to enter co-operations with partners from industry.

- **Knowledge production** in order to expand strategic competencies of the organisation appeared to be the second strongest motivation for the participation in those projects. Receiving additional funding for own strategic research is important for organisations without particular R&D department. Furthermore, implementing projects beyond the internal competences and building personal competences were mentioned as specific goals.

– Finally, aspects of **knowledge diffusion and exploitation** (such as validation, policy advice; products & services, prototypes; awareness; technology adoption and transfer) were mentioned as additional goals within these projects.

3.1 Criteria for partner choice

We were interested in looking at the criteria for partner choice in collaborative arrangements within EU-funded research projects. For this purpose, we looked at both the criteria affecting the formation of the current partnerships, and the expected future collaboration based on the current experiences. In general, prior collaboration between partners, personal and organisational characteristics of the partners and the formal status of the partners in past or current collaborative projects were found to be important criteria in partner choice.

Prior collaboration

There is a distinct tendency for organisations to forge durable collaborative links in the Framework Programmes, especially so amongst a smaller group of key actors (Roediger-Schluga & Barber 2006). Similarly, network patterns between European actors have remained quite fixed and build on previous cooperation regardless of the input from Framework Programmes (Okubo and Zitt 2004). On the level of project networks, this is reflected in the extent to which there is previous collaborative history between the project partners, and the plans for the partners to continue collaboration in the future. Prior collaboration thus has to be seen as an important stock of social capital for coordinators seeking to establish a project consortium, as well as for potential partners in accepting the invitation to join a consortium. Sustainability of FP funded R&D networks depends on good personal relations, institutional ties, availability of funds, joint publications work, easy communication and sharing a research paradigm (Pohoryles 2002a, Okubo & Zitt 2004). Also good will, favourable prior beliefs, active interaction and mutual psychological commitment contribute to sustainable collaboration (Geisler 1995, Ring & van de Ven 1994).

Our empirical results from the three approaches are in accordance. As revealed in the NEST sample, previous collaboration typically takes a form of **participating in shared**

international or national research projects, joint publishing, joint teaching or PhD supervision, and **working previously in the same organisation**. The motivations given by our interviewees for selecting prior collaborators as partners in current EU projects were focussed on questions on trust and reliability. It was argued that by selecting previous collaborators, one would know that they would “do their job” and would have the needed expertise. One interviewee also described that he would not consider doing expensive, intensive and time consuming experiments with people he did not know and trust. In some cases the collaboration and “friendship” may have spanned several decades. Current projects were in some cases also directly based on knowledge acquired in a previous project, or collaborators may have had the research idea for years and have been waiting for a suitable call for a long time. Once such a call emerges, prior collaboration and trust makes it possible for the partners to organise the consortium in a short time.

The importance of prior relations occurs in the IP sample as well, **prior contacts** actually **build a sort of backbone** in the formation of the project consortia. Each of the interview partners indicated that they collaborated in previous projects with three to six of their current project partners; one interview partner (a company within a large multinational group) named even 20 prior contacts. Frequently, organisations work within the current IP in close collaboration with especially those organisations, they know from previous occasions. Summing up the existing contacts within one project, one half of the current project participants had prior contacts to at least one of the interview partner. The **coordinators play an essential role**: up to a third of the project partner had prior relations to the co-ordinator.

The econometric model based on the survey of FP5 participants reveals very similar results: **Prior acquaintance** of two organisations is **by far the most important determinant** for partner choice. This factor even increases slightly for close scientific collaboration within the project. Hereby, most of the prior collaborations occurred in a **preceding Framework Programme**. The quantitative estimate of this determining factor tells us that the probability of collaboration between two organisations increases by about 70.4 percent when they are prior acquaintances.

Complementary expertise, recommendation and reputation

The NEST sample highlighted significant criterium for partner choice. It was based on the potential partners having required **complementary expertise**. If the field of research was small, the interviewees often indicated that they knew all the actors in the field, or that necessary expertise and equipment were only available in few selected institutions in Europe. Similarly, partner choice was often described to be based on **recommendation** by already existing project partners or trusted colleagues, or on the **scientific reputation** of individuals. Recommendation and reputation were mentioned as criteria especially in terms of multidisciplinary projects, where the lead partner was not familiar with the other disciplines included in the project.

Previous collaboration, expertise, recommendation and reputation as central criteria highlight how personal contacts and competencies, rather than organisational contexts, play a significant role in partner selection. Having access to specific infrastructure was less frequently mentioned as criterion for partner choice, although most of the included projects also had very specific requirements in terms of the infrastructure.

From the econometric model, we reveal two other important determining factors for partner choice that can be interpreted in the context of complementarity and reputation (Paier and Scherngell 2008). The first factor supportive to partner choice is **thematic proximity of the involved organisations**, measured by the similarity of their project profiles in the Framework Programme. The second factor conducive for bilateral collaboration is the difference in local clustering of the organisations in the FP network. This means that organisations outside of dense clusters are very eager to partner with those inside cliques, and vice versa. Thus, **insiders** with high reputation **are attractive for outsiders**, while **insiders tend to widen their collaborative opportunities.** Both aspects could be an indication for the existence of an optimal cognitive distance for scientific collaboration.

Expected future collaborations

Durability of the collaborative networks is also evident in the future plans of the collaboration partners, who in most cases expressed their wish to continue working with the same partners. In the IP sample, up to two thirds of the project participants are mentioned by at least one of the interviewees as potential partners for future projects. As outlined above, expanding the organisation's co-operation potential with new partners was declared as one of the most important goals for participating in these projects. Against this background, **partners with few current contacts are likely to add more**, whereas **partners with many current contacts are likely to be selective** in their future partner choice.

We observed a strong coincidence between prior contacts, current collaborative links and intended joint projects in the IP sample: Reliable prior contacts are frequently repeated in form of intensive R&D relations within the current project and, additionally, often taken up again in future projects. In other cases, intended future collaborations correlate either with prior contacts, which persist without intensive co-operational links in the current project; or future contacts are intended, due to positive experiences with new partners in the current project.

The NEST sample showed us that motivations to continue working with the same partners include both aspects related to the content of the research, as well as more personal aspects. In many cases, project partners had further plans to continue with an **application of the knowledge** acquired in the current research project, or otherwise **continue with a similar type of research** with similar expertise. **Sharing the intellectual property rights** from the first project also necessitates cooperation in any application based on it. On the other hand, **established relationships and trust, and generally successful cooperation** make it "natural" to continue cooperation.

Although all types of participation in EU projects seems to have favourable influence on future collaboration opportunities, the **coordinators and work package leaders** can especially seen as **desirable partners for future collaboration**. In the IP sample, partners with formal roles are likely to be included in future collaborations, whereas low visibility in the intra-project network poses an entry barrier for future collaborations. With respect to the position of the interviewees in the project (being partner, work package leader or co-ordinator) it is remarkable that especially co-ordinators were reluctant to quote individual organisations as desirable partners for future collaboration. Rather they declared that they intend to collaborate with all of the current project partners. Being aware of their leading role and integrative tasks in the project they obviously wanted to avoid favouring individual partners.

In the NEST sample, the interviewees indicated that partners holding formal positions in the projects were seen as achieving greater visibility and contacts, having the trust of the other partners, as well as possessing useful experience in acquiring EU funding and steering the project. On the other hand, not all the interviewees in the NEST sample were convinced that an official position in a project counted in future partner selection. Instead, participating in any role in an EU project was seen as equally beneficial; or it was argued that **personal performance** and contacts matter more than an official position.

On the other hand there were also cases where **interviewees indicated that they did not wish to continue working with the same partner(s)**. Possible reasons for that included that a partner had **not fulfilled the expectations** and performed well. Alternatively, there were reasons related to more structural than personal aspects, such as **not being able to find a suitable call for the particular constellation** of capacities in the Seventh Framework Programme, or that the **focus of the institution was changing** so that different subject areas were favoured.

3.2 Learning and knowledge production in collaborative projects

We have investigated the connectivity of R&D networks through what can be seen as the primary aims of establishing the networks, namely learning and joint knowledge production. In the following section we will highlight some key elements: Learning modes, the importance of communication for knowledge production and the special role of key individuals.

By learning, we refer to internal processes of acquiring new skills, norms, values and new ways of thinking within the inter-organisational collaboration. Learning refers to the meta-level process resulting from the internal communication within the collaboration projects, such as learning to use particular theories or technical infrastructures, or new ways of solving problems arising in the course of the research. Learning is not communicated outside the participating organisations, nor is it necessarily always explicitly recognised by the project partners themselves. Learning encompasses both explicit and tacit knowledge. (c.f. Beeby & Booth 2000, Nonaka 1994, see also Argyris & Schön (1996) on organisational learning 1996).

We identified three kinds of **learning effects**. First, the partners described to have learned **content related issues**, such as new methodologies, facts and theories from the other partners. Second, learning **communication**, such as learning to communicate with the other partners across organisational and disciplinary boundaries, learning to trust other partners and work as a tram and learning a shared terminology to facilitate communication were listed as primary learning effects during the project. Third, the project participation lead to kind of procedural **learning** on **how to apply and participate** efficiently in EU projects with the specific rules related to applications, as well as learning reporting, risk-control, managing of international teams and coping with different organisational styles.

Communication and joint knowledge production

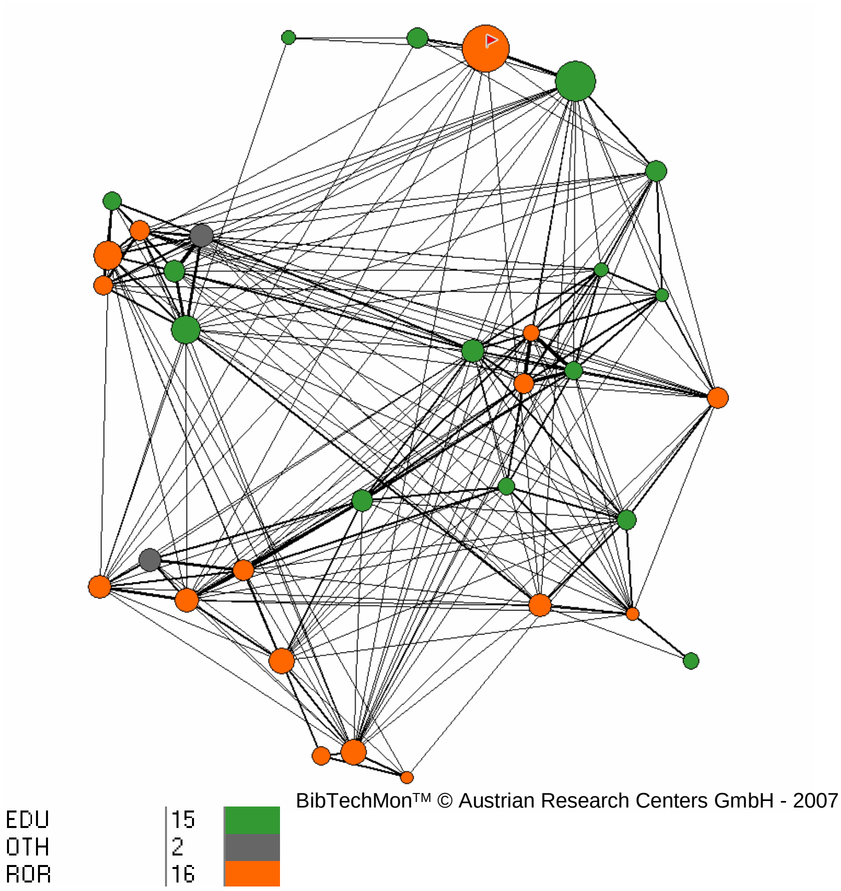
By knowledge production we refer specifically to the process and outcomes of research: conducting of research resulting in research papers, technical innovations, patents and other research outcomes produced by the project's participants. It primarily refers to explicit communicable knowledge aimed to be disseminated to a wider audience (c.f. Gibbons et al 1994.)

Communication is essential for joint knowledge production. In our research on the NEST projects, most interviewees indicated that they communicate primarily with those partners with whom they share a particular research task. In such cases, the partners did not necessarily see much need to communicate with other partners outside the project meetings, indicating that they identified primarily with their own research task.

Communication is seen as **facilitated by the small size of a project** and knowing and trusting the other partners. In the small NEST projects, there typically were two or three partners in each work package; in the smallest ones all partners could be involved in all of the work packages. **Joint knowledge production** seems to take place **primarily within the individual work packages,** thus supporting the idea of partly connected networks (Paier et al. 2007). In the NEST sample comprising smaller, less tightly pre-regulated research tasks and smaller and thus perhaps less formal project structures, the boundaries of work packages were sometimes seen as fluid. Unexpected collaborations were occasionally reported to arise during the course of research projects, which was mentioned to be an advantage of this type of blue skies research.

Also in large projects like the Integrated Projects with many participants, it turns out that not all partners cooperate with each other but conduct R&D in smaller teams. Identifying real-life intra-project (sub-) structures, our interview based research reveals that actual collaboration structures follow quite closely the formal cooperation structures as laid out in official work plans. Based on information about the participating organisations in single work packages we calculated a network graph (for an example, see Figure 2) which visualises the topology of formal collaboration structures between the members of each IP. Nodes represent the participating organisations. They are linked if they formally participate in the same work-package. Node size corresponds with the number of work packages the organisations is involved. The more often two organisations are part of a joint work-package, the stronger the connection between them. In the network graph, these partners are connected by thicker lines and grouped together. Organisations with network links to many different partners are often centrally positioned in the network.

Figure 2: Organisation network based on joint work-package collaboration (example: sustainable development project)



Note: Node size reflects the number of work-packages an organisation is involved in. Organisation type labels: EDU = university sector, ROR = research organisations, OTH = other organisations.

Confronted with the visualisation of the formal cooperation structures of their projects, most of the interviewees agreed that the network graph based on the formal work package structure reflects the actual cooperation structures. There was some discussion about the position of single project partners in the network and some partners argued that in fact there were fewer effective linkages between subprojects than formally represented. But generally speaking, the network map captures the actual R&D groups in the network quite well: Knowledge production in the project takes place in R&D groups according to formal agreements (work plan).

Our findings indicate that the structure of Integrated Projects reflects the organisation's R&D strategy in terms of exploration and exploitation of knowledge (March 1991). Exploration, i.e. access to new and external sources of knowledge and thus broadening the organisation's knowledge base, seems to be the dominant strategic orientation at the project (IP) level. Exploration focuses on learning about new markets and technologies, and studying the environment for new opportunities is considered the central goal. In general, organisations preferably seek research partners more than industry partners for these exploration tasks. The knowledge value of such links is comparatively weak. They are seen as 'contacts'.

Exploitation, i.e. enhancing capabilities by improving and refining current routines, seems to be the dominant strategic orientation at the sub-structural (work package) level. In the interviews, on average only a third of the project partners is effectively cited as collaboration partner by an organisation – the focus is on existing core technologies. To improve these, a firm will initially focus on its internal competences. Recognizing the comparatively high information value of embedded network ties (Hagedoorn et al. 2007), we can expect strong, knowledge-related links.

In summary, we may conclude that Integrated Projects as a whole are about exploration, while their substructures (work packages) are about exploitation. Thus, the strength and the presence, or absence, of links reflects also the nature of interactions within the project. This is especially true for IPs which – due to their size – exhibit sufficiently differentiated substructures.

Reputation and visibility of key partners

Enabling large scale research projects and fostering joint knowledge production is one of the primary aims of the Framework Programmes, and an inherent value in the collaborative projects for many scientists. However, the expertise, motivation and commitment of individuals may still be seen as an important driving force for knowledge production, and according to the NEST sample, senior group members were clearly seen as key drivers in knowledge production, which may be demonstrated in solitary as well as in collaborative efforts, while larger research groups or institutions were said to lend support and to create a favourable environment. In research groups, the senior scientist was seen as they key figure, around whom the expertise of the group was built, and who was seen to be bringing the primary intellectual capital to the group, thus often also being the basis of partner selection.

Also the IP sample yielded similar results. On average one third of the participants in the IP sample are perceived as important actors by their partners. Based on the interviews we may draw a distinct profile of primary actors or key players in projects. In most cases key players assume formal functions and roles in the project. Co-ordinators and work package leaders are deemed as most important project participants, whereas work package leaders are considered the more as key players, the more work packages they are leading. Furthermore, key players are best equipped with project resources (in terms of person-month) and take part in many work packages; they are directly connected to more partners than others and centrally positioned in the collaboration networks. Most of the key players are well known to the interviewees from previous collaborations, are often identical with their current direct collaboration partners in the project and frequently taken into account as potential partners for future collaboration.

In a nutshell, current leadership in IPs is associated with visibility (derived from their high involvement and their role in the project), central positioning in the collaboration network, reputation and the likelihood to be invited for future collaboration.

3.3 Factors promoting and impeding collaboration

Prior cooperation, trust and personal relations, active interaction in related fields and long-term orientation and commitment to the partnership contribute both to the fruitfulness of the learning process and the sustainability of the collaborative networks (Larsson et al 1998, Powell 1990, Pohoryles 2002a). Our studies have shown that there is considerable willingness for collaborative partners to forge durable formal collaboration links. Those links are enforced by shared positive experiences and trust between the collaborators. On the other hand, there seems to be considerable variation on the extent to which the formal links translate to shared knowledge production within the projects. Our analyses of NEST projects and IP in FP6 as well as the survey of FP5 participants are able to shed light on the factors promoting and impeding collaboration within the research projects but also more generally on the European level.

Size of the project

According to Powell et al (1996), barriers to collaboration include a lack of trust between parties, difficulties in relinquishing control, the complexity of joint projects, and different ability to learn new skills. Also the partners' size and position, level of technological sophistication, resources and prior experiences with alliances may play a role. Size of the project, or in case of the large projects, the work package, seems to be a key factor in determining the cohesion of the project, which in turn contributes to the perceived collaborativeness of knowledge production. In the IP sample project size ranges from 16 partners to 56 partners, but, as outlined above, factual collaboration is done in the work packages comprising between 1 and 11 partners. In the NEST sample, all projects studied were small in size, comprising three to ten partners. All of the interviewees, although recognising that different projects may require different amounts of partners and scope of expertise, preferred small projects of approximately 5-10 partners, each of the partners normally bringing two to four people into the consortium. Larger projects were in general described requiring well-organised hierarchical substructures and different levels of communication.

Communication in larger projects was often described to be slower and more cumbersome, and managing the project harder and more time consuming. In larger consortia, following the activities of other partners was described to be harder, and the likelihood of conflicts and non-integration was seen to be increased.

Project management

In the NEST sample, issues related to management of the project were frequently mentioned as having an effect on the smoothness of cooperation. **Good atmosphere, well structured work packages** with clear rules and task division, and **managing any emerging problems** contribute to the willingness of partners to collaborate. One coordinator pointed out that even in small projects, one did not want to end up with a situation where, should one of the partners have to drop out of the project, there would be no-one else in the work package to pick up the task.

Cohesion of the project consortium is closely linked to the joint knowledge production and the eventual success of the project. Cohesion is facilitated by trust, teamwork, the feeling of a shared purpose and good personal relationships, which all contribute to the effective cooperation and successful project. A well-made contract with clear task division, making an effort to manage possibly emerging problems and emphasising communication and conscious collaboration between the partners contributes to the cohesion of the project. **Positive previous experiences** about international collaboration and supportive attitude of the institution towards international collaboration also play a role in facilitating cooperation and contributing to the perceived success of project.

Disciplinary background of the partners

Besides the amount of partners, another significant factor in determining the smoothness of collaboration is the disciplinary background of the partners. Bruce et al's (2004) study on interdisciplinarity in the FP5 funded research projects highlights the challenges of interdisciplinary research and emphasises the importance of careful coalition building and communication in facilitating it. Our study shows similar results. **Establishing a shared terminology** and **understanding of the research questions** was deemed as challenging and time consuming, especially in projects bringing together very different disciplinary fields.

On the other hand, **multidisciplinary cooperation was seen as inspiring and enriching experience**, although it was seen as requiring specific efforts to establish shared language and terminology. One interviewee pointed out that multidisciplinary cooperation requires the collaborators to have a specific, curious mindset, while another one argued that this should also be cultivated in young researcher early on in their career. Certain amount of **disciplinary overlap was seen as making communication easier**, but on the other hand it **may also cause rivalries and difficulties** in task division.

Organisational background of partners

Inter-organisational collaboration between different types of partners is likely to be hampered by different motivations or different institutional practises and norms, and facilitated between similar types of organisations, or organisations with similar, e.g. disciplinary, cultures (c.f. Becher & Trowler 2001). In the NEST sample, different types of organisations were seen as having **different interests in knowledge production**: universities were described as being primarily interested in supervising PhD students and getting peer reviewed scientific publications, where as research centres and companies may primarily be interested in reports or patents. Interviewees representing universities or research institutes often also pointed out the different interests of industry in getting involved in R&D collaboration projects, describing industry as “pursuing their own strategies” which may lead to rivalries especially between companies operating on the same field, secretive attitude in knowledge production or reduced creativity in knowledge production due to the wish to achieve limited, previously specified outcomes. Academic and commercial organisations were described as having different perceptions of time, different expectations regarding the outcomes of the project, and different styles of managing them.

On the other hand, the interviews amongst the NEST projects revealed that **different dynamics were also sometimes seen as positive driving forces** within the project, contributing to fruitful conflicts and forcing the partners to consider different types of perspectives and driving them to broaden the scope of outputs resulting from the project. While many interviewees argued that disciplinary and organisational backgrounds do have an effect on the collaboration, not all argued with this sentiment. Researchers were described as “experts” and “educated people”, who are able to collaborate regardless of their institutional backgrounds, and cannot be dictated by them. Some interviewees argued that because the people are highly motivated and as scientists used to abiding by the rules of science, there is no need for steep hierarchies or rigorous management. Similarly, trust between partners diminishes the need for formal rules and formalised communication procedures (c.f. Coleman 1988).

In the IP sample differences in institutional background are considered influential on co-operation behaviour in general. Research based organisations are experienced in inter-organisational collaboration and organised to enable effective cooperation with external partners. This is, in general, not the case for e.g. small companies or municipalities (representing typical demonstration partners). Their organisational structure is not prepared and the participation in an Integrated Project represents a significant burden in terms of paperwork and bureaucracy compared to the benefits in terms of the financial support received and the promotional value of involvement in the project.

In other cases not the organisational background of the partners but rather financial framework conditions, namely the Additional Cost Model (AC) and the Full Cost Model (FC) in FP6 are mentioned as instrumental for cooperation. AC means personnel dedicated for the specific project, which allows for more flexibility in handling the project. FC requires additional funding and the experience shows that the research staffs were not permanent and so it turns out to be harder to receive good quality work. Even though differences by type of organisation are expected among partners, they are, however, seldom perceived as effective co-operation barrier, especially in those cases where the partners of the consortium were experienced in collaborating with each other.

The composition of consortia with respect to the partners´ organisation type may also influence what is going on in the project: the overall orientation of the project, collaboration styles, type of output etc. Applying a principal component analysis to FP5 project consortia, we obtain three main components that allow to distinguish between six different types of consortia:

Regarding the first component (‘orientation of research’), we identify the group of ‘basic research’ consortia on the one hand, characterised by a high share of universities and public research organisations, and the group of ‘industry’ consortia on the other hand, with a high share of industrial companies. With regard to the second component (‘societal concern’), we identify ‘policy’ consortia on the one hand, with a significant share of government organisations and public research, and ‘technology transfer’ consortia on the other hand, with strong unversity-industry collaboration. And the third component (‘mission orientation’) allows to discriminate between the group of ‘deployment’ consortia, representing the collaboration of public research and industrial companies, and the group of ‘applied research’ consortia with universities and other organisations (Paier and Wagner-Luptacik 2007). It is interesting, that the involvement of a governmental organisation in a consortium seems to ensure a balanced participation of virtually all organisation types.

Language and geographic proximity

Other background factors, related to the **language** spoken by partners or their **geographic proximity**, were largely not seen as factors significantly affecting collaboration in either NEST or IP sample. As relevant for successful co-operation the IP interviewees mentioned not geographical distances between project participants as barriers but personal meetings as carriers. Only **personal meetings** are able to bring the project forward, telephone and video conferences lack in commitment and don’t lead to the expected results. Some of the problems within one project even appeared due to the absence of personal contacts (because of a to small dimensioned travel budget).

Equally language is not considered as highly influential in either IP or NEST samples. **English is established as the lingua franca** in the RTD community. Fluency in English may influence the perception of individual performance and cooperation is more difficult for those who are not comfortable working in English – which is obviously unfair on them. Only single interview partners regard language as a cooperation barrier, e.g. with respect to differences in technical languages. However, some NEST interviewees acknowledge that **sharing a language other than English did have an effect on the social dynamics**

Nevertheless, we get a quite different impression about the impact of geographic distance and language on collaboration when we analyse the declared factual collaborative links between partners in the IPs: actually most of these partners came from the same language area as the interviewee, and beyond, in some cases even the whole project consortium has a certain language in common.

The interviewees state in the IP sample the influence of geographical distance, language, or organisational background has low impact on co-operation patterns and behaviour. While the NEST interviews also viewed language and location as less important, the organisational background was considered significant, and most interviewees demonstrated a preference towards working with academic rather than commercial organisations. However, in both samples the person-bound competences (skills, reliability, and the like) were considered highly influential. Individual factors, i.e. person-specific attributes, were much more influential on effective co-operation structure. Project performance and success is strongly linked to individual competence and skills, interpersonal relationships (‘chemistry’, ‘reliability’, ‘good will’) and the importance of face-to-face communication.

In the econometric analysis of the survey data, geographical factors, i.e. geographical distance and country borders, turn out to be significant barriers to choosing each other as partners. The respective parameter estimate indicates that for any additional 100 km between two organisations the mean collaboration probability decreases by about 11.1 percent. For close scientific collaboration, this geographical effect even increases slightly (Paier and Scherngell 2008).

4 Summary and conclusions

This paper compares three different approaches to analyse project formation and intra-project linkage in R&D collaboration. With in-depth qualitative data as well as broadly representative quantitative methods, we are able to reveal similar results in many aspects of the internal life of the projects. These results, based on the actions and perceptions of real-life actors, provide a starting point for modelling realistic sub-structures and processes in the later stages of the NEMO project.

The most striking feature of R&D collaboration in EU Framework Programme projects turns out to be the durability of partnerships: Prior acquaintance is by far the most important determining factor for partner choice in the econometric model we employed. Likewise, half of the interviewees indicated that they had already contact with at least one of the project partners. The coordinator reported prior relations to one third of the project partners. Prior collaboration contributes to trust and “scientific friendship” between partners, which is conducive to smooth collaboration. Furthermore, there seems to be an optimal cognitive distance that enables fruitful collaboration: Thematic proximity is crucial, but a significant degree of complementarity is also influential in consortium building. Generally speaking, recommendation and reputation are important factors for partner choice. Also, prior co-ordinators and work package leaders are more attractive for future collaboration than ‘ordinary’ project partners; which underlines the importance of formal project roles for visibility in the scientific community.

The key functions we found in the FP projects were networking and exploration, learning, knowledge production, and exploitation. Learning appears in three different contexts. The central aspect is content-related learning, but also communication-related learning was mentioned, which seems to be especially important in interdisciplinary collaboration. Moreover, procedural learning – how to apply and participate efficiently in EU projects with the specific rules related to applications, as well as learning reporting, risk-control, managing of international teams and coping with different organisational styles – is an important dimension of learning for the partners. Learning how to play the EU game is additionally one important aspect contributing to the desirability of former coordinators and work package leaders as partners also in future collaborations.

The most important factors enabling the effective production of knowledge in research projects are both intensive communication among the partners and the involvement of key individuals with high visibility and reputation. Communication is most easily facilitated within small research groups, be it in small projects, or in larger projects with small sub-structures (i.e. formal workpackages as well as informally developed collaboration structures). Projects as a whole are likely to be about exploration, while the smaller (workpackage) sub-structures provide a better infrastructure for scientific knowledge production and the exploitation of existing capabilities.

The senior scientists, their motivation and scientific capacity are seen as key determinants of the success of the project. Formal position either as project coordinator or work package leader is associated with high reputation and visibility, which in turn are both important for partner choice, and for perceived leadership of the knowledge production during the collaboration. Collaboration was also seen to be facilitated by experienced project management, and clear and well structured research tasks and work packages. Managing emerging problems and effort of all participants to work towards a common goal contributed to a good and productive atmosphere in the project.

In addition to project level factors, such as the size and management of the projects, we considered the perceived effects of the attributes of partners on the collaboration, such as the organisational and disciplinary background of the participants, and the language spoken by partners and their geographical distance. Cultural and thematic proximity of organisations are perceived to be important for the success of the collaborations. Diverging disciplinary and organisational backgrounds, while challenging for shared knowledge interests and communication, also contribute to dynamic knowledge production. More important than organisational background of the participants as such, may in fact be the costing models applied to the participations, as they determine the extent to which individual researchers may concentrate effectively on the current project (Additional Cost Model), or whether they are involved in other tasks in their own organisation and require additional funding (Full Cost Model). The experience shows that permanent staff within the Full Cost Model is to a smaller extent exclusively active in the project, which might adversely affect project efficacy. In a longer perspective, however, the greater experience of permanent staff seems to be necessary for visions, project management and knowledge transfer. Thus, the two cost models can be seen as complementary instruments.

The language and geographical distance as attributes of partners, point towards an interesting discrepancy in the different datasets. In the interviews, language spoken by partners or their geographical distance, were not reported to be significant factors in collaboration. However, the empirical results from the survey as well as from the Integrated Projects indicate that they still hamper collaboration in European projects. This discrepancy possibly indicates that the interviewees wish to consider these as secondary elements in collaboration, which should be based on bringing together best expertise across Europe regardless of language or geographic background.

Based on these findings we are able to formulate some basic rules about collaboration patterns in EU R&D projects concerning partner choice, learning and knowledge production, and factors impeding and promoting collaboration. These rules will provide the basis for modelling realistic sub-structures and processes in such projects and will be used in the SKEIN model (Pyka and Scholz 2008), an agent-based model of network dynamics, developed within the NEMO project.

In the next stage of our analysis, we intend to use the qualitative data described above, to construct a model of 'ideal project composition' that would favour a successful project. We then intend to to use the quantitative survey data to test whether the project composition favoured by our informants as the most collaborative and productive ones actually appear so in the empirical analysis.

5 References

Argyris, C. & Schön, D. (1996). Organizational Learning II: Theory, Method and Practice. Addison-Wesley, Reading, MA.

Barber, M., Heller-Schuh, B., Roediger-Schluga, T. and Scherngell, T. (2008): The sysres EUPRO database manual. NEMO Deliverable D4.1. Vienna. http://www.nemo-net.eu

Barber, M., A. Krueger, T. Krueger & T. Roediger-Schluga (2006), The network of EU-funded collaborative R&D projects, Physical Review E, 73.

Becher, Tony & Trowler, Paul (2001). Academic tribes and territories: intellectual enquiry and the cultures of disciplines. Ballmoor: Society for Research into Higher Education.

Beeby, Mick & Booth, Charles (2000). Networks and inter-organizational learning: a critical review. The Learning Organization. Vol. 7 No. 2.

Borgatti, S. P. F., Pacey C. (2003). The network paradigm in organisational research: a review and typology. Journal of Management, 29(6), 991-1013.

Bruce, Anne; Lyall, Catherine; Tait, Joyce & Williams, Robin (2004). Interdisciplinary integration in Europe: the case of the Fifth Framework programme. Futures 36 (2004), 457-470.

Caloghirou, Yannis; Tsakanikas, Aggelos; Vonortas, Nicholas S.(2001). University-Industry Cooperation in the Context of the European Framework Programmes. Journal of Technology Transfer, 26 (2001) 153-161.

Coleman, James (1988). Social Capital in Creation of Human Capital. The American Journal of Sociology, VOL 94. Supplement: Organizations and Institutions. Sociological and Economic Approaches to the Analysis of Social Structure.

Georghiou, Luke (1999). Socio-Economic Effects of Collaborative R&D – European Experiences. Journal of technology Transfer 29: 69-79, 1999.
Geisler, Elizier (1995). Industry-University technology Cooperation: A Theory of Inter-Organizational Relationships. Technology Analysis& Strategic Management. Vol. 7 No 2 1995.
Gibbons, Michael; Limoges, Camille; Nowotny, Helga; Schwartzman, Simon; Scott, Peter & Trow, Martin (1994). The New Production of Knowledge. The Dynamics of Science and Research in Contemporary Societies. Sage, London
Jones, C., Hesterly, W. S. and Borgatti, S. P. (1997), A general theory of network governance: Exchange conditions and social mechanisms. Academy of Management Review, 22(4), 911-945.
Larsson, Rikard; Bengtsson, Lars; Henriksson, Kristina and Sparks Judith (1998). The Interorganizational Learning Dilemma: Collective Knowledge Development in Strategic Alliances. Organization Science Vol. 9, No 3.
Luukkonen, Terttu (2001). Old and new strategic roles for the European Union Framework Programme. Science and Public Policy. Vol. 28 No 3. 205-218.
Malerba, F., Vonortas, N., Cassi, L., Corrocher, N. and Wagner, C. (2006). Networks of Innovation in Information Society: Development and Deployment in Europe - Interim Report, CESPRI, Milan, pp.29.
March, J.G. (1991), Exploration and exploitation in organisational learning. Organisation Science, 10(1), 299-316).
Okubo, Yoshiko & Zitt, Michel (2004). Research integration. Searching for research integration across Europe: a closer look at international and inter-regional collaboration in France. Science and Public Policy, volume 31, number 3, June 2004, pages 213–226.
Nonaka, Ikujiro (1994). A Dynamic Theory of organizational Knowledge Creation. Organization Science, Vol. 5, No1.
Paier M., Ahrweiler P., Barber M., Brandes, A., Heller-Schuh B., Jonard N., Kutz M., Pyka A., Sanditov B., Wagner-Luptacik P., Weber M. (2007): NEMO - Network Models, Governance and R&D Collaboration Networks. Deliverable D1.1: Conceptual and empirical foundations of R&D network dynamics. Austrian Research Centers GmbH – ARC
Paier, M. and P. Wagner-Luptacik (2007), Towards new network construction rules: Stylised facts from FP5 survey and FP6 case studies. NEMO Workshop. Vienna, 14 November 2007.
Paier, M. and Scherngell, T. (2008): Determinants of collaboration in European R&D networks: Empirical evidence from a binary choice model. SSRN Working Paper No. 1120081. Rochester [NY].
Pyka, A. and R. Scholz (2008), A narrative Description of the Agent Based NEMO-Model. NEMO Working Paper #11, Bremen. http://www.nemo-net.eu
Pohoryles, Ronald J. (2002a). The European Research Area: Bureaucratic Vision versus Academic Mission? Innovation, Vol. 15, No. 4, 2002.
Pohoryles, Ronald J. (2002b). The Making of the European Research Area—a View from Research Networks. Innovation, Vol. 15, No. 4, 2002.
Powell, Walter W. (1990). Neither market nor hierarchy: network forms of organization. Research in Organizational Behaviour. Vol. 12, 295-336.
Powell, Walter W.; Koput, Kenneth K. & Smith-Doerr, Laurel. (1996). Interorganizational Collaboration and the locus of Innovation: Networks of Learning in Biotechnology. Administrative Science Quarterly. Vol. 41, 116-145.
Ring, Peter Smith & van de Ven, Andrew H. (1994). Developmental Processes of Cooperative Interorganizational Relationships The Academy of Management Review, Vol. 19, No. 1.
Roediger-Schluga, Thomas & Barber, Michael, J. (2006). The structure of R&D collaboration networks in the European Framework Programmes. NEMO working paper #3.

Van Der Wende, Marijk & Huisman, Jeroen (2004). Europe. In Huisman, Jeroen & Van der Wende, Marijk (eds.) (2004). On Cooperation and Competition. National and European policies for the Internationalisation of Higher education. Bonn, Lemmens.